Ecosystem Overview and Assessment Report for the Bras d'Or Lakes, Nova Scotia

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ECOSYSTEM OVERVIEW AND ASSESSMENT REPORT FOR THE BRAS D'OR LAKES, NOVA SCOTIA

by

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EXECUTIVE SUMMARY

Parker, M., M. Westhead, P. Doherty and J. Naug. 2007. Ecosystem Overview and Assessment Report for the Bras d'Or Lakes, Nova Scotia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2789: xxii + 223 pp.

This Ecosystem Overview and Assessment Report (EOAR) is intended to provide a general overview of the major ecological components of the Bras d'Or Lakes watershed which encompasses land, freshwater, and marine features. It was developed by the Oceans and Coastal Management Division of Fisheries and Oceans Canada as a background document for integrated management (IM) and planning in the Bras d'Or watershed. Planning at the watershed level requires the compilation and integration of available ecological knowledge and information. This overview will therefore be a useful reference for the continued development of IM plans in the watershed.

This document is also intended to support the future identification and ranking of Ecologically and Biologically Significant Areas (EBSAs) of the Bras d'Or Lakes ecosystem, as well as support the future management of the natural resources in the area. To facilitate these uses we have identified where information gaps exist in the terrestrial and aquatic study of the Bras d'Or.

This report has two main components. The first is an overview of the Bras d'Or Lakes as an ecosystem. It presents our current knowledge on the physical and biological systems that are found within the Bras d'Or. Scientific literature has been reviewed and staff from various government, private, and First Nations organizations have been queried. Information from a Bras d'Or Lakes Traditional Ecological Knowledge Workshop has also been included. The second component is a description of some of the human activities, in terms of uses and resource extraction, that take place within the terrestrial and aquatic regions of the watershed.

To evaluate the ecosystem of the Bras d'Or, the Lakes were examined at a major subwatershed and bay-scale resolution. These areas, which may be considered for future management units, have terrestrial, freshwater and marine components. Together these areas constitute the whole of the Bras d'Or Lakes watershed. Information on each area has been assessed and presented to give the reader some sense of the spatial ecological and biological significance of the various parts of this ecosystem.

The Bras d'Or Lakes is a series of estuarine bodies linked together in a manner that forms a unique coastal ecosystem within the Nova Scotian coastline. One of the marine characteristics that helps define the Bras d'Or is the very small amplitude tides that exist relative to most of the Atlantic coast. The small tides result from the significant physical constriction introduced at the Great Bras d'Or Channel, the point through which almost all marine water enters the Lakes. Much of the Bras d'Or can also be characterized as a two layer aquatic system where warmer less saline water that flows toward the ocean lies atop a cooler more saline layer that brings marine waters into the Lakes. Despite the generality of a small tide, nearly all other characteristics of these waters vary both spatially and temporally around the Lakes.

Recently within the Lakes, herring and American plaice fish stocks have gone from abundant to scarce, two populations of cod that spawn in the Lakes have been identified, invasive species like the green crab have become widespread, and the deepest waters (St. Andrews Channel 280 m) have been found to be relatively well oxygenated, saline and stable. On the land, moose were hunted to near extinction, and both moose and non-native White tail deer were successfully reintroduced to the Bras d'Or ecosystem where they both now flourish. Humans have facilitated

other large mammals', like coyote and bobcat, invasion of the Bras d'Or watershed from the mainland by building the Canso causeway. These, and many other pieces of information, provide us with an overview of the Bras d'Or Lakes ecosystem, where large open water bodies remain relatively unimpacted while the landbase and nearshore areas are influenced by the pressures of resource use and shoreline development.

The most impacted area of the Lakes appears to be the nearshore fringe where science has documented conditions of coliform pollution, sedimentation, metals, isolated areas of anoxia and hypoxia, and other stressors such as road development, shoreline development, and various resource uses and extraction activities. This shoreline fringe is also where significant population changes have been observed at herring spawning and oyster grounds, along with other species. However, there is still a lack of current and comprehensive evaluation of the nearshore habitats, species, energy flows, and conditions that allow us to determine the state and trend of the ecosystem interactions in this area.

Biological system information gaps that exist for the Bras d'Or Lakes watershed are primarily related to: (1) knowing habitat use by species and life stage, and (2) having more current information upon which to base decisions. Also of importance is the need to identify potential keystone species in the Bras d'Or and to define their food web relationships to confirm the importance of these species in providing balance in the system, and to allow us to anticipate and manage significant changes.

A basic freshwater biological gap exists in that comprehensive species lists do not exist for freshwater systems of the Bras d'Or. Mammals and birds have been inventoried, and broad marine inventories have been completed at various times. However, a similar species inventory of the diverse barachois habitats or even the major river systems of the Bras d'Or is lacking. Filling this gap would not only provide a record for future comparison, but also help describe freshwater habitats within the watershed of the Lakes.

The biological gap for the terrestrial Bras d'Or watershed is the lack of appropriate spatial coverage of information. Studies have focused either on small areas within the watershed for which there is higher productivity or congregation by the target species, or on much broader geographic scales that cover the Bras d'Or within a provincial or regional study, and therefore provide less detail. Lack of a consistent scale of study either creates such detailed results that they are difficult to apply to the entire Bras d'Or watershed or such general results that it is difficult to distinguish or describe species use or habitats within the watershed. Using a consistent scale, such as the bay-scale watersheds, would help fill this gap. There is also a strong bias of terrestrial studies reporting on findings for the western and northern parts of the watershed, as few written studies have examined the eastern portion of the watershed or areas south of the Barra Strait, with the exception of Denys Basin.

Eelgrass is one species in the marine environment that appears linked to many processes and species within the Bras d'Or ecosystem. Because of the lack of current and complete information on this species, interpretation of other study results and prediction of ecosystem changes are inhibited. Eelgrass is linked to the productivity, and species diversity of the Lakes, and increasing our knowledge of even basic distribution and densities around the Lakes may answer a number of critical questions for resource users and managers.

Future studies within the Bras d'Or Lakes should be based on three basic premises to support ecosystem management:

1. Studies should focus on ecological linkages (physical-biological, or biological interactions) and move away from inventories and species specific study.

2. Studies should generally be undertaken at the bay-scale watershed resolution.
3. Studies should be designed in part using environmental effects monitoring approaches which evaluate relationships between biota and their environment.

From a human use perspective, a range of activities have been discussed within the Bras d'Or that place ecological stress upon the system. These activities include general land use development, the harvesting of renewable and non-renewable resources, shipping, and recreational activities, among others. A range of governance processes and jurisdictional responsibilities have also been reviewed relative to these activities.

There is a notable lack of reference to grey literature and internal government data (unpublished reports and databases) in this report. Analyses of these data should be considered for any future revisions of this document. As a management tool, the EOAR needs to be periodically reviewed and updated. This will ensure that the basis upon which decision making is conducted remains current, and best management will be supported.

RÉSUMÉ

Parker, M., M. Westhead, P. Doherty et J. Naug. 2007. Ecosystem Overview and Assessment Report for the Bras d'Or Lakes, Nova Scotia. Rapp. manus. can. sci. halieut. aquat. 2789: xxii + 223 pp.

Ce rapport sur l'aperçu et l'évaluation de l'écosystème (RAEE) vise à fournir un aperçu général des composantes écologiques principales du bassin versant des lacs du Bras d'Or, formé d'éléments terrestres, dulcicoles et marins. Il a été élaboré à titre de document de référence pour la gestion intégrée (GI) et la planification au sein du bassin versant des lacs du Bras d'Or par la Division de la gestion côtière et des océans de Pêches et Océans Canada. La planification à l'échelle du bassin versant requiert une compilation et une intégration des connaissances et des renseignements écologiques disponibles. Cet aperçu servira donc de référence utile pour l'élaboration continue de plans de GI dans le bassin.

Ce document vise également à appuyer la désignation et le classement futurs des zones d'intérêt écologique et biologique (ZIEB) de l'écosystème du lac Bras d'Or, ainsi que la gestion future des ressources naturelles du secteur. Pour favoriser l'atteinte de ce double objectif, nous avons recensé les lacunes en matière d'information de l'étude terrestre et aquatique du lac Bras d'Or.

Ce rapport est composé de deux volets. Le premier consiste en un aperçu des lacs du Bras d'Or en tant qu'écosystème, qui expose nos connaissances actuelles sur les systèmes physiques et biologiques s'y trouvant. La littérature scientifique a été passée en revue, et des spécialistes de divers organismes publics, privés et des Premières Nations ont été consultés. Des renseignements provenant de l'atelier sur le savoir écologique traditionnel sur les lacs du Bras d'Or ont aussi été inclus à ce rapport. Le deuxième élément est une description de certaines des activités anthropiques relatives à l'utilisation et à l'extraction des ressources dans les secteurs terrestres et aquatiques du bassin hydrographique.

Afin d'évaluer l'écosystème du Bras d'Or, les lacs ont été observés en majeure partie à l'échelle des sous-bassins hydrographiques et des baies. Ces régions, qui pourront être prises en considération en tant qu'unités d'aménagement futures, sont composées d'éléments terrestres, dulcicoles et marins. Elles constituent, une fois réunies, l'ensemble du bassin versant des lacs du Bras d'Or. L'information concernant chacune des régions a été évaluée et présentée de façon à offrir au lecteur un aperçu de l'importance écologique et biologique sur le plan spatial des différentes composantes de cet écosystème.

Les lacs du Bras d'Or sont un groupe de formations estuariennes reliées de façon à constituer un écosystème unique le long de la ligne de côte de la Nouvelle-Écosse. La région des lacs du Bras d'Or détient la plus faible amplitude de marées de la majeure partie du littoral atlantique, caractéristique marine permettant de la reconnaître. Ces petites marées sont causées par le resserrement physique qui commence au chenal Great Bras d'Or, lieu où la presque totalité de l'eau salée pénètre dans les lacs. La majeure partie du Bras d'Or se distingue aussi par un réseau aquatique à deux couches, où les eaux plus chaudes et moins salées s'écoulant vers l'océan se superposent aux eaux plus froides et plus salées provenant de l'océan et se dirigeant vers les lacs. Sauf la constance des faibles marées, presque toutes les autres propriétés de ces eaux varient spatialement et temporellement.

Des études récentes effectuées dans le lac ont abouti aux constatations suivantes : les stocks de hareng et de plie canadienne, autrefois abondants, sont aujourd'hui rares; deux populations distinctes de morue frayent dans le lac; des espèces envahissantes comme le crabe européen s'y

trouvent maintenant en abondance et les eaux les plus profondes (chenal St. Andrews, 280 m) sont relativement bien oxygénées, salées et stables. Sur terre, les orignaux avaient pratiquement disparu en raison de la chasse excessive. Tout comme le cerf de Virginie – une espèce non indigène – ils ont été réintroduits avec succès dans l'écosystème du Bras d'Or et les deux espèces se portent bien aujourd'hui. En construisant la chaussée de Canso, l'homme a par ailleurs facilité l'arrivée massive, dans le bassin hydrographique du Bras d'Or, d'autres grands mammifères en provenance du continent tels que le coyote et le lynx roux. Ces constatations, de même que plusieurs autres données, nous ont procuré un aperçu de l'écosystème des lacs du Bras d'Or, où de grandes étendues d'eau sont encore relativement non perturbées, tandis que les terres et les zones littorales sont influencées par les pressions exercées par l'utilisation des ressources et le développement du littoral.

La zone la plus touchée du lac semble être la frange littorale où les scientifiques ont constaté des cas de pollution par les coliformes et de sédimentation, la présence de métaux, des cas d'anoxie et d'hypoxie dans quelques zones isolées ainsi que l'existence d'autres facteurs de stress tels que la construction de routes, l'aménagement du littoral et diverses activités d'utilisation et d'extraction des ressources. Sur cette frange littorale, des changements importants de populations ont également été observés dans les sites de reproduction des harengs, des huîtres et d'autres espèces. Malgré toutes ces observations, les évaluations continues et approfondies des habitats, des espèces, de la productivité et des conditions en milieu côtier sont encore insuffisantes pour nous permettre de déterminer l'état et les tendances des interactions de l'écosystème de cette région.

Les lacunes dans les données biologiques sur le réseau du bassin versant des lacs du Bras d'Or sont principalement reliées à : 1) la connaissance sur l'utilisation de l'habitat par les espèces ainsi que sur leur stade biologique; 2) l'accès à des renseignements à jour sur lesquels fonder les décisions. Il est également nécessaire d'identifier les espèces clés potentielles du Bras d'Or et de définir leurs interactions dans la chaîne alimentaire afin de confirmer l'importance du rôle qu'elles jouent dans l'équilibre de l'écosystème et d'être en mesure de prévoir et de gérer les modifications importantes.

Une lacune élémentaire dans les données sur l'eau douce résulte du fait que les espèces du réseau des lacs du Bras d'Or n'ont pas toutes été répertoriées. Certes, des mammifères et des oiseaux ont été inventoriés, et d'importants inventaires marins ont été dressés à quelques occasions. Il n'existe toutefois pas d'inventaire semblable des espèces vivant dans les divers habitats des barachois ni même dans les principaux réseaux hydrographiques du Bras d'Or. Remédier à cette lacune permettrait d'obtenir des références en vue de comparaisons futures mais également de décrire les habitats d'eau douce du bassin hydrographique du lac.

Les lacunes dans les données biologiques sur les terres du bassin des lacs du Bras d'Or, sont caractérisées par une couverture spatiale insuffisante de l'information. Des études ont été menées tantôt sur de petites zones du bassin dans lesquelles la productivité et la concentration des espèces ciblées sont plus élevées, tantôt selon une échelle géographique plus large et couvrant les lacs du Bras d'Or dans le cadre d'une étude régionale ou provinciale, ce qui fournit moins détails. Le manque de constance dans l'utilisation des échelles d'étude entraîne soit des résultats si spécifiques qu'ils sont difficilement applicables au bassin versant entier, soit des résultats si génériques qu'il devient difficile de distinguer ou de décrire les utilisations des espèces ou leurs habitats. L'utilisation d'une échelle constante, comme celle des baies, aiderait à corriger ce problème. Les études terrestres sont aussi considérablement biaisées, car elles ne font état que des découvertes concernant les portions nord et ouest du bassin. De plus, peu de recherches documentées ont été effectuées dans l'est du bassin ou dans les zones situées au sud du détroit de Barra, à l'exception du bassin de la rivière Denys.

La zostère marine est l'une des espèces du milieu marin qui semble liée à de nombreux processus et espèces de l'écosystème des lacs du Bras d'Or. À cause d'un manque de renseignements exhaustifs et récents sur cette espèce, l'interprétation des résultats d'autres études et la prédiction des changements écosystémiques sont biaisées. La zostère marine est liée à la productivité et à la diversité des espèces dans le lac, et le fait d'en savoir plus sur elle, ne serait-ce qu'à propos de sa densité et de sa répartition de base dans les lacs, pourrait répondre à certaines questions cruciales des gestionnaires et des utilisateurs des ressources.

Les études futures au sein des les lacs du Bras d'Or doivent être basées sur trois principes fondamentaux appuyant la gestion des écosystèmes :

1. Les études doivent être axées sur les liens écologiques (interactions biophysiques ou biologiques) et s'éloigner des inventaires et des études propres à certaines espèces;
2. Les études doivent être menées, de manière générale, à l'échelle des baies;
3. Les études doivent privilégier, entre autres, les approches de surveillance des effets environnementaux qui évaluent les relations entre le biote et son environnement.

Nous avons analysé, selon une perspective d'utilisation humaine, un éventail d'activités au sein des lacs du Bras d'Or, activités qui exercent une forme d'agression sur le milieu. Parmi ces activités figurent l'utilisation générale des sols, l'utilisation de ressources renouvelables et non renouvelables, la navigation et les activités récréatives. Certains processus de gouvernance et des secteurs de compétence ont aussi été revus en rapport à ces activités.

Il existe un manque considérable de renvois à la littérature grise et aux données internes du gouvernement (rapports inédits et bases de données) dans ce rapport. Une analyse de ces données doit être prise en considération aux fins de toute révision ultérieure de ce document. À titre d'outil de gestion, le RAEE doit être régulièrement révisé et mis à jour. Cette démarche fera en sorte que les bases du processus décisionnel demeurent à jour et qu'une gestion optimale en résultera.

INTRODUCTION

1. Project Definition

1.1 Context and Purpose of Report

This Ecosystem Overview and Assessment Report is intended to provide an overview of the major ecological components of the Bras d'Or Lakes terrestrial, marine and freshwater areas encompassed in the surrounding watershed. It was developed by the Oceans and Coastal Management Division of Fisheries and Oceans Canada, and is primarily intended as a background document for integrated management and planning in the Bras d'Or watershed. Planning at the watershed level requires the compilation and integration of available ecological knowledge and information. This overview will be a useful reference for the continued development of integrated management plans in the watershed.

To evaluate the ecosystem of the Bras d'Or Lakes area we included the entire Bras d'Or Lakes watershed and examined the area at a major subwatershed and bay-scale resolution, the latter referring to the larger bay and channel areas such as St. Patricks Channel, West Bay and Denys Basin (Figure 1). These areas, which may be considered for future management units, have terrestrial, freshwater and marine components. Together these areas constitute the whole of the Bras d'Or Lakes watershed. In addition, the "within bay/basin" scale is a finer resolution and represents a subcategory of the bay-scale areas. As there is insufficient research at this level to adequately cover all of the Bras d'Or Lakes, the "within bay/basin" scale is not discussed in depth, and no graphical representation of such subcategories is presented.

The nomenclature of the various areas of Bras d'Or Lakes has varied over the years, leading to the possibility of confusion. The names used here tend to be those most commonly used in recent papers and documents regarding the area, but may not correspond fully to names used in older documents or by local residents. For the purposes of this document, the term "Bras d'Or" is used to refer to the entire system. From the north, the "Great Bras d'Or" or "Great Bras d'Or Channel" is the narrow body of water along the western side of Boularderie Island, roughly from Kempt Head to Carey Point (Figure 1). "North Basin" is the area south of the Great Bras d'Or Channel and Kempt Head to the Barra Strait, and bounded to the west by St. Patricks Channel and the east by St. Andrews Channel. It should not be confused with the smaller cove called North Basin, found in Denys Basin. "Whycocomagh Bay" is considered separately from the remainder of St. Patricks Channel with the boundary being at Little Narrows. South of the Barra Strait lies "Bras d'Or Lake", loosely bounded to the west by West Bay and Denys Basin, the south by St. Peters Inlet, and the east by East Bay. Bras d'Or Lake is differentiated from the whole watershed, the latter being referred to in plural form as the Bras d'Or Lakes or simply as "the" Bras d'Or.

This document is an overview of the various ecosystem components of the Bras d'Or Lakes. As such, greater detail on the various components presented here can be found in the documents referenced. Presented are the main structural components that define this ecosystem, and a few of the more detailed characteristics that make the Bras d'Or Lakes or its subcomponents ecologically and biologically significant at a local, regional, or global scale. The information provided is not believed to be comprehensive, for our knowledge of the Lakes is not so. However, this report does identify the relationships and components of the ecosystem that we do have an understanding of, and puts them in context based on our knowledge at hand.

1.2 Boundaries of Study Area

This report covers the entire Bras d'Or watershed, which includes land, freshwater and marine features. The watershed has an area of 3565 km^2, of which 2479 km^2 (70%) are terrestrial and freshwater, and 1086 km^2 (30%) are marine (Johnston pers. comm. 2006). The length of the coastline is approximately 1000 km. There are 12 subwatersheds, ranging in size from 83 km^2 at McKinnons Harbour to 332 km^2 at East Bay (Figure 1).

For the purposes of the Bras d'Or Lakes ecosystem overview, a typical watershed boundary was established for all freshwater systems that would enter the Bras d'Or Lakes and exit through the Great Bras d'Or Channel at Carey Point or the Little Bras d'Or Channel at Alder Point (Figure 1). The entire watershed covers a third of Cape Breton Island and includes portions of all four Cape Breton Island Counties (Richmond, Victoria, Inverness, Cape Breton) (Table 1). The drainage areas, including open water, are roughly 1500 km^2 and 2200 km^2 for the regions north and south of the Barra Strait, respectively (Gurbutt and Petrie 1995). Six of the rivers that flow into the Lakes, Denys, Benacadie, Baddeck, Middle, Skye, and Washabuck Rivers, account for 42% of all freshwater flowage. The remaining 58% flowage results from smaller systems (UMA Group 1989).

Table 1. Approximate area of the Bras d'Or watershed located in each county[3]

County	Total area of Bras d'Or watershed within County (km^2)	% of watershed in County
Victoria	1005	40
Inverness	693	28
Cape Breton	528	22
Richmond	262	10
Total	**2488 km^2**	**100%**

The Bras d'Or Lakes is part of the Eastern Scotian Shelf LOMA (Large Ocean Management Area), the largest scale of Integrated Management (IM) planning under the Federal *Oceans Act*. It is then categorized into a smaller IM unit called the Coastal Management Area (CMA). For their purposes, Environment Canada has defined an area surrounding the Bras d'Or as the Northwest Atlantic Marine Ecozone of Canada.

2. Methodology of Study

This report has two main components. The first is an overview of the Bras d'Or Lakes as an ecosystem. It presents our current knowledge on the physical, biological, and human systems that are found within the Bras d'Or. Scientific literature has been reviewed and staff from various government, private, and First Nations organizations have been queried. Information from the proceedings of the Traditional Ecological Knowledge (TEK) Workshop for the Bras d'Or Lakes, held in May 2006 specifically to gather TEK of the Bras d'Or, has also been included. The second is a description of some of the human activities, in terms of uses and resource extraction, that take place within the terrestrial and aquatic regions of the watershed.

[3] Figures calculated by the Cape Breton Regional Municipality

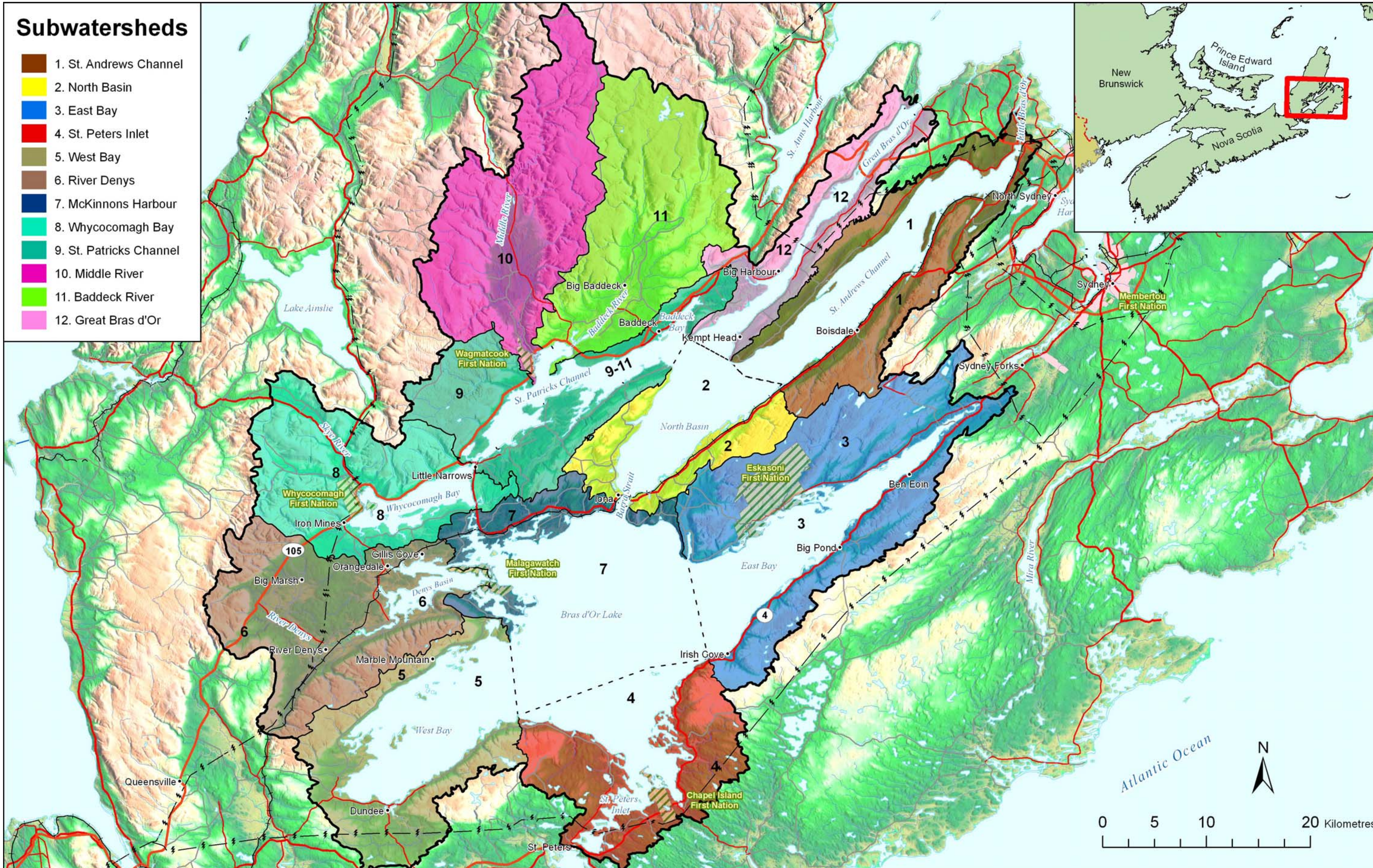


Figure 1. Overview of the Bras d'Or Lakes showing approximate boundaries of the twelve major subwatersheds and ten bay-scale areas
Data sources: DFO (2003); NSGC (1999); Basemap (Natural Resources Canada, National Topographic Database 1:250,000 3rd Edition)

2.1 Information Use and Reliability

As much as possible, this document relies on scientific literature, and peer reviewed information. However, where gaps exist, scientists familiar with the Bras d'Or have been asked for personal comment, manuscript reports have been used, and non-peer reviewed literature assessed. These sources have been used with caution, and the most widely supported understandings of the ecosystem are presented. In addition, information gathered at the TEK Workshop for the Bras d'Or Lakes (CEPI 2006) is included to supplement the scientific literature. The complete proceedings of the TEK Workshop are included in Appendix A.

In certain sections of this document, the inclusion of internal government data would have been helpful, and in some cases may have been the main source of data. However, references to the grey literature are notably lacking (e.g., internal government reports) in this document as are unpublished data in various forms, including internal databases, due to inaccessibility to the authors. A major effort would be required to summarize and interpret these data, which should be a consideration for any future revisions of this document.

PART A – GEOLOGICAL SYSTEM

3. Geological Components

The Bras d'Or Lakes, as we see them today, are a relatively young feature. The marine nature of the Lakes and similar sea levels as are observed today have only existed for the last 4 - 5 thousand years. The Lakes formation is largely glacial in nature, scoured during the Wisconsinan Glaciation that ended some 10 000 years ago. The thickness of stratified sediment in the Bras d'Or Lakes that overlies the glacial tills deposited during the last ice age, shows a step-like retreat of the ice toward the west. As the glaciers retreated through melting, a much smaller freshwater lake was the beginning of a drainage through what is now known as the Little Bras d'Or Channel. Marine waters then influenced this freshwater system during sea level rise some
9 - 10 thousand years ago, before falling seas again made the area of the Bras d'Or largely freshwater. Finally, from lake bottom sediments we know that marine conditions returned to the Bras d'Or some 4 - 5 thousand years ago with the rise of the sea levels to near present day levels (Shaw et al. 2002).

3.1 Bedrock Features

In its most simple geological description, the Bras d'Or is bounded to the North by the Nova Scotia Highlands, and on all other sides by the Atlantic Uplands of Nova Scotia. Locally, however, the geology around the Bras d'Or is complex, with a large variety of geological processes and layers apparent both in the watershed topography, and the underlying lake floor. To the Northwest around St Patricks Channel, Whycocomagh Bay and Denys Basin is an area called the North Bras d'Or uplands, formed during the Carboniferous Period. The rivers flowing from these watersheds bring a significant source of silicate from the Triassic-Carboniferous rocks of the area to the Lakes. The coastal shoreline area around these three bodies consists primarily of the more erodible limestone, sandstone, and siltstone of the Windsor and Horton groups. The Windsor Group is the major group forming the floor of these bays.

For all the geological complexity of the watershed, the shoreline of the Bras d'Or consists almost exclusively of Windsor Group strata known as the Submerged Lowland. The Windsor group is particularly soft, and easily eroded. During the Tertiary period, deepening rivers originating at the glaciers that were retreating toward the west washed some of this material away. Through this process the Great Bras d'Or Channel was formed and Bras d'Or Lake deepened (Shaw et al. 2002).

Higher ground and lake floor geology is considerably more varied than the shoreline of the Bras d'Or. St. Andrews Channel is underlain by the relatively soft sandstone and conglomerate rocks of the Grantmire formation, with the transition between this Northeast bedrock geology and the Northwest geology occurring around the Grand Narrows. South of East Bay around to West Bay the higher ground is composed more of earlier Paleozoic era intrusive granite and quartzite, as well as slate and basalt of the Fourchu and George River Groups that date to the late Proterozoic era. This is some of the oldest surficial geology visible around the Lakes. This being said, Windsor and Horton group formations still exist as an eroding broken fringe at sea level in most of these areas and extend out as the lake floor (Davis and Brown 1996b). To the north through Denys Basin and the southern boundary of St. Patricks Channel lie much of the watershed lowlands. Windsor group formation rocks dominate this area with the exception of some intrusive rock that forms Marble Mountain. Finally, the surficial geology of the north shore of St. Patricks Channel and the Great Bras d'Or is some of the most complex in the watershed. More than a dozen geological groups are represented there, many within the Middle River sub-basin alone. Some of the more unique being the Middle River Metamorphic Suite; Fisset Brook Formation; granodiorite, diorite and gabbro intrusive; Canso Group sedimentary rocks; and the andesite, schist, and amphibolites of the McMillan Flowage Formation (Province of Nova Scotia 1994). These layers influence the unique metal signatures of the larger rivers of the Bras d'Or Lakes that drain to St. Patricks Channel (Dalziel et al. 1998).

4. Geomorphology

4.1 Topography of Coastal Landscapes

Much of the coastal topography around the Bras d'Or Lakes is very steep, rising almost immediately from the shoreline to elevations of 250-270 m. The southern boundary of the Lakes is not quite as abrupt, but elevations of 150 m are still gained within a few kilometres of the shoreline. The highland areas include the East Bay Hills and Boisdale Hills surrounding East Bay, Kelly Mountain north of the Great Bras d'Or, and North Mountain and Sporting Mountain on either side of West Bay. These highland features provide stunning views of the Lakes and limit some land uses adjacent to the lake in these areas. A lowland exception to this general topography exists in three locations. An area of lowland between Whycocomagh Bay and Denys Basin in the Northeastern watershed area of the Lake; the southwest boundary of West Bay between North Mountain and Sporting Mountain; and the boundary of St. Peters Inlet toward the Atlantic. In all three of these areas, topography is much gentler, rarely exceeding 75 m elevation as much as 10 km from the coastline (Taylor and Shaw 2002). These lowlands are part of what is informally called the Bras d'Or Lowlands of Cape Breton Island, partly connected to other lowland areas of the island that are developed mainly on Carboniferous sedimentary rock ranging from 10-200 m elevation (Grant 1994). Together the highlands and lowlands influence the weather of the Bras d'Or, including higher amounts of precipitation in the northern watershed.

There are 1234 km of coastline around the Bras d'Or Lakes. Only 13.5% or 165 km are rock. The majority is unconsolidated material of the Windsor Formation that contributes to the silty, muddy bottom of the Lakes as it erodes. Nearly 30% of the Bras d'Or Lakes shorelines are sheltered from higher wave energy and eroding forces by the enclosed nature of the many bays. This allows vegetation to extend to the shoreline in these areas. Artificial or human made shorelines account for nearly 20 km (Taylor and Shaw 2002). Much of these human altered coastlines are coastal barrier beaches on which roads have been built, and subsequently armoured with stone to prevent loss of infrastructure.

Coastal barriers, generally backed by fresh or brackish water, are a significant and scenic feature of the Bras d'Or Lakes. These barriers form a large number of barachois ponds, as they are locally known. They are small lagoons that are partially or completely enclosed by a sandy spit. Few exceed 12.2-16.2 ha in size (Smith and Rushton 1964). In total, coastal barriers line nearly 150 km of shoreline in the Lakes (Taylor and Shaw 2002). Features such as spits and barrier beaches found along the Lakes shores are comparable in their horizontal extent to other coastal Nova Scotian locations. However, they are somewhat unique in that they are smaller in their vertical scale, mainly because a reduced magnitude of tidal range and wave energy found in the Lakes (Taylor and Shaw 2002). In the Bras d'Or Lakes large barrier beaches >1 km can be found. Some have existed for a very long time. Gillis Beach, for example, has been estimated to be 300-1300 years old. However, a subset of 80 barrier beaches was surveyed (Taylor and Shaw 2002), and nearly 44% were classed as in breakdown and collapse phases of barrier evolution. As such they are particularly sensitive to human activities. Even in 1961, Smith and Rushton

(1964) noted that “Few of the barriers appear to be of a stable nature…”. The larger coastal barriers north of the Barra Strait and those along the northern shores of Bras d’Or Lake and East Bay, south of the Barra Strait, in general appear more stable than those along the southern extremes of the Bras d’Or Lake and East Bay. No other coastal geology studies are known to have been completed on the Lakes since the early 1900s.

Rock shores are concentrated along the high upland backshores of the Great Bras d’Or Channel and St. Andrews Channel. However, to the south exist some low-lying volcanic rock shores in East Bay and St. Peters Inlet. The most common rock shore cliffs are usually less than 15 m, and are formed in the Windsor Group limestone, sandstone, and gypsum. Unconsolidated material also forms shore cliffs where erosional processes occur. Eroded drumlins and deep till layers are associated with cliffs as high as 30 m in East Bay (Taylor and Shaw 2002).

With some 77% of the Bras d’Or Lakes shoreline being composed of unconsolidated material, tides, winds, waves, and sea ice are the short-term, more regular sculpting forces responsible for reshaping shoreline morphology. On a smaller scale, these forces rework the southwest northeast trending topography that was sculpted by the erosive forces of glaciation. Given the nature of the local geology, sinkholes occur in coastal areas near the Barra Strait where the dissolution of evaporates has occurred, creating what is known as Karst topography. As outcrops of rock salt associated with the Windsor Group were fractured because of geological processes and exposed to freshwaters, they would quickly dissolve leaving the sinkhole features in the coastal landscape.

Although there is a somewhat complex coastline of inlets and bays around the Bras d’Or Lakes, there are relatively few islands, especially north of Barra Strait. The exception is where glacial drumlin deposits form the islands in West and East Bays (Taylor and Shaw 2002).

According to TEK, the nearshore area has undergone dramatic changes in the Bras d’Or Lakes (CEPI 2006). The most significant changes over the last 60 years are attributed to erosion, in part due to Nor’easters and warm water. At least two small islands have disappeared in recent years: one in St. Peters off Burkes Point and the other in West Bay west of the Cranberry Islands. Similarly barrier beaches have had large breaches at Cape St. George and MacKinnon’s Harbour. The graveyard in the Little Narrows is close to shore, and has been eroded by wind and rain. It is believed that the lack of ice in recent years has allowed winter storms to accelerate erosion.

4.2 Hydrography and Watersheds

The land base of the Bras d’Or Lakes is approximately 2500 km^2 and the total catchment some 3600 km^2 (Krauel 1976). The watershed covers a third of Cape Breton Island and includes portions of all four Cape Breton Island Counties (Richmond, Victoria, Inverness, Cape Breton) (UMA Group 1989). Because of the steep topography surrounding the Lakes, the watershed is comprised of many small basins that account for well over one half of the land base of the watershed (see Table 2). All but the Benacadie and Black River enter the smaller shallow protected bays to the northwest. There are virtually no lake headed systems draining into the Lakes except a few small bodies. Those lakes that do exist typically have less than 1 km^2 surface area, and enter the Lakes directly through small first or second order streams. The exceptions are the First, Second, and Third Lake O’Law in the headwaters of the Middle River, and a series of three small lakes at the headwater of the Baddeck River.

Table 2. Primary river watersheds of the Bras d'Or

Major River	Subwatershed	Total Area (km^2)
Middle River	St. Patricks Channel	319
Baddeck River	St. Patricks Channel	273
River Denys	Denys Basin	211
Skye River	Whycocomagh Bay	109
Humes River	St. Patricks Channel	48
Benacadie River	East Bay	41
Black River	West Bay	39
Washabuck River	St. Patricks Channel	24
Total of eight largest rivers		**1064 km^2**
Total of Bras d'Or watershed land base		**2500 km^2**

4.3 Bathymetry and Seascapes

The Bras d'Or, as we see it today, is significantly different in both physical and chemical properties than those that existed a short 6000-9500 years ago (Shaw et al. 2002). At the end of the Wisconsinan Glaciation the lake level was 25 m lower than it is today, and all tidal exchange is expected to have occurred through the very small Little Bras d'Or Channel. Denys Basin, Whycocomagh Bay, the Great Bras d'Or Channel, and a large part of East Bay did not have significant lake bodies of water, but may have had some surface water drainage features such as streams and rivers. Since the end of the last glaciation, there has twice been a changing of topography to bathymetry with a rise, fall and rise again in sea levels. Each change in lake water composition from fresh to marine has brought changes in lake boundaries through erosion processes. In some areas, a prominent erosion surface at -25 m can be found that marks the final freshwater lake levels that occurred in the early Holocene (Shaw et al. 2002).

Today the brackish fjordal system of the Bras d'Or Lakes has a surface area of some 1.07 billion m^2, a volume of 32 billion m^3 (Petrie and Bugden 2002), and an average depth of ~30 m (Strain and Yeats 2002). It is most clearly defined as an estuarine system, in which the partially enclosed body has tidal exchange that is measurably diluted with freshwater from the land base. St. Andrews Channel, which has a small tidal exchange directly to the Atlantic through a shallow channel known as the Little Bras d'Or Channel, is the deepest body within the lake system at 280 m (Figure 2). St. Andrews Channel along with North Basin (to 229 m), and Bras d'Or Lake (to 119 m) constitute the most significant deepwater areas of the Lakes (Dupont et al. 2003). The bathymetric contours drop quickly to the deepest areas of North Basin and St. Andrews Channel, but more gently in the Bras d'Or Lake. Contrasting with these deep open water areas are the many shallow protected embayments and inlets around the Lakes, such as Baddeck Bay and Benacadie Pond.

There are hundreds of small coves, inlets, and bays along the Bras d'Or Lakes coastline. One of the larger is Denys Basin. This basin is shallow and flat with a mean depth of ~5 m (Strain and Yeats 2002) connecting it to Bras d'Or Lake through an approximately 3 km long 180 m wide channel of some 10 m depth (Dupont et al. 2003). Not all of these small basins are bathymetrically uniform. The geometry of Whycocomagh Bay, for example, is more complex. It displays both deep and shallow characteristics. Whycocomagh Bay has a pair of deep basins of 38 and 46 m deep. A sill of approximately 7 m depth separates these two basins from each other. The whole of Whycocomagh Bay is further separated to the east from the remainder of St. Patricks Channel by a sill less than 12 m deep at Little Narrows.

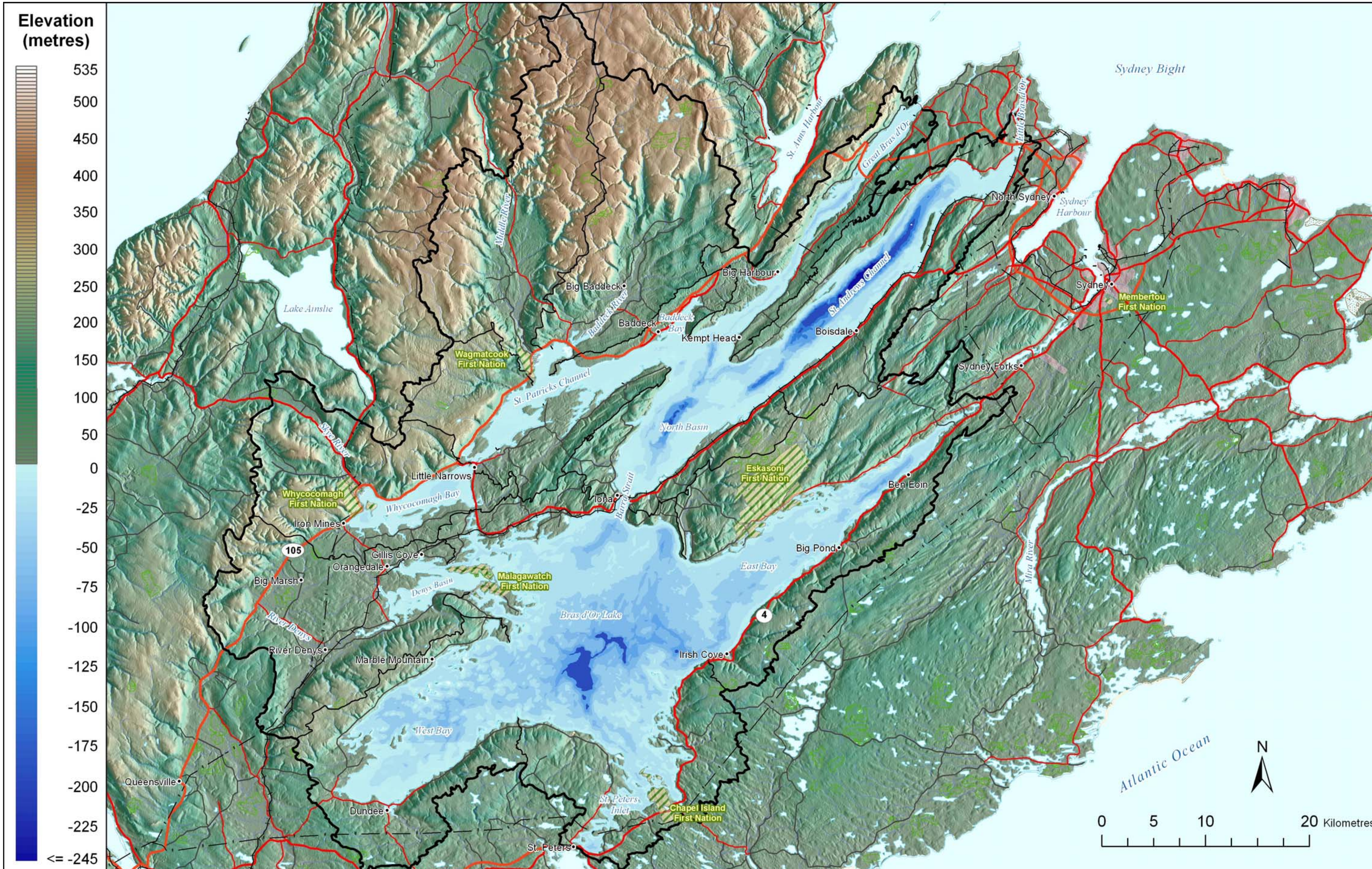


Figure 2. Topographic map highlighting the deep basins and constricted passages within the Bras d'Or Lakes
Data sources: DFO (2003); Bathymetric data (Canadian Hydrographic Chart digital vector data sets); Hydrographic data (Canadian Hydrographic Service, Fisheries and Oceans Canada); Basemap (Natural Resources Canada, National Topographic Database 1:250,000 3rd Edition)

All of the five major channels of the Lakes (St. Patricks, Great Bras d'Or, Little Bras d'Or, St. Andrews, and East Bay) have a similar northeast – southwest orientation (Krauel 1976). Rifting and regional tectonic plate movements some 360 million years ago formed this directional series of small fault bounded basins between highlands of resistant crystalline rock (Calder 1998 cited in Shaw et al. 2002). The Great Bras d'Or is unique amongst these channels in that it provides the primary tidal interchange. The Great Bras d'Or Channel is approximately 30 km long and has an average width of 1.3 km, and at its narrowest it is a mere 320 m wide with a depth of 16.2 m (Petrie and Bugden 2002).

The Bras d'Or Lake, the largest and most open body, varies between 50 m and as much as 180 m deep in a few locations (Davis and Brown 1996b). Irregular features such as moraines and drumlins provide some bathymetric relief in Bras d'Or Lake and West Bay (Grant 1994). These structures were left behind as the last of the ice that had covered the Bras d'Or receded to this area at the end of the Wisconsinan glaciation.

One of the most significant features of the Lakes, affecting its chemical and biological character, is related to the bathymetry. Shallow sills (see Table 3) appear to be a key feature affecting both water and biota movement within the Lakes. These sills tend to divide the Lakes both at a larger bay-scale and a smaller "within bay or basin" scale. The sills create a form of compartmentalization of water chemistry and biology by limiting exchange and inhibiting flushing below the sill depth. The sill-related changes in physical and biological components are not necessarily drastic, but boundaries of observable and measurable differences can almost always be related to shallow sill locations. For example, Strain and Yeats (1999) showed that the presence/absence of sills is the dominant factor determining the sensitivity of inlets to eutrophication. In East Bay, a study of water chemistry in the deeper basins of the bay showed that these areas seasonally become filled with cold, saline water and are essentially capped by the less-dense, intermediate-depth water floating above (Arseneau et al. 1977). The sills, which divide one basin from another, then prevent a direct horizontal exchange of deepwater layers (Kenchington and Carruthers 2001) thereby, at least temporarily, isolating the chemical properties of the deep areas from other areas of the Lakes. Strain and Yeats (2002) suggest the sill at Barra Strait limits marine nitrate supply to areas south of the Strait and in part accounts for total production being significantly lower in that region of the Lakes. Shih et al. (1988) believe this same sill likely limits copepod dispersion to the south. The shallow and relatively small cross-sectional area of the Great Bras d'Or Channel limits the entrance of saline marine waters to the Lakes. The lower salinity limits the presence of rock crab and scallops to the entrance to the Lakes nearest the Sydney Bight (Tremblay 2002). The isolation of Whycocomagh Bay from the rest of the Lakes by the shallow sill at Little Narrows that leads to St. Patricks channel is attributed to the nearly non-existent upwelling in the Whycocomagh Basin (Petrie and Bugden 2002). The further isolation of the western basin in Whycocomagh Bay by a second sill likely contributes to the observation of the strongest and most variable thermoclines and haloclines recorded in the Lakes during July 1974 (Gurbutt and Petrie 1995).

At the bay-scale there are sills like that of the Barra Strait that separates North Basin and Bras d'Or Lake. The "sill depth" at Barra Strait (the greatest depth at which there is a clear passage) is not in the Narrows itself, where the water often flows strongly and erodes the seabed, but somewhat further north where the sill shallows to about 15 m (Kenchington and Carruthers 2001). Shallow sills also exist at the "within bay or basin" scale separating deeper basins within a single bay. These sills facilitate a different character by partially isolating the physical and biological processes of one basin from the other. One of the best examples of this scale is found in Whycocomagh Bay where a pair of deep basins is separated from each other by a sill of approximately 7 m depth, and the Bay's further separated from the remainder of St. Patricks Channel to the east by a 13 m deep sill at Little Narrows. In total, there are some eleven primary sills that appear to impact the physical and biological character of the waters they divide (Figure 3). These sills are as shallow as 1 m for some smaller bays (Denas Pond), to around 16 m for the Great Bras d'Or.

Table 3. Bathymetric sills of the Bras d'Or Lakes and some of the demonstrated or expected controls they have on the physical and biological properties of the bays with which they are associated

Basin or Bay	Sill Depth	Basin Depth	Sill Location	Apparent sill controls
St. Andrews Channel	5 m	280 m	Little Bras d'Or Channel	Limits tidal and other oceanographic influences and exchange (Petrie and Bugden 2002; Gurbutt et al. 1993); Copepod dispersion (Shih et al. 1988)
St. Andrews Channel	60 m	160 m	Point Clear	Inhibits deep mixing and flushing in the basin (Gurbutt et al. 1993).
North Basin	n/a 60 m 15 m	229 m	Kempt Head, Point Clear, Barra Strait	Tidal mixing; Marine nitrate supply barrier to areas south of Barra Strait (Strain and Yeats 2002), Copepod dispersion (Shih et al. 1988).
East Bay	25 m	80 m	MacDougall Point	Temperature and Salinity (Arseneau et al. 1977)
St. Peters Bay	10 m	40 m	Handley's Point	Salinity (Kenchington and Carruthers 2001) Nitrate retention (Strain and Yeats 2002)
Denys Basin	5 m	n/a	The Boom	Not discussed in the literature.
Whycocomagh Bay	7 m	48 m	Mid Bay	Flushing time of approximately two years, facilitating the anoxic character of those bodies (Petrie and Bugden 2002; Gurbutt and Petrie 1995; Gurbutt et al. 1993); strongest and most variable thermoclines and haloclines recorded in the Lakes during July 1974 (Gurbutt and Petrie 1995)
Whycocomagh Bay	13 m	38 m	Little Narrows	Prevention of flushing in Whycocomagh Bay (Petrie and Bugden 2002). Flushing time of approximately two years, facilitating the anoxic character of those bodies (Petrie and Bugden 2002), Oxygen replenishment, seal movement, seal worm reproduction, copepod dispersion (Shih et al. 1988)
Denas Pond	1 m	30 m	At outlet	High phosphate retention (Strain and Yeats 2002) Nitrate retention (Strain and Yeats 2002)
Great Bras d'Or Channel	16 m	95 m	Kempt Head	Tidal mixing (Petrie and Bugden 2002, Petrie 1999, Gurbutt and Petrie 1995); Copepod dispersion (Shih et al. 1988).
Great Bras d'Or Channel	12 m	Sydney Bight	Middle Shoal, Cape Dauphin	Limits tidal influence, exchange, and mean circulation (Petrie and Bugden 2002)
Herring Cove – Baddeck Bay	10 m	n/a	Near Long Hill	Nitrate retention, anaerobic decomposition and low DO (Strain and Yeats 2002)
Indian Cove - Washabuck River	<5 m	n/a	Near Cranberry Pt.	Not discussed in the literature.

Backscatter sonar surveys in the location of many of the sills highlighted in Table 3 indicate that harder substrates do exist in most of these locations (Shaw and Potter 2006d). However, most of these substrates would be interpreted as gravels to cobbles, not bedrock. Therefore, they are effective at influencing physical oceanography and biological distributions in the generally low tidal velocities that exist in the Lakes. A few locations, including eastern East Bay, even indicate fine substrates at the sill locations (Shaw and Potter 2006d).

A further bathymetric feature of the Lakes has been identified through unpublished multibeam bathymetry imagery of the lake floor. Deep pocket like structures that are similar to the land based sink holes near the Barra Strait also exist on the lake floor of that area. These bathymetric features likely resulted from the same dissolution of Windsor Group rock salt outcroppings. The same process may also be responsible for the extremely deep areas of St. Andrews Channel (Shaw et al. 2002) where the sidewalls of that deep area are near vertical.

In general, morphology of the Lakes' floor differs south of the Barra Strait relative to the north. In the south seabed morphology is principally related to the presence of glacial deposits in the form of drumlins, moraines and coastal features at previous lake levels (Shaw and Potter 2006a). In the north morphology is more related to past freshwater fluvial processes and current day tidal action.

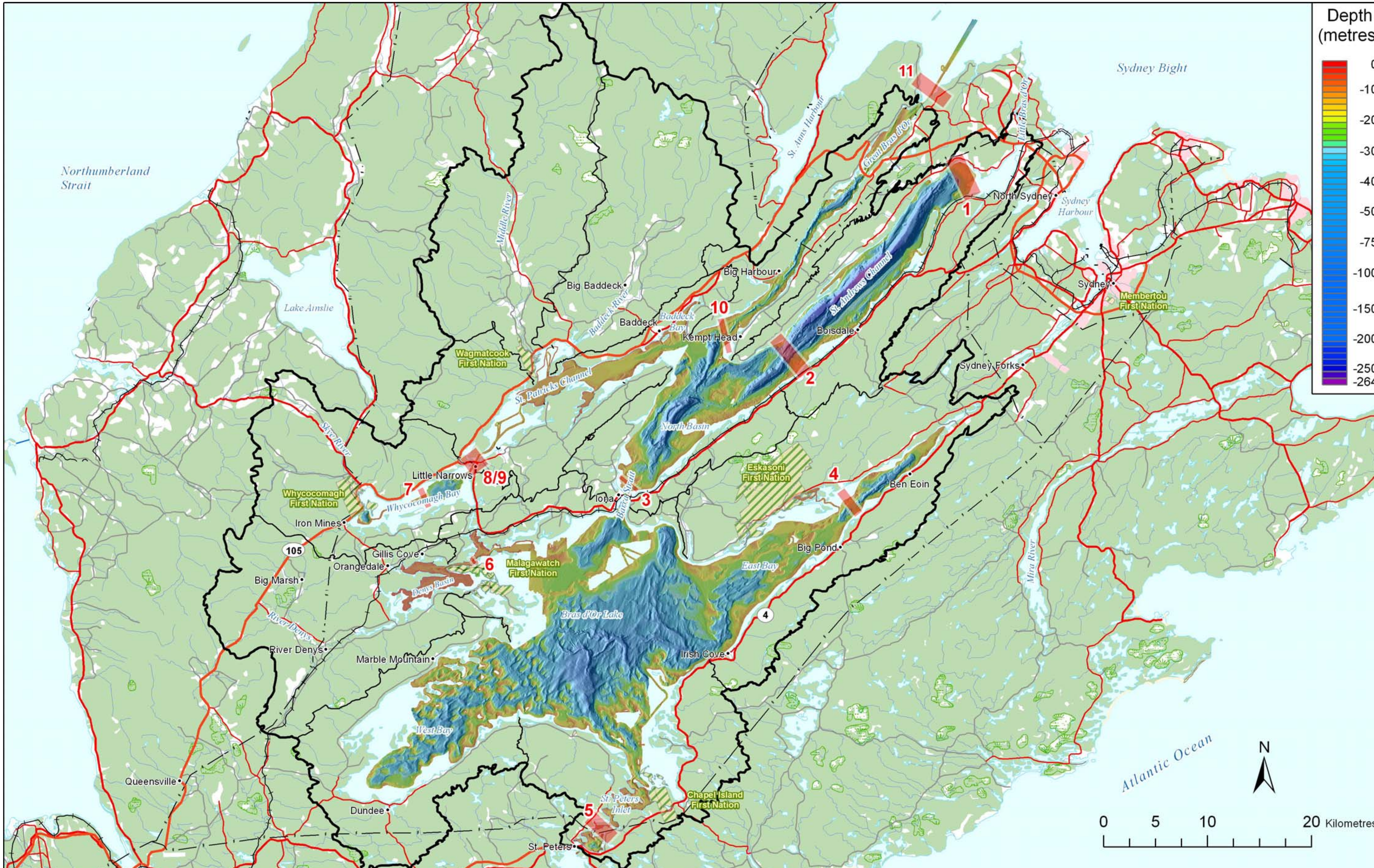


Figure 3. Multibeam coverage of the Bras d'Or Lakes and approximate location of the larger sills within the Lakes
Data sources: DFO (2003); Multibeam data (Geological Survey of Canada, Natural Resources Canada and the Canadian Hydrographic Service of Fisheries and Oceans Canada); Basemap (Natural Resources Canada, National Topographic Database 1:250,000 3rd Edition)

5. Sedimentology – Lake Bed

5.1 Nature and Characterization of Surface Sediments

Although the Bras d'Or's major sculpting mechanisms were plate tectonics and faulting followed by glacial scour, the surficial substrate on the bottom of the Lakes has been deposited after those events by erosional and depositional processes. Glacially deposited tills, which would have provided the Lakes with a much more diverse and hard substrate are commonly found overlying the bedrock to depths of 30 m or more (Shaw et al. 2002). These underlying till materials have created many of the barrier beaches and spits around the Bras d'Or (Davis and Brown 1996b) where wave action in the shallow waters has kept them exposed. However, much of the glacial substrate, recessional moraines, and drumlins have since been overlain in nearly every area by finer glacial rock flour, post glacial sediments transported to the Lakes by rivers, and by mud and fines deposition from both freshwater processes and marine diatom and dynoflagelate cysts. This geological history means, in short, that 3-9 m of mud and silts are covering the floor of the Bras d'Or system in all but the highest velocity current areas. Steep wall features of some of the deeper channels, shallow areas where wave action occurs, and the larger glacial moraine and drumlin features are areas where less muddy substrates have been found to occur (Shaw et al. 2002), but even in such areas a carpet of mud exists.

Creation of these fines from landscape and shoreline erosion is understandable, as only 13.5% or 165 km of the 1234 km coastline of the Bras d'Or Lakes are rock (Taylor and Shaw 2002). The majority is unconsolidated material of the Windsor Formation, found in the local surficial geology and along a majority of the Lakes' shoreline. These materials erode relatively easily and contribute to the silty, muddy bottom of the Lakes. In 1967 (Vilks), some 196 substrate stations were sampled and analyzed for grain size. Depth and current were important factors in determining grain size, and as such the Great Bras d'Or Channel and more shallow regions of the Lakes typically contain coarser sediments (Vilks 1967). Fines are typically twice as thick in basins as over ridges, and this thickness appears to be influenced by the tidal currents between the Great Bras d'Or Channel and the Barra Strait. Sands, which are some of the coarser substrate, are found in some tidal current flushed areas such as the Great Bras d'Or Channel and Barra Strait. The more exposed shallow fringes of the Lakes are also commonly floored by gravelly sandy mud, where wave action prevents the buildup of fines. Similarly, West Bay, which was one of the final ice centres during the last glaciation, has less muddy deposits over till layers (Shaw et al. 2002).

Land based erosion transported by the rivers around Bras d'Or to the marine environment has also contributed to the layer of mud that has settled over the glacial features of the Lake floor. Naturally occurring in some surficial geology, heavy metals may be found in some of these sediments, carried from the land base by freshwater flows. These may include cadmium, zinc, lead, copper, manganese, and iron depending on location (Strain and Yeats 2002). Heavy metals of this nature are found primarily in the geology north of St. Patricks Channel.

Throughout most of the Bras d'Or Lakes, the appreciable layer of fine sediments forms an unstable substratum that affects the biological character of the Lakes. The muddy unconsolidated bottom impedes macrophyte growth by providing few hard anchoring points. In turn, the lack of macrophyte growth then limits various other habitat values for many marine fauna. The Great Bras d'Or Channel and the various shallow parts of the Lakes that have coarser sediments, ranging from sand to boulders (Kenchington and Carruthers 2001) often become covered in algae in areas otherwise free of aquatic vegetation (McLachlan and Edelstein 1971).

Recently the lakes have undergone multibeam sonar surveys. Backscatter measures allow determination of surficial "hardness" and interferometric sidescan reflects the solid bottom contour that underlies the surface muds. A series of maps have been produced interpreting some of the results of the multibeam surveys (Shaw and Potter 2006a-d). These maps show a detailed morphology of the Lakes, highlighting submerged river beds and drumlins, oyster bioherms and deltas.

Backscatter mapping is interpreted based on photographic evidence and core samples from the seabed in order to characterize the sea floor substrate. Hard substrates that are bouldery gravel are found on the Cod Shoals of the Bras d'Or Lake. These appear to be a part of an old moraine that extends from Malagawatch in a northeastern direction (Shaw and Potter 2006a). Similar substrates are found in both East and West Bays where drumlins, which would have been exposed 6500 years ago when the water level of the Lakes was 25 m lower, were eroded by wave action during that time exposing a coarse shoreline substrate that has since become submerged (Shaw and Potter 2006c). North of the Barra Strait, St. Patricks Channel has the lowest backscatter values indicating the most area covered by mud. A large delta exists where St. Patick's Channel and the Great Bras d'Or Channel meet with the North Basin, indicating where a former river emptied from St. Patricks Channel into a lake body at Red Head during the Holocene (Shaw and Potter 2006d).

Shaw et al. (2002) have further described the marine geology of the Bras d'Or. This work is primarily based on two seismic surveys and sediment core surveys conducted in 1985 and 1996.

6. Geological System Information Gaps

Geological information gaps within the Bras d'Or Lakes watershed primarily relate to how the surficial geology affects the biota, and how the geology responds to human disturbance. The interaction with the biological community is least well defined for the marine substrates. Detailed description of what habitats may be present for both marine plants and animals is lacking. Recent multibeam imagery of the lake bottom has been mapped (Shaw and Potter 2006a-d). If detailed assessment of these mapping products from both geological and biological perspectives takes place, it will allow for a much better description of lake bed habitat types and locations, and partially fill this gap in knowledge. Additionally, a new sidescan survey method tested in shallow waters of Denys Basin (Vandermuelen pers. comm. 2006) may help to fill the information gap in the nearshore that could not be covered by the deeper water multibeam surveys. Knowledge of substrate types and locations is critical for the future management of critical habitats and keystone species within the Bras d'Or.

Erodible soils can have significant implication for aquatic health if they are disturbed by land use and cause excessive sedimentation. Many of such impacts are cumulative in nature, and need to be addressed across a broad scale. Assessment of land use such as forestry, agriculture, and road densities, on erodible soils may indicate higher environmental risks. Assessing suspended sediment loads in streams and rivers would help quantify potential impacts and identify areas of concern. Although sedimentation has been observed, for example in Denys Basin (Shaw and Potter 2006 a, c; Barrington 2005), and potential sources identified (ECA 2001), rates of sedimentation and areas of impact have not been quantified. This gap needs to be filled to allow prioritization of sedimentation as a management issue.

Metals have been observed in both the coastal waters, sediments (Yeats 2005; Creamer et al. 1973), and biota (Chou et al. 1999; Young 1973a, b) of the Bras d'Or Lakes, and some assessments of metals in rivers have been made (Strain et al. 2001; Dalziel et al. 1998; Young

1973d). These studies indicate that there may be areas of concern for a few measured parameters. This leads to a need to quantify natural metal levels from local geology and determination of accelerated delivery associated with land use.

PART B – OCEANOGRAPHIC SYSTEM

7. Atmospheric Components

7.1 Seasonal Climatic Patterns

7.1.1 Air Temperature

Cape Breton has a climate generally typical of its part of Atlantic Canada, with the combined influences of the Atlantic Ocean and of the continental upwind. The effects of sea ice, largely from the Gulf of St. Lawrence, accentuate the usual pattern of an island in a cold sea and give Cape Breton later springs and shorter summers than much of the adjacent mainland enjoys (Kenchington and Carruthers 2001).

Baddeck has the only weather station on the Bras d'Or Lakes that meets the World Meteorological Organization's standards for temperature and precipitation. These standards mean that the station can be used to prepare 30-year normals for these parameters. Daily average temperatures for the Baddeck location are highest in July and August at just over 18 C for the 1971-2000 data. The extreme maximum for this location was recorded in August of 1935 at nearly 37 C. Between 1963-93 the winter months of December through February averaged –4.5 C. An extreme minimum was recorded at the station in February 1833 of –32 C. The most recent thirty-year average for the coldest month, also February, is –6 C (Environment Canada 2005a).

According to TEK, in general the weather is much warmer in the Bras d'Or area than in previous years (CEPI 2006). The winters are warmer with more rain. Summers are hotter than before. There are a lot more storms that are more severe.

7.1.2 Precipitation

Most of the Bras d'Or watershed has a mean annual runoff of 1200-1300 mm based on the 1969-1983 provincial isograms (Davis and Brown 1996a). However, some headwater areas of the Baddeck and Middle Rivers are likely to receive more than the mean annual precipitation.

Periods of heavy rainfall can significantly alter salinity in the Lakes to a depth of 5 m or more (Wright 1976). Compared with other systems in Atlantic Canada, river and marine inputs of nitrogen to the Bras d'Or are relatively small. Given this, precipitation becomes relatively more important to the system than it is in other locations. Although precipitation levels are not significantly different than other locations, the atmospheric deposition of nutrients through precipitation is a greater percentage of the total nutrient input to the Bras d'Or (Strain and Yeats 2002).

At Baddeck, Krauel (1976) noted that the long-term average annual precipitation was 1250 mm, with a seasonal cycle that features a maximum monthly amount in November and a minimum in July. Current data from Environment Canada (2005a) suggest some changes (Table 4). Although the average low still occurs in July, the 1971-2000 data show that a monthly high total precipitation of 172 mm occurs in December, a month later than Krauel observed. Furthermore, the long-term annual precipitation for the normal period 1971-2000 has averaged just over 1500 mm, up some 250 mm from the previous 30 years. An increase is also found at Sydney airport (1340.9 to 1504.6 mm), and there does not appear to be any data inconsistencies.

Therefore, there appears to be a gradual increase in precipitation amounts at Baddeck over the past 60 years (Morin pers. comm. 2005).

Greatest snowfall occurs in December and January, the two months for which Baddeck averages over 70 cm. On the ground snow pack reaches a high monthly average of 23 cm in February, which corresponds with the coldest average temperatures for the station. This reflects the snow not only falling, but also staying on the ground with the colder temperatures. The thirty-year average, ending in 2000, shows that there is no snow on the ground by the end of April (Environment Canada 2005a).

Table 4. Climatology data for the weather station in Baddeck, the only station on the Bras d'Or meeting the World Meteorological Organization's standards to prepare thirty-year normals

	Spring	Summer	Winter	Fall	Annual
Precipitation 1961-1990	423 mm	344 mm	452 mm	579 mm	1500 mm*
Rainfall 1971-2000	-	-	-	-	1202 mm
Snowfall 1971-2000	-	-	-	-	298 cm
Temperature 1963-1993	2.3 °C	16.2 °C	8.5 °C	-4.5 °C	6.2 C*

Source: Environment Canada 2005a
* Annual averages from 1971-1990, all others as listed.

The locally higher temperatures and the protection of the surrounding hills, mean that the Bras d'Or Lakes avoid much of the sea fog seen offshore, except for the Great Bras d’Or Channel and St Peters areas. Early morning radiation fog may develop in coves for a short time during the summer (Bowyer 1995) and has been observed along the entire length of St. Patricks Channel (Lambert pers. comm. 2005).

7.1.3 Prevailing Winds and Storms

Prevailing winds during summer are from the southwest, and stronger winds from the north-northwest dominate the fall and winter (Parkes and Gray 1992 cited in Taylor and Shaw 2002). These winds are shaped by low-pressure storms that typically track over or south of the area in winter and north of it in summer. The result is winter winds averaging 20 knots (Kenchington and Carruthers 2001), and prevailing southwesterly summer winds of 10 to 15 knots with gusts up to 25 knots (Bowyer 1995).

Fall winds on the Bras d’Or are significant to the seasonal chemical properties of the water. The winds deepen the surface mixed layer through increased wave action, and are thereby one of the mechanisms that contribute to higher surface nitrate levels in the fall (Strain and Yeats 2002).

Although winds can generate currents, strong wind driven currents are typically not seen in the Bras d’Or because of the constricted watershed geography that leads to relatively short fetch, or open water distance over which winds can blow. When these phenomena do occur, they are very small in magnitude (Krauel 1975). Turbulent mixing from wind generated currents is only of significance in its effect on the chemical structure of the Lakes where the water depth is quite shallow (Ocean Science Associates 1972) and in Bras d’Or Lake where fall waves of 2-3 m are not uncommon (Lambert pers. comm. 2005).

Within the Lakes, the surrounding hills cause channelling of the winds, "corner effects" around prominent headlands, and in some places funnelling which all lead to local increases in wind speeds. The multiple directions from which wind can reach certain parts of the Lakes as it flows around the complex landmasses, can set up confused cross-seas. For example, St. Patricks Channel is subject to violent gusts and "lee waves" from oscillations in the air produced as it flows over the mountain barrier to the west. At the same time, gentle "katabatic" winds will blow into Nyanza Bay in the evenings as cool, dense air flows down the hill slopes (Kenchington and Carruthers 2001). These two wind directions can set up crossed waves in the area.

7.2 Heat Exchange and Budgets

Atmospheric and geothermal heat exchange and budgets with the waters of the Bras d'Or have not been explored in detail. It is known that surface waters go through a period of significant warming through the summer months, changing from a frozen surface to temperatures as high as 23 C in the mixed waters of the Barra Strait. Meanwhile waters from the deep portions of St. Andrews Channel tend to stay between –1 C and 1 C year round (Petrie and Bugden 2002).

The only work on atmospheric heat exchange is preliminary estimates made for Whycocomagh Bay. This Bay had the highest surface water temperatures within the Lakes in the 1974 data set examined (Gurbutt and Petrie 1995). Gurbutt and Petrie estimated net heat flux into the surface to be 130 W/m^2 based on the June 1974 data. As surface temperatures in other areas of the Lake were colder, it would be expected that greater heat flux from the atmosphere was likely occurring elsewhere (Gurbutt et al. 1993).

Additionally, Rankin and Hyndman (1971) tested a method used for measuring the upward flow of geothermal heat through the deep-ocean floor by applying it in the deepest basin in St. Andrews Channel. During this process they produced an estimate of the heat flux (after a number of corrections) of 63 mW/m^2. That value was slightly higher than the values previously reported for other points in the Maritimes, though not unexpected for the wider Appalachian region. This heat flow value is too low to have any appreciable effect on the temperature of the bottom water in the Lakes (Kenchington and Carruthers 2001).

7.3 Air Quality

Various human activities can affect air quality which, in turn, can have adverse effects on species and environments. Air quality indexes (AQI) are measured at more than 20 sites in Atlantic Canada by the Atlantic Region Ozone Monitoring Network (Environment Canada 2003). This Network is a provincial/federal partnership between Environment Canada and the New Brunswick Department of Environment and Local Government, the Nova Scotia Department of Environment and Labour, the Prince Edward Island Department of Fisheries, Aquaculture and Environment, and the Department of Environment of Newfoundland & Labrador.

The AQI is an indicator of air quality, based on hourly pollutant measurements of some or all of six common air pollutants: sulphur dioxide (SO2), ground-level ozone (O3), nitrogen dioxide (NO2), total reduced sulphur (TRS), carbon monoxide (CO) and fine particulate matter (PM2.5) (Environment Canada 2003). Values for the AQI fall into 4 categories (Table 5).

Table 5. Air quality index interpretation

Air Quality Index Value	Category/Interpretation
≤25	Good
26-50	Fair: there may be some adverse effects on very sensitive people.
51-100	Poor: may have some short-term adverse effects on the human or animal populations, or may cause significant damage to vegetation and property.
>100	Very poor: may cause adverse effects on a large proportion of those exposed.

Source: Environment Canada 2003

There are two measurement sites in Cape Breton: Sydney and Port Hawkesbury. The AQI measured at the Sydney site is generally of good condition. For example, in 2005, there were only 11 days in the calendar year that had maximum AQI in the fair (8), poor (2) or very poor (1) category (Environment Canada 2005b).

The Air Quality Branch of the Nova Scotia Department of Environment and Labour is responsible for the management of outdoor air quality. One of the priorities of the Branch is to develop Nova Scotia's approach to airshed management and identify airsheds in Nova Scotia. There are no known studies of air quality in the area of the Bras d'Or Lakes.

8. Physical Oceanography

The Bras d'Or Lakes physical oceanographic character is that of minimal mixing, movement, and tidal change. A pronounced thermocline exists throughout much of the year, influenced by solar warming and freshwater inputs. Only in a few constricted areas does tidal exchange create enough turbulence to mix the waters of the surface layer with those below throughout the year.

8.1 Freshwater Inputs

Compared to the surface area of the Lake, freshwater inputs are relatively small. This is because the watershed basins that exist around the Lake are small. However, it is this freshwater input that makes the Bras d'Or Lakes an estuarine system. Much of the freshwater resource entering the Lakes drains the land through first and second order streams. However, there are a few large rivers, almost exclusively in the northern half of the Lakes, that have formed significant deltas and wetlands where they enter the Lakes. The largest extent of coastal wetland and marsh shores lie within Denys Basin and head of Whycocomagh Bay, but large estuarine wetland and marsh communities also cover the deltas of Skye, Middle, Baddeck, Denys, Washabuck, Black and Benacadie Rivers (Taylor and Shaw 2002).

The larger drainages on Cape Breton Island, such as the Margaree River, Mira River, and River Inhabitants, do not flow into the Bras d'Or but instead flow directly to the Atlantic Ocean. The six largest rivers flowing into the Lake account for 42% of all flowage (Table 2), with the remaining 58% resulting from streams (UMA Group 1989). The land mass associated with the small first and second order stream watersheds that feed directly to the Lakes is significant to the total Bras d'Or Lakes watershed area.

The watershed areas, both land and water, are about 1500 and 2200 km^2 for the regions north and south of the Barra Strait, respectively, with a mean freshwater inflow of 140 m^3/s[1] (Gurbutt and Petrie 1995). There does not appear to be significant differences in freshwater runoff per unit of surface area between the watersheds north and south of the Barra Strait. However, at the bay-scale, St. Patricks Channel does receive a disproportionately large input for its surface area for the large Baddeck and Middle River watersheds, and several smaller watersheds that empty into the Channel.

The Bras d'Or Lakes surface area covers approximately 1080 km^2, or 1/3rd of the total watershed area (both land and water surfaces). Given the relatively small watershed area and large surface area of the Lakes, rainfall on the surface and evaporation from it must be considered when determining the total inflow. Maximum inputs of freshwater occur during the spring months of April/May when almost 250 m^3/s enters the Lakes. The melting of ice cover on the Lakes and surrounding snow, followed by spring rains contributes to this maximum (Gurbutt and Petrie 1995). This is followed by base flows of 50 m^3/s from July to September, and a second peak of approximately 170 m^3/s in November - December (Petrie and Bugden 2002) associated with fall rains. Overall, the weak inflow of freshwater to the Lakes would annually amount to only 14% of the Lakes total volume.

Although it is relatively small in volume, the freshwater input is one of the major factors contributing to circulation in the Lakes because it significantly alters the salinity and density of surface waters in much of the Lakes. Freshwater inputs reduce the salinity of surface waters to 20-21 in the eastern end of East Bay (Davis and Brown 1996b), and near fresh water can be found in some of the more enclosed shallow bays that have moderate stream or river inputs. For example, salinity in Denys Basin has been measured at 4-5 ppt in the top 0.5 m of water (Petrie pers. comm. 2006). Along with influencing salinity, the freshwater bodies likely have local impact on the temperature regime of the bays into which they flow. At yet a smaller scale it has been suggested that groundwater has great influence on some of the coastal barachois ponds, not only bringing freshwater characteristics but also potentially creating localized conditions of hyper salinity as salt domes are dissolved into surface waters (DFO 2006). Elders have observed lower water levels in freshwater systems compared to 50 years ago, and some brooks have simply dried up (CEPI 2006).

MacMillan et al. (2005) recently documented June 15 - September 5 average temperatures for the Middle River, Baddeck River and River Denys as being 19.9 C, 17.9 C and 18.1 C, respectively. All had days above 20 C, and the River Denys had a high one day average of nearly 25 C in 2000. Stevens and Denny (1993) reported that Indian Brook at Eskasoni varied from 21 - 24 C between July and August 1993. These temperatures, although not scientifically evaluated, likely contribute to the warming of surface waters in several localized areas of the Bras d'Or. Nonetheless, the Middle River and Baddeck River are still two of the cooler systems in the Province (MacMillan et al. 2005), a characteristic that helps support freshwater salmonid production.

At the time of writing this EOAR, efforts were underway to create a description of the fresh water resources of the Bras d'Or Lakes watershed for a State of the Environment Report. Although it does not include new information, all the existing information on the physical/chemical characteristics of climate, groundwater, and streams was being compiled (ADI 2006).

8.2 Sea Level and Tides

The Bras d'Or is an area of limited tidal movement. Both tidal currents and tide height tend to be very small in all but a limited number of locations of the Lakes. The narrow and shallow sections of the Great and Little Bras d'Or Channels, that connect the Lakes to the open ocean, limit the volume of tidal exchange that can occur on each cycle (Dupont et al. 2003). The friction and turbulence resulting from the constriction of the Great Bras d'Or Channel's physical character is the primary factor responsible for moderating the semi diurnal and diurnal lunar tidal amplitudes within the Lakes by limiting the volume of water that can enter the Lakes during the peak periods of the tidal flow (Petrie and Bugden 2002). Within 2 km of Sydney Bight along the Great Bras d'Or Channel, the tidal amplitudes are already reduced by ~50% (Petrie 1999). This attenuation increases further into the Lakes with the result being a small tidal range of 0.15 m near Baddeck that becomes almost imperceptible in other smaller sub-basins. A 21-day record from the western end of Whycocomagh Basin indicated no detectable semidiurnal or diurnal tides (Dupont et al. 2003; Petrie 1999).

Tidal currents in the Lakes as a whole are generally less than 0.1 m/s based on modeling. Smaller basins, like Denys Basin, have tidal currents less than 0.03 m/s and amplitudes of less than 0.03 m (Dupont et al. 2003).

Although overall tidal flows are small throughout the Lakes, there are locations such as the Barra Strait and the Great Bras d'Or Channel where huge volumes of water try to pass through constricted areas on each tidal cycle. The result is significant tidal velocities and related turbulence and mixing. Maximum velocities for the Lakes occur at the Barra Strait (1 m/s) and Great Bras d'Or Channel (3 m/s). These areas are dominated by strong semi-diurnal tidal currents (Petrie and Bugden 2002).

The Bras d'Or has the smallest tidal ranges of shorelines around Nova Scotia. Interestingly, barometric pressure can have a greater effect on water levels within the Lakes than lunar tides. These non-tidal sea level fluctuations associated with barometric changes retain at least 85% of the magnitude that is observed outside the Lakes at Sydney Bight. With variations of up to 50 cm, barometric tides are about 10 times larger than the lunar tides. These non-tidal changes maintain much greater percent of their magnitude when compared to the lunar tidal changes because of the length of time over which the relevant fluctuations occur (Petrie and Bugden 2002; Petrie 1999). Barometric changes occur over days to weeks while lunar tides are occurring over approximately twelve hours. Friction and resulting turbulence in the Great Bras d'Or inhibit water level changes driven by higher frequency tides, but have less effect on the longer time frames associated with the barometric tidal changes. As this barometric influence is related to weather fluctuations, water levels within the Lakes have less predictability (Krauel 1976).

One of the ecological results of Bras d'Or's small tides is the extreme limitation of intertidal zones and the variety of species that such habitats support. As water levels do not rise and fall significantly over a cross-section of the nearshore, biota that specialize in living in the tidal areas around other parts of Nova Scotia are undoubtedly limited by the narrow fringe of intertidal habitat that is available around the Lakes.

Sea levels, and likely currents, have been very dynamic in the Bras d'Or over a relatively short time frame. During the Holocene epoch, the area of the Bras d'Or Lakes began as a freshwater system with sea levels about 16 m below current levels. Subsequently, the area was flooded by marine water some 9-10 000 years ago. The sea levels then dropped allowing the system to once again become freshwater. An eroded shoreline some 25 m below the current level of the Lakes is still visible, and marks the shoreline elevation of that freshwater system. Finally, rising sea levels again made the Bras d'Or a marine system 4-5000 years ago (Shaw et al. 2002).

Although there has been little direct study of sea level change in the Bras d'Or Lakes, TEK indicates a noticeable decline in the water level around the Bras d'Or (CEPI 2006). Elders have observed more low tides in recent times, and a lower water level around the Bras d'Or compared to the past. Although the water level is lower in the Bras d'Or, it quickly rises much more than the few centimetres it would have risen 30 years ago after a rainfall (CEPI 2006). This is attributed to the fewer trees in the area compared to years ago, which cannot absorb as much rainfall.

8.3 Water Masses and Currents

There is a net outward flow of surface waters and a net inward flow of the bottom marine layer to the Bras d'Or that characterize the system and are driven by the freshwater input to the Lakes (Figures 4a & 4b) (Petrie and Bugden 2002). This results in the freshwater inflows leaving the Lakes (advection) through the surface current, and the saltier waters entering as a subsurface flow from the marine environment. Temperature and salinity stratification of the Lakes enhances this circulation. The less saline surface layer tends to flow at a slightly higher velocity on the outgoing tide, varying with seasonal freshwater discharge changes, and helping to contribute to a dynamic equilibrium of salinity within the Bras d'Or. In this way, the Bras d'Or mimics a typical estuarine environment (Krauel 1976).

Wind and other meteorological conditions are the major factors affecting circulation, being responsible for as large or larger variations than the tide (Krauel 1976). However, the mean water circulation from spring through to fall consists of surface flow toward the ocean and bottom flow into the Lakes (Petrie and Bugden 2002). This pattern does not exist just in the Great Bras d'Or Channel, but is measurable through both the Barra Strait and Little Narrows (Gurbutt and Petrie 1995). Instances of vertical and horizontal exchange between these layers have been measured depending on seasonal and local changes and properties. Gurbutt and Petrie (1995) constructed a multiple box model of the water layers in the Bras d'Or Lakes consisting of two vertical boxes in most areas and a third box in deepwater areas. Circulation and exchanges between boxes were then derived from mass, heat, and salt balances. The deepwater layers, located in Whycocomagh Basin, St. Andrews Channel, and North Basin, are isolated waters with only vertical exchange with the box layer directly above it, and no horizontal circulation. Because of bathymetric isolation there is no direct horizontal connection to other deepwater areas.

The complex bathymetry of the Bras d'Or does, however, provide an opportunity for some vertical exchange. Gravity flows can move water away from a previously stable position whenever dense water reaches the lip of a deep basin filled with water that is less dense. One example of this may occur episodically at the Seal Island sill. Salty Sydney Bight water, with only a limited mixture of Lake water acquired in passing Carey Point, will reach the sill at the end of an ingoing tide. Passing the sill under the highway bridge, it could then pour down a slope into the first deep basin of Great Bras d'Or Channel providing it is denser than the water below. Similar gravity-driven flows are probably involved in the flushing of each of the deep basins, at least those north of the Barra Strait, with saline water (Kenchington and Carruthers 2001).

Outflow from the Lakes is about 1100 m^3/s (Petrie and Bugden 2002). Tidal currents in the Great Bras d'Or Channel typically are 250 cm/s in deeper layers during flood and 150 cm/s for surface water during ebb. It has also been noted that currents at the entrance to the Great Bras d’Or on the Atlantic side, reach six knots or more from the combination of tides and mean circulation, particularly when the Lakes are elevated by spring runoff and/or northeast gales (Davis and Brown 1996b). Tidal currents at the Barra Strait are consistently 40 cm/s whether an inflow or outflow (Petrie and Bugden 2002).

Compared to these primary constrictions within the system, currents within the various basins around the Lakes are weak, with typical mean amplitude of 0.3 cm/s (Gurbutt and Petrie 1995). In the more studied areas we know that areas of low circulation include Whycocomagh Bay, Denys Basin, and small bays in St. Patricks Channel such as Nyanza Bay (Strain and Yeats 2002).

Given the constriction of the Great Bras d’Or, the flushing rates for a body the size of the Lakes is quite long, with some enclosed and deep areas flushing at extremely low rates. Theoretical flushing times derived from modeling suggest that Whycocomagh Bay has the longest flushing time in the Lakes at approximately two years, and the deepest part of the Lake in St. Andrews Channel follows at about 260 days (Petrie and Bugden 2002; Gurbutt et al. 1993).

The overall pattern of outward surface layer flow is from the southwestern region of the Lakes toward the Barra Strait, with transports from the West Bay about 3 times stronger than those of East Bay. The surface water moves through Barra Strait into North Basin where it combines with weaker flows from St. Patricks and St. Andrews Channels. This surface circulation that contains freshwater surface discharge then flows strongly through the Great Bras d’Or Channel to the Atlantic. Subsurface flow moves in the reverse direction from the marine environment to the various bays of the Bras d’Or, and carries higher salinity water into the system (Petrie and Bugden 2002; Gurbutt and Petrie 1995). Sand waves and rippled sands have been observed on sidescan sonar throughout much of the Great Bras d’Or Channel, indicating significant levels of bottom current activity and sediment transport (Myers and Gilbert 1993).

Tidal jets at Barra Strait may be of crucial importance to the ecology of the Lakes since the associated turbulence seems to be responsible for a very high proportion of the mixing of surface and deeper waters in Bras d'Or. This draws deeper water up into the surface, and at the same time brings up salt (to maintain the salinity of the surface layer) and the nutrients needed to promote plant production in the summer. It has been speculated that the flow through this Strait may prove to be the primary engine driving the Bras d'Or ecosystem (Kenchington and Carruthers 2001).

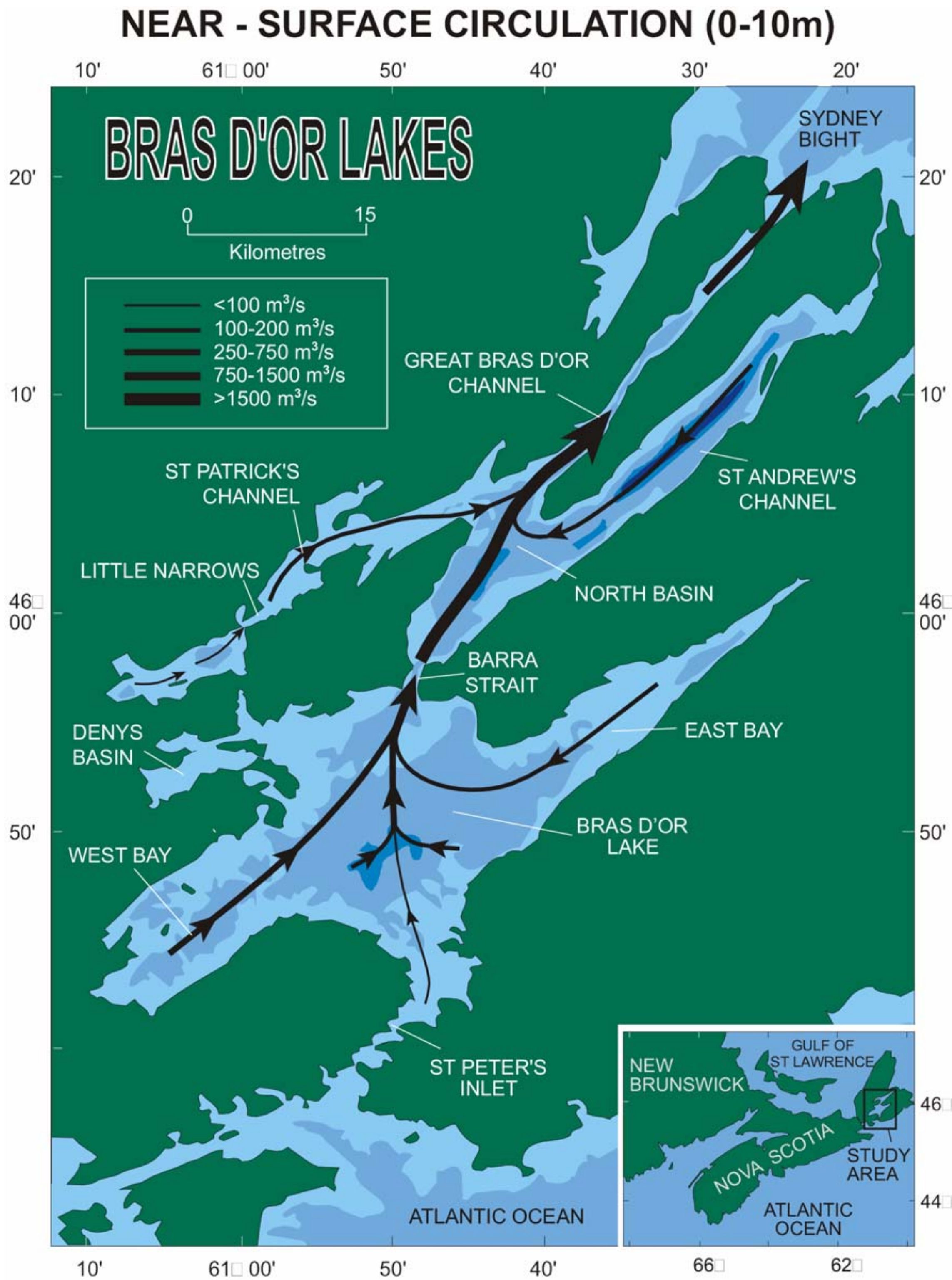


Figure 4a. Net flow of near-surface circulation in the Bras d'Or Lakes (Petrie and Bugden 2002)

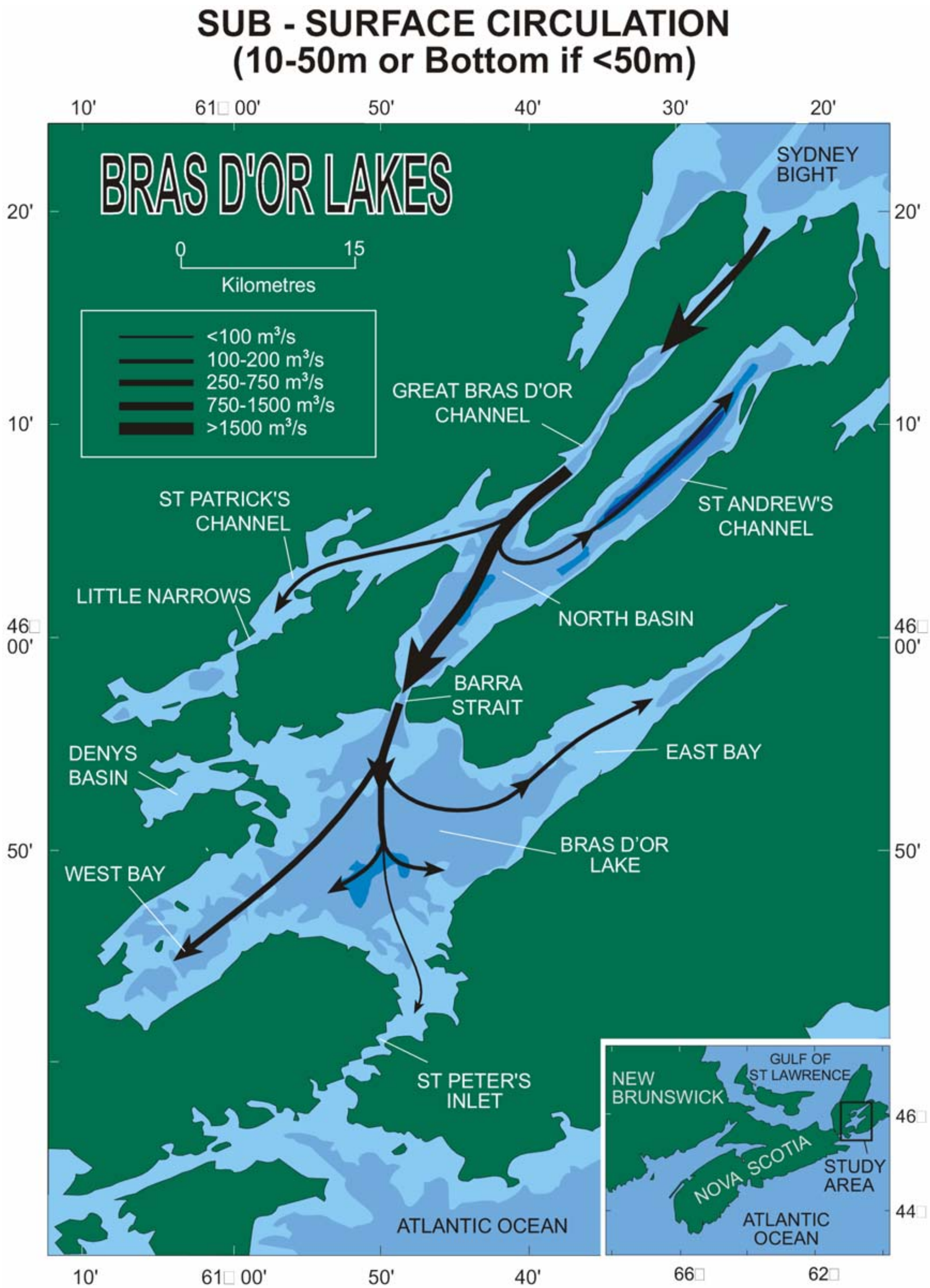


Figure 4b. Net flow of sub-surface circulation in the Bras d'Or Lakes (Petrie and Bugden 2002). Figures 4a and 4b reproduced with the permission of the Proceedings of the Nova Scotia Institute of Science.

8.4 Stratification, Mixing and Upwelling

Both salinity and temperature stratification are critical components of the Bras d'Or Lakes ecosystem. The halocline and thermocline that occur in the Lakes influence circulation and mixing. Since these layers of stratification occur at or below the depth of some of the shallow bays and sills throughout the Lakes, unique local chemical properties result, influencing the composition of local biota.

The salinity stratification typically occurs along with the thermocline at about 10 m below the surface (Krauel 1976). However, the thermocline and halocline are most well defined during summer, existing at between 10-20 m throughout much of the Lakes (Krauel 1976). A minor reverse thermal stratification, where the surface waters are cooler, can exist during the winter months because of ice cover (Wright 1976). However, the lack of winter studies of the Lakes leaves details of this situation still unclear. It is not just the larger more open bodies of the Lakes that exhibit this pattern of stratification.

Water in the restricted channels, such as Little Narrows, the Great Bras d'Or Channel, and Barra Strait also feature a bottom layer of more dense saline water. The interface between these layers can often be a substantially thick mixed body. The variability in the depth of the mixed layer between the seasons, and within the same season but between locations in the Lakes, can be large. For example during one study in November the mixed layer was found to be on average about 22 m deep, with a large standard deviation of 24 m (Petrie and Bugden 2002).

In terms of mixing within the Bras d'Or, three layers are generally discussed: a relatively fresh surface layer and a more saline middle layer that can mix vertically with each other or have horizontal exchange of layer characteristics; and a third deep layer that is categorized for a few locations such as Whycocomagh Bay, St. Andrews Channel and North Basin, where only vertical exchange with the middle layer above can occur as the deep morphometry of these basins separates and prevents horizontal exchange of this deep layer. It has further been estimated that mixing in the two deepest parts of the Lakes, North Basin and St. Andrews Channel, is 10-20 times less than in the surface layers, and is associated with weak currents at these depths (Petrie and Bugden 2002). Gurbutt and Petrie (1995) have generally defined three layers for the Lakes as being 0-10 m, 10-50 m, and >50 m, although there are both seasonal and local variations.

Mixing enhances the estuarine circulation of the lake; that is, the tendency for fresher surface waters to move toward the ocean and more saline bottom waters to move into the Bras d'Or (Petrie and Bugden 2002). Mixing within the Lakes occurs because of wind forcing, upwelling, tides, and current shear. Some of the more typical mixing characteristics within the Lakes are presented in Table 6. The most significant mixing force appears to be the strong tidal currents in the Great Bras d'Or Channel and the Barra Strait (Gurbutt and Petrie 1995). This mixing is the result of the shallow sill depth and adjacent vertical shear that cause waters to become vertically well mixed during the strongest tidal currents that occur at mid-tide (Krauel 1976), and therefore no thermocline exists (Wright 1976). Kenchington and Carruthers (2001) suggest that most of the downward mixing in the Great Bras d'Or Channel occurs as the tide flows past the Seal Island obstruction, rather than occurring more uniformly throughout the Channel. The Barra Strait is another area of significant tidal flows that promote mixing of fresh surface with more saline waters.

Table 6. Some select mixing characteristics within the Bras d'Or Lakes

Mixing Characteristic	Great Bras d'Or Channel	Whycocomagh Bay, East Bay, St. Andrews Channel	West Bay, St Patricks Channel, North Basin, Bras d'Or Lake
Relative mixing intensity	100-150	1	10-30
Strongest Mixing Factor	Current associated with semi diurnal lunar tide, downwelling	Limited surface mixing and upwelling.	Upwelling, surface mixing.

Source: Based on Petrie and Bugden 2002

It has been suggested that vertical mixing at the Barra Strait might be the primary engine driving productivity in the Bras d'Or ecosystem (Kenchington and Carruthers 2001). In fact, research supports the concept if not the magnitude of this suggestion. Gurbutt and Petrie (1995) have modelled significant vertical mixing in North Basin, leading Strain and Yeats (2002) to suggest that the flux of nitrate to surface layers is 5-10 times greater north of Barra Strait than in Bras d'Or Lake, and making the northern areas significantly more productive. However, if the Barra Strait is the dominant mixing mechanism bringing nutrients to the surface waters, as suggested, then one would expect the horizontal flow of water across the Strait to the south would cause higher levels to be observed there as well.

Upwelling, the simple transport of water vertically in the water column, mixes the salinity, dissolved oxygen, nutrients, and temperature from the deep bottom layer to the surface layer of the water column. There are few areas of upwelling within the Lakes, with the strongest being in North Basin and Bras d'Or Lake. The Barra Strait separates these two areas, and the largest influences on the local upwelling are seasonal surface water temperature changes and tidal turbulence that occurs at the Strait. The presence of significantly deep basins on each side of the Barra Strait further contributes to the temperature profile and marine nutrient stores that are key components of the upwelling. In contrast, Whycocomagh Bay has no upwelling, despite the two deep basin features in the Bay. This is likely a result of the shallow sill leading to St. Patricks channel isolating Whycocomagh Bay from the rest of the Lakes (Petrie and Bugden 2002).

Downwelling within the Lakes occurs almost exclusively in the Great Bras d'Or Channel. In contrast to the rest of the Lakes, there is net downward mixing in the Channel, which means that much of the fresher surface lake water is recirculated. This substantial downward mixing is a key feature of the Bras d'Or system and differentiates it from other estuaries. It means that three-fifths of the surface water passing Kempt Head outbound is recirculated back into the Lakes in the deep layer (Gurbutt and Petrie 1995). Kenchington and Carruthers (2001) suggest that recirculation of surface waters to the Bras d'Or could be even greater than the three-fifths that has been modeled.

As temperatures and density of surface waters cool in the fall and become closer to density of the deeper waters, vertical mixing occurs more easily. It is likely that the degree of mixing between the surface and middle layers is greatly increased when early-winter storms disturb the more uniform temperature waters. After this period, ice cover likely reduces such mixing (Kenchington and Carruthers 2001). Ice cover can reduce circulation within the Lakes by cutting off direct contact with atmospheric forcing (Petrie and Bugden 2002).

Once the surface begins to freeze, other processes may become important, yet our ability to study these processes becomes more limited. When saltwater freezes, the salt content of the ice is lower than that of the water from which it forms and the excess salt raises the salinity of the water immediately under the ice (Krauel 1976). This will produce very cold (approx. –1 C) water of a salinity greater than 20 ppt, though how much greater is unclear. This very cold, salty water is also of increased density. Therefore, it is likely to sink in many areas displacing the intermediate-depth water below it. Whether the water's density and salinity is high enough (about 22 ppt) for it to sink to the bottom of Bras d'Or Lake is uncertain, but it is possible that much of the more saline bottom water south of Barra Strait is produced by this local sinking of surface water rather than by inflow from the deeper waters of the northern basin. North of Barra Strait, bottom salinities are much higher (around 25 ppt) and it is unlikely that this under-ice sinking is a major contributor (Kenchington and Carruthers 2001). The bottom temperatures in the deepest basins are cold as well as saline (0.33 C and 25.43 ppt in St. Andrews Channel, Petrie and Bugden 2002). The mixing processes in Great Bras d'Or Channel can only form water with those characteristics during winter and early spring, as both the Sydney Bight inflow and the Lake-surface outflow are substantially warmer from May until late in the fall. Thus, the seawater inflow to these deep basins, though not necessarily to the Bras d'Or system as a whole, appears to be seasonal (Kenchington and Carruthers 2001).

Overall the mechanism for deepwater mixing is not well understood, and likely occurs between early winter and ice off in the spring when few in situ observations are available. Dissolved oxygen (DO) measurements in some of the deepest basins indicate that exchange occurs. Vilks (1967) noted that anoxia did not occur in most areas, and others have shown that in the deepest portions of St. Andrews Channel and North Basin DO levels are typically 75% saturation or better (Krauel 1975; Strain and Yeats 2002; Petrie and Bugden 2002). Given that photosynthesis does not occur at such depths and oxygen consuming processes of detrital decomposition and respiration by fish and bottom dwelling animals do occur, oxygen replenishment in the deep areas must be occurring. The most logical explanation is a mixing of oxygen rich surface waters with the deepwaters of the Lakes at a time of year that has not been documented by surveys (Ocean Science Associates 1972).

8.5 Waves and Turbulence

During 1992-93, wave rider buoy data were collected in North Basin and Bras d'Or Lake by Environment Canada. The typical range of the period between waves was documented as 2-4 seconds. Waves in the North Basin tend to be smaller than those in Bras d'Or Lake (roughly half the significant wave height) for a given wind speed. This is most likely attributable to the greater fetch, or distance the wind blows over water from the lands edge, in Bras d'Or Lake. The greatest fetch for the dominant wind direction over Bras d'Or Lake, the most open body in the watershed, was 28 km (Petrie and Bugden 2002).

The limited fetch across the Lakes constrains wave height and length formation. They may be steep, and even quite high when winds are strong, but they cannot be long, since the development of long waves requires the wind to blow across a wave train for a prolonged period - which it cannot do if the waves reach a lee shore in only a few kilometres. Since it is the length of waves, rather than their height, which determines how far down into the water column their action is felt, this lack of fetch means that Bras d'Or waves may stir the surface layer but they cannot have any influence below a few metres of depth (Kenchington and Carruthers 2001). However, as stratification weakens and mixing occurs more easily, fall winds on Bras d'Or Lake become significant to the seasonal chemical properties of the water. The winds deepen the surface mixed layer through increased wave action and through the generation of wind-driven currents, and are thereby one of the mechanisms that contribute to higher surface nitrate levels in the fall (Strain and Yeats 2002).

The most significant turbulence occurs in the Great Bras d'Or Channel as a result of tidal action and low frequency currents. However the combination of the finer grain sizes of muds and sands that dominate substrates in most areas of the Bras d'or Lakes and the minimal regular sea level changes result in little intertidal turbulence over the entire system. This is unique compared to most shorelines of Nova Scotia where strong tides move over rocky shorelines creating significant turbulence and mixing in the intertidal zone.

8.6 Ice Cover

Most of the Bras d'Or Lakes becomes ice covered in winter. Ice cover typically begins to form in January with a peak cover occurring in early March. Greater and longer ice cover occurs in the area north of the Barra Strait compared to Bras d'Or Lake and other areas to the south where greater wind and wave action inhibit formation and encourage ice breakup. All cover is usually gone by early May. Normal ice cover approximates 70%, but ice cover varies considerably (Table 7). During cold winters there will be 100% coverage (Petrie and Bugden 2002), and ice can be as thick as 1.5 m (Fournier and Pocklington 1984). It has been observed that up to the early 1980's ice conditions were safe enough to carry vehicles, with as much as 40 cm thickness being noted during winter hydrographic surveys. In the 1920's through the '50's, an ice route marked with spruce trees was regularly established across the St. Andrews Channel. Since the mid 1990's locals have observed the Great Bras d'Or with ice cover only once in 2002 (DFO 2006).

Traditional ecological knowledge indicates that no ice forms on the Lakes in the winter whereas about 40-50 years ago there was 4-6 ft of ice on the Bras d'Or Lakes (CEPI 2006). This lack of ice cover has been particularly evident in the last 10 years. A lack of ice on roads and land near Whycocomagh has also been observed by Elders, and ice has not formed on Baddou Island in recent years. Forty years ago, it was colder and the ice would stay until June. Although not located within the watershed, Elders recount a story of Sydney Harbour being frozen all year in the late 1890s. Residents drove from Crane Cove to East Bay on the ice 50 years ago but this can no longer be done. Residents would drive from Malagawatch across Bras d'Or Lake to Kelly's Shoal to go ice fishing in the winter. Cars could drive on the ice by Christmas in the past. Horse races used to be held on the ice. Contrary to the greater ice in the past, it was also noted that in 1933 one resident's father rowed across St. Peter's inlet for all but two weeks, so it was also warm at some points in the past. Although in general winters are warmer now, about 3-5 years ago in Nyanza, the winter was very cold and the ice froze to the bottom and killed the eels (CEPI 2006).

Trends analyzed for rivers and lakes of the Northern Hemisphere indicate an average freeze date that is 5.8 days/100 years later and a breakup date of 6.5 days/100 years earlier between 1846-1995 (Magnuson et al. 2000). A preliminary review of river ice data for Atlantic Canada show that in the shorter time frame of 1955-1998 the number of days with ice in the river has significantly increased, and that this appears to correspond to the North Atlantic Oscillation that influences our coastal winter weather (Brimley and Thomas 1999).

The Bras d'Or Lakes' surface layer is less saline than ocean water, freezing at a slightly higher temperature than the more saline water found in the open ocean or Sydney Bight. Ocean water typically freezes at -2.3 C. In the Lakes a less dense, very cold layer can float above slightly warmer but more saline water. In the absence of much wave action or much tidal mixing, this allows the surface to cool faster than the body of the Lakes and thus to freeze when the nearby waters of Sydney Bight and Chedabucto Bay do not (Kenchington and Carruthers 2001).

Table 7. A summary of the typical and range of measures for selected physical oceanographic parameters of the Bras d'Or Lakes

Parameter	High	Low	Typical or Average
Flushing Times	1.5 d	260-700+ d	7-90 d
Tidal Current Surface (out)	150 cm/s (Great Bras d'Or)	Near 0	0.3 cm/s
Tidal Current Bottom (in)	250 cm/s (Great Bras d'Or)	Near 0	0.15 cm/s >20 m
Depth	5 m (Denys Basin)	280m (St. Andrews Channel)	30 m
Lunar Tidal fluctuation	16 cm (Great Bras d'Or)	0 cm (Whycocomagh Bay)	3-5 cm
Barometric Tidal Fluctuation	50 cm	0	-
Ice Cover	100%	-	70%

Ice plays a role in the stratification of the Lakes by impacting both the temperature and salinity of the surface layer (Krauel 1976). It can profoundly affect circulation within the Lakes by cutting off direct contact with atmospheric forcing (Petrie and Bugden 2002), one of the more significant tidal influences in the Bras d'Or.

Ice floes from the Cabot Strait have been observed to enter the Great Bras d'Or Channel during the spring (Parkes and Gray 1992 cited in Taylor and Shaw 2002). Sea ice is often blown into large piles (rafts) in early and late winter along the shores of the Bras d'Or.

8.7 Underwater Sound – Sources and Propagation

There has been no apparent study of sound sources or impacts of noise pollution within the Bras d'Or Lakes (Hemphill pers. comm. 2005). Few potential sources of noise pollution exist, as there is minimal industrial development within the watershed. Some land based activities that may generate moderate noise level, such as mining and logging do occur, but little occurs adjacent to or on the waters of the Bras d'Or. Commercial fishing, aquaculture operations, and some localized shipping traffic are the most probable sources of sound that could affect the aquatic species of the Lakes. No research has been conducted locally to determine whether any impact exists. However, ecological impacts associated with sound disturbances that may exist in the Bras d'Or Lakes are expected to be minimal. Impacts would likely be associated with cumulative impacts from a number of noise sources, rather than from any single event or source. Evaluation of such cumulative sound impacts is not found in the literature. The following is a discussion centred on the most probable source of noise in the water column of the Bras d'Or Lakes, large and small vessel operation.

Sound from all sources diminishes (attenuates) with distance. Attenuation in water is fairly rapid close to the source but is more gradual at longer distances because sound levels diminish as a function of the logarithm of the distance from the source. As the distance from the source increases, the amplitude of the sound diminishes and the frequency spectrum broadens. Most of the loss in pressure is the result of spreading in the water. Spreading downwards in the water column is described as spherical spreading, whereas horizontal sound propagation is by cylindrical spreading (LGL Ltd. 2001 cited in TEC 2005). As shown in Figure 5, for spherical spreading in seawater, the sound loss is 20 log R dB, where R is the distance from the source in metres. This means that the transmission loss is 6 dB with each doubling of the distance (i.e. pressure decreases by one half with each doubling). For cylindrical spreading, which occurs to the sides, after some amount of spherical and intermediate spreading, the sound attenuation is 10 log R dB, or a loss of 3 dB with each doubling of the distance. In general, spherical spreading occurs out to a distance approximately equal to the water depth. Thus in deeper marine waters, the spreading loss is spherical, whereas in shallow waters such as exist in the Bras d'Or, spreading loss typically becomes cylindrical more quickly and sound attenuates more slowly.

Sound speed in the ocean is variable, and depends on the parameters of temperature, salinity, and pressure (depth). The speed at which sound will travel through the water increases an average of 4 m/s per C rise in temperature, 1.5 m/s per psu rise in salinity, and 0.0018 m/s per 1 m increase in depth (Jones 1990). Given that temperature and salinity vary vertically with depth and laterally with location, sound speed is spatially variable within the Bras d'Or Lakes. It is also temporally variable for a given location as temperature and salinity of the water column change over time. However, the magnitude of these changes is small, and temperature would be expected as the dominant factor influencing sound speed in the Bras d'Or.

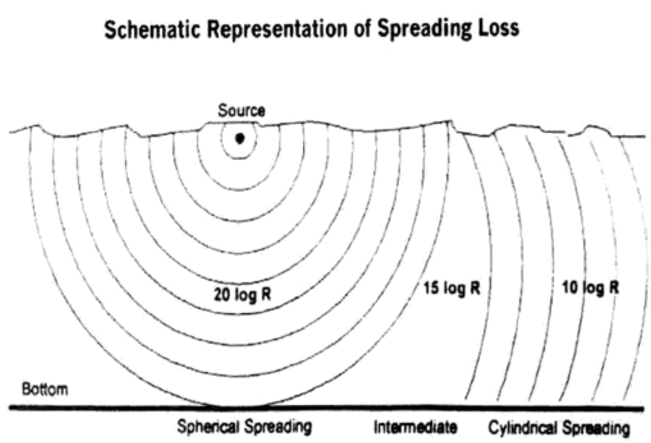


Figure 5. Sound attenuation in marine waters as presented by LGL Ltd (2001 cited in TEC 2005)

With regard to boat propulsion, it is estimated that 85% of vessel noise results from propeller cavitation. This sound is the result of wasted energy from the perspective of moving a boat through the water (Barlow and Gentry 2004). The energy associated with this noise is determined primarily by such propeller characteristics as number of blades, diameter, and most importantly the propeller tip speed. The ship size and tonnage does not necessarily affect the level of noise other than that larger ships may have more and larger propellers (Leggat et al. 1981). Sound frequency, sound energy, and speed of propagation are all variable factors that would influence response of marine biota to introduced noise sources in the aquatic environment.

Ship transport of gypsum through St. Patricks and the Great Bras d'Or Channel is likely the greatest potential source of noise to the marine environment in the Bras d'Or, although it has never been quantified or assessed. In the Gulf of St. Lawrence it was estimated that ship noise may reach up to 190 dB (TEC 2005), and other studies have estimated large ship noise to produce broadband levels up to 178 dB and discrete tones up to 201 dB (Leggat et al. 1981). This level of sound is high enough to affect behaviour of marine animals (Table 8) but will dissipate in approximately 70 m from the source to a level below which there are significant impacts.

Table 8. The effect of noise on fish and marine mammals based on air gun testing as would be used for seismic assessment

Noise Intensity (DB re 1 uPa)	Effect on fish
160	Behavioural change
192	Transient stunning
220	Internal injuries
220	Egg/ larval damage
230 - 240+	Fish mortality

Source: Modified from Turnpenny and Nedwell 1994

Herring, a previously important commercial species in the Bras d'Or, are known to be more sensitive to, and inclined to avoid noise than other species (DFO 1997). Schwarz and Greer (1984) studied the responses of penned herring to various sounds and noted three kinds of responses including a startle response and avoidance. Twenty- five percent of the fish groups habituated to the sound of a large vessel and 75% of the responsive fish groups habituated to the sound of a small boat. These are the two most likely sources of sound pollution in the Bras d'Or Lakes. Chapman and Hawkins (1969) also noted that fish react rapidly to high sound levels in the open sea; fish that are to the side of a boat will avoid the sound of a moving boat by swimming away from it or trying to outrun it. Most schools of fish will not show avoidance if they are not in the path of the vessel. When the vessel passes over fish, some species, in some cases, show sudden escape responses that include lateral avoidance and/or downward movement of the school. Avoidance reactions are quite variable and depend on species, life history stage, behaviour, time of day, whether the fish have fed recently, and sound propagation characteristics of the water (Misund 1997).

Within the Bras d'Or, sound levels might be expected to be somewhat different than those shown in Table 9 because of the less saline waters than those for which the example has been developed. Certainly it could be expected that the speed of propagation is likely higher in the Bras d'Or relative to marine waters for a given depth because of the warmer water temperatures, although this would be somewhat offset by the lower salinities in the Lakes. Further, given that much of the Bras d'Or is less than 30 m deep, sound attenuation can be expected to occur more slowly as spreading quickly changes from spherical to cylindrical once sound waves meet the Lake bottom. Therefore, sound impacts from shipping traffic in the shallower areas of the Bras d'Or Lakes, including across sills and through the Great Bras d'Or Channel, may be more significant than those experienced in more open marine waters.

Table 9. Predicted noise impacts under ideal conditions of transmission vertically in water column or laterally from source

Distance from source	Shipping dB levels	Fish response
4 m	190	Transient stunning zone for fish and panic reaction
8 m	184	Behavioural change zone avoidance and significant behaviour changes
16 m	172	
32 m	166	
64 m	160	

Source: Modified from TEC 2005

9. Chemical Oceanography

The Bras d'Or Lakes is a generally well oxygenated body of water, even in areas of great depth. There is typically little suspended particulate matter in the water column, including near the mouths of the larger rivers that enter St. Patricks Channel. This contributes to high water clarity and the significant depth at which photosynthesis can occur. However, low levels of nutrients, particularly nitrogen, limit production within the system. The chemical fingerprint of the Lakes remains relatively unaltered by human activity, yet there are a limited number of areas for which some metals are found to be elevated. A number of studies in the 1960-70s show that the Lakes are not homogeneous, but rather are chemically heterogeneous over various vertical, horizontal, and spatial scales.

9.1 Temperature and Salinity

The waters of the Bras d'Or are characterized primarily by a two-layer system of a low salinity, variable temperature outflowing surface layer and a higher salinity, relatively stable temperature inflowing bottom layer. The mixed layer depth, that interface between the fresher surface layer and more saline marine layer, occurs at approximately 4 m from May through August, at which time it begins to drop toward 22 m found in November. However, there is significant variability in this depth during the fall around the Lakes (Petrie and Bugden 2002). The variability in the mixing layer depth is less in the spring through summer when temperature and salinities between the surface and bottom layers is more pronounced. Later in the year, when surface temperatures begin cooling, and when surface salinity increases because the dry season has reduced the freshwater contribution to the surface layer, mixing occurs more readily. A third layer of water does exist, generally below 50 m, in only the limited deep basin portions of the Lakes (Petrie and Bugden 2002).

In July of 1974, the western Whycocomagh Bay had the strongest and most variable thermoclines and haloclines recorded (Gurbutt and Petrie 1995). This was likely attributable to the geographic isolation of this basin, enclosed by shallow sills at both Little Narrows and in the middle of the Whycocomagh Bay that serve to restrict inflow of cooler more saline marine waters found deeper in the Bras d'Or system. Deepwater properties of salinity and temperature in St. Andrews Channel vary considerably from the same depth in the marine Laurentian Channel. St. Andrews long-term temperature and salinity characteristics at depth are 0.33 ^{o}C and 24.4, whereas the marine channel is 5.8 ^{o}C and 34.5 (Petrie and Bugden 2002). The colder temperature and lower salinity of the deepwater Bras d'Or site provides a markedly different habitat than that found in the marine environment.

9.2 Temperature

Generally, the surface waters of the Bras d'Or Lakes are of a low salinity, variable temperature, out flowing surface layer that is influenced by atmospheric temperatures and freshwater runoff from the land base. A higher salinity, relatively stable cool inflowing bottom layer exists, influenced by the character of the marine waters of Sydney Bight. During winter, water temperatures fall to roughly 0 C throughout the Lakes. By May, surface temperatures approach 6 C while deeper areas remain closer to zero. Surface temperatures warm significantly in the spring, with more than a 10 C increase in water temperatures in the May to July period, creating a strong thermocline throughout much of the Lakes at 20 m. Exceptions exist in the deep and well-mixed areas; for example, even in July the deep part of North Basin remains at around 1 C (Petrie and Bugden 2002), and Rankin and Hyndman (1971) recorded a relatively constant 0.14 C bottom water temperature in St. Andrews Channel over a nine month period indicating that little to none of the solar warmed surface waters were mixed with the deepest layers. In the Great Bras d'Or Channel where mixing raises bottom temperatures by about 8 C, only a weak thermocline exists in the summer. Here, surface to bottom temperature differences peak at around 4°C (Gurbutt and Petrie 1995) compared with nearly a 20 C gradient found in many areas of the Lakes.

High surface layer temperatures in early August, and lows in February, closely follow seasonal air temperature fluctuations (Krauel 1976). In some of the more shallow embayments, even bottom temperatures will reach 20 C during the late summer. However, where depths exceed 60 m, water temperatures are typically below 6 C year-round (Petrie and Bugden 2002). This vertical temperature stratification, based on 1972 data, largely disappeared in early October (Gurbutt et al. 1993). This timing coincides with the strong winds and heavy rainfall that are typical of the fall season on the Bras d'Or Lakes.

Rankin and Hyndman (1971) made reference to a continuous series of bottom temperature records from the deep basin of St. Andrews Channel that extends from December 1968 to August 1969. They noted that a "remarkably constant 0.14 C" was recorded throughout that time. Kenchington and Carruthers (2001) suggest these data indicate that the basin was isolated from other waters; specifically so through the winter and spring period when exchange might have been considered most likely. At the same time, they note bottom water and the sediments were oxygenated, suggesting that some circulation occurs. Kenchington suggests the solution to these contradicting data may be that the basin is flushed in the fall, but that the flushing only occurs intermittently, and did not occur in the 1968-69 period during which the recording instrument was active. However, Petrie and Bugden (2002) compiled various deepwater temperature data for St. Andrews that covered six months of the year over the period of 1924-2000. Below 100 m, temperatures stayed between –1 and 1 C (and salinity changed less than 2 ppt). This, they suggest, indicates changes in the deep basins over time are likely very small. This does not address the issue of moderate dissolved oxygen levels at this great depth, which Strain and Yeats (2002) recorded as being between 55 - 57% saturation. However, they suggest that, based on 1974 DO measures that were 78% deep in St. Andrews, advection of new water must occur. Interestingly, the study during which these 1974 oxygen data were collected (Krauel 1975), also collected the salinity and temperature data used by Petrie and Bugden (2002) which do not vary from longer term collections.

In summary, DO levels tell us that some exchange must take place, in order to oxygenate the deepest layer of St. Andrews. Stable temperature and salinity at depth tells us this exchange must be slow, otherwise we could expect to see variation in these parameters over time.

9.3 Salinity

In May, surface water salinity is about 30 ppt at the entrance to the Great Bras d'Or Channel, 25 - 26 ppt in deepwater basins, and 20 – 21 ppt in surface waters of East Bay and North Basin. Even lower salinities have been found in the sheltered bays and near the mouths of the larger rivers (Davis and Brown 1996b). Heavy rainfall events can significantly affect lake water surface salinity to a depth of 5 m (Wright 1976). Both Denys Basin and Whycocomagh Bay tend to have some of the warmest surface water temperatures in May and lowest near surface salinities (Petrie and Bugden 2002), largely because of the significant freshwater rivers entering these enclosed bays. The large salinity gradient in surface waters that occurs in the relatively short distance between Sydney Bight and North Basin reflects the freshwater inflow into a body that has restricted exchange with the marine environment (Petrie and Bugden 2002).

Given the low tidal range in the Bras d'Or Lakes, the fluctuations caused by barometric changes have a greater impact on salinity. It has been suggested that barometric tides draw in a measurably greater amount of ocean water to the Lake system, and thereby alter the salinity of the Lakes more significantly than the regular tidal regime (Davis and Brown 1996a). As there is no vigorous tidal mixing in the open body of the Lakes, salinity distributions are somewhat horizontally uniform within each major body of the Lakes. Seasonal surface salinity changes occur based on stream discharge amounts to the Bras d'Or. Spring runoff and fall rains lower salinity in May and November, whereas the dry days of August and the low liquid precipitation in February account for higher salinities in surface waters at these times of the year. The deeper water, typically below 10 m, is influenced by salinity changes in the Gulf of St. Lawrence where maximum salinity occurs in January because of ice formation and lowland based runoff. Overall, these salinity fluctuations produce a mean low salinity within the Lakes from spring to late summer, and a mean maximum occurring in winter (Krauel 1976). The only areas with significant temperature and salinity changes directly related to the tides are the Great Bras d'Or and Little Bras d'Or Channels that connect the Lakes to the open ocean (Krauel 1976). Here, even surface salinities can exceed critical salinity of 24.7 ppt. This allows the waters of the Great Bras d'Or to behave more like seawater, mixing to a greater depth during periods of seasonal cooling. The highly restrictive 8 km long Little Bras d'Or Channel does not appear to have a significant influence on temperature and salinity distributions within the Lakes (Gurbutt and Petrie 1995).

Evaluation of salinity data collected at St. Peters (Krauel 1975) has led to an interesting theory by Kenchington and Carruthers (2001). St. Peters canal operation allows a few thousand cubic metres of seawater to mix with Bras d'Or Lake water during the transit of every boat. This Atlantic water, being saltier and usually colder would be much denser than the Lake water of St. Peters Inlet. Therefore, it could be expected to flow beneath the Lake water and down into the deep basin just beside the inner end of the Canal. At least, that is the most reasonable explanation of the data collected by Krauel (1975) at his Station 24, centred over this deep basin (see Table 10) (Kenchington and Carruthers 2001).

Table 10. Subsurface salinities in St. Peters Inlet (after Krauel 1975). Data from three different years were rearranged into a seasonal sequence.

Date	Depth (m)	Salinity (ppt)
22 May 1974	10 to 50	23 to 24
18 June 1974	10 to 26	25
24 July 1973	15 to 32	27
22 August 1972	5	27
14 September 1972	6	25
6 November 1972	5	28

Source: Modified from Kenchington and Carruthers 2001

Kenchington and Carruthers propose that these high salinities cannot have been produced by salty water entering St. Peters Inlet from Bras d'Or Lake since even the deepwaters in Bras d’Or Lake do not show salinities as high as 24 ppt (Krauel 1975). Marine water entering through the Canal is the most likely alternative. In summer, it appears that inflow slowly floods the basin until, sometime in August, salinities approaching 30 ppt reach up to the depth of its sill (approx. 7 m), when this water must spill into the Lakes. In winter, with the Canal inactive, surface cooling probably leads to downwelling of very cold Lake surface water and a drop in the bottom salinity of the basin to below 25 ppt, before the resumption of Canal traffic in the spring causes salinity to increase again. While this pattern of inflow through the Canal is interesting and may have some local biological significance in St. Peters Inlet, the quantities concerned are too small to influence Bras d’Or Lake (Kenchington and Carruthers 2001).

Another example of the diverse character of the Lakes was recorded by Young (1973d). He noted that a substantial inter-day change in salinity levels was observed in Nyanza Bay with the passing of an August storm and high winds. Surface and bottom salinities changed from 4.3 and 10.2 ppt respectively one day to 8.4 and 16.8 ppt the next.

9.4 Dissolved Oxygen – Areas of Hypoxia

Overall dissolved oxygen (DO) content for July 1974 showed super saturation of surface waters, and as much as 78% saturation at depth, even at a depth of 250 m in St. Andrews Channel (Krauel 1975). The surface saturation of DO was apparent in 1996 samples that had a median value of 104% in spring through summer, dropping slightly during fall sampling (Strain and Yeats 2002). Extended flushing times in the deepest portions of the Lakes, St. Andrews Basin and North Basin, have slightly reduced oxygen concentrations of 55 - 75% and 90 - 95% respectively (Petrie and Bugden 2002, Strain and Yeats 2002). However, these values, and those in nearly all deep areas of the Lakes remain relatively high (Gurbutt et al. 1993). Whycocomagh Bay is the one exception, as the only bay-scale, or major lake region having poor oxygen saturation levels throughout.

Whycocomagh Bay has two deep basins and a flushing time of approximately two years. This slow water exchange facilitates the unique anoxic and hypoxic character of the deep basins within the Bay (Petrie and Bugden 2002). The eastern basin in Whycocomagh Bay, immediately west of St. Patricks Channel, has DO levels as low as 38% at the bottom (38 m) (Strain and Yeats 2002). The 48 m deep western basin has only 47% saturation at 15 m depth, and is typically anoxic below 25 m (Krauel 1975), a characteristic that appears consistent over the year and over time (Strain and Yeats 2002). Black’s (1958) observation of only a few organisms of two shallow water species of mysid shrimp in Whycocomagh Bay is a further indication that low dissolved oxygen levels have likely existed for some time in the deeper waters at this location. In all other areas of the Lakes a larger number of mysid species are found at all depths. The only other locations to show evidence of anoxia within the Bras d'Or Lakes are some of the protected barachois ponds (Smith and Rushton 1964). Surprisingly, anoxic conditions were observed in as little as 5 m of water in some of these areas.

Generally, the oxygen saturation within the Lakes, particularly the larger and deeper bodies, is good. Each of the areas of the Lakes that exhibits a drop in oxygen saturation tends to be horizontally isolated from other regions of the Lakes by shallow sills or barrier beaches. During a study to evaluate coastal areas of Nova Scotia at risk for eutrophication, several basins that were isolated from other areas of the Bras d'Or by shallow sills were ranked as at high risk (Strain and Yeats 1999). Although nutrient loading from anthropogenic sources overall is not significant within the Bras d'Or Lakes system, in some isolated areas of the Lakes eutrophication or the risk of eutrophication does exist.

Strain and Yeats (2002) have noted that areas such as Denys Basin, Herring Cove, Denas Pond, and Indian Cove have all had seasonal drops in dissolved oxygen to below 50% in waters between 10-30 m deep.

9.5 Suspended Particulate Matter

Although active erosion occurs along the shorelines of the Bras d'Or Lakes where waves break apart unconsolidated material and soft rocks of the Windsor formation, and although metres of fine silts carried by the erosive forces of glaciers and rivers over time blanket the bottom of the Lakes, little information can be found regarding suspended particulate matter (SPM). That which does exist does not indicate elevated levels of SPM. Strain and Yeats (2002) present results that show that precipitation (11 $mg/m^2/d^1$) rivals the rivers' (4.7-12.3 $mg/m^2/d^1$ seasonally) contribution of SPM to the Lakes, and is much more significant than the contribution from sewage sources (0.67 $mg/m^2/d^1$). During the summers of 1973 and 1974 Arseneau et al. (1977) recorded an average June – August surface water turbidity in the protected eastern end of East Bay of 9 JTU (Jackson Turbidity Units) and in the open waters of East Bay of less than 3 JTU.

The remaining information on SPM comes from environmental monitoring at the western entrance to the Great Bras d'Or Channel (Warner and Warner 1996 cited in Kenchington and Carruthers 2001). During this monitoring it was noted that during periods of calm weather, the water passing over the Middle Shoal had suspended sediment concentrations just below 10 mg/L. However, during rain events, when fine sediments might wash from the adjacent shoreline cliffs, and waves may suspend material from beaches and in the shallows, the concentration of suspended material rises to about 200 mg/L. This material then moves as a visible plume, 100 to 300 m wide, along the shoreline. There can also be sustained concentrations of over 30 mg/L (DFO 1997). This is the most significant source of sediment supply to the Great Bras d'Or Channel, which is estimated to deposit more than 900 m^3 of sediment into the Channel on a single tide under storm conditions (Warner & Warner 1996 cited in Kenchington and Carruthers 2001).

9.6 Organic Carbon (DOC/POC)

It is believed that a majority of organic material in the Bras d'Or is of a dissolved nature (DOC). Primary sources of carbon include phytoplankton production, algal and sea grass breakup, re-suspension of bottom materials, and detrital input from the land base (Wright 1976). Dissolved organic carbon and particulate organic carbon (POC) measures made in 1973/74 were noted to be unreliable. However, based on observed chlorophyll levels at that time, it was felt that organic carbon production per unit area was somewhere slightly greater than 55 gC/m^2/yr (Wright 1976). The instantaneous contribution to standing stocks of POC by phytoplankton standing crops was estimated to be between 25-50 mgC/m^3 in 1973. Based on this, POC was estimated to be present at the 500 mgC/m^3 level. Based on replacement rates that were calculated, production could be as much as 1000 gC/m^2/yr (Wright 1976). These values are similar to those of Geen (1965) who calculated daily production of 100-300 mgC/m^2 and annual production of 55 gC/m^2/yr in the Lake and 170 gC/m^2/yr in one of the small embayments. Plankton observations indicate that the amount of detritus and debris present represents a volume of POC several times greater than the volume of phytoplankton, while it generally represents several times less volume than the zooplankton present (Wright 1976).

Organic carbon levels peak in autumn, showing maximum concentrations at the bottom, suggesting a relationship to macrophyte breakup and degradation. During the summers of 1961-63, an average of 0.14% of photosynthetic energy was estimated to have converted to plant carbon (Geen and Hargrave 1966). Based on available nitrogen from all sources, total primary production varies from 20 - 40 mgC/m^2/h^1 between late spring and summer. Hargrave and Geen (1970) interpreted summer of 1964 data that they collected on major herbivorous copepods in the Bras d'Or Lakes to indicate that the phytoplankton carbon ingested by copepods removed 100% of the daily primary production at a 5 m depth (depth of maximum photosynthesis). Such grazing levels could be an important factor limiting primary production. An estimated 50-70% of total new production in the Lakes occurs in St. Andrews Channel where nitrate and ammonia stored in deepwaters get brought to the surface through upwelling (Strain and Yeats 2002). All sources of external and deepwater nitrogen can account for new production between 5.3-6.7 mgC/m^2/h^1 between late spring and fall. Nitrate levels then build over winter during biological inactivity that is associated with ice cover and during the mixing of surface water with both deeper lake waters and the inflowing waters from Sydney Bight. Based on limited measures and modeling, the elevated spring time mean surface nitrate concentrations are estimated to support an average new production rate of 27 mgC/m^2/h^1. This 4-5 fold increase in new primary production during the spring bloom is based on nutrient accumulation over winter, whereas later in the season, new production is driven by nutrients from deepwaters within the Lakes (Strain and Yeats 2002).

9.7 Nutrients – Flux and Budgets

Generally speaking, productivity within the Bras d'Or Lakes ecosystem is low even though the water clarity and stratification characteristics that exist in the Bras d'Or would be capable of supporting good primary production. Therefore, nutrient levels are most likely the factor controlling surface productivity (Strain and Yeats 2002).

Phytoplankton requires nitrogen and phosphate in approximately a 16:1 ratio, the Redfield Ratio, in order to grow abundantly. Through evaluation of these nutrients within the Lakes it becomes apparent that nitrogen is the most likely limiting factor to production. N: P ratios are 5.4 in spring, 4.6 in summer and 2.7 in fall (Strain and Yeats 2002). It is only in February that Sydney Bight N: P ratios approach the Redfield Ratio (Petrie et al. 1999), so a similar seasonal high might be expected for the Lakes if data were collected through this winter period. Almost all of the nitrogen available for new production in the Lakes is supplied from marine sources, either with the incoming tide from Sydney Bight or through deepwater marine nutrient reserves of the Lakes. An even higher percentage of the phosphorus supply is derived from these same sources (Strain and Yeats 2002). Although the amount of nitrate and phosphorus appear to be largely derived from marine sources, we also know that the processes that promote mixing and that allow marine incursion to the Lakes are both very limited. The small cross-sectional area of the Great Bras d'Or Channel through to Sydney Bight, and the numerous shallow sills around the Lakes, limit the amount and distribution of bottom layer marine waters entering the Lakes. Few constrictions and moderate tidal exchange within the Lakes further limit the magnitude of currents that might mix waters. Strong stratification through much of the year inhibits upwelling. Despite the nature of these processes within the Bras d'Or limiting nutrient exchange and distribution, marine waters entering through the Great Bras d'Or Channel remain the largest source of nutrients to the Lakes.

In addition to the marine derived forms of nitrate and phosphorus, the other primary nutrient sources for the Lakes include freshwater river inputs, atmospheric deposition, sewage, aquaculture, and other man made sources. Although precipitation levels are not significantly different than other locations around Nova Scotia the atmospheric deposition of nutrients through precipitation is a greater percentage of the total nutrient input for the Bras d'Or Lakes (Strain and Yeats 2002). Nitrogen and phosphate inputs from sewage to the Lakes are small when compared to the natural fluxes in and out of the Lake from marine sources. These inputs may cause local eutrophication in some of the basins and barachois ponds that have restricted water circulation, but they have little impact on the Lakes as a whole (Strain and Yeats 2002, Strain and Yeats 1999). This has been evidenced by reduced oxygen concentrations and sometimes hypoxia or anoxia, and bacterial contamination in a few of these hydraulically isolated locations (Strain and Yeats 2002).

In summary, marine derived nutrients are the largest source to the Lakes, but the processes that bring these nutrients into the Lakes and then to the surface are not strong. Therefore, at a large bay-scale the Bras d'Or Lakes remain somewhat nutrient poor. As a matter of fact, the morphometry of the Lakes, including the presence of deepwater basins and the relative isolation caused by the many shallow sills (see Table 3), means that vertical mixing appears to bring 5-10 times more nitrate to surface waters north of Barra Strait than to the south. Finally, with marine sources being relatively smaller, precipitation is a proportionately higher source of nutrients in the Bras d'Or than in other coastal areas of Nova Scotia. Typical seasonal nutrient levels for the Bras d'Or are presented in Table 11.

In contrast to low surface nutrients at the large bay-scale, significant nutrient loads exist in some of the enclosed bays and barachois ponds. Eutrophication at these locations is generally attributable to human inputs. Although the total area exhibiting eutrophication is small relative to the Bras d'Or watershed, it does encompass a fair amount of the shallow nearshore area of the Lakes. Given that contribution to overall lake productivity may be minimal the presence of much flora and fauna along the coastal fringe means that the biological relationship could be significant, although interactions have not been examined through studies at this time.

Table 11. Real or predicted, average or typical values for a variety of chemical and physical properties of the Bras d'Or Lakes. These values do not reflect extremes, or unique character of individual bays and basins.

Nutrient	Spring	Summer	Fall	Winter
Nitrate+ nitrite (surface)	<0.14 µM	<0.14 µM	-	4.9µM
Surface Nitrate (NO_3-N)	-	1-1.5 µg/L	-	-
Surface Ammonia (NH_4-N)	1.3 µM	0.67 µM	<1µM	-
Dissolved Phosphate (surface)	0.2 µM	0.2 µM	0.2 µM	-
Phosphorus bottom	-	3.8 µg/L PO_4-P	-	-
Silicate	0.81 µM	1.82 µM	4.4 µM	-
New production	6.7 mgC m^z/h	5.3 mgC m^z/h	6.3 mgC m^z/h	27 mgC m^z/h (bloom)
N: P Ratio	5.4	4.6	2.7	16
Chlorophyll – *a*	0.24 µg/L	0.40 µg/L	0.80 µg/L	µg/L
Surface Salinity	20.5-30 ppt	22-27 ppt	-	-
Depth Salinity	24.8-26.5 ppt	24.8-26.5 ppt	24.8-26.5 ppt	24.8-26.5 ppt
Thermocline	20m	20m	-	-
Surface Temperatures	-	16 ^{o}C	-	-
Depth Temperatures	-1 C to +1 C	-1 C to +1 C	-1 C to +1 C	-1 C to +1 C
Dissolved Oxygen(surface)	104%	104%	97%	-
Surface mixed layer	-	3-5 m	10-15 m	22+ m
Freshwater inflows	250 m^3/s	50 m^3/s	100 m^3/s	170 m^3/s

9.7.1 Nitrate

Seasonal variations of nitrate in the Bras d'Or Lakes tend to follow typical patterns for northern temperate climates. Nitrate is high in February and March and drops sharply by May. Nitrate levels sampled in the spring of 1996 were typically below detectable limits with a median value of 0.1 µM to 0.2 mg.-at/m^3. In the spring, dissolved phosphate appeared to be in excess of the total inorganic nitrogen available for phytoplankton growth, suggesting that primary production is most likely nitrogen limited at this time of the year (Strain and Yeats 2002). Nitrate levels appear to be limiting during the summer through autumn period as well. However, in the mid 1970s the cycle of nitrate regeneration was apparent by November or December (Wright 1976), and more recently was visible indirectly through measured increases in chlorophyll *a* and phaeophytin concentrations (Strain and Yeats 2002). The fall nitrate increase supports some new primary production. Ammonia, an alternate inorganic nitrogen source, was maximal in late autumn and otherwise showed variations throughout the year (Wright 1976). It has been suggested that fall winds deepen the surface mixed layer, and that this mechanism contributes to higher surface nitrate levels in the fall (Strain and Yeats 2002). However, it is also suggested that fall storms are unlikely to have much deepwater influence, given the lack of long wave formation (which reach deeper into the water column) within the Lakes (Kenchington and Carruthers 2001). Regardless, stratification is known to weaken in the fall, and this undoubtedly facilitates some mixing.

9.7.2 Phosphate

Although dissolved phosphate concentrations are clearly in excess of the total inorganic nitrogen available for phytoplankton production, and are therefore not production limiting, only about 10% of surface samples collected in spring 1996 were considered in the medium range of concentration as defined by the NOAA National Estuarine Eutrophication program (Strain and Yeats 2002). Phosphate in the Bras d'Or Lakes, surprisingly, does not show a typical annual cycle for coastal Nova Scotia but rather rose and fell irregularly through the summer and fall. Minima occur in May, but maxima were observed at various times except winter. The elevated levels seem to correlate with depressed salinities (Wright 1976), and this may be indicative of an inshore phenomenon of phosphate-rich runoff overriding the normal marine nutrient cycle (Kenchington and Carruthers 2001).

9.7.3 Silicate

Rivers and freshwater inputs are the most significant source of silicate to the Bras d'Or Lakes. This is particularly true in summer and fall (Strain and Yeats 2002). Spring distribution of silicate sampled in 1996 from surface waters tended to be consistently less than 1.0 µM (see Table 11), with the exception of Denys Basin, Whycocomagh Bay, and St. Patricks Channel. These bodies exhibited variable and high levels of silicate concentration in spring through summer, most likely from the larger freshwater rivers entering the coastline and the associated Triassic-Carboniferous rock formations through which those rivers had passed (Strain and Yeats 2002). Surface silicate levels in the rest of the Lakes begin to rebuild through the summer to slightly less than double that of the spring results. It is expected that diatoms are a large part of a spring bloom, and draw down silicate levels at that time of year. As spring river flows continue past the bloom, rebuilding occurs in the subsequent months allowing silicate supply to exceed the demand for diatom growth (Strain and Yeats 2002). Some low level variations in silicate levels occur through to fall, and likely coincide with increases in diatom numbers (Wright 1976). Highest silicate levels are found in February and March in all Lake areas, followed by the significant springtime drop. Silicate supplies will not affect overall new production in the Lakes, but it will determine the abundance of diatoms within the phytoplankton given that diatoms require silicate for growth (Strain and Yeats 2002). This internal source and cycling of silicate is more important to the Bras d'Or Lakes productivity than is advection-transported concentrations of silicate from outside of the Lakes.

9.7.4 Chlorophyll a

During 1996 surveys, chlorophyll *a* was very low in the spring, with no signs of an active bloom (Strain et al. 2001). Although levels increased slightly in summer, phytoplankton biomass remained low. Chlorophyll *a* and phaeophytin concentrations increased in the fall with higher inorganic nitrogen levels. Median chlorophyll concentration had more than tripled from spring levels and doubled from summer surveys to 0.88 µg/L during the fall survey. Whycocomagh Bay, Denys Basin, St. Patricks Channel, St. Peters Channel, and the southeast end of St. Andrews Channel all had levels greater than 2 µg/L during the fall 1996 survey (Strain and Yeats 2002). Chlorophyll in detritus of some of the nearshore bays is likely contributing measurable amounts to samples collected in areas such as Whycocomagh Bay, St. Patricks Channel, Denys Basin, and St. Peters Inlet (Strain and Yeats 2002), all locations where large rivers enter semi-enclosed bays.

The only other studies to make quantitative estimates of plant production in Bras d'Or were those of Young (1973c, 1974). Young (1973c) measured chlorophyll-*a* and detrital phaeo-pigment concentrations as an indicator of the density of phytoplankton as a means to determine what might be available as oyster food. In 1972, he found that concentrations were low in the rivers and streams flowing to the Lakes (typically 0.1 to 0.5 μg/L), higher in the Lake water (0.5 to 1.0 μg/L) and higher still along the shoreline and in deltaic areas. In the smaller enclosed coves that Young was evaluating for oyster production, such as Holiday's Cove (on the west side of Great Bras d'Or Channel), he found chlorophyll levels of up to 6 μg/L. Young's (1974) 1973 data indicated a broadly similar pattern in small embayments, with site-average concentrations as high as 4.9 μg/L in Otter Harbour and 6.5 μg/L in Malagawatch. He also found that chlorophyll levels tended to decrease outward from the shoreline. In Nyanza Bay the shoreline concentrations of 1.2-1.8 μg/L were observed to drop to 0.6-0.9 μg/L in the surface waters of the open central bay (Young 1974). These latter values are more akin to values found in the other more open areas of the Lake (see Table 11).

9.8 Dissolved Trace-Metals and Organic Contaminants

Heavy metal contamination of the Bras d'Or's waters from the freshwater systems is not significant, although several hotspots have been noted and mapped (Young 1976). The freshwater runoff in the larger rivers is not sufficiently acidic to dissolve the naturally occurring heavy metals that are quite limited in the surficial geology (Kenchington and Carruthers 2001). Field surveys have confirmed heavy metal content of silt in the rivers flowing into Bras d'Or as being generally low, though somewhat higher in Baddeck and Middle Rivers (Creamer et al. 1973; Young 1976). More recently, sediments in Denys Basin have been found to contain levels of cadmium, zinc, copper, and lead greater than threshold effects levels (but less than probable effects levels) (Yeats pers. comm. 2005). An earlier study (Chou et al. 1999) reported that Denys Basin had the lowest ranking for metal concentrations in sediments of five basins evaluated in the Bras d'Or during 1997 over a wide range of metals examined. However, samples from this study were not corrected for grain size, likely resulting in an under reporting of metal concentrations in sediments. Limited sampling from East Bay sediment has shown localized copper and zinc above threshold effects levels and lead above probable effects levels (Yeats pers. comm. 2005). Studies have shown some areas of the Bras d'Or as having high zinc in oysters (Young 1973a) and in water (Strain et al. 2001). Most recently, in an as yet unreported study, zinc was found to be elevated in both oysters and water at the same location within the Bras d'Or (Yeats pers. comm. 2005). Evaluation of the significance of these observations is ongoing.

Surveys conducted in 1995 showed that dissolved metal concentrations in the Bras d'Or Lakes were consistently lower than in Nova Scotia's more industrialized harbours, and comparable to the relatively pristine Ship Harbour. This, despite the fact that salinities are lower in the Bras d'Or, and higher concentrations of metals are generally found in less saline waters (Strain and Yeats 2002). Dissolved and particulate amounts of seven metals have been estimated by modelling. The predicted values, which seem reliable based on limited field sampling, are typical for other embayment locations around Nova Scotia with the exception of cadmium (Cd) (Strain and Yeats 2002). The 2-4 times higher levels of Cd have not been verified. The model predicts that the main source of heavy metals in the Lakes is inflowing water from Sydney Bight through the Great Bras d'Or Channel (Strain and Yeats 2002), and not from the freshwater systems that enter the Lakes.

Various studies have documented as many as 21 metal concentrations in the tissues of Bras d'Or aquatic biota (Chou et al. 1999; Creamer et al. 1973; Young 1973a,b) but levels have been consistently low. Chou et al. (1999) found that zinc occurred in the highest concentration in flounder tissues, by comparison with 20 other metals assessed. Very limited sampling of sediment and water in the Bras d'Or has been conducted for PAHs (polycyclic aromatic hydrocarbons) and PCBs (polychlorinated biphenyls). Sirota et al. (1984) examined PAH concentrations in natural mussel and lobster populations of Sydney Bight. Lobsters sampled from Point Aconi, near the ocean side of both the Great and Little Bras d'Or Channels had small traces of benzo(a)pyrene, similar to the control sites. Mussels analyzed part way along the Great Bras d'Or Channel at Seal Island showed little more than traces, whereas those sampled from the ocean side of the Little Bras d'Or Channel at Alder Point had low, but measurable results for a range of PAHs. Unless local point sources are identified as the site of origin, such levels within the Lakes are most likely of no significance on a broader scale. There is no indication that any persistent organic or heavy metal contaminants are a concern within the Bras d'Or Lakes given the concentration levels found in the water, sediments, and biota (Strain and Yeats 2002).

The locations within the Lakes that are most likely to be susceptible to, and exhibit signs of, heavy metal and organic contaminants would be those bays in which flushing and water movement is minimal. Therefore, any works to identify natural or anthropogenic metals and contaminants have tended to target Whycocomagh Bay, Denys Basin, East Bay, Baddeck Bay, and Nyanza Bay. In a survey of basins with restricted water exchange, dissolved iron and manganese concentrations from near bottom samples were some 500 times higher than in a broader survey of 1995. The elevated concentrations of these metals, however, were attributed to their natural redox chemistry in the oxygen-depleted basins from which the samples were collected (Strain and Yeats 2002).

Long Range Transport of Airborne Pollutants is usually considered in terms of acid rain, which is a very significant problem for the ecosystems of rivers in southern and south western Nova Scotia that have little buffering capacity. There seems to be enough calcareous rock in the Bras d'Or drainage basin that acidification is of no great significance. Certainly, it is of little concern in salty waters as the chemical balance in the sea serves to "buffer" changes in acidity. Other pollutants are, however, transported long distances on the wind and certainly arrive in the Bras d'Or watershed, if only in trace quantities (Kenchington and Carruthers 2001).

10. Oceanographic Information Gaps

Much of the physical and chemical oceanography in the open water bodies of the Bras d'Or has been well documented over time (Dupont et al. 2003; Strain and Yeats 2002; Petrie and Bugden 2002; Petrie and Raymond 2002; Strain et al. 2001; Petrie 1999; Gurbutt and Petrie 1995; Gurbutt et al. 1993; Arseneau et al. 1977; Krauel 1976; Krauel 1975; Rankin and Hyndman 1971). At this larger bay-scale, there is now a need to understand why some unique observations that have been recorded exist. For example understanding the oxygen replenishment mechanism in St. Andrews Channel, the nutrient upwelling around the Barra Strait, and the importance of these mechanisms to the broader health of the Bras d'Or ecosystem is a key gap at the bay-scale. The more temporally broad gap that exists at the bay-scale is understanding oceanographic processes that occur over winter. Little formal study has been completed over the winter due in part to problems associated with ice cover.

A spatially large gap exists regarding the oceanographic character of the nearshore fringe of the Lakes. This area is both much more diverse and much less documented. As an estuarine system, the freshwater inputs to the Bras d'Or are a key component. Assessment of freshwater inputs in terms of seasonal discharge, bacterial loading, and chemistry is not comprehensive, nor have trends over time been assessed in the larger river systems for which some data are available. These parameters will have great influence on the oceanographic character of the ‘within bay’ or inlet scale of the Bras d’Or watershed. A large portion of the freshwater gap, and potentially a more important one to understanding the oceanographic character of the Bras d’Or ecosystem, is of groundwater inputs. Residents and biologists have noted areas where groundwater influence is apparent, or may have implication in processes observed. These include areas of hypersalinity, oxygen renewal in deepwater areas, and diversity of character of the barachois ponds that occur around the Lakes. A hydrogeological assessment of groundwater inputs to the Bras d’Or is likely to help us understand the biological significance of a number of areas within the Lakes, and would fill an existing knowledge gap.

Nearshore and winter conditions are significant gaps within the scientific literature published on the Bras d’Or Lakes. However, it has been suggested that extensive data exist for both of these gaps, collected by the oyster and finfish aquaculture industry (DFO 2006). It is necessary to augment such data with current sampling, yet existing data also may offer the opportunity to better design a current sampling program and may allow trend analysis to detect changes that have occurred. Most important is the need to process existing data, and formally assess and report on the findings, relating them to what is known of the oceanography of the Bras d’Or for the other three seasons.

An additional gap in winter knowledge is associated with ice cover trends. Atlantic Canada has 47 hydrometric stations that were screened under a standard set of criteria for inclusion into a network of long-term stations to address climate change. These stations are part of a nation wide effort to develop a ‘Reference Hydrologic Basin Network’ (RHBN). A thorough evaluation of river ice records on the data that has been collected since 1955 has not been completed (Brimley and Thomas 1999), and could add significant insight into seasonal and biological changes in the project area.

As precipitation has a relatively large influence on the Bras d’Or Lakes’ temperature and salinity regime, it is important to know the other ways in which precipitation may impact the Lakes. Investigation of rainfall chemistry in terms of the long-range transport of atmospheric pollutants is important to understanding changes that may occur in both the freshwater and marine portions of the project area. Knowledge of the role of rainfall chemistry within the Bras d’Or currently exists as an information gap.

PART C – BIOLOGICAL SYSTEM

11. Flora and Fauna

11.1 Planktonic Communities

Planktonic communities are the base of the food web within the Bras d'Or. The tiny plants undertake photosynthesis, and are grazed by microscopic aquatic animals. Productivity at this level of the food chain has significant implications for higher-level production. Low nutrient levels, particularly nitrate, limits planktonic production in the Lakes through much of the year, although local eutrophication in some bays does occur.

11.1.1 Phyto- and Zooplankton

In general, the Bras d'Or waters are quite clear for coastal waters, allowing adequate light levels to penetrate to significant depths for photosynthesis. The photic zone typically extends to 20 m (Geen and Hargrave 1966), a significant amount of the 30 m average water column depth in the Lakes. As discussed, strong to moderate stratification of the water column exists year-round, which helps ensure that phytoplankton cells remain in surface waters where photosynthesis can occur, yet we also know that new carbon production is relatively low. The existence of favourable physical conditions further supports the idea that nutrients are most likely the factor controlling primary productivity (Strain and Yeats 2002).

During the winter and early spring, diatoms and dinoflagellates constitute the bulk of the phytoplankton, similar to the surrounding ocean. Geen (1965) found that the principal phytoplankton types were *Ceratium tripos* in fall and winter and *Chaetoceros* spp. in spring. *Ceratium fuscus, Nitzschia closterium* and *Distephanus* sp. occurred occasionally during the fall-spring period. The major primary producers during the summer are nanoflagellates, predominately cryptomonads (Geen 1974; McLachlan and Edelstein 1971), whereas *Cryptotnonas* sp. and the chrysomonad *Ochromonas* sp. were common flagellates. Other phytoplankton samples were also almost exclusively composed of flagellates (Hargrave and Geen 1970). In 1973 and 1974 microflagellates and chromogenic bacteria were observed to dominate the summer plankton (Wright 1976). Unlike many areas, a fall peak does not dominate seasonal distribution of phytoplankton in the Bras d'Or Lakes. Instead, although not directly observed, nitrate concentration fluctuations suggest that a late winter or early spring bloom may occur (Wright 1976) near first ice off. Plankton observations that have been made indicate that the amount of detritus and debris represents a volume of particulate organic carbon several times greater than the volume of phytoplankton while it generally represents several times less volume than the zooplankton present (Wright 1976). Hargrave and Geen (1970) figured that the major herbivorous copepods of the Lakes ingested phytoplankton carbon at a rate that exceeded midsummer daily primary production by 58% at 5 m depth. They further suggested that these consumption levels likely limited the production of large rotifer and ciliate populations that were not found in the Bras d'Or.

Early surveys have shown there to be no significant production rate differences in the various large lake basins despite varied morphometry and hydrography. Only in well-mixed shallow areas was production substantially higher. Phytoplankton cells were seldom distributed uniformly even in well-mixed upper layers, but were frequently concentrated near the surface and at discontinuities. There was no evidence of vertical migration of flagellates during the day, nor was there a pronounced afternoon reduction in photosynthesis (Geen and Hargrave 1966).

Fifteen species of copepod were collected in tow net samples from 24 sites around the Lakes during the end of June and early July 1981 for the National Museum of Canada (Shih et al. 1988). During these tows, *Pseudocalaus minutus*, *Oithona similis*, *Temora longicornis*, and *Tortanus discaudatus* were found to be the dominant species in both abundance and distribution. Sampling from the top 10 cm of water accounted for all of the *Anomalocera opalus*, most of *Tortanus discaudatus*, and all but one of the harpacticoids. Distribution of copepods in the Lakes was uneven, with Bras d'Or Lake having the lowest diversity, and St. Andrews Channel the highest, including the only occurrences of four species. One of those four, *Microcalanus pusillus*, is a common cold water species in the Arctic (Lambert 2002), adding to the diversity of Arctic relict species identified in the cold deepwaters of North Basin and St. Andrews Channel. Diversity south of the Barra Strait and Whycocomagh Bay is limited, with only the four most common species typically being found. Shih et al. (1988) suggest that shallow sills at Little Narrows and Barra Strait may act as effective barriers to dispersion of some deeper water species of copepod. Similarly, they believe the shallow sills of the Great and Little Bras d'Or Channels further limit dispersion of some Gulf of St. Lawrence species into the Lakes.

Plankton blooms recorded from the Continuous Plankton Recorder (CPR) of 66 different taxa in the North Atlantic over 44 years were compared to spring sea surface temperature (SST), and a majority of the dinoflagellates assessed, which compose a large portion of the Bras d'Or Lakes plankton (Geen 1974; McLachlan and Edelstein 1971; Hargrave and Geen 1970) were blooming as much as 27 days earlier in 2002 than 1958 (Edwards and Richardson 2004). Diatoms, which have been shown to be important in the Bras d'Or Lakes spring bloom because of the high silicate load coming from the larger rivers in the northwestern portion of the watershed (Strain and Yeats 2002), have not shown a significant change in bloom times with warming spring SST, presumably because of length of day being a significant driver in bloom timing for this taxon (Edwards and Richardson 2004). Edwards and Richardson (2004) suggest that the varied response to warming SST creates a mismatch between successive trophic levels, and that the change in synchrony between primary, secondary and tertiary consumers may have an impact on the higher level consumers that require efficient energy transfer up the food chain. Although no long-term data has been presented specifically for the Bras d'Or Lakes, 127 years of data for the Mirimachi River (New Brunswick) from 1822-1955 show a 7.3 day earlier ice breakup trend (Magnuson et al. 2000), and local residents of the Bras d'Or have noted that there is less ice cover and thinner ice cover on the Lakes over the past 50-80 years (CEPI 2006; DFO 2006). The lack of a consistent temperature measurement program in the Bras d'Or Lakes coupled with the large seasonal temperature range encountered in the surface waters of the Lakes precludes the statistically significant determination of any trends within the Bras d'Or at this point in time.

11.1.2 Icthyoplankton (larval fishes)

Little information exists on the icthyoplankton of the Bras d'Or, however an annual plankton survey was initiated in 2000 as a partnership between the Department of Fisheries and Oceans and the Eskasoni Fish and Wildlife Commission. Preliminary results of the late May and early June 2000 sampling show the most abundant icthyoplankton were Four-beard rockling (*Enchelyopus cimbrius*), Winter flounder (*Pseudopleuronectes americanus*), cod (*Gadus morhua*), and smelt (*Osmerus mordax*). Significant numbers of eggs were found for the same rockling, as well as cunner (*Tautogolabrus adspersus*), Windowpane flounder (*Scophthalmus aquosus*), and mackerel (*Scomber scombrus*). Other species known to be common were likely not caught because the timing of the survey did not correspond to the relevant life stages. Detailed analysis of this, and subsequent tows, are being conducted by the Eskasoni Fish and Wildlife Commission and will be reported elsewhere (Lambert 2002).

11.2 Benthic Communities

11.2.1 Macrophytes

Benthic algae prefer silt free substrata, and this preference limits them to a narrow shoreline band in the Bras d'Or, as most of the lake bottom is sand and silt (Simpson 1976). This band is especially narrow in the Bras d'Or because the small tidal amplitude limits the area over which wave action can effectively prevent fines from settling. Throughout most of the Lakes there exists an appreciable layer of fine sediments that form an unstable substratum. Where large boulders do emerge from the fines, they often become covered in algae in areas otherwise free of aquatic vegetation (McLachlan and Edelstein 1971). Beyond the physical habitat limitations, the principal control on algal flora is a combination of saline waters excluding freshwater species and low water movement limiting marine species (Kenchington and Carruthers 2001). Macroalgal development in the Lakes is nowhere rich.

Other marine flora have formed important and extensive beds in the Lakes system. Eelgrass (*Zostera marina*) can root in the muddy and loose substrates that dominate so much of the Bras d'Or seabed, and was found to be more common than seaweeds at all sample sites examined by McLachlan and Edelstein (1971). Eelgrass is known to have provided important spawning grounds for herring historically (Denny et al. 1998), and may also have a significant contribution to the productivity of the Lakes. Eelgrass dominated areas include St. Patricks Channel, Denys Basin, North Basin, and the upper reaches of East Bay and St. Peters Inlet (MacLachlan and Edelstein 1971). Unfortunately, we only have rough estimates of the abundance of eelgrass beds in the Bras d'Or and the relative importance of these plants needs to be revisited (Vandermeulen pers. comm. 2006).

Most work directly related to seaweeds in the Bras d'Or was conducted in 1970. In this work (McLachlan and Edelstein 1971), seaweeds of the Bras d'Or system were characterized in two ways. Either they were similar to those of the open Atlantic Coast of Cape Breton in species composition, or they were a shallow warm-water assemblage characteristic of protected bays along the Northumberland Strait. Predominant oceanic species that existed in the colder water areas of the Lakes were rockweed (*Fucus vesiculosus)*, knotweed (*Ascophyllum nodusum*), kelp (*Laminaria agardii*), and Irish moss (*Chondrus crispus*). In the warmer water areas of shallow bays, sea lettuce (*Ulva lactuca*), *Bryopsis hypnoides*, twig weed (*Ahnfeltia plicata*), chenille weed (*Dasya pedicellata*), and banded weed (C*eramium fasigiatum*) were a few of the more common species identified. In all, 92 species were identified, most restricted to a narrow band along the shoreline not exceeding three or four metres in depth. In discussing the productivity of seaweeds, McLachlan and Edelstein (1971) state, "undoubtedly their contribution to the productivity of the lake is small".

More recently, during lobster surveys (Tremblay 2004), it was noted that large drift kelp was present at depths of more than 16 m. These somewhat limited areas included locations in the North Basin, St. Patricks Channel near Washabuck, East Bay, and at the entrance to the Great Bras d'Or Channel.

Of interest are a few observations made of rare occurrences of marine macrophytes within the Bras d'Or Lakes. In 1966 a warm water alga, crustose coralline *(Phymatolithon laevigatum),* was recorded by Adey in East Bay (pers. comm. cited in McLachlan and Edelstein 1971). Additionally, a rare and sparse species around the Atlantic Provinces, *Nemalion helminthoides* was found at several sites in the Bras d'Or. The population of this species outside of McIver's Cove in St. Patricks Channel was very dense and the most abundant occurrence encountered by the surveyors in the Lakes (McLachlan and Edelstein 1971).

11.2.2 Invertebrates

Epibenthic invertebrates are those that live on the surface of the sea floor, including large crustaceans, mollusks, and echinoderms. Infaunal invertebrates live within the sediments and include worms and small crustaceans. The composition of benthos is strongly affected by bottom type. Benthic invertebrates have a diversity of life histories. Most have a planktonic larval stage, but upon settling some become sedentary while others remain mobile. Crustaceans are the primary moulting group, while most others grow continuously. Finally, some are grazers, others filter feeders, and still others are predatory. One of the key physical features of the Bras d'Or Lakes that impacts the presence and distribution of invertebrates is its lower salinity. Typically, larval stages of marine invertebrates are more sensitive to low salinity, and adult phases less sensitive (Tremblay 2002). Echinoderms, such as starfish and urchins, have been the dominant invertebrate biomass collected during surveys of the Bras d'Or Lakes (Tremblay 2004).

11.2.2.1 Commercial Species

Lobster (*Homarus americanus*), oysters (*Crassostrea virginica*), scallops (*Placopecten magellanicus*) and rock crab (*Cancer irroratus*) are the most significant commercial benthic invertebrate species in the Lakes. The longest standing of these fisheries has been for the wild populations of oyster. Oyster aquaculture has also occurred in the Lakes for decades. Distribution of all of these species, none of which tend to be particularly deepwater inhabitants, is controlled by the wide ranging temperature and salinity spectrum of the shallow bays of the Bras d'Or. Distribution and productivity is also influenced by the limited hard bottom habitats of the predominantly silt laden Bras d'Or substrates. Recent surveys clearly show that the Bras d'Or Lakes have substantially lower densities of lobsters and rock crabs than can be found at the mouth of the Great Bras d'Or Channel (Tremblay 2004).

Oysters

Not all of the Bras d'Or Lakes offer an ideal environment for the native oyster (*Crassostrea virginica*), athough the water is productive in many areas. There have been doubts about the productivity of the waters, and hence the food supply for oysters, and Needler (1934, 1936) suggested that the shorelines outside of the enclosed bays do not reach sufficiently high temperatures in the summer for the oysters to spawn. Therefore, temperature confines the oyster to the sheltered bays where the shallows warm to over 20 ^{o}C. These warm bays often correspond to areas with more freshwater runoff (or at least lower circulation) than the open Lakes, thus reducing the salinity. As a consequence, the productive beds are close to the lowest tolerable salinity for oysters (Kenchington and Carruthers 2001). It has been estimated that only 5% of the total area of the Bras d'Or Lakes is suitable for bottom cultivation of oysters (Ocean Science Associates 1972). In the key growing area of Denys Basin, it has been estimated that hard bottom habitats may have decreased by as much as 60% because of the sedimentation from land based sources (ECA 2001). According to TEK, the decline of oysters off Eskasoni has also been attributed to silt deposition which has accumulated as much as 2-3 inches in the last five years (CEPI 2006).

Recent interferometric sidescan sonar in Denys Basin shows what are likely oyster bioherms, hard organic mounds of shells, in an otherwise muddy bottom. These mounds are typically 5 m in diameter, but at least one is up to 20 m. Oyster beds appear to be on top of these bioherms which are up to 4 m tall, but surrounded by muds. Where these bioherms could not keep pace with sediment deposition, they are now buried below mud (Shaw and Potter 2006c). Photographs document the suspended sediment in River Denys that is carried to the basin, and residents suggest that clearcutting and poor road ditching adjacent to waterways are the likely cause of sedimentation (Barrington 2005), although no quantitative assessment has been completed.

Oysters have been over fished in their native habitats in the Lakes, and although small wild pockets still exist, today they are only found in large numbers at aquaculture sites (Lambert 2002). In 1990, 85% of oysters were found on lease sites, and only 15% on public beds. Seven percent were in areas closed because of bacterial contamination (DFO 1996). These oysters typically reach spawning condition fairly early in the summer (Wright 1976) in shallow, warm summer waters. Significant wild oyster production within the Bras d'Or is limited to Denys Basin, St. Patricks Channel, Whycocomagh Basin, West Bay, East Bay and St. Peters Inlet (Tremblay 2002, Needler 1936). Denys Basin, influenced by River Denys, is of regional interest as the centre of the Bras d' Or oyster industry both historically with wild oyster and today with aquaculture. It is the most extensive area within the Lakes that provides water within the species' tolerance limits for both temperature and salinity. Denys Basin long supported the major wild oyster fishery in the Lakes (Kenchington and Carruthers 2001), and it has also been suggested that the warmer waters of Denys Basin reduce the competition from blue mussels that typically would compete with oysters for the limited habitat available (ECA 2001).

Lobsters

The Bras d'Or Lakes support a limited commercial lobster fishery. Lobster landings are lower in the Lakes than in open areas of coastal Cape Breton Island, although it is not fully understood why (Petrie and Raymond 2002). Within the Lakes, lobster landings are poor at present, and fishermen have reported a decline. Traditional ecological knowledge also indicates that lobsters have declined in the Bras d'Or (CEPI 2006). Tremblay (2002) reports the industry's heaviest effort appears to be in the West Bay and St. Peters areas. However, observations cannot be quantified for areas north of the Barra Strait through existing data as fishermen in that area of the Bras d'Or also set in Sydney Bight, and catch rates are reported together (Tremblay 2002). Stevens and Denny (1993) reported that "...the lobster resources supported the most economically important fisheries for Natives and non-natives..." for Lobster Fishing Area 28 south of the Barra Strait in the early 1990s.

Scientific catches within the Bras d'Or Lakes have typically been small, with the North Basin and Great Bras d'Or Channel being relatively more productive. Low salinity, limited habitat, limited food, and low egg production are the factors most frequently cited as working alone or together to limit lobster production. Current investigation points to all of these possibilities but does not confirm or eliminate any (Tremblay 2002). For example, much of the Bras d'Or system has a silty to sandy substrate that is generally less favourable for lobster. However, a recent survey of habitats in the Lakes identified a relatively significant 30% boulder and cobble habitat in West Bay. Other studies have found 4-7 times more lobsters in areas of similar habitat outside the Bras d'Or, leading to the suspicion that physical habitat is not limiting lobster production, at least in the West Bay area (Tremblay 2004).

During a 1993 at-sea sampling of fishermen's traps, 647 trap-hauls were observed in the East Bay and St. Peters vicinity, with 392 lobsters measured (Stevens 1993). Carapace lengths ranged from 60 to 142 mm, with most being between 70 and 105 mm. Lobsters on the outer coasts of Cape Breton were observed to be predominately smaller than 90 mm, whereas nearly half of those measured in the Lakes were larger than 90 mm, suggesting that lower fishing pressure allows for improved survival to larger sizes (Stevens 1993). Stevens' data also indicate that larval release by the "berried" females occurs in the surveyed areas of the Bras d'Or during July. Her trap survey showed that egg-bearing female lobsters make up a high proportion of the total females caught when compared to the trap catch in Sydney Bight. Yet the overall production of lobsters from the Lake is low (Kenchington and Carruthers 2001).

Of interest is an unconfirmed indication that the Bras d'Or lobsters maintain some degree of genetic isolation from the Sydney Bight lobster population. This appears through the documentation of a higher occurrence of a bright orange colormorph lobster within the Lakes compared to those outside (Tremblay 2002). This is a characteristic that is genetically based, and therefore a different percentage within the Lakes is most readily explained by isolation from other neighbouring populations.

Rock Crab

Rock crab (*Cancer irroratus*) is commercially fished in the northern end of the Great Bras d'Or Channel adjacent to Sydney Bight. Their distribution is most abundant in this area because of salinity requirements (Lambert 2002), but they can be found throughout the Bras d'Or (Tremblay 2004). Reduced salinities, such as are found in most of the Lakes, likely influence rock crab production more than lobster production. However, unless the rock crab in the Bras d'Or have adapted, many would be unable to achieve metamorphosis in the lower salinity waters that exist in much of the Lakes (Tremblay 2002). But even with such limitations, rock crab is widespread, and has been found in tow surveys south of the Barra Strait (MacDonald 1968; Lambert pers. comm. 2001 cited in Tremblay 2002). The highest percentage of rock crab within the Bras d'Or is generally found at 3-10 m depth (Tremblay 2004).

Scallops

Sea scallops (*Placopecten magellanicus*) are relatively intolerant of low salinities, and as such are not found in most areas of the Lakes. A small commercial fishery for this species takes place on the outer part of the Great Bras d'Or Channel. Their distribution is not well documented, but they have been found incidentally in fish surveys trawling in the Great Bras d'Or, St. Andrews Channel, and the North Basin (Lambert 2002). Significant scallop beds are limited to the northern end of the Great Bras d'Or Channel by salinity requirements (Lambert 2002).

11.2.2.2 Non-Commercial Key Species

Few species have been well studied within the Bras d'Or Lakes ecosystem. However, some of the smaller organisms that make up the base of the food web have been studied in some depth. These include the polychaetes (Fournier and Pocklington 1984), mysids (Lambert 2002; Black 1956, 1958, 1976) and foraminifera (Vilks 1967).

Polychaetes

The polychaetes, or "bristle worms" as they are known, include a wide range of types from burrowers, to mobile predators, to filter-feeders (Kenchington and Carruthers 2001). More than 70 species of polychaetes were identified by Fournier and Pocklington (1984) through benthic surveys of the Bras d'Or Lakes in 1981. Their observations led them to suggest that two assemblages exist within the Lakes. The first is the relatively geographically limited warm water 'Virginian' enclave, and second is the more widespread distribution of Arctic-boreal species.

The Great Bras d'Or Channel, with its extensive mixing, warms enough at depth for Virginian species to breed during the summer. In the winter and spring, breeding of sub-Arctic species is possible as the cooler weather cools the fresh water component mixing in the Channel. Bottom temperatures in the Channel have been shown to increase by 8°C between May and July (Gurbutt and Petrie 1995). Likely because of the seasonal range of temperatures in the Great Bras d'Or Channel, that area had the greatest diversity of polycheate species in the 1981 survey. The Channel had the greatest overall abundance of all areas surveyed in the Lakes (Fournier and Pocklington 1984), and 19 of 43 species were unique to the Channel.

However, a single ecotype can not equally satisfy all requirements of such a wide range of species. In fact, the sub littoral area of the Great Bras d'Or Channel consisted primarily of warm water 'Virginian' species. Interestingly, the Virginian enclave species of the Northumberland Strait and southern Gulf of St. Lawrence are typically confined to the littoral zone (Bousfield and Thomas 1975 cited in Fournier and Pocklington 1984). Therefore, the collection of these species in the Bras d'Or Channel to depths of 50 m appears regionally unique.

In the remaining sublittoral zone of the Lakes, a thermal stratification tends to keep most deep lake bottom areas significantly cool year round, with bottom temperatures not tending to exceed 2°C in the summer (Gurbutt and Petrie 1995). This favours the Arctic and Arctic-boreal polychaete species found throughout much of the remainder of the Lakes (Fournier and Pocklington 1984).

Only one species from the Great Bras d'Or Channel's sub littoral Virginian assemblage, *Ninoe nigripes*, was found in other basins around the Lakes. Most other more widely distributed species were typical of an Arctic-boreal distribution. The most common species within the whole Lakes was *Euchone papillosa* (Lambert 2002), whereas the most widespread species, found regularly at all sites around the Lakes, was *Nephtys incise*. Fournier and Pocklington (1984) summarize the polychaete community of the Bras d'Or as primarily an isolated Arctic enclave, with the exception of a Virginian enclave in the Great Bras d'Or Channel that reflects the southern Gulf of St. Lawrence. *Clymenura polaris* found in Bras d'Or Lake is the only record south of Baffin Island for this Arctic relict species (Fournier and Pocklington 1984).

Although Fournier and Pocklington's (1984) sampling of polychaetes spread broadly through the Lakes, it was restricted to a single week of sampling (in late June and early July), and was carried out only in deeper water. With little additional sampling having been done since, it is possible that some seasonally-abundant species or shallow water species may exist. Given the diversity of temperatures and salinities in the shallow bays of the Lakes, a greater species diversity is likely. The Eskasoni Fish and Wildlife Commission are currently undertaking invertebrate identification from a limited number of shallow water sights around the Bras d'Or (Paul pers. comm. 2005).

Mysids

Mysids are an important food source for many bottom feeding fish, and within the Bras d'Or are particularly important to cod of less than 50 cm length. These small shrimp-like organisms are more complex than copepods but are still more primitive than euphausiids (krill), which in turn are simpler still than the true shrimps (Kenchington and Carruthers 2001). Most adult mysids are approximatey one centimetre in length, though Muhammad (1966 cited in Kenchington and Carruthers 2001) reported *M. stenolepis* from Baddeck Bay as large as 25 mm.

Five species of mysid shrimp were identified from 1951-52 bottom trawl surveys in the Bras d'Or Lakes (Black 1958). These surveys were limited in their coverage, occurring only in a handful of locations north of the Barra Strait. The two most common species, *Neomysis aericana* and *Mysis stenolepis*, are boreal inshore forms with wide tolerances for salinity and temperature, and as such were found in all surveyed parts of the Lakes. Two Arctic-boreal forms, *Mysis mixta* and *Erythrops erythrophthalma*, were found predominantly in the cold water of the deep areas, although they did move into some of the shallow bays during winter when surface temperatures cooled significantly. Finally, one species was found only in the deeper cold waters. *Mysis oculata* is a true Arctic species, and as such survives a considerable distance from its normal home range by staying in the deep, cold portions of the Lake year round (Lambert 2002). *Mysis oculata* was found at Kempt Head at the opening of St. Andrews Channel in the 1950s (Black 1976). In later years Krauel (1975) showed that Whycocomagh Bay was hypoxic and anoxic within its two deeper basins, which helps explain why Black (1958) observed low numbers of mysids there.

Based on Black's (1958) research, *Mysis* in the Lakes are primarily bottom dwellers rather than plankters, although some evidence collected supports seasonal migration of two cold-water species from deep basin areas to the shallower bays. A few of the species observed also seem to exhibit diurnal vertical migration, triggered by light intensity.

Foraminifera

In 1967, Vilks (1967) surveyed the Bras d'Or for foraminifera. Thirty-nine species of this single-celled shelled protist were identified and associated with specific sediment types. They feed on bacteria, diatoms, and other single cell phytoplankton. Overall, the species assemblage found was similar to that of St. Margaret's Bay and Mahone Bay, Nova Scotia. The exception to this statement being two common Arctic inshore species that were identified in the Lakes: *Eggerella advena* (the most common in the Lakes) and a group of *Reophacidae* (Vilks 1967).

When the stations were clustered into five groups, based on the similarity of their foram populations, there was a markedly discrete, marine group in the mouth of Great Bras d'Or, seaward of Seal Island. With this exception, most stations fell into one of three classes: a deep group, found in most of the deeper parts of the Lakes and in deeper portions of shallower bodies; a shallow group found through most of Whycocomagh Bay, St. Patricks Channel, Denys Basin, much of West Bay, St. Peters Inlet, and generally in other shallow areas; and finally, an intermediate-depth group found widely around the rest of the Lakes (Kenchington and Carruthers 2001).

Others

Green crab (*Carcinus maenas*) is believed to have arrived as an invasive species to the Bras d'Or between 1992 and 1995 (Tremblay 2002). Within coastal Nova Scotia they are known to be most common in protected embayments and prey voraciously on common bivalves (Elner 1981). Green crab is found widely distributed throughout the Lakes in typical surveyed depths of 1-5 m (Paul pers. comm. 2005).

Blue mussels (*Mytilus edulis*) occur throughout the Lakes on the limited harder substrates. Trawl surveys of 1999-2000 documented them as most naturally abundant in St. Peters Inlet and Bras d'Or Lake, although they were not quantified (Tremblay 2002). Mussels were sampled from Seal Island in the Great Bras d'Or Channel and at Alder Point on the Sydney Bight end of the Little Bras d'Or Channel in 1981-82 (Sirota et al. 1984). This study was evaluating presence of PAH in the mussels, and the results were low to non-detectable.

However, they did note that abundance at both locations varied greatly during the two years. In 1981 both locations had abundant mussels; Alder Point had a complete range of mussel sizes whereas Seal Island mussels were of a relatively narrow size range. In 1982 the abundance was extremely low at each site with limited size ranges present. It was further noted that those sampled from the Great Bras d'Or had very thin and easily broken shells. The authors offered no explanation for the size variation or the thin shells; however it is now believed that these mussels were another species, *Mytilus trossulus*.

Sea urchins (*Stronglyocentrotus droebachiensus*) and starfishes are important grazers and predators for which little is known within the Bras d'Or system. Sea urchins have been found throughout the Bras d'Or Lakes in non-targeted surveys, dominating the invertebrate catch in Bras d'Or Lake, and East and West Bays. Sea urchins on mud and or sand are most characteristic of depths greater than 15 m (Tremblay 2004). Likewise, starfish (particularly *Asterias vulgaris*) are found in all areas (Tremblay 2002). According to TEK there has been a decline in the urchin population of the Bras d'Or (CEPI 2006).

11.2.3 Groundfish

Groundfish have been sampled in several surveys of the Bras d'Or Lakes. A total of 46 species of fish have been caught and identified in the Bras d'Or Lakes from a number of trawl surveys from 1952-2000 (Lambert 2002; Black 1976; MacDonald 1968). Most are demersal and are also resident fish that never leave the Lakes system. Lambert (2002) categorized only five of the species as migratory, and four of the rare species as vagrants that had strayed beyond their normal home ranges in atypical situations. Winter flounder (*Pseudopleuronectes americanus*) were the most widespread species, found in all trawl locations throughout the Lakes. Windowpane flounder *(Scophthalmus aquosus)*, white hake (*Urophycis tenuis*) and winter skate (*Raja ocellata)* were other groundfish with wide distribution. White hake and winter flounder seem to have increased in abundance since the late 1960s, with the greatest increase being found in the flounder. Conversely, American plaice (*Hippoglossoides platessoides*) abundance has decreased significantly in the same time frame. Overall, standardized to weight per unit length of trawl, fish seem to be about three times more abundant in 2000 over 1967 surveys (Lambert 2002). This may be misleading as several species, not all benthic, have measured declines over the same time period, including American plaice and herring.

11.2.3.1 Commercial Species

During a comparison of 1952 and 1967 groundfish trawls of the Bras d'Or with 1999/2000, changes in abundance and distribution of major groundfish species were noted. The most common species was winter flounder, which supported commercial fisheries until 1992 when trawling activity was banned in the Lakes (Lambert 2002). Of the groundfish caught in the scientific trawls and assessed by Lambert (2002), winter flounder dominated the catch, with nearly twice the number of the next most abundant species (plaice) in the 1950s (Black 1976), fell to second by weight in the late 1960s (MacDonald 1968), before rebounding after the closure of the trawl fishery to be the most abundant by weight in the late 1990s (Lambert 2002).

Cod

One might expect cod (*Gadus morhua*) to be the most common commercial fish in the Bras d'Or Lakes given its historic importance throughout Atlantic Canada, however seal worm heavily infests nearly all of the Bras d'Or cod. This fact has greatly impacted the market value of Bras d'Or cod and severly limited the fishery for this species.

In all scientific trawl surveys from 1952-2000, cod were the most plentiful benthic species captured. They were also one of the most widespread of all species within the Lakes, and seem to have increased in abundance since the late 1960s (Lambert 2002). Contrarily, TEK suggests that cod have declined in the Lakes (CEPI 2006). According to TEK, in the 1980s and early 1990s longline gear was allowed in West Bay, following which there was a decline in cod. Now there are hardly any cod left. Cod in the Bras d'Or Lakes are smaller and do not look the same anymore (CEPI 2006).

The Lakes contain one, if not two resident populations of cod (Lambert 2002). A resident population was first suspected during evaluations of seal worm (*Pseudoterranova decipiens*) present in the cod of Bras d'Or Lakes. Bras d'Or cod have significantly higher incidence of seal worm than do cod of Sydney Bight. However, cod from within Whycocomagh Bay, within the Bras d'Or Lakes, had virtually no seal worm. It has been suggested that populations in Sydney Bight, most of Bras d'Or Lakes, and Whycocomagh Bay might exchange their planktonic eggs and larvae, and even a few adults, but there could not be much movement of larger fish between these areas. The hypothesis is that since cod over 50 cm length do not seem to eat the stationary mysids which carry the seal worm (Scott and Black 1960; Black 1956, 1958), infestation must occur when fish are young. However, these highly infested fish do not get distributed to Sydney Bight or Whycocomagh Bay because the fish are not moving freely between these areas. A reasonable explanation is that separate populations created by a lack of movement were established early in the cod life cycle and maintained through adulthood (Kenchington and Carruthers 2001).

Subsequent evidence for the separation between Bras d'Or cod and cod from the Scotian Shelf came from exercise experiments that determined a physiological distinction between the two populations (Nelson et al. 1994). Fish from these two areas were able to achieve and maintain the same activity level. However, cod from Bras d'Or had higher metabolic, ventilatory, and cardiac rates during experiments than did fish from the Scotian Shelf. The Bras d'Or fish appear to use more anaerobically derived energy production to achieve the test activity level. Why Bras d'Or fish used more anaerobic energy production is not fully understood, but it is believed to be related to morphological differences that relate to drag profiles, or a smaller scope for activity requiring a need to supplement aerobic metabolism. Regardless, the cause appears to have affected natural selection of blood constituents, and Nelson et al. (1994) suggested that differences in blood chemistry enabled Bras d'Or cod to use oxygen and energy efficiently in the lower salinity water of Bras d' Or.

Recently, Lambert (2002) pointed to an additional temporal difference between the populations. A month separates spawning times of those fish within the Lakes from those of Sydney Bight, which further supports the theory of separate populations. Finally, genetic differences were confirmed between Bras d'Or Lake and Scotian Shelf cod by Pogson et al. (2001).

Typically, salinity is a key physical attribute affecting distribution of marine fish in the Bras d'Or Lakes, however it appears that cod in the Lake are more tolerant to reduced salinity than are cod external to the system. This may indicate some local adaptation to salinities (Lambert 2002). It is hypothesized that the relative salinity tolerances of different species in the Lakes are the same as have been measured elsewhere (Tremblay 2002).

11.2.3.2 Non-Commercial Key Species

The biggest change in trawl survey data over time has been a reduction in abundance of American plaice, which became rare in the recent trawl surveys. Although historically widespread and found in significant numbers, the most recent scientific trawl surveys of 2000 indicate American plaice have dropped significantly in numbers and are now confined to the deeper areas of St. Andrews Channel and Bras d'Or Lake (Lambert 2002).

11.3 Pelagic Communities

11.3.1 Turtles

There are over 200 species of turtles living in the world. Only seven are represented in Nova Scotia (Table 12). Four are freshwater and three are marine. None of the marine reptiles are expected in the Bras d'Or Lakes, and there have been no documented cases of any of these species of turtle straying into the Lakes. The shallow depth and significant tidal velocities of the Great Bras d'Or Channel are likely effective barriers to these species. Several of the terrestrial species likely occur in the greater watershed of the Bras d'Or, however the Wood turtle is the only species of concern that may occur in the watershed. In 1996 the Wood turtle was designated Special Concern on the official list of species at risk of the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2006) and legally listed as Vulnerable by Nova Scotia's *Endangered Species Act* in 2000. Its distribution is likely limited to the southwestern extents of the watershed.

Table 12. List of terrestrial and marine turtles of Nova Scotia, and their status as listed with the Nova Scotia *Endangered Species Act*. This table is based on notes from the Nova Scotia Museum of Natural History.

Species	Common Name	NS Endangered Species Act Status	Likelihood in Bras d'Or
Emydoidea blandingi	Blandings Turtle	Red	No, and rare on mainland
Chrysemys picta picta	Eastern Painted Turtle	Green	No records on Cape Breton
Clemmys insculpta	Wood Turtle	Yellow	Most common in southwestern Cape Breton Island
Chelydra serpentina serpentina	Common Snapping Turtle	Green	Somewhat common on the mainland, but rarely sited in Cape Breton
Dermochelys coriacea coriacea	Atlantic Leatherback Turtle	Not listed	Fairly common along coastal Nova Scotia, not in Bras d'Or
Lepidochelys kempi	Atlantic Ridley Turtle	Not listed	Rare, none in Cape Breton
Caretta caretta caretta	Atlantic Loggerhead Turtle	Not listed	Rare, none in Cape Breton

Source: Nova Scotia Museum 2005

11.3.2 Pelagic Fish

Although some 46 species of fish have been surveyed within the Lakes (Lambert 2002), most are benthic resident fish. Of the pelagic species, several are migratory and move into or out of the Lakes based on life cycle needs, primarily spawning. Such migratory species of the Bras d'Or include mackerel, herring, and Atlantic salmon. The majority of fish found in the Lakes are boreal or Arctic-boreal species.

Eels, pollock, haddock, dogfish, and pout, which were present in trawl surveys of the 1950s and 1960s (MacDonald 1968; Black 1976), were not found in more recent 1999-2000 surveys (Lambert 2002).

11.3.2.1 Commercial Species

Assessing the magnitude of the commercial fishery in the Bras d'Or Lakes is difficult, as many fish are landed at wharves outside of the watershed and catch numbers are not allocated as having come from inside or outside of the Bras d'Or. Additionally, many fishermen do not rely on fishing as a sole or main means of income (UMA Group 1989). Based on records from Fisheries Officers in the mid 1980s, the greatest number of full time fishermen (76) harvest lobster along the Big Bras d'Or Channel. A moderate number from Little Narrows and Orangedale were involved in the herring fishery prior to its closure in 1999. Another 35 part time fishermen from Iona and Baddeck also fished herring, as well as a number of other species (UMA Group 1989).

Commercial fisheries on the Bras d'Or Lakes have included such species as herring, mackerel, and cod (Kenchington and Carruthers 2001), with the main commercial fishery in the Bras d'Or Lakes being herring (*Clupea harengus*) (Crawford et al. 1982). A commercial fishery for Atlantic salmon (*Salmo salar*) in eastern Cape Breton was closed in 1985 (Robichaud-LeBlanc and Amiro 2004).

Herring

The spring spawning herring (*Clupea harengus*) stock of the Bras d'Or contrasts with the predominantly fall spawning stock(s) along the Atlantic Coast (Crawford et al. 1982). Based on counts of various physical features such as vertebrae and fin rays, Scott (1975) concluded that the Bras d'Or Lake herring constituted a population distinct from spring and autumn spawners from all other regions of the Bay of Fundy, Bay Chaleur, and the Northumberland Strait. Studies by Crawford et al. (1982) in 1980-81 found the Bras d'Or fish to be physically different than other stocks (potentially indicating a unique population). They also spawned in some areas in record shallow waters of 25-75 m, and had a higher female fecundity than the spring spawning herring of the Northumberland Strait. The length-to-age values for herring aged 4-11 years in the Bras d'Or were generally less than for fish sampled along the Atlantic Coast and eastern Northumberland Strait, whereas fish at age 3 were longer than the other locations (Crawford et al. 1982). A similar observation was made of the weight-to-length values. This is believed to primarily be the result of the gonad maturation stage of the fish. Data indicate that there are no fundamental differences between the sexes of Bras d'Or Lakes' herring concerning the length – somatic weight relationship.

Although herring spawning takes place primarily in early April in the Lakes, autumn spawning herring have been seen but not confirmed spawning in the Lakes. Denny et al. (1998) noted that some fishermen recognise a run of large, dark ("blackback" or "bank") herring in the St. Peters area in the fall, which are different from the spring-spawning herring. A sample collected by DFO staff at St. Peters in September 1997 did contain roe fish, and herring from the adjacent Sydney Bight area are fall spawners (Scott 1975). No spawning beds have been observed at this time of year although spawn has been found in East Bay in October trawl surveys (Lambert pers. comm. 2005).

The herring fishery in the Bras d'Or Lakes was closed in 1999 after overfishing brought the herring population to the point of collapse. This was the result of increased fishing effort on the declining herring stock as fishermen looked for a cheaper alternative to mackerel for lobster bait. In 2002, the catch at age data for Bras d'Or show a higher percentage of the older 9-11+ year fish than in other coastal areas, as might be expected given reduced fishing effort. However, the younger age classes of 3-5 are much lower than other coastal Nova Scotia fishing areas (Power et al. 2003), showing some indication that the Bras d'Or stock is not immediately responding to the closure.

Green crab, which is a recent invasive species to the Bras d'Or that has become widespread and plentiful, has been observed to damage significant volumes of eelgrass in other Atlantic coastal areas (Davis et al. 1998). As noted, eelgrass beds, particularly in West Bay, were a key spawning location for herring. More recent video and SCUBA surveys have shown that the highest densities of green crab are in West Bay (Tremblay 2004), and recent field surveys in Denys Basin have shown eelgrass beds to be significantly smaller than previously indicated (Vandermeulen pers. comm. 2005).

Others

A number of attempts have been made to raise finfish through aquaculture within the Lakes. Rainbow trout (*Onchorhynchus mykiss*), Atlantic salmon (*Salmo salar*), and Arctic char (*Salvelinus alpinus*) have all been reared at one time within the Lakes for commercial resale, however there is currently no significant sustained finfish aquaculture in the Bras d'Or. The Nova Scotia Department of Agriculture and Fisheries provincial aquaculture data indicates that there were no active finfish sites as of 2004, although there were six licenses being held.

There have also been attempted commercial rainbow trout ("steelhead") aquaculture operations in the Lakes. Over a million individuals escaped from the pens during a ten-year period and they appear to have formed a feral, reproducing population (Sabean 1983 cited in Alexander et al. 1986).

11.3.2.2 Non-Commercial Key Species

Mackerel, eel, and smelt of the Bras d'Or Lakes support a limited recreational fishery. Much of this actually takes place in or near the rivers that flow into St. Patricks Channel, Denys Basin, Baddeck Bay, and Nyanza Bay (UMA Group 1989).

Traditional ecological knowledge indicates that eels have declined in the Bras d'Or Lakes (CEPI 2006). The bridge at Barra Straight was first built in 1900, and Elders then thought it had disrupted the flow and altered channels in the area, impacting nutrient flow to East Bay. This resulted in the slow decline of the eel, until by the 1950s harvests had greatly diminished. Elders believe the Canso Causeway contributed to the decline of the eel. Contrarily, a local diver reports a shallow lava rock shoal off the end of Long Island in St. Andrew's Channel where high densities of eel can still be observed. Eels are still seen in Crinkle Lake near West Bay. Residents report a big kill of eels of all sizes in the area where Middle River meets Nyanza Bay (Wagmatcook), however no timeframe was given (CEPI 2006).

According to TEK, the smelt population has declined (CEPI 2006). Smelts only come into the streams to spawn. In Breac Brook, the smelt numbers were very high in 2005. However, declines have been observed at Benacadie.

Traditional ecological knowledge indicates that gaspereau is declining (CEPI 2006). It is no longer observed anymore in May-June when it was once abundant. Gaspereau still spawn relatively strongly at Red Point and South Side Road near Whycocomagh, Jamisville barachois and Grass Cove near Iona. They used to be abundant in the barachois at Eskasoni but there are very few now.

In 1992 a newly discovered form of stickleback (*Gasterosteus*), termed the white stickleback, was reported from within the Bras d'Or Lakes (Jamieson et al. 1992). These fish were observed at Nyanza Bay, Gillis Cove, and Campbell's Cove in Whycocomagh Bay, but are found much more widespread through the Lakes. These fish exhibit both behavioural differences from the common threespine stickleback (*Gasterosteus aculeatus*), and utilize different microhabitat for spawning in the nearshore areas.

11.3.3 Marine Mammals

Approximatley 32 species of marine mammals can be found in the waters around Nova Scotia (Scott and Hebda 2004), although very few of these are found within the Bras d'or Lakes. Harbour seals (*Phoca vitulina*) and grey seals (*Halichoerus grypus*) are frequently sighted during the winter months, but scarcely seen during the summer. Residents suggest that seal numbers have increased in recent years, and believe it to be related to the reduced winter ice cover (CEPI 2006, DFO 2006). Although few written records of these seals exist, they are found around the Lakes and even in shallow bays like Denys Basin (Barrington 2005). Most frequently seals are found in North Basin between Baddeck Bay and Grand Narrows (Scott and Black 1960). In the 1950s, several hundred individuals of the two species were present in the Lakes from late November until March (Scott and Black 1960; Scott and Fisher 1958). Both Scott and Black (1960) and Scott and Fisher (1958) noted that seals were actively feeding on cod, and that both immature and adult seal worm were found within this host. The seals likely enter the Lakes for feeding, before their prolonged fast on the whelping beaches. The seals in the Lakes carry a greater seal worm load than those seals found outside the Bras d'Or system. This may indicate that some individual seals make a habit of swimming to Bras d'Or to feed, thus exposing themselves to the "wormy" cod (Kenchington and Carruthers 2001), as this cod population has been shown to be separate from the Sydney Bight fish (Pogson et al. 2001). It has been noted that the seal distribution within the Lakes coincides with local variations in the incidence of the seal worm in cod (Scott and Black 1960).

The only other written report of a marine mammal in the Lakes is a record of a single porpoise by Scott and Black (1960), although locals note that dolphins are seen periodically in the St. Peters area (DFO 2006).

11.4 Terrestrial Communities

This ecosystem overview and assessment report (EOAR) is based on watershed boundaries. Watersheds and bodies of water tend to have reasonably definable boundaries for study. Terrestrial communities are more a function of surficial geology and climate factors, and therefore much of what is documented on terrestrial species within the Bras d'Or Lakes watershed comes from larger geographic scale studies that have taken place both on Cape Breton Island and across Nova Scotia. However, there is often reference to the unique communities or habitats that occur within portions of the Bras d'Or Lakes watershed, and those highlights have been compiled here to the extent possible with limited reference to more general large scale studies and observations.

11.4.1 Mammals

There are 51 species (46 native, five introduced) of terrestrial mammals currently found in Nova Scotia (Scott and Hebda 2004). The native species represent boreal, Transition Zone, and Austral elements, which result from the province's mid-latitude position on the continental coast. Nova Scotia is a location around which climatic zones have historically shifted, isolating both plant and animal populations. In fact, six disjunct, or somewhat isolated, mammal populations exist in the province. All exist in Cape Breton, while two exist only in Cape Breton, predominantly in the highlands. There is no area of similar size to Nova Scotia north of Mexico that has a comparable proportion of disjunct mammal species (Scott and Hebda 2004). This section of the EOAR will focus on the top order herbivores and carnivores, in part because these top trophic level species tend to be more sensitive to disturbances, and in part because they tend to be more studied.

Historically, Cape Breton has had eight fewer mammal species than the adjacent mainland. With the construction of the Canso Causeway in 1953-55, the western portion of the Strait of Canso began to freeze over in winter allowing mammals to travel across the ice to the Cape Breton. Four large mammals have since become established in Cape Breton: the coyote *Canis latrans*, the racoon *Procyon lotor*, the skunk *Mephitis mephitis*, and the bobcat *Lynx rufus* (Scott and Hebda 2004). Those species that tend to hibernate have not moved, and are unlikely to move, back and forth between Cape Breton and the mainland. During ice free times of the year the causeway is the only link to the island for species that hibernate, and it is a narrow highly travelled rocky causeway that would generally prove inhospitable to most mammals.

Moose

The American moose (*Alces alces*) was extirpated on Cape Breton Island in 1924. Eighteen individuals were subsequently reintroduced from Alberta in 1947-48, and moose is once again common on the Island (Scott and Hebda 2004). Traditional ecological knowledge confirms that moose are much more common than 30 years ago and are thriving (CEPI 2006). The largest and most stable population of moose in Nova Scotia occurs in a 2400 km^2 area of the highlands region of Cape Breton (Pulsifer and Nette 1995). On the mainland of Nova Scotia road density, and road density in combination with habitat suitability index values predict the presence of moose (through moose pellets), whereas habitat suitability values alone do not (Beazley et al. 2004). In short, moose avoid areas where road densities are greater, even if appropriate habitat exists. This would seem to correlate with the core moose distribution within the Bras d'Or Lakes occurring north and west of Whycocomagh Bay, and west of St. Patricks Channel and the Great Bras d'Or Channel (Snaith and Beazley 2004) into the Cape Breton Highlands and the Highlands National Park. Traditional ecological knowledge indicates that moose are now seen closer to the Whycocomagh Reserve, on the south side (CEPI 2006). It has also been noted that where moose numbers are high, accessibility by road is seasonally restricted or extremely difficult because of terrain (Pulsifer 1995). Preferred food species of the moose include white birch, balsam fir, mountain ash and various species of maple (Basquille and Thompson 1997 cited in Snaith and Beazley 2004).

Unlike mainland moose, which are severely infected with a parasitic worm (*Parelaphostrongylus tenuis*) that gets transported by White tail deer, the moose of Cape Breton Highlands have less contact with deer and therefore are less infected. According to TEK, there is a belief that on the mainland, acid rain neutralizes natural salt areas that moose depend on and thereby creates a weaker animal and facilitates the negative effects of the deer parasite (CEPI 2006).

Long winters and deep snow on the highlands force deer to lower elevation habitats, and reduces competition between the two species. Moose densities within the Bras d'Or Lake project area and the southern highlands are about 1.0/km^2 (Pulsifer 1995). This is about half of the density of the northern highlands, but as much as 10 times the density found on the mainland.

There are no significant natural predators of moose, particularly since the most significant predator in other locations, the wolf, has apparently been rare in Nova Scotia historically and extirpated since about 1847 (Pulsifer and Nette 1995). In Cape Breton black bears may prey on young moose calves (Pulsifer 1995) as has been seen in other areas. Humans have long been the most significant predator of Cape Breton moose. By 1825 the effects of unrestricted moose hunting were causing declining numbers in Cape Breton, with nearly all of the harvested animals being exported from the province. Efforts to rebuild the population with introductions from New Brunswick in the late 1920's and Alberta in the late 1940's, along with surviving animals from the eastern race, have formed the basis of the current herd in the northwestern part of the Bras d'Or Lakes watershed (Pulsifer and Nette 1995). The Cape Breton population is considered genetically distinct, and is quite distinct from all other eastern Canadian moose populations because of its origins from the introduced Albertan animals. The Cape Breton population was estimated at 4-6000 animals in 1994 (Broders et al. 1999).

Deer

White tail deer (*Odocoileus virginianus*) are not a native species to Nova Scotia, having been introduced in 1908. The deer is now common throughout the Bras d'Or watershed, as it is in the rest of Nova Scotia. Approximately 200 deer winter from January to March in a 24 km^2 area of the Denys Basin subwatershed called Eden (Patterson et al. 1998 cited in Patterson et al. 1999). This is the largest wintering yard within the Bras d'Or watershed (see Table 13). These deer come from a minimum surrounding area of 180 km^2 or 18 010 ha, and although most seem to remain in the low lands of the River Denys watershed at winters end, nearly all disperse in a north westerly direction. A few animals do leave the valley for their summer ranges in the highlands between Skye Mountain and the Bornish Nature Reserve (MacDonald 1996).

Table 13. Approximate area of deer wintering range in each of the major Bras d'Or Lakes subwatersheds

Watershed	Km² of Deer Winter Range
River Denys	38.3
St. Patricks Channel	15.6
East Bay	17.6
West Bay	11.5
North Basin	7.9
St. Andrews Channel	5.5
MacKinnon's Harbour (Bras d'Or Lake)	3.9
Whycocomagh	2.6
St. Peters Inlet	2.4
Great Bras d'Or Channel	2.4

Source: NSDNR 2004

Annually, hunting and predation are the largest mortality factors for adult deer, and coyote predation is most influential on fawns (Patterson et. al. 2002). In the area of Eden, fawns have been killed by coyotes at a greater proportion than they represent in the local population, but this is likely due to greater snow depths increasing fawn vulnerability. Overall, it appears that mortalities of deer due to coyote predation in the area of the Bras d'Or Lakes watershed are additive to those that die from other factors such as natural causes, road kills, and other injuries (Patterson and Messier 2003). This has been determined by observing that the proportion of deer removed by coyotes in Nova Scotia has decreased with increasing deer densities; and thus, such predation may destabilize declining populations, but is unlikely to regulate deer densities (Patterson 1999 cited in Patterson et al. 2002). There has been at least one record of an adult female deer being killed at Eden by a Bobcat or lynx (MacDonald 1996), and predation of deer by Black bear (*Ursus americanus*) and lynx is not uncommon based on data from elsewhere. Parker et al. (1983) suggested that deer were the second most important food source to lynx on Cape Breton Island, but that only during summer did it surpass 5% occurrence in lynx scat. Although not noted in Parker's work, this seasonal peak may be related to the presence of new fawns in early summer, and be similar to increased deer predation by coyotes on those young as noted by Patterson et al. (1998). Parker et al. (1983), however, suggest that the impact of lynx as a predator on deer is minor and that most remains of deer in stomachs and scats are from bait or carrion.

In Nova Scotia, it appears that individual deer health, as determined by body condition, decreases over winter with increased snow depth, and that snow depth is more critical in determining body condition than air temperature or density of deer within the area. Fawns are most impacted by snow depth, followed by males and lastly females. It is suggested that this may be due to fawns having entered winter with the highest probability of being in poor body condition, having expended energy for both growth and fat stores, and males more likely to enter winter in poor body condition due to energy expenditure in the fall rut (Garroway and Broders 2005). If this observation of snow depth being more important than competition from density or cold air temperatures in affecting individual deer health holds true for those animals around the Bras d'Or Lakes, it may at least in part explain why many animals move to the overwinter area in Eden: to avoid the higher snowfall typically found in the highlands area of the western watershed. It should also be noted that although winter weather has an impact on individual health and can affect deer population growth, it is density dependant forage competition that appears to exert the greatest influence on deer population growth in Nova Scotia. Such density dependant negative influences generally will not be seen in the population until two years after densities have become critical (Patterson and Power 2002).

The population within the Bras d'Or Lakes currently appears to be in good health and abundance. Deer densities have averaged 3-4/km^2 in Cape Breton, nearly twice that of some mainland areas, and may approach 9.8/km^2 in Eden during more severe winters (Patterson and Messier 2003). Not all deer in the highland areas around Denys watershed migrate to Eden in the winter. However, deer densities on the highlands have been estimated as low as <0.2 /km^2 during the winter, or 60-80 animals in more than 375 km^2 of highlands area surveyed (Patterson et al. 1998).

Traditional ecological knowledge indicates that deer have declined around the Bras d'Or Lakes (CEPI 2006). This decline has been noted near Eskasoni since the 1960s. The reasons for the decline are not known, however coyotes and overhunting are considered potential causes. Despite the decline, TEK suggests that deer counts will be higher in 2006 because of the mild winter.

Black Bear

Black bears (*Ursus americanus*) are Nova Scotia's largest terrestrial carnivores. They consume a variety of vegetable and animal matter, ranging from roots, berries, nuts and grasses to fish, small mammals, moose and deer calves, and carrion (Pulsifer et al. no date). Due to their broad diet, and because bears are highly mobile, they can be found (at least seasonally) throughout most of the province. Although they prefer forested habitats with mixed woods and wetlands, they will approach settled areas to search for food sources when foods in their natural habitat are in short supply. Traditional ecological knowledge indicates that bears are seen more often closer to homes than previously in the Bras d'Or Lakes area (CEPI 2006).

In Cape Breton there has never been recorded evidence of an established bear population in the area south and east of the Bras d'Or Lakes (Nette pers. comm. 2006). During the years when there were bounties on bears in Nova Scotia, Richmond and Cape Breton Counties never offered a bounty. Bears are common north of the Lakes and abundant in the Cape Breton Highlands (Figure 6).

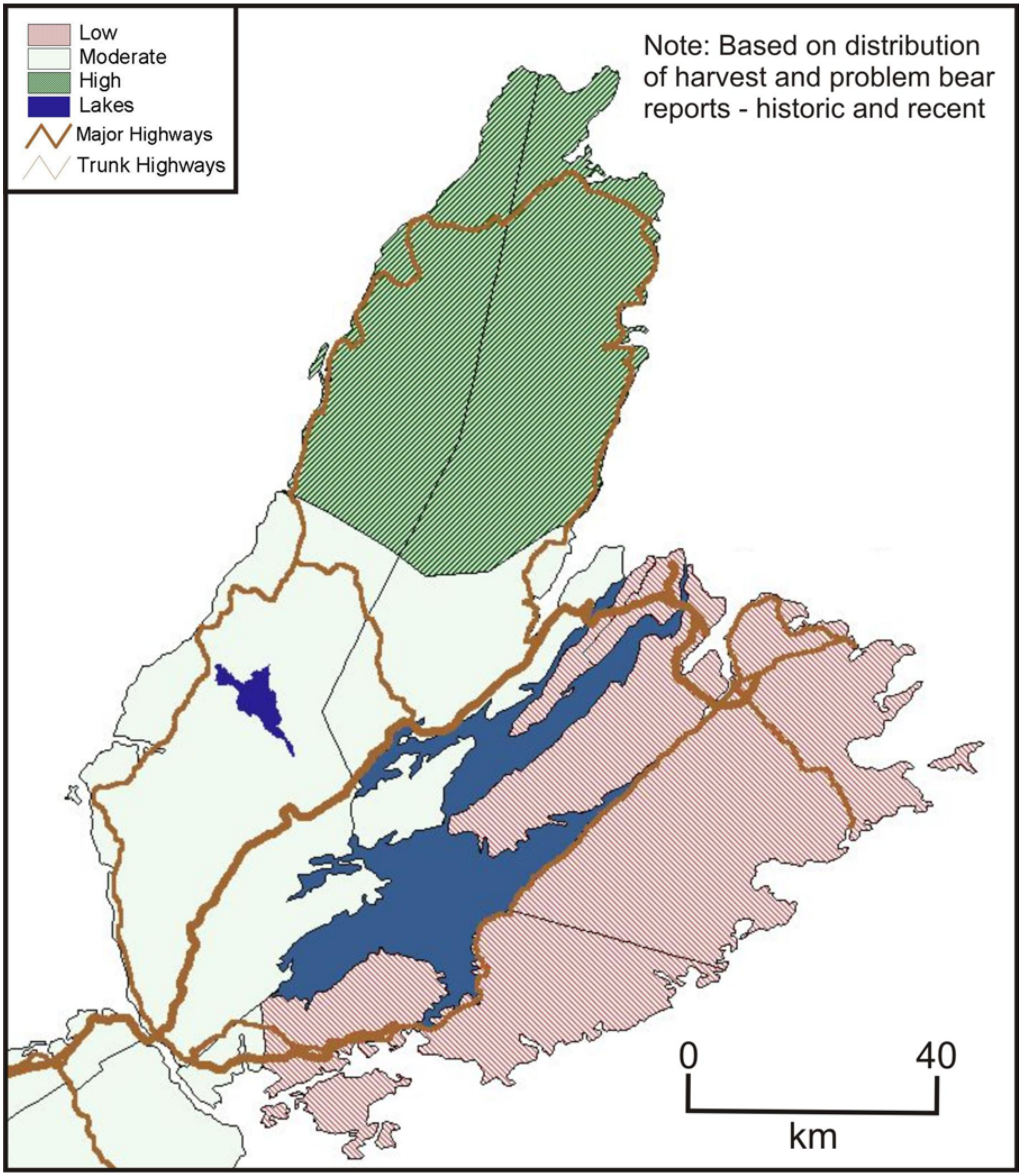


Figure 6. Relative abundance of black bears on Cape Breton Island (NSDNR unpublished files. Confirmed current by A. Nette - October 2006)

Bear density and population estimates are not available for any area of the province. The basis of knowledge on bear distribution is derived from hunter and snaring harvest records and the frequency of nuisance and sighting reports (Nette pers. comm. 2006). In recent years, there is lower confidence in the harvest estimate numbers due to a declining return rate of bear hunter report forms (NSDNR 2006a). This is a serious problem because key indicators on bear age/sex ratio, the number of bears taken from specific areas and/or from the province as a whole are derived from hunter reports. Without reliable data on these parameters, it is difficult to assess bear distribution and population trends.

Bobcat and Lynx

The Canada lynx (*Lynx lynx* or *Lynx canadensis*) is listed as a species of special concern by the Province (NSDNR 1998). It was extirpated from the mainland around 1930, and the population on Cape Breton Island is completely isolated from the continental range of the species. Recruitment of lynx on the island decreased from 1977-1979, concurrent with a decrease in its preferred food prey, the snowshoe hare (Parker et al. 1983). Densities during this time were estimated at 18-20 lynx / 100 km^2. The lynx seems increasingly rare and restricted to higher elevations on Cape Breton Island, although sightings between 1987-1999 have been made around much of the Bras d'Or Lakes watershed (Hoving et al. 2005). According to TEK, lynx have been seen at Malagawatch and Nyanza (CEPI 2006). Its movement to higher ground may be the result of competition with Bobcats *(Lynx rufus)* that have recently moved from the mainland with the construction of the Canso Causeway (Scott and Hebda 2004), although current research does not seem to indicate such through broad scale predictors (Hoving et al. 2005). According to TEK, bobcats are declining within the watershed. Residents report observing two kinds of bobcats (long and short tail) in the Bras d'Or Lakes area (CEPI 2006). The difference in tail length is a physical difference between the bobcat and lynx, suggesting that both species have been observed in the area.

Cape Breton accounts for 5% of the potential habitat of the lynx in Eastern North America. Known distribution of this population can be predicted with 94% accuracy by parameters of snowfall and deciduous forests. Snowfall greater than 270 cm/yr and absence of deciduous tree cover are the greatest broad scale predictors of where lynx will be found. Harvest of bobcats and density of two-wheel drive roads were not good indicators of where lynx might occur around the watershed (Hoving et al. 2005), indicating that they may or may not occur in the same areas as bobcats, and are not confined by the density of two-wheel drive accessible roads. The physical adaptation of both lynx and their prey to snow, and the lynx's preference for conifer dominated forests are the likely explanations for this high predictive capability of snowfall and deciduous forest cover. The paws of lynx in Cape Breton tend to support approximately twice the weight of small bobcat paws, yet bobcats are reported to average 40% heavier. Therefore, whereas deep winter snow presents little obstacle to lynx, it would greatly compromise the bobcat's ability to move and hunt (Parker et al. 1983).

Spatial presence of the Provincially listed endangered Canada Lynx (*Lynx canadensis*) found within the project watershed of the Bras d'Or Lakes is highly correlated with snowfalls > 270 cm/year and with presence of deciduous forests (Hoving et al. 2005). Thus, climate change that alters snowfall, particularly in the higher elevations of the northwestern portion of the watershed, could have a negative impact on the lynx, and cutting of coniferous forests could also fragment preferred habitats and negatively impact this species.

During a study of 154 hunter trapped lynx from the highlands area west of the Great Bras d'Or Channel and St. Patricks Channel, the oldest lynx were aged at 11 years (Parker et al. 1983), although they are reported to live to 15 years. Home ranges for lynx in Cape Breton highlands are about 15 km^2 in winter and 27 km^2 in summer.

Marten

A small population of American marten (*Martes americana*) in the Cape Breton Highlands is one of only two known to currently exist in Nova Scotia. This Provincially red listed member of the weasel family (NSDNR 1998) was extirpated on the mainland, but has been successfully reintroduced (Scott and Hebda 2004). Although it mates in late June through early

September, the egg does not develop until the following February or March, with young being born about one month afterwards (Banks 1994).

The preferred habitat of the marten is mature softwood or mixed wood forests. Females will seek high tree cavities for birthing and the first two months of raising offspring. Therefore, forest cover and related land use are likely to limit spatial distribution of the marten in the Bras d'Or watershed. The long time separation of this population from the mainland means that they may be genetically distinct (Austin-Smith and O'Brien 2003).

Other Mammals

Seven species of bats can be found in Nova Scotia (Scott and Hebda 2004), the most abundant and widespread of which is the Little Brown bat (*Myotis lucifugus*). Caves and abandoned mines are two primary locations for bat hibernacula (hibernation sites). Cave formations in Nova Scotia are often found in karst topography, where Windsor Group rocks dissolve. Such areas exist around the Denys watershed and near the Barra Strait, and a number of abandoned mines occur both in these same areas and around the Bras d'Or Lakes. Therefore, the potential for bat hibernacula exists within the watershed. There is documented confirmation of one such site in Denys Basin. Diogenes Cove in the Denys River watershed has been noted to have a colony of bats (Barrington 2005). There has not been extensive sampling at hibernacula within Nova Scotia, so species use patterns and composition is not well understood (Garroway 2004).

Snowshoe hare (*Lepus americanus*) populations are well documented as being cyclical in nature. Hare densities in Cape Breton were decreasing from 1977-1980 (Parker et al. 1983) and then appeared to have almost tripled from 1992-1997, ranging from 25-65 animals / km^2 in 1996 (Patterson et al. 1998). Assessment of locations where hare scat was found indicated a winter preference for successional forest habitat (16-30 years post harvest). Scat densities were three times that of the next most important winter habitat type. This habitat preference is likely attributable to the availability of hardwood browse and optimum conifer cover (Parker et al. 1983).

In the highland areas in the northwestern portion of the Bras d'Or Lakes watershed, Parker et al. (1983) noted that the red-backed vole (*Clethrionomys gapperi*) was the most abundant small mammal in the area, and along with the masked shrew (*Sorex cinereus*) accounted for 96% of animals captured in a small mammal survey.

11.4.2 Freshwater/Anadromous Fish

Much of the documentation of freshwater fish species within the Bras d'Or Lakes watershed is focused on recreational sport fish found in the larger drainages of the watershed. These rivers offer the greatest volume of habitat and therefore tend to be the most studied. Therefore, this section is biased to the most human-valued and potentially sensitive species (salmon and trout) in the larger river systems (Baddeck, Denys and Middle Rivers) of the western watershed. Other species and distributions are noted as found in written accounts.

Atlantic salmon (*Salmon salar*) enters the Lakes to spawn in some of the larger river systems during September and October. The two largest populations within the Bras d'Or Lakes watershed exist in the Middle and Baddeck Rivers, although by 2003 neither had met conservation levels since 1989 and 1994 respectively. In 2003, Middle River did meet conservation levels (470 large and 80 small salmon) with an estimated 554 large and 61 small salmon. Baddeck River remained below conservation levels (450 large and 80 small salmon) with 305 large and 36 small salmon in 2003. Middle River historically had both a summer and fall run of salmon, however, in recent times the summer run has been practically non-existent (Robichaud-LeBlanc and Amiro 2004). Efforts in the late 1980's to rebuild the summer run with fish from nearby North River were unsuccessful (Marshall et al. 1996 cited in Robichaud-LeBlanc 2004). Salmon juvenile densities in the Middle River and Baddeck River between 1996-2001 have generally been very near (above and below) the predicted "Elsom" norms of 29 fry and 38 parr per 100 m^2. Limited surveys of salmon parr and fry in the Hume's River, Indian River, Skye River, and River Denys indicate the presence of Atlantic salmon within these Bras d'Or watershed systems, albeit at densities below normal index of abundance, which suggests conservation requirements are generally not met in these other systems (Robichaud-LeBlanc and Amiro 2004).

Recent electrofishing surveys for salmonids in the Baddeck, Middle, and Denys Rivers indicated that brook trout and salmon were found in all three systems, while a lone Brown trout (*Salmo trutta*) was also identified in River Denys (MacMillan and Crandlemere 2005a). The lack of other competitive species in the fish surveys of these three rivers has been cited as indicative of high-quality coldwater streams in other locations of Nova Scotia (Kanno and MacMillan 2004). There is currently no stocking of hatchery-reared salmon in the Middle River (Robichaud-LeBlanc and Amiro 2004) although salmon and sea run brook trout (*Salvelinus fontinalis*) have been stocked in various areas of the Lakes and its rivers to support the recreational fishery (Murrant pers. comm. 2005). In recent years, salmon and rainbow trout have been observed reproducing in Irish Cove.

According to TEK, salmon have declined in numbers and size (CEPI 2006). The largest salmon caught in a net was 44lb. In 1974, a 30lb wild salmon was caught in Benacadie Pond. As late as 1925, locals were still catching more salmon than locally was demanded, and they would have to fillet and salt it to prevent it from spoiling. In Sampsonville (St. Peters) during the 1920s-1930s there was a mill that would put sawdust in a brook that would wash into the lake, and in the winter they would dump sawdust on the ice. Large piles of sawdust formed on the floor of the inlet that would be visible as "yellow" through the water. There were many small worms associated with the sawdust that fish of all kinds would come to feed on and it was a great place to catch trout, smelt, salmon and eels. The sawdust dumping no longer occurs, and none of these fish are prevalent there now. Similarly, in the 1920s and 1930s, there were lots of salmon in the Washabuck area but now there are few, even in Margaree River. St. Peters Inlet area was also once a major spawning area.

Brook trout surveys conducted in 2004 on Cold Brook of Middle River and River Denys were used to estimate population size. A significant population of approximately 43 000 trout was calculated for River Denys (MacMillan and Crandlemere 2005b). Primary upstream trout migration in the Middle and Denys Rivers occurred during June and July as fish sought cooler headwater streams. Maximum age to mortality for trout in these systems tends to be four years (MacMillan and Crandlemere 2005b). It has been found that maximum age of sampled brook trout in Kejimkujik National Park changed from 4–5 years to seven years after the implementation of no-catch recreational fishing zones. Furthermore, in 2003, 4-6 year old fish made up ~36% of the population in the no-catch zone while 4-5 year olds (5 being the oldest fish caught) made up ~20% of the population in a catch and keep zone (Baird and Corbett 2003). According to TEK, the brook trout population has declined but has come back in the Whycocomagh area in recent years (CEPI 2006).

Brown trout (*Salmo trutta*) is an introduced species that is native to Europe. Small numbers occur in the southeast corner of the Bras d'Or system, having probably been introduced there from a hatchery at St. Peters in the 1930's. They are known in some of the rivers draining to the Lakes but mostly seem to remain within the Lakes themselves (Hurley Fisheries Consulting 1989). According to TEK, brown trout are only found at St. Peters (CEPI 2006). However, brown trout are currently stocked in some tributaries to the Bras d'Or Lakes to support the recreational fishery (Murrant pers. comm. 2005).

After a number of large aquaculture escape occurrences in the Bras d'Or Lakes, a run of rainbow trout (*Onchorynchus mykiss*) was found to exist in the Skye River in the late 1980's, as well as lesser numbers of them in other rivers (Hurley Fisheries Consulting 1989). Rainbow trout are an introduced species to the Atlantic coast. Since 1998, small numbers of juvenile rainbow trout (<12/100 m^2) have been found during electrofishing surveys of the Middle River (Robichaud-Leblanc and Amiro 2004). Juvenile rainbow trout, which would indicate a reproducing population, have also been found in recent years in the Baddeck River and Skye River, and south of the Barra Strait in Brec's Brook and McPhee's Brook, two small tributaries to West Bay (MacMillan pers. comm. 2006). According to TEK, rainbow trout have declined in the Bras d'Or Lakes area (CEPI 2006).

Although the systems mentioned above are the most current documentation of where various species exist, in 1884 Fredrick Vieth noted salmon, trout, shad and gaspereau as occurring in many other systems around the Bras d'Or Lakes (Vieth 1884), for which more recent documentation does not exist. These are summarized in Table 14.

Table 14. Observations made by Vieth (1884) regarding the state of rivers around the Bras d'Or Lakes

System/Location	Species	Observation
Kane’s Pond (Cain’s)/St. Patricks Channel	Gaspereau	“... a famous resort for gaspereax”.
Benacadie River/Bras d’Or Lake	Gaspereau, salmon	“Benacadie Forks…is yearly visited by shoals of gaspereaux.” Regarding Bryden’s grist mill on the east fork, “…and to its pollution may be correctly attributed the fact that salmon do not seek to enter that branch at all.”
Georges River/St. Andrews Channel	Sea trout, gaspereau, salmon	Regarding the 85ft long fish ladder at McQuarrie’s mill dam, “…sea trout yearly take to it, but that gaspereaux have never been seen to ascend. Salmon have forsaken this stream altogether….Mr. Alex Moore….had not seen one for thirty years”.
Barachois ponds/East Bay, St. Andrews Channel	Gaspereau	“…gaspereaux are seen in them during the spawning season, and the young gaspereaux have been caught while escaping to the sea.”
Barasois (MacLeod Brook)/St. Andrews Channel	Sea trout	Regarding McLean’s mill and dam, “Large quantities of sea trout yearly enter the estuary, and failing entrance to the fresh water, go out to sea again.”
Sunacadie and Cameron’s Brooks/(Beaver Cove)St. Andrews Channel	Sea trout	“Both are unobstructed and the resort of hundreds of large sized sea trout.”
Washabuk (Washabuck)/St. Patricks Channel	Shad, salmon	“Salmon are seldom caught here….but this season shad were found close to the mill wheel, seeking to ascend….before the dam was erected shad were in the habit of breeding in these waters”.
River Denys	Salmon, trout, gaspereau	“It is a large stream, and salmon, gaspereaux and trout resort to it in their season; but, I am told, not in the same numbers as in past years.”
Black River/West Bay	Salmon, trout	“The Warden, McRae, informed me salmon make their appearance in October, and that then the streams are full of them. Trout are earlier. I saw great quantities of the latter about the bridge…They were a very large size”.
Salmon River and Robertson’s Brook / St. Peters Inlet	Salmon, trout, gaspereau	“The former (Salmon River) was, at one time, so I was informed, much sought by salmon, but continued poaching with spears has effectually done its deadly work of destruction. A few trout yearly ascent it; but gaspereaux take to an adjoining stream …Robertson’s, which, all residents agree, is one of the finest resorts of these fish on the whole of the Bras d’Or Lake. Last spring they were unusually numerous.”

11.4.3 Avian Community

Eagles

As a bird of prey at the top of the food chain the Bald Eagle (*Haliaeetus leucocephalus*) can be an important indicator of health of other wildlife species and the environment. In late April, these birds nest in tall, strong-limbed trees surrounded by discontinuous canopies near open water and buffered from human activity (Macdonald and Austin-Smith 1989). The young generally hatch a month later. Reproduction has averaged 1.2 young for each nest (Cash et al. 1985). Cape Breton has had the highest concentration of breeding Bald Eagles in eastern North America, with up to 24 nests in a 10 km^2 area (MacDonald and Austin-Smith 1989). The area around the Bras d'Or Lakes is home to a major provincial concentration of nesting eagles (MacDonald 1994), and the watershed houses as much as 83% of all the nests found on Cape Breton Island (Cash et al. 1985). Clustering of nests has been most noticeable around Denys Basin and St. Patricks Channel. The Bras d'Or Lakes are also one of the favoured overwinter areas of the eagles in the province because of the greater abundance of food found in this region during these months compared to other parts of the province.

According to TEK, the entire watershed of the Bras d'Or Lakes is important for eagle nesting and breeding habitat (CEPI 2006). Eagles in the Bras d'Or Lakes area are being fed by people more often. As a result, the eagles do not hunt and they remain in the area in the winter. In the Cape Breton Highlands during the moose hunt, at least 300 eagles are present because there is a feast for them. When the hunt is over they go away. This is an interesting note because Cape Breton is home to the highest density of eagles and such a food source may be significant to their current or increasing numbers.

Studies of food remains from eagle nests around the Bras d'Or indicate thirty-six different vertebrate species were eaten between 1977 and 1981. However, fish were the most frequently consumed item with cod topping the list at 71% of all fish consumed. Interestingly, TEK indicates that cod have been observed coming to the surface to feed in the Bras d'Or (CEPI 2006) which may explain why eagles catch them in such large numbers. Together cod, winter flounder and skates accounted for 53% of all identified prey (Cash et al. 1985). All three of these fish appear to have increased in abundance (Lambert 2002) since the time of the eagle food remains survey, and should therefore still be a primary food source today. Interestingly these are all marine fish, yet the third most abundant fish species consumed was identified as brown bullhead. Bullhead is a species usually found in slow moving or stagnant freshwater. All of the bullhead samples were collected from two of the 76 nests surveyed. At the time, bullheads were only known in four of the 61 lakes on Cape Breton Island, so a few eagle pairs appear to have used this food source. Cash et al. (1985) felt that fish may even have been under-represented in the survey results because of the speed with which their bones would decay, and the ability of the eagle to consume some bones, both factors which would reduce the number identified in the survey. Birds were the second most common food item found in the eagle nests, and Great Blue Heron (*Ardea herodias*) remains constituted nearly 10% of all occurrences (Cash et al. 1985). Herons were seen regularly during surveys of the brackish water areas at the major river deltas of Denys Basin and St. Patricks Channel during the 1960's (Erskine 1971). However, TEK indicates that herons have been declining since the 1930s-40s (CEPI 2006).

Unexpectedly, eagle nests in the Bras d'Or watershed had a strong negative correlation with coastline length. This was unexpected, as irregular coastlines that restrict visibility and interaction between nests in other locations have had higher densities of eagle nests. Around the Bras d'Or Lakes, nest locations were more frequently located near water with depths <5m and less frequently near water >5m (Macdonald and Austin-Smith 1989). This likely relates to feeding locations where the birds can capture their preferred marine benthic fish species of cod and flounder that venture into shallow water. Cod and winter flounder in Whycocomagh Bay and cod in Denys Basin were found at catch rates of near 50 kg / nautical mile of trawl survey in 1999/2000 (Lambert 2002).

Although most scientific studies have identified the concentration of eagle nests in the north and western portions of the Bras d'Or Lakes watershed, birders have noted that eagles have been common in East Bay at Ben Eoin beach in the fall, feeding on silversides that enter the barachois pond there (Cohrs 1991).

According to TEK, the eagle population is either stable or increasing (CEPI 2006). Provincial estimates in 1994 were more than 800 birds (MacDonald 1994).

Breeding Birds

Erskine (1992) prepared a breeding bird atlas for the Maritime provinces. The atlas indicates that there are approximately 135 bird species for which breeding evidence exists within the Bras d'Or Lakes watershed (Table 15).

Table 15. Breeding evidence for birds in the Bras d'Or Lakes watershed

Species	Breeding evidence	Species	Breeding evidence
Water Birds			
Common Loon *Gavia immer*	Confirmed	Pied-billed Grebe *Podilymbus podiceps*	Possible
Great Blue Heron *Ardea herodias*	Confirmed	Canada Goose *Branta canadensis*	Confirmed
Wood Duck *Aix sponsa*	Confirmed	Green-winged Teal *Anas crecca*	Probable
American Black Duck *Anas rubripes*	Confirmed	Mallard *Anas platyrhynchos*	Confirmed
Blue-winged Teal *Anas discors*	Confirmed	American Wigeon *Anas americana*	Confirmed
Ring-necked Duck *Aythya collaris*	Confirmed	Common Goldeneye *Bucephala clangula*	Confirmed
Common Merganser *Mergus merganser*	Confirmed	Red-breasted Merganser *Mergus serrator*	Confirmed
Sea Birds & Gulls			
Great Cormorant *Phalacrocorax carbo*	Possible	Double-crested Cormorant *Phalacrocorax auritus*	Confirmed
Herring Gull *Larus argentatus*	Confirmed	Great Black-backed Gull *Larus marinus*	Confirmed
Arctic Tern *Sterna paradisaea*	Possible	Common Tern *Sterna hirundo*	Confirmed
Eagles, Hawks & Falcons			
Bald Eagle *Haliaeetus leaucocephalus*	Confirmed	Osprey *Pandion haliaetus*	Confirmed
Northern Harrier *Circus cyaneus*	Confirmed	Sharp-shinned Hawk *Accipiter striatus*	Confirmed
Northern Goshawk *Accipiter gentilis*	Possible	Broad-winged Hawk *Buteo platypterus*	Possible
Red-tailed Hawk *Buteo jamaicensis*	Confirmed	Merlin *Falco columbarius*	Possible
American Kestrel *Falco sparverius*	Confirmed		
Fowl-like birds			
Spruce Grouse *Dendragapus canadensis*	Confirmed	Ruffed Grouse *Bonasa umbellus*	Confirmed
Marsh Birds			
Sora *Porzana carolina*	Confirmed		
Shore Birds			
American Woodcock *Scolopax minor*	Confirmed	Killdeer *Charadrius vociferus*	Confirmed
Spotted Sandpiper *Actitis macularia*	Confirmed	Common Snipe *Gallinago gallinago*	Confirmed
Cuckoos			
Black-billed Cuckoo *Coccyzus erythropthalmus*	Confirmed		
Woodpeckers, Sapsuckers & Flickers			
Downy Woodpecker *Picoides pubescens*	Confirmed	Hairy Woodpecker *Picoides villosus*	Confirmed

Table 15. Breeding evidence for birds in the Bras d'Or Lakes watershed *continued*

Species	Breeding evidence	Species	Breeding evidence
Woodpeckers, Sapsuckers & Flickers			
Three-toed Woodpecker *Picoides tridactylus*	Confirmed	Black-backed Woodpecker *Picoides arcticus*	Confirmed
Northern Flicker *Colaptes auratus*	Confirmed	Pileated Woodpecker *Dryocopus pileatus*	Probable
Yellow-bellied Sapsucker *Sphyrapicus varius*	Confirmed		
Doves & Pigeons			
Rock Dove *Columba livia*	Confirmed	Mourning Dove *Zenaida macroura*	Probable
Nighthawks & Whip-poor-wills			
Common Nighthawk *Chordeiles minor*	Possible		
Kingfisher			
Belted Kingfisher *Ceryle alcyon*	Confirmed		
Owls			
Great-Horned Owl *Bubo virginianus*	Confirmed	Barred Owl *Strix varia*	Confirmed
Northern Saw-whet Owl *Aegolius acadicus*	Possible		
Swifts & Hummingbirds			
Chimney Swift *Chaetura pelagica*	Confirmed	Ruby-throated Hummingbird *Archilochus colubris*	Probable
Song Birds			
Olive-sided Flycatcher *Contopus borealis*	Probable	Eastern Wood-Pewee *Contopus virens*	Confirmed
Yellow-bellied Flycatcher *Empidonax flaviventris*	Confirmed	Alder Flycatcher *Empidonax alnorum*	Confirmed
Least Flycatcher *Empidonax minimus*	Confirmed	Eastern Phoebe *Sayornis phoebe*	Probable
Eastern Kingbird *Tyrannus tyrannus*	Probable	House Sparrow *Passer domesticus*	Confirmed
Tree Swallow *Tachycineta bicolor*	Confirmed	Bank Swallow *Riparia riparia*	Confirmed
Cliff Swallow *Hirundo pyrrhonota*	Confirmed	Barn Swallow *Hirundo rustica*	Confirmed
Gray Jay *Perisoreus canadensis*	Confirmed	Blue Jay *Cyanocitta cristata*	Confirmed
American Crow *Corvus brachyrhynchos*	Confirmed	Common Raven *Corvus corax*	Confirmed
Black-capped Chickadee *Parus atricapillus*	Confirmed	Boreal Chickadee *Parus hudsonicus*	Confirmed
Red-breasted Nuthatch *Sitta canadensis*	Confirmed	White-breasted Nuthatch *Sitta carolinensis*	Probable
Golden-crowned Kinglet *Regulus satrapa*	Confirmed	Ruby-crowned Kinglet *Regulus calendula*	Confirmed
Brown Creeper *Certhia americana*	Confirmed	Winter Wren *Troglodytes troglodytes*	Confirmed
Veery *Catharus fuscescens*	Probable	Gray-cheeked Thrush *Catharus minimus*	Probable

Table 15. Breeding evidence for birds in the Bras d'Or Lakes watershed *continued*

Species	Breeding evidence	Species	Breeding evidence
Song Birds			
Swainson's Thrush *Catharus ustulatus*	Confirmed	Hermit Thrush *Catharus guttatus*	Confirmed
American Robin *Turdus migratorius*	Confirmed	Gray Catbird *Dumetella carolinensis*	Possible
Northern Mockingbird *Mimus polyglottos*	Probable	Cedar Waxwing *Bombycilla cedrorum*	Confirmed
European Starling *Sturnus vulgaris*	Confirmed	Solitary Vireo *Vireo solitarius*	Confirmed
Philadelphia Vireo *Vireo philadelphicus*	Probable	Red-eyed Vireo *Vireo olivaceus*	Confirmed
Tennessee Warbler *Vermivora peregrina*	Confirmed	Nashville Warbler *Vermivora ruficapilla*	Confirmed
Northern Parula Warbler *Parula americana*	Confirmed	Yellow Warbler *Dendroica petechia*	Confirmed
Chestnut-sided Warbler *Dendroica pensylvanica*	Confirmed	Magnolia Warbler *Dendroica magnolia*	Confirmed
Cape May Warbler *Dendroica tigrina*	Possible	Black-throated Blue Warbler *Dendroica caerulescens*	Confirmed
Yellow-rumped Warbler *Dendroica coronata*	Confirmed	Black-throated Green Warbler *Dendroica virens*	Confirmed
Blackburnian Warbler *Dendroica fusca*	Confirmed	Palm Warbler *Dendroica palmarum*	Confirmed
Bay-breasted Warbler *Dendroica castanea*	Confirmed	Blackpoll Warbler *Dendroica striata*	Confirmed
Black-and-white Warbler *Mniotilta varia*	Confirmed	American Redstart *Setophaga ruticilla*	Confirmed
Ovenbird *Seiurus aurocapillus*	Confirmed	Northern Waterthrush *Seiurus noveboracensis*	Confirmed
Mourning Warbler *Oporornis philadelphia*	Confirmed	Common Yellowthroat *Geothlypis trichas*	Confirmed
Wilson's Warbler Wilsonia pusilla	Confirmed	Canada Warbler *Wilsonia canadensis*	Probable
Rose-breasted Grosbeak *Pheucticus ludovicianus*	Probable	Chipping Sparrow *Spizella passerina*	Confirmed
Savannah Sparrow *Passerculus sandwichensis*	Confirmed	Sharp-tailed Sparrow *Ammodramus caudacutus*	Confirmed
Fox Sparrow *Passerella iliaca*	Possible	Song Sparrow *Melospiza melodia*	Confirmed
Lincoln's Sparrow *Melospiza lincolnii*	Confirmed	Swamp Sparrow *Melospiza georgiana*	Confirmed
White-throated Sparrow *Zonotrichia albicollis*	Confirmed	Dark-eyed Junco *Junco hyemalis*	Confirmed
Bobolink *Dolichonyx oryzivorus*	Confirmed	Red-winged Blackbird *Agelaius phoeniceus*	Confirmed
Rusty Blackbird *Euphagus carolinus*	Confirmed	Common Grackle *Quiscalus quiscula*	Confirmed
Brown-headed Cowbird *Molothrus ater*	Probable	Pine Grosbeak *Pinicola enucleator*	Probable
Purple Finch *Carpodacus purpureus*	Confirmed	Red Crossbill *Loxia curvirostra*	Confirmed

Table 15. Breeding evidence for birds in the Bras d'Or Lakes watershed *continued*

Species	Breeding evidence	Species	Breeding evidence
Song Birds			
White-winged Crossbill *Loxia leucoptera*	Probable	Pine Siskin *Carduelis pinus*	Confirmed
American Goldfinch *Carduelis tristis*	Confirmed	Evening Grosbeak *Coccothraustes vespertinus*	Confirmed

Source: Based on Erskine 1992

Water Fowl

In studies of breeding waterfowl conducted in the early 1960's it was noted that the species composition in Cape Breton varied markedly from other areas of the Maritimes, and required both spring and summer surveys to cover the diversity of species that use the area. Cape Breton areas, which included the deltas of Middle River, Baddeck River, Skye River, and River Denys were much more productive than similar habitats in Prince Edward Island and New Brunswick. Ring-necked Ducks (*Aythya collaris*), Common Merganser (*Mergus merganser*), and Black Ducks (*Anas rubripes*) made up 90% of the ducks observed over three years of study (Erskine 1987). Erskine believed that some broods of Common Goldeneye (*Bucephala clangula*) and Common Merganser likely hatched further upriver and descended to the estuaries of the Baddeck and Middle Rivers later in the season. Nearly all Wood Duck (*Aix sponsa*) sightings were made at River Denys.

Black Ducks move to the urban parks around the Sydney area of Cape Breton in the winter, where people have fed them for more than 30 years. There they coexist with Mallards (*Anas platyrhynchos*), which were introduced in Nova Scotia in the 1930's. Although there was concern that Mallards may have been causing declines in the Black Duck population, and that mating competition and production of hybrids were significant factors, recent assessment of the local populations between 1992-2002 indicate otherwise. Neither were Black Ducks found to be declining over this time period, nor were Mallard numbers increasing. Black Ducks consistently outnumbered Mallards by 5:1, and the proportion of hybrids was observed to remain at about 5% (McCorquodale and Knapton 2003).

Big Harbour Island, on the shores of Bras d'Or Lake, has been identified as a site on which many marsh birds and waterfowl can be found because of the shallow ponds, and as a location where songbirds like the Bobolink (*Dolichonyx oryzivorus*) and Lincoln's Sparrows (*Melospiza lincolnii*) might be seen in the old farmlands (Cohrs 1991). Erskine (1971) generally categorized three waterfowl areas as fresh marshes; brackish, non-tidal areas (which included the Bras d'Or Lakes sites); and brackish, tidal areas.

The significant inventories conducted by Erskine (1971, 1987) tended to report on the most common and abundant species. No Federal or Provincial species at risk were noted within the species lists presented, and therefore it would seem numbers of such species were low or not detected within the Bras d'Or Lakes watershed.

The Common Goldeneye and Black Duck, which have been noted in the literature to be within the watershed (Erskine 1987), along with Canada Geese (*Branta canadensis*) which are common, Atlantic Brant (*Branta bernicula hrota*) and Barrows Goldeneye (*Bucephala islandica*) (which are possible within the watershed and yellow listed species in Nova Scotia) all feed directly on eelgrass beds or on organisms that occur in such beds (Hanson 2004).

Therefore, estuaries where eelgrass beds have been noted in the Bras d'Or, such as St. Peters Inlet, Denys Basin, Whycocomagh Bay, and St. Patricks Channel (MacLachlan and Edelstein 1971) are likely to be important to local waterfowl. According to TEK, Barrows Goldeneye have been sighted near Whycocomagh Bay shore at dusk with an increase on the west side of the island (CEPI 2006). Traditional ecological knowledge suggests that, in general, wild ducks and Mergansers are increasing in the Bras d'Or Lakes area (CEPI 2006).

Colonial Sea Birds

There is some use of the Lakes by various coastal bird species. There are limited amounts of cliff and island habitats in the Bras d'Or system, two habitat types more typically used by colonial nesting species. The most current surveys of the Lakes by the Nova Scotia Department of Natural Resources in 1995, 1999, and 2003 have documented moderate numbers of Common Tern (*Sterna hirundo*) occupying and nesting on several islands in the West Bay and Malagawatch areas (Milton pers. comm. 2005). The Spectacle Islands at the entrance to St. Patricks Channel have been home to a Double-crested Cormorant (*Phalacrocorax auritus*) colony of 165-810 pairs on surveyed years between 1982 and 1993. Cormorant numbers increased over this time across Nova Scotia, but appear to have stabilized or decreased since (Milton pers. comm. 2005). According to TEK, cormorants appear to be increasing and have been noticed more in the last 50 years (CEPI 2006). In 1989 it was reported that cormorants had become numerous on the many smaller islands of the Bras d'Or, and that they, along with seals, could be reducing the viability of commercial fishing at that time (UMA 1989). Traditional ecological knowledge indicates that cormorants have been very destructive toward fish, especially perch (CEPI 2006). A relatively large number of birds have been observed at a few locations in Denys Basin and East Bay. Nesting has been observed in most locations included in these surveys, but numbers vary by location and by year. Periodic surveys within the Lakes for other species have occurred irregularly since the early 1970s (Environment Canada 2002b). Virtually all observations have been made on islands, with the exception of a few locations where coastal barrier sandbar beaches have been utilized by a colony. In all, six species have been documented (Table 16): Double-crested Cormorant, Great Black-backed Gull (*Larus marinus)*, Common Tern, Arctic Tern *(Sterna paradisaea)*, Herring Gull (*Larus argentatus*), and Great Blue Heron (*Ardea herodias).* No trend analysis or reporting is available based on the completed field surveys.

Table 16. Colonial bird records for Bras d'Or Lakes watershed (Milton pers. comm. 2005)

Subwatershed Name	Species Common Name	Year	Method	Platform	Individuals
Bras d'Or Lake	Common Tern	2003		Aircraft	120
Bras d'Or Lake	Common Tern	2003		Ground	? (6 nests)
Bras d'Or Lake	Common Tern	2003		Aircraft	150
Bras d'Or Lake	Common Tern	2003		Ground	75
Bras d'Or Lake	Common Tern	2003		Aircraft	2
Bras d'Or Lake	Common Tern	2003		Aircraft	6
Bras d'Or Lake	Common/Arctic Tern	1999	Visual estimate	Aircraft	50
Bras d'Or Lake	Double-crested Cormorant	1980			1,196
Bras d'Or Lake	Great Black-backed Gull	1980			684
Bras d'Or Lake	Herring Gull	1980			82
Denys Basin	Common Tern	2003		Aircraft	180
Denys Basin	Common Tern	2003		Aircraft	25
Denys Basin	Common/Arctic Tern	1999	Visual estimate	Aircraft	14
Denys Basin	Common Tern	1999	Direct count	Ground	10
Denys Basin	Common/Arctic Tern	1999	Visual estimate	Aircraft	18
East Bay	Common Tern	2003		Aircraft	160
East Bay	Common/Arctic Tern	1999	Visual estimate	Aircraft	150
East Bay	Common/Arctic Tern	1999	Direct count	Ground	50
East Bay	Great Black-backed Gull	1985			36
East Bay	Common Tern	1984			8
East Bay	Herring Gull	1984			52
North Basin	Common/Arctic Tern	1995	Visual estimate	Aircraft	20
St Patricks	Common Tern	2003		Aircraft	17
St. Patricks	Double-crested Cormorant	1991			1,662
St. Patricks	Great Black-backed Gull	1988			0
St. Patricks	Great Blue Heron	1981			8
St. Patricks	Great Blue Heron	1977			0
St. Patricks	Herring Gull	1971			5
St. Patricks	Common Tern	1966			100
St. Peters Inlet	Common/Arctic Tern	1999	Direct count	Ground	110
St. Peters Inlet	Arctic Tern	1995	Visual estimate	Aircraft	40
St. Peters Inlet	Arctic Tern	1995	Visual estimate	Aircraft	284
St. Peters Inlet	Common/Arctic Tern	1995	Visual estimate	Aircraft	2
St. Peters Inlet	Double-crested Cormorant	1971			610
West Bay	Common Tern	1995	Visual estimate	Aircraft	4
West Bay	Common Tern	1995	Visual estimate	Aircraft	2
West Bay	Common Tern	1995	Visual estimate	Aircraft	2
West Bay	Common Tern	1995	Visual estimate	Aircraft	2
West Bay	Arctic Tern	1995	Visual estimate	Aircraft	18
Whycocomagh	Common/Arctic Tern	1999	Visual estimate	Aircraft	12
Whycocomagh	Great Blue Heron	1978	cursory visits	Ground	0

Other Birds

Erskine (1971) noted individual observations of a Saw-whet Owl (*Aegolius acadicus*) in a steep hardwood forest near Whycocomagh, and a Barred Owl *Strix varia* on the upper Middle River. He also suggested that Red-tailed Hawk (*Buteo jamaicensis*), Bald Eagle, Osprey (*Pandion haliaetus*), and Sparrow Hawk (*Falco sparverius*) were the only diurnal raptors seen often enough to provide useable frequency data. All were present in the Baddeck River, Middle River, Skye River, and River Denys watersheds. Parker et al. (1983) noted that Ruffed Grouse (*Bonasa umbellus*) and Spruce Grouse (*Canachites canadensis*) were both common in the highlands area in the northwestern portion of the Bras d'Or Lakes watershed. The main area of Pheasant (*Phasianus colchicus*) habitat in the Bras d'Or has been described as the head of East Bay (UMA 1989).

11.4.4 Herptofauna

Herptofauna is the term used to describe amphibians and reptiles. Nova Scotia has five salamander species, eight species of frogs and toads, five snake species, and four species of turtles (Gilhen 1984). Herptofauna recorded by Gilhen (1984) from at least one site within the Bras d'Or Lakes watershed are listed in Table 17.

Table 17. Herptofauna recorded from within the Bras d'Or Lakes watershed

Species	Habitat
Salamanders & Newts	
Blue-spotted Salamander *Ambystoma laterale* (Hallowell)	Coniferous, deciduous and mixed woodlands adjacent to alder swamps, ponds and slow-moving streams
Yellow-spotted Salamander *Ambystoma maculatum* (Shaw)	Coniferous, deciduous and mixed woodlands adjacent to aquatic breeding sites such as woodland ponds, vegetated coves of lakes and quiet, vegetated portions of streams
Red-spotted Newt *Notophthalmus viridescens viridescens* (Rafinesque)	Newly transformed young: damp, deciduous, coniferous or mixed woodlands in the vicinity of aquatic habitats Post terrestrial juvenile stage: vegetated coves of lakes, woodland ponds, oxbow ponds and quiet stretches of streams
Eastern Redback Salamander *Plethodon cinereus* (Green)	Deciduous, coniferous and mixed woodlands
Four-toed Salamander *Hemidactylium scutatum* (Schlegel)	Spring breeding season: sphagnum areas bordering streams and in sphagnum bogs. Summer: woodlands
Frogs & Toads	
Eastern American Toad *Bufo americanus americanus* (Holbrook)	Shores of ponds, lakes and streams and in adjacent woodlands. Expected to occur in most terrestrial situations, including forest (coniferous and deciduous), agricultural areas, suburban areas and disturbed habitats (e.g., gravel pits).
Northern Spring Peeper *Hyla crucifer crucifer* (Weid)	Coniferous, deciduous or mixed woodlands adjacent to ponds, lakes and streams. Particularly common in the woodlands adjacent to roadside ponds.

Table 17. Herptofauna recorded from within the Bras d'Or Lakes watershed *continued*

Species	Habitat
Frogs & Toads	
Green Frog *Rana clamitans melanota* (Rafinesque)	Lakes, ponds and streams. Practically any body of fresh water is potential habitat.
Wood Frog *Rana sylvatica* (Le Conte)	Damp woodlands, particularly deciduous and mixed woods. Spawning occurs in roadside ponds adjacent to any type of coniferous or deciduous woodland.
Northern Leopard Frog *Rana pipiens* (Schreber)	Old fields, meadows, grassy-sedge woods roads and grassy roadside ditches. Juveniles are often seen resting on sphagnum at the margins of roadside ponds.
Pickerel Frog *Rana palustris* (Le Conte)	Along streams and shores of lakes in both cool, rocky and sparsely vegetated or warm, silty-bottomed and densely vegetated aquatic environments. They forage along grassy-sedge woods roads, roadsides, meadows and old fields.
Turtles	
Common Snapping Turtle *Chelydra serpentina serpentina* (Linnaeus)	Vegetated shallows of lakes and streams. May be found in practically any type of freshwater habitat.
Snakes	
Northern Redbelly Snake *Storeria occipitomaculata occipitomaculata* (Storer)	Grassy and grassy-heath habitats along the shores of lakes, ponds and streams. Particularly common along roadsides, cut-over areas, railroad rights-of-way, abandoned gravel pits, margins of old fields, heath barrens and blueberry fields adjacent to deciduous, mixed or coniferous woods.
Maritime Garter Snake *Thamnophis sirtalis pallidula* (Allen)	Common along shores of ponds, lakes and streams, and the coastal shore above the high-tide mark. Common in woodland and agricultural situations. They frequent rocky roadsides, margins of heath barrens, blueberry fields, old fields, meadows, swamps, bogs, gravel pits, clearings surrounding abandoned mines, and around the foundation of farms, lake-shore cottages, camps and abandoned buildings.
Eastern Smooth Green Snake *Opheodrys vernalis vernalis* (Harlan)	Grassy and shrubby areas along the shores of ponds, lakes and streams. Particularly common along grassy-heath-fern roadsides and in old fields. In barren coastal areas they are also found in grass near sphagnum, cranberry and old heath bogs. Also frequents lawns and gardens in suburban areas.

Source: Based on Gilhen 1984

More recently, a five-year program (1999-2003) was undertaken to create a provincial herptofaunal atlas for Nova Scotia. The results of that volunteer atlas program are expected to be published in the near future, and will better detail the distribution by species of herptofauna around the Bras d'Or Lakes watershed based on the more than 6000 entries that have been made (Acadia University 2006). However, there is very little current literature on any of the Provincial herptofaunal species found around the Bras d'Or Lakes. The exceptions are a few accounts regarding Wood turtles, a Federally and Provincially listed species at risk.

In 1965, a Wood turtle (*Glyptemys insculpta*) was found just outside of the Bras d'Or Lakes watershed on the River Inhabitants system that headwaters adjacent to the River Denys watershed (Gilhen and Grantmyre 1973). At that time, the only other observation of a freshwater turtle on Cape Breton Island was a Common Snapping turtle thought to be an escaped captive. Since that time a second population of Wood turtle has been found in the River Denys watershed. The presence of nests, juveniles and adults indicate a reproducing population (Graf et al. 2003). Based on observation and scat analysis these omnivorous turtles are known to feed on dandelions, blueberries, and choke cherries within the watershed.

Wood turtles typically inhabit slow moving streams and rivers with sand and gravel banks, and they are often found in agricultural fields or natural meadows and alder groves adjacent to the water (Pulsifer et al. 2004). In Nova Scotia this species is listed as "vulnerable" because of its particular sensitivity to human activities, and with a 60-year life span there is much time for an individual to become exposed to a number of risks. Miller (2004) identified three Stora Enso Port Hawkesbury forestry company owned parcels of land that border the River Denys, and represent forested floodplains and rare intervale flora of the Bras d'Or Plain that are suspected breeding habitat for the Wood turtle. He suggests that these properties would be good candidates for reserve planning on private lands because of the representative habitats and ecological functions they would serve to protect.

Minimal written records appear in the literature about other amphibians and reptiles specifically within the Bras d'Or watershed. Along with River Denys, Wood turtles have also been identified as being found on Mill Brook of the Baddeck River watershed, and Scott's River and smaller tributaries between French Cove and Roberta in the St. Peters Inlet watershed (Adams 1995). It also appears through unpublished herptofauna atlas records that Wood turtles have recently been identified west of the Great Bras d'Or Channel (Anonymous 2003). In recent years, Wood turtles have also been sighted in Whycocomagh and River Inhabitants where they are thought to be abundant (CEPI 2006).

The other spatial herptofaunal records come from local residents who have noted that the River Denys watershed herptofauna includes an abundance of Blue-spotted Salamanders, Maritime Garter snakes, Mink frogs (*Rana septentrionalis*), Leopard frogs, and Northern Spring Peepers (Barrington 2005). The Nova Scotia museum notes that the Blue-spotted Salamander, unlike the other species mentioned here in the River Denys, are not widespread across Cape Breton but are found in five widely separated localities on the Island (NS Museum 2006).

11.4.5 Freshwater Mollusca

According to Clarke (1981), there are 15 snail species and 17 species of clams and mussels that may be found within freshwater systems of the Bras d'Or Lakes watershed (Table 18). Molluscs are affected by all three types of water pollution (thermal, inorganic, organic) and thus may make good pollution indicators (Clarke 1981). When analyzed, the distinct growth ring on their shells that is formed every winter can reveal if and when water pollution from radioactive or heavy metals has occurred. Similarly chemical analysis of the soft parts of molluscs can reveal recent pollution by insecticides. Low diversity, and in particular, the presence of only a single species, is often indicative of organic pollution. In general, high mussel diversity indicates high fish diversity and the presence of clean water.

Table 18. Potential freshwater mollusca within the Bras d'Or Lakes watershed

Species	Habitat
Snails	
Ribbed Valve-Snail *Valvata sincera sincera*	Principally in lakes, usually on mud among submersed aquatic vegetation, often at considerable depth.
Ordinary Spire Snail *Amnicola limosa*	All kinds of unpolluted, perennial water habitats where aquatic vegetation grows.
Modest Fossaria *Fossaria modicella*	Perennial lakes, ponds and streams; in vernal pools and ditches; and on moist sandy or muddy beaches.
Lake Stagnicola *Stagnicola (Stagnicola) catascopium catascopium*	Large lakes and rivers but also found in smaller bodies of water, frequently on rocks exposed to waves and currents.
Common Stagnicola *Stagnicola (Stagnicola) elodes*	Ubiquitous, found in all kinds of aquatic habitats. Especially abundant in thick vegetation and on muddy substrates.
Eastern Physa *Physa heterostropha*	All kinds of perennial water and temporarily flooded habitats, usually among vegetation.
Polished Tadpole Snail *Aplexa hypnorum*	Principally in vernal habitats (water bodies that dry up during part of the year). Very abundant in temporary shallow pools during the spring. Prefers habitats with thick vegetation and mud bottom.
Irregular Gyraulus *Gyraulus deflectus*	All kinds of permanent water eutrophic habitats, generally with a mud substrate. Lives on vegetation but occasionally found on the bottom.
Modest Gyraulus *Gyraulus parvus*	Lives on submerged aquatic vegetation in all kinds of permanent or temporary water-filled habitats that support vegetation.
Keeled Promenetus *Promenetus exacuous exacuous*	Various kinds of temporary water and permanent water habitats (e.g., large and small lakes, ponds, streams, roadside ditches and swamps), generally with submerged vegetation and mud.
Say's Toothed Planorbid *Planorbula armigera*	Among vegetation in most kinds of perennial water habitats, especially stagnant, heavily-vegetated water bodies with a mud substrate.
Two-ridged Ramshorn *Helisoma (Helisoma) anceps anceps*	Lakes, ponds, rivers and streams among vegetation and on various substrates.
Bell-mouthed Ramshorn *Helisoma (Planorbella) campanulatum campanulatum*	Lakes and ponds of all sizes and slow-moving or backwater portions of rivers, usually with vegetation but bottoms are of all types.
Larger Eastern Ramshorn *Helisoma (Pierosoma) trivolvis trivolvis*	Well vegetated perennial-water lakes, ponds and slow-moving streams with mud as the usual substrate.
Flat-sided Lake Limpet *Ferrissia parallela*	Lakes, swamps and slow-moving rivers among thick or moderately thick vegetation.

Table 18. Potential freshwater mollusca within the Bras d'Or Lakes watershed *continued*

Species	Habitat
Clams & Mussels	
(Eastern-River) Pearl Mussel *Margaritifera margaritifera*	Small and medium-sized running streams, often on sandy shoals and in pools under overhanging branches. Appears to be restricted to soft water. Brook trout and brown trout may be hosts.
Eastern Elliptio *Elliptio complanata*	Shallow water of permanent lakes, rivers and medium-sized streams, on gravel, sand, clay or mud bottoms. The yellow perch is its only known host.
Newfoundland Floater *Anodonta cataracta fragilis*	Diverse, permanent water habitats (e.g., ponds, lakes and streams of various sizes), principally in mud but also in sand.
Alewife Floater *Anodonta implicata*	Restricted to coastal streams and lakes that can be reached by its anadromous host fish, the alewife. Principally in sand and gravel, rarely in mud.
Delicate Lamp-Mussel *Lampsilis ochracea*	Principally in quiet water (ponds, canals and slow-moving parts of rivers) on mud or sand bottoms.
Arctic-Alpine Fingernail Clam *Sphaerium (Sphaerium) nitidum*	Large and small lakes, and in rivers of various widths on diverse substrates.
Grooved Fingernail Clam *Sphaerium (Sphaerium) simile*	All kinds of perennial water habitats that contain submersed vegetation and muddy or sandy bottoms.
Lake Fingernail Clam *Sphaerium (Musculium) lacustre*	Perennial water lakes, ponds, rivers and streams, mainly found on mud but sometimes on sand.
Pond Fingernail Clam *Sphaerium (Musculium) securis*	Lakes, ponds, rivers and streams, and in both perennial-water and vernal habitats, generally on mud substrate with abundant vegetation.
Ubiquitous Pea Clam *Pisidium (Cyclocalyx) casertanum*	Lakes, ponds, rivers, small streams, ditches, swamps and temporary water habitats.
Ridged-Beak Pea Clam *Pisidium (Cyclocalyx) compressum*	Permanent lakes, ponds, rivers and streams on a variety of substrates and usually among vegetation in shallow water.
Rusty Pea Clam *Pisidium (Cyclocalyx) ferrugineum*	Lakes, ponds, rivers and streams, usually among vegetation on a sandy or muddy bottom.
Lilljeborg's Pea Clam *Pisidium (Cyclocalyx) lilljeborgi*	All permanent water habitats, especially lakes. Inhabits clay, mud, sand or gravel.
Quadrangular Pill Clam *Pisidium (Cyclocalyx) milium*	Lakes, ponds and slow-moving streams, on muddy bottoms among vegetation.
Shiny Pea Clam *Pisidium (Cyclocalyx) nitidum*	All kinds of perennial water habitats on various substrates and most commonly in shallow water.
Triangular Pea Clam *Pisidium (Cyclocalyx) variabile*	All natural perennial water habitats, in various substrates (most frequently mud) and usually amid vegetation.
Arctic-Alpine Pea Clam *Pisidium (Neopisidium) conventus*	Principally at considerable depths in large lakes.

Source: Based on Clarke 1981

12. Biodiversity and Species at Risk

The limits to biodiversity in a semi-enclosed system such as the Bras d'Or are complex. Active migration, drift and interspersion are all ways for biota to colonize new areas. However, there are barriers to more active distribution methods between the Bras d'Or Lakes and the open ocean. These include higher temperatures and lower salinity within the Lakes, and the need for aquatic biota to pass through the relatively shallow and high energy water of the Great Bras d'Or Channel to enter the Lakes. These factors can be barriers to the colonization of the Lakes by deepwater and/or estuarine intolerant species. At the same time, habitat parameters such as depth, salinity, and temperature that may limit some marine diversity may also serve to encourage colonization by species for which the Bras d'Or's physical and chemical character is appropriate. A wide range of temperatures and salinities within the Lakes make the Bras d'Or hospitable to a number of cold Arctic and warm water Virginian relict species that are found in very limited numbers or not at all elsewhere around coastal Nova Scotia.

Biodiversity is also dependant on habitat diversity. The physical habitat of the Bras d'Or is quite diverse with many embayments, extremely deep basins, varied hydraulic conditions, heterogeneous physical and chemical properties, and a variety of geological coastlines. However, some of the key physical attributes that affect marine production and biodiversity, such as substrate types and intertidal zones, are extremely limited in quantity or diversity. A tidal height of only a few vertical centimetres in most areas of the Lakes creates little to no intertidal zone. The metres of fines and mud that cover most of the floor of the Bras d'Or Lakes are preferred by fewer species than the more limited harder coarse grained substrates. Similarly, as with the physical habitat parameters, some of the chemical parameters within the Lakes do not support diversity and production. Nutrients, particularly nitrate, are very low within the Lakes' photic zone, with few inputs and little deepwater mixing to bring marine nutrients from deepwater areas toward the surface. The result is low productivity at the base of the food chain throughout much of the Lakes. This lack of primary production ultimately impacts on the overall biodiversity supported by the Lakes, as higher trophic levels can only be supported by significant production at lower trophic levels. Inability to support the higher trophic levels means the associated species diversity with these levels will be lower.

12.1 Species at Risk – COSEWIC

Environment Canada's *Species at Risk Act* (2002a) web mapping application indicates the presence of four SARA Schedule 1 species (endangered, threatened, and special concern risk categories) within the Bras d'Or watershed (Table 19) (Environment Canada 2004). The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) lists all four as species of Special Concern. Barrows Goldeneye (*Bucephala islandica*) and the Harlequin Duck (*Histrionicus histrionicus*) are both small diving ducks. Barrows Goldeneye is documented as being within the watershed. During winter, this species feeds on mollusks and crustaceans of coastal waters and would therefore likely move to the outer coast of Cape Breton as the Lakes freeze over. When the Bras d'Or Lakes are ice free, Barrows Goldeneye is seeking nesting, and nesting typically takes place some distance inland in wooded areas. COSEWIC documents the Harlequin Duck as occurring outside of the Bras d'Or watershed in the St. Peters Inlet area, and along the eastern shoreline of Cape Breton Island. The open coastal Cape Breton shoreline is where it would winter and feed. This species moves to freshwater rivers in the spring to breed, but no records are known for within the Bras d'Or Lakes watershed (Milton pers. comm. 2005).

The Atlantic wolfish (*Anarhichas lupus*) is also listed by COSEWIC as a species of special concern. It is unlikely to be found within the Bras d'Or as its habitat requirements are for cold deepwater areas of rocky bottom. Ground trawl data, even in the deepest portions of the Bras d'Or, have not revealed the presence of wolfish within the Lakes (Lambert 2002). The only other SARA Schedule 1 species listed as occurring in the watershed of the Lakes is the Monarch butterfly (*Danus plexippus*). The Monarch is likely found in old abandoned fields where milkweed and wildflowers are found. They annually migrate south in late summer and early fall.

The Maritimes population of Atlantic cod (*Gadus morhua*) was designated special concern by COSEWIC in 2003 and, at the time of publication of this report, was pending public consultation for addition to Schedule 1 under SARA (Environment Canada 2006a). Atlantic cod is widespread throughout the Bras d'Or Lakes (Lambert 2002). The Eastern Scotian Shelf population of winter skate (*Leucoraja ocellata*) was designated threatened by COSEWIC in 2005 (Environment Canada 2006b). Although not plentiful in the Lakes, winter skate is widespread (Lambert 2002).

Two additional SARA Schedule 1 species occur on Cape Breton Island but not within the watershed. The Piping Plover (*Charadrius melodus melodus*) is endangered (Environment Canada 2006c). It is found on Cape Breton Island but is only recorded on the northwestern and southwestern extents of the Island. The yellow lampmussel (*Lampsilis cariosa*) is listed as special concern and is found in Sydney River (Environment Canada 2006d).

Table 19. Summary of various species' protected provincially and nationally for the bay-scale areas of Bras d'Or Lakes

Watershed	Total Species at Risk	Species with Nat. Protection (COSEWIC)	Species with Prov. Protection (NS ESA)	Prov. Rare Species (S1-S2)
St. Patricks Channel	7	4 SC, 1 TH	2 En, 2 Vul	54
Great Bras d'Or Channel	5	3 SC, 1 TH	1 En, 1 Vul	18
West Bay	4	2 SC, 1 TH	1 En, 1 Vul	6
St. Andrews	4	2 SC, 1 TH	1 En	13
Whycocomagh Bay	4	2 SC, 1 TH	1 Vul	29
Denys Basin	3	2 SC, 1 TH	1 Vul	26
North Basin	3	2 SC, 1 TH	1 Vul	16
St. Peters Inlet	3	2 SC, 1 TH	1 Vul	8
East Bay	3	1 SC, 1 TH	1 En	7
Bras d'Or Lake	2	1 SC, 1 TH	-	11

SC = Special Concern, En = Endangered, TH = Threatened, Vul = Vulnerable
Source: ACCDC 2006

Other Listed Species

Table 20 lists species that are or likely could be identified in the Bras d'Or Lake Watershed and are listed either by COSEWIC under the *Species At Risk Act* (SARA) or under the Nova Scotia Endangered Species Act (NSESA) as occurring in and around Cape Breton Island. These are species which are protected under Federal or Provincial acts. For a complete list of species assessed provincially within the Bras d'Or Lakes watershed by subwatershed, refer to Appendix B.

Table 20. A summary of species confirmed in the Bras d'Or watershed and listed by COSEWIC as a species of Special Concern and/or protected under the *Endangered Species Act* (ESA) of Nova Scotia, and the general locations for which they have been recorded. Note that those species that are found in other Nova Scotian locations but not expected in the Bras d'Or watershed are not shown.

Common Name	Species Name	COSEWIC/SARA	NS ESA	Watersheds
Birds				
Bicknell's Thrush	*Catharus bicknelli*	Special Concern	Vulnerable	SPC
Plants				
Prototype Quillwort	*Isoetes prototypus*	Special Concern	-	SAC
Mammals				
Canada Lynx	*Lynx canadensis*	-	Endangered	GBC, SPC, WB, EB, SAC
American Marten (Cape Breton pop.)	*Martes americana*	-	Endangered	SPC
Gaspe Shrew	*Sorex gaspensis*	Special Concern	-	GBC, SPC, WHY
Fish				
Atlantic cod	*Gadus morhua*	Special Concern	-	GBC, SPC, NB, WB, EB, WHY, DB, SPI, SAC, BL
Winter skate	*Leucoraja ocellata*	Threatened	-	GBC, SPC, NB, WB, EB, WHY, DB, SPI, SAC, BL
Reptiles				
Wood Turtle	*Glyptemys insculpta*	Special Concern	Vulnerable	GBC, SPC, NB, WHY, DB, WB, SPI
Amphibians				
None				
Insects				
None				

SPC=St. Patricks Channel, SAC=St. Andrews Channel, GBC=Great Bras d'Or Channel, WB=West Bay, EB=East Bay, WHY=Whycocomagh Bay, NB=North Basin, DB=Denys Basin, SPI=St. Peters Inlet, BL=Bras d'Or Lake
Source: ACCDC 2006

12.2 Bras d'Or Species of Concern

Several other species found in the Bras d'Or watershed, which are not listed by COSEWIC or under the Nova Scotia *Endangered Species Act* (NSDNR 1998), may be undergoing population changes of significance based on the observations of the scientists who have studied and observed them. These organisms may not be a class of biota yet assessed as part of the existing lists; changes may simply be occurring on too local a scale to be significant to a species status report, or the changes could be undocumented. Regardless, a few such biota changes that have been noted are presented here for consideration.

In the Bras d'Or Lakes, American plaice (*Hippoglossoides platessoides*) is now found confined to the deepwater areas of St. Andrews Channel and Bras d'Or Lake after historically being found both widespread and plentiful around the Lakes (Lambert 2002). Discussion on this change in distribution and reduction in numbers is undocumented in the scientific literature.

Arctic remnant species found in the cold depths of Bras d'Or include the copepod (*Microcalanus pusillus*), mysid shrimp (*Mysis oculata*), polychaete worms (*Clymenura polaris, Sabellides borealis* and *Lysippe labiata*), and foraminifera (*Eggerella advena* and *Rheophax artica*). Warm water species that are not widely found or nonexistent in other parts of coastal Nova Scotia include the oyster, (*Crassostrea viginica*), windowpane flounder (*Scophthalamus aquosus*), and polychaete worms (*Euchone elegans, Polydora quadrilobata* and *Myriochele heeri*) (Lambert 2002). Because these species are isolated by temperature requirements, changes that impact the temperature regime of the Bras d'Or would tend to impact either the Arctic or warm water species before the more typical boreal biota.

American oyster (*Crassostrea virginica*) is a culturally and economically important species within the Bras d'Or. Natural stressors of blue mussel competition and starfish predation are now combined with additional stressors of green crab predation, and human harvest of both spat and adults.

Rare and sparse around the Atlantic Provinces, the marine algae *Nemalion helminthoide*s was found at several sites in the Bras d'Or. The population outside of McIver's Cove in St. Patricks Channel was very dense, the most abundant occurrence encountered by the surveyors (McLachlan and Edelstein 1971).

Denny et al. (1998) has noted that some fishermen recognise a run of large, dark ("blackback" or "bank") herring in the St. Peters area in the fall, which are different from the spring-spawning herring. It is also possible that these fish are not part of the Bras d'Or stock at all but are from other stocks, which spawn outside the Lakes.

Herring is a large stock that has collapsed within the Bras d'Or. It is an important food source at several life stages to other species, and as a fish that migrates in and out of the Bras d'Or it is potentially significant as a source of marine derived nutrients being brought into the Lakes to feed resident species. The magnitude and impact of this decline on other species does not appear to have been evaluated. In a system that is nutrient poor to begin with, loss of this nutrient source may be significant.

Wild oyster, as opposed to aquaculture stocks within the Lakes, used to support a very large commercial fishery. With the advent of aquaculture, commercial harvest of wild stocks has been reduced, yet their numbers have fallen significantly in many areas of the Bras d'Or Lakes. These animals are still harvested, and spat is collected for aquaculture operations. As well, it is expected that they have lost valuable habitat to sedimentation in some key areas like Denys Basin. Introduced threats of parasites such as MSX and SSO are found in a wide range of the Lakes, and are known to cause mortality between 20-95%. A declining population and the presence of several known risk factors make the wild oyster a Bras d'Or species of concern.

13. Marine Habitat Components

A wide range of habitats and bottom types can be found in the Bras d'Or. Bottom types from rocky through gravel and sand to mud exist. Marshy flats, barachois ponds, bays, inlets and deep basins all exist in the Lakes. This variety of habitats helps support a diversity of marine life. The Bras d'Or Lakes are home primarily to boreal species and the overall species assemblage found here tends to be characteristic of those that can be found along other portions of Nova Scotia's coastline. However, it is also distinguished from the rest of coastal Nova Scotia in that both a group of coldwater Arctic species and a group of warm water Virginian enclave biota are also found here. Both are remnant populations from different times when the local climate was more similar to characteristics of the Arctic or the Virginian coasts of today. The deepwater areas of St. Andrews Channel, the North Basin, and Bras d'Or Lake remain cold enough to support the Arctic species. Warm water species are supported by the shallow, well mixed, and surface water areas where temperatures rise in the summer to in excess of 20^{o}C (Lambert 2002). These characteristics are primarily found in shallow protected bays, and along the Great Bras d'Or Channel.

Lambert (2002) identified 25 species of fish as being in common, medium, or low abundance within the Lakes and that were not migratory. These species are referred to as being "resident", meaning that they have found appropriate habitat conditions within the Lakes to meet requirements of all life stages, including spawning, rearing, overwintering, and feeding. Although appropriate conditions exist outside the Lakes for at least some portion of their life cycle, they do not leave the Lakes, but instead satisfy all of their life stage requirements within the confines of the Bras d'Or system.

Other coastal marine organisms, such as marine mammals and colonial birds, are highly mobile with the ability to move freely into or out of the Bras d'Or watershed. The home ranges of such species are often large, and one would expect these animals to utilize habitats outside of the watershed for at least some of their life cycle functions. Still others like shellfish, mollusks, and other invertebrates are less motile, most often only moving into or out of the Lakes passively with water exchange or with larger host organisms. However, the existence of such immobile organisms within the Lakes indicates their ability to survive through their complete life cycle within the habitats provided by the Bras d'Or Lakes.

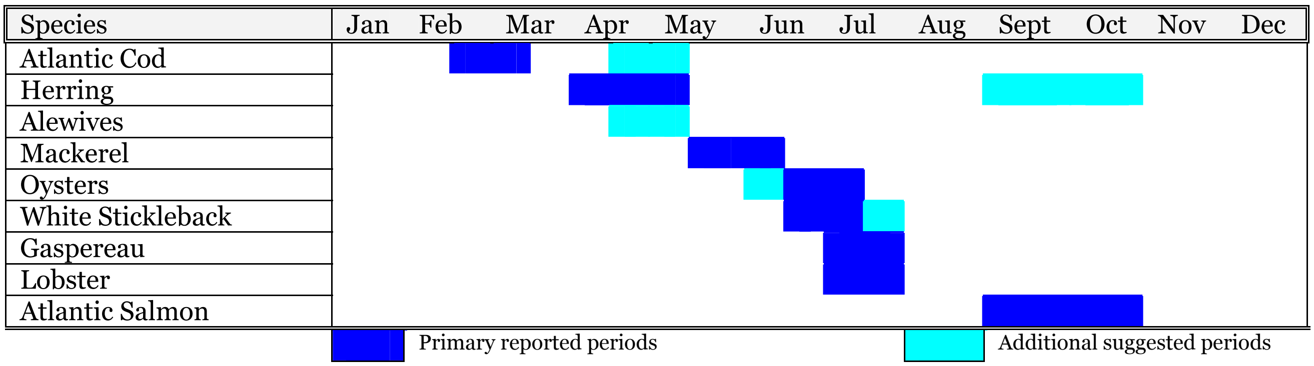
The following discussion considers habitats from the perspective of life cycle functions of various species of the Bras d'Or watershed as noted in the reviewed literature. Description of such habitats remains an information gap, as very little is described in detail beyond a few spawning locations.

13.1 Spawning/Reproduction Areas

Cod and herring are pelagic species that appear to have unique spawning stocks in the Bras d'Or (Pogson et al. 2001; Crawford et al. 1982). Many other migratory species spawn in the Lakes as part of larger populations that extend into Sydney Bight and surrounding waters. An example would be Atlantic salmon, which enter the Lakes to spawn in rivers like the Middle and Denys. Still other species likely spawn in the Lakes as vagrants or strays. Together, the fish of Bras d'Or Lakes engage in some spawning activity nearly all year round (Table 21).

Although cod are regionally important, the extent of worm infestation in the Bras d'Or results in limited commercial interest in this species within the Lakes. The literature has documented studies of seal worm, and genetic isolation of the cod in Bras d'Or, but little detail exists on the spawning behaviours of this unique stock. Black (1976 cited in Kenchington and Carruthers 2001) reported that his April and May 1952 trawl surveys had taken running ripe female cod (those on the point of spawning when they were caught) from both Baddeck and Whycocomagh Bays, indicating spawning activity in those areas. However, most cod spawning in the Lakes has been documented as occurring in late February and early March, more than a month earlier than the adjacent Sydney Bight stock. Most Bras d'Or Lakes cod spawning occurs in St. Andrews Channel and East Bay (Lambert 2002).

Table 21. Approximate spawning times in the Bras d'Or Lakes for selected species as noted in the reviewed literature



Herring spawning is the best documented spawning activity within the Lakes. Traditionally, the main herring spawning areas were along the western shore of West Bay, in Denys Basin, St. Peters Inlet, and East Bay. Typically, 80% of eggs were deposited on eelgrass (*Zostera marina*) and most of the remainder on sea lettuce (*Ulva lactuca*). Eelgrass-dominated areas include St. Patricks Channel, Denys Basin, North Basin, and the upper reaches of East Bay and St. Peters Inlet (MacLachlan and Edelstein 1971), all of which correspond strongly with the historic spawning locations. However, an increased demand from the lobster fishery which began using herring as bait, brought the already declining stock to the point of collapse and resulted in closing of the commercial fishery in 1999 (Lambert 2002). Spawning at the time of closure was nearly non-existent south of the Barra Strait, while Baddeck Bay had one of the more significant spawn sites in the Lakes, a reversal of the traditional spawning site distribution within the Lakes. During 1997 field surveys, no spawning was observed in the traditional areas of West Bay, East Bay, and St. Peters Inlet (Denny et al. 1998). During 2002 spawning surveys, it was noted that spawning was still absent in some traditional areas, and the observed biomass of spring spawners was very low (Power et al. 2003).

Herring move into the shallow waters to spawn in April and early May, shortly after the ice disappears (Crawford et al. 1982). They spawn in small groups, with groups tending to spawn year after year in a particular cove with little interaction with fish from other coves. Later in summer, after spawning, it is assumed that the fish migrate out to Sydney Bight and return again to the Lakes in late winter or early spring, although recent identification of a unique elemental fingerprint of herring otoliths suggests that the Bras d'Or Lakes herring likely spend extended periods in the Lakes (Denny pers. comm. 2004 cited in Westhead 2004). It has also been noted by fishermen that a fall run of herring occurs in St. Peters (and nowhere else in the Lake), and ripe females have been collected there by DFO in September and large schools observed with a sounder (Denny et al. 1998). Little is known about this run.

During a 1981 survey of herring spawning areas in West Cove, spawning occurred on a single day. Larvae over the spawning bed peaked at about 4655 larvae/m^3 four days after hatching began, and dispersion appeared to be primarily associated with currents of lunar and barometric tides. Larval capture dropped to zero within eight days of first hatching. The spawning bed in Ross Cove appears to have been one of the shallowest on record for the Atlantic coast (25-75 cm deep), although spring spawners do tend to have shallower beds than fall spawning herring. During a limited evaluation, the observed 6.5-8.5% egg mortality from environmental factors such as salinity and temperature was higher in Ross Cove, West Bay than that observed in other spawning locations of the North Atlantic where 1-2% was typical (Crawford et al. 1982). Most spawning beds in the Lakes are not well defined. However, a bed found in 1997 near Big Harbour Island extended 365 m along the shore and some 18 m out from the tide line, covering an area of eelgrass growing on sand. The water temperature was around 8°C and the salinity a little over 21 ppt (Denny et al. 1998).

The number of Alewife (*Alosa pseudoharengus*) peaked in scientific trawls carried out during the last week of May and first week of June 1952 (Black 1976). This is more of a temporal distribution observation, but may have some relevance to spawning period, as this species would only be entering the Bras d'Or Lakes and its freshwater systems to spawn. Greater numbers might be expected just prior to the height of the spawning period.

Mackerel begin spawning in Sydney Bight in late May and early June. However, Kenchington and Carruthers (2001) suggest that individuals of species like mackerel, which happen to stray into the Lakes at the appropriate season, will spawn, but that the Lakes are in no way important to the broader population.

Oysters (*Crassostrea virginica*) spawn where the shallow water temperature exceeds 20 C for several days, usually in late June or early July. Low tidal exchange, weak currents, and a short planktonic period help ensure oyster larvae are retained in high numbers at spawning locations (Tremblay 2002). Studies completed in Gillis Cove, within Denys Basin, between 1938-1940 documented the greater part of any year's spatfall as occurring during about a week of single mass spawning (Medcof 1955). Medcof also found three behavioural characteristics of the ready-to-settle larvae: they are benthic, light stimulates them to settle, and they settle most readily on surfaces lower in the water column. He observed a maximum settlement rate of 0.4 spat cm^2/hr. Wild oysters are found in Denys Basin, St. Peters Inlet, St. Patricks Channel, Whycocomagh Basin, West Bay and East Bay. Of these areas, Denys Basin has been the historic centre for wild oyster production. Recent interferometric sidescan sonar has revealed a number of bioherms that may have been significant spat settlement areas in the Basin (Shaw and Potter 2006c). Denys Basin is the most extensive area within Bras d'Or Lakes that lies within the species' tolerance limits for both temperature and salinity, although many smaller coves in other parts of the Lakes have small wild populations (Needler 1936; Smith 1936 cited in Kenchington and Carruthers 2001). Along with doubts about the food supply of the Bras d'Or waters and the minimal area of hard bottom habitats, Needler (1934, 1936) further suggested that the shores of the open Lakes do not reach sufficiently high temperatures in the summer for the oysters to spawn. The oysters are therefore confined to sheltered bays, where the shallows are in excess of 20 C (Lambert 2002). Unfortunately, those areas typically have more freshwater runoff than the open Lakes, which reduces local salinity to below the rather low levels found elsewhere in Bras d'Or. In consequence, the warmer areas are close to the lowest tolerable salinity for oysters. Spawning has been observed as early as the first half of June (Smith 1936 cited in Kenchington and Carruthers 2001), but late June or some time in July is more typical (Smith 1936, 1937; Medcof 1938a, 1940 cited in Kenchington and Carruthers 2001).

Stevens' (1993) data indicate that larval release by the "berried" female lobsters from West Bay and St. Peters occurs in the Bras d'Or during July. However, no specific reference is made of the habitats in Bras d'Or associated with larval release.

Observations of threespine (*Gasterosteus aculeatus*) and the newly discovered white stickleback (*Gasterosteus*) in the Bras d'Or Lakes indicate that both are fairly widespread. They both spawn in the relatively shallow water around the Lakes' shore. Threespine utilize a predominantly gravel or rocky substrate in 10 – 60 cm of water whereas the white stickleback nests in 40 –180 cm of water with dense filamentous algae growth (Jamieson et al. 1992). Spawning of both occurred in late June to early July. Threespine fish tend the nest for a period of time, whereas the White stickleback male will pull the eggs from the nest and distribute them over the surrounding algae, at which time both male and female fish leave the site.

Several anadromous fish species spawn in the rivers of the Bras d'Or Lakes watershed, including brown trout, rainbow trout, and Atlantic salmon. A substantial run of rainbows existed in the Skye River in the late 1980s after significant escapements from aquaculture operations occurred. There is no current literature documenting their existence or demise in the Skye River, or a number of other rivers in which they had been found. Records for brown trout indicate spawning in two small systems of St. Peters inlet, and Atlantic salmon have been most abundant in Middle and Baddeck Rivers (Hurley Fisheries Consulting 1989). More discussion of spawning locations for these anadromous species is presented under section 14.2 Freshwater River Habitats.

American plaice (*Hippoglossoides platessoides*), once found widespread and plentiful around the Lakes is now found confined to deepwater areas of St. Andrews Channel and Bras d'Or Lake (Lambert 2002). Although no research has been conducted, it is possible that these areas are also currently the key spawning locations for this species.

Finally, Veith (1884) made several observations of fish habitats and uses around the Bras d'Or 120 years ago. His observations document the importance of barachois ponds for spawning and rearing of gaspereau within the Bras d'Or Lakes. He also identified a run of shad that were trying to enter the Washabuck River to spawn but were stopped by a dam that had been built a few years earlier. Additional observations are presented in Table 14 Section 11.4.2 – Freshwater and Anadromous Fish.

13.2 Rearing Areas

Complete species' life cycle descriptions specific to the Bras d'Or Lakes ecosystem are very limited. Components like rearing, foraging, and migration are usually only described in passing. Therefore, the following is more a collection of brief species-specific observations, as opposed to a detailed explanation of rearing behaviours and habitats.

Preliminary indications of cod tagging carried out in 2000 suggest that Bras d'Or Lakes cod overwinter in relatively warm and deep waters of the Lakes. Such waters can be found in Bras d'Or Lake, North Basin, and St. Andrews Channel. To date all tagged cod found in winter were located in St. Andrews Channel (Lambert 2002). Juvenile Atlantic cod densities in Newfoundland are highest in eelgrass beds (Ings et al. 2004 cited in Gregory 2004) which are similar to eelgrass habitats in the Bras d'Or.

Based on plankton surveys and trawl surveys, white hake larvae and adult fish were rarely captured, yet juvenile fish were caught with an increasing size trend moving from the Lakes' entrance inward. It is therefore possible that the Bras d'Or is a nursery area for at least some portion of an external stock of white hake (Lambert 2002). Rareness of larvae and adults would indicate that the Lakes are not a primary spawning location for hake. It has been found in the Kouchibouguac estuary in New Brunswick that juvenile White hake and small cunners (<3cm in length) were only found in eelgrass habitats (Joseph et al. 2004). Thus eelgrass habitats in the Bras d'Or may provide rearing areas for these species.

The best substrates for oyster spat to settle on are a combination of pebbles or shells that provide very hard surfaces and eelgrasses. Those on soft mud will sink and die, and those that settle on eelgrass may die when the grass is blown ashore during storms. Within the predominantly silt layered Bras d'Or system, this requirement limits the areas in which successful rearing of oyster will occur to locations where wave action and localized tidal currents expose larger grain substrate.

Preliminary studies indicate the lack of presence of early larval stages of the green crab (*Carcinus maenas*) in the enclosed embayments of the Lakes. These larvae are intolerant of low salinity. This result would seem to indicate that this species might be rearing offshore within the Lakes. Using a vertical migration strategy, the early zoeae larvae would first migrate along with outflowing surface waters before dropping into deeper more saline waters which would carry them back. Later they would migrate higher in the water column to be carried even further into the Bras d'Or and embayments as late zoeae or megalopae larvae by onshore wave action (Cameron 2003). Juvenile crabs would then overwinter and remain in the embayments.

13.3 Foraging/Feeding Areas

The following are a series of observations and hypotheses made by various authors regarding the foraging behaviours and locations for their species of study. None of the studies specifically aimed to define foraging behaviour or habitats within the Bras d'Or Lakes, and therefore no further discussion has been presented here.

Studies of herring in 1980-81 revealed a pronounced increase in the herring nematode (*Aniskasis simplex*) infestation from small fish to larger fish. This may suggest that small fish remain within the Bras d'Or for summer feeding, whereas older fish may move out to the Atlantic (Crawford et al. 1982).

Muhammad (1966 cited in Kenchington and Carruthers 2001) found that the shrimp, (*Crangon septemspinosus*), ate mostly bivalve molluscs plus some crustaceans and a few gastropod snails. They seemed to overwinter at depth and to migrate into Baddeck Bay in the spring.

Lobster trap buoys in Bras d'Or Lake proper during the regulated May to July 1993 season were in shallow water, typically 5-10 m depth, along the shore and around islands and shoals (Stevens 1993). July and September video and SCUBA surveys also documented the greatest percentage of lobster at 6-10 m depth (Tremblay 2004). That almost certainly reflects the distribution of the lobsters in the spring (Kenchington and Carruthers 2001), though they may well move deeper in the summer, as the water warms, and perhaps deeper still in the winter to avoid surface cooling.

Crawford et al. (1982) noted that winter flounder in the coves off West Bay were feeding on herring spawn during the spring. Given the more recent decline of the Bras d'Or herring population, and virtual disappearance of spawning in West Bay, this forage source for winter flounder has undoubtedly been affected, however this impact has not been evaluated.

Bras d'Or supports a substantial seal population during the winter months (Kenchington and Carruthers 2001). Both harbour and grey seals enter in November, the former remaining until spring but the latter moving to their breeding areas in January (Scott and Fisher 1958 cited in Kenchington and Carruthers 2001). The Bras d'Or serves as a winter feeding ground for these marine mammals.

13.4 Migration Routes

Only a few general observations of seasonal migration into, out of, or around the Lakes have been made, and none provide any degree of detail on actual routes taken by a given species. No relationship between local water chemistry, currents, or other parameters and any particular species' migration movements in the Lakes has been made, however any population of fish moving seasonally in or out of the Lakes would almost exclusively pass through the Great Bras d'Or Channel. Within the Lakes, spawning migrations for most species that have large numbers, such as herring, alewife, and mackerel, indicate that peak entrance movement through the Great Bras d'Or Channel occurs in early spring to early summer (DFO 1997).

It is generally supposed that herring migrate out to Sydney Bight in the late summer or fall, and return in late winter or very early in the spring, however the evidence for this is limited (Kenchington and Carruthers 2001).

The anadromous fish species that come to spawn in the various rivers entering the Bras d'Or Lakes use the Lakes primarily as a migration route, although a few species such as the rainbow and brown trout likely never leave the Lakes for more open water. Alewives and Atlantic salmon likely pass through the Lakes only as a means of reaching their spawning grounds in the freshwater and estuaries of the inflowing rivers. It has been noted that Atlantic salmon pass over Middle Shoal entering the Lakes in Late June or early July (DFO 1997).

13.5 Limited Marine Habitats

As with any ecosystem, some habitat types are abundant, and others are relatively limited. The fact that a given habitat is limited does not necessarily mean that it is more ecologically important than the abundant habitats. However, because they are limited their sensitivity to degradation, their contribution to local biodiversity and productivity, and their significance at greater spatial scales all need to be evaluated.

13.5.1 Rocky substrates

Rocky substrates are limited to a few areas of the Lakes. The most significant amount of this habitat type is in the Great Bras d'Or Channel where tidal currents prohibit the settling of finer materials. Similarly, the Barra Strait, Little Bras d'Or Channel, and Little Narrows have some limited hard bottom habitats associated with the stronger currents found here. Shorelines around the Lakes have somewhat coarser grained substrates where wave action prohibits accumulation of fines. West Bay and Denys Basin also have areas of limited current and wave action that still have some coarse grain substrates associated with the final glacial retreat from the basin areas that are now the Bras d'Or Lakes. Sidescan radar has highlighted isolated underwater bedrock outcrops and/or ridges both in Bras d'Or Lake and St. Andrews Channel

(Myers and Gilbert 1993), and multibeam imagery recently collected is currently being analyzed to help classify substrates (Shaw and Potter 2006a-d). However, most of the Lakes are a very uniform substrate of fines and mud deposited meters deep from marine, glacial, and erosion events.

Many marine species require rocky substrates as part of their physical habitat requirements. For example, many macrophytes require gravel and rocks to anchor to before they can grow into the water column. In areas where these macrophytes cannot attach, other species that require their presence for food, shelter or spawning, will be absent. Shellfish such as oyster, mussels, lobster and crab typically need coarse-grained habitats during some or all of their life cycle. The limited amount of such habitat is one of the factors that may limit the production or distribution of such commercial species within the Lakes.

13.5.2 Saline Wetlands

Included in the saline wetlands category are any areas greater than 0.5 ha in size classified as a salt marsh, estuarine flat, or a marine flat (Table 22) by the Nova Scotia Department of Natural Resources. Saline wetlands are areas typically covered by low and high salt marsh communities, while eelgrasses are found on the estuarine and marine flats.

Table 22. Summary of wetland surface area by subwatershed within the Bras d'Or watershed

Watershed	Total Saline Wetlands (km²)	Total all wetlands (km²)
St. Patricks Channel	20.9	64.7
East Bay	36.7	53.4
West Bay	32.5	36.1
Denys Basin	20.3	31.8
Bras d'Or Lake	28.5	29.9
St. Peters Inlet	14.0	20.8
St. Andrews	12.2	17.2
Whycocomagh Bay	8.5	15.4
North Basin	11.9	13.6
Great Bras d'Or Channel	6.8	8.3
Total	**192.3 km²**	**291.2 km²**

Source: NSDNR 1999

The largest continuous shoreline coverage of wetlands and marshes are within Denys Basin and the head of Whycocomagh Bay (Figure 7), but large wetland and marsh communities also cover the deltas of the Skye, Middle, Baddeck, Denys, Washabuck, Black and Benacadie Rivers (Taylor and Shaw 2002).

Wetland habitats support a number of important ecological functions, and host a diversity of species not typically found in other habitats. In addition they support many plants (e.g., sweetgrass) used for traditional medicines (CEPI 2006). Within Nova Scotia much of our coastal wetland areas have been drained and dyked for agricultural uses, a practice that began over three hundred years ago with the arrival of the Acadians. Less of this practice has occurred in the Bras d'Or watershed, however, the magnitude of conversion of wetlands within Nova Scotia makes this a limited habitat provincially, even if it is less so locally. It is for these reasons that wetlands are identified as limited habitats of the Bras d'Or Lakes.

Traditional ecological knowledge indicates that wetlands and marshes with cattails in the Bras d'Or are declining and/or disappearing (CEPI 2006). Many marshes are "sinking" or being covered over. They used to be firm but are now turning into mud flats. Tractors were used in the past to collect salt hay but the marshes will no longer support the vehicles. Cattails were used as torches, and harvest may have had an impact either in helping renewal or depletion. According to TEK, potential reasons for the decline in wetland habitat include pollution, sewage, siltation, bad land use practices, overuse of chemicals, farming, and mining.

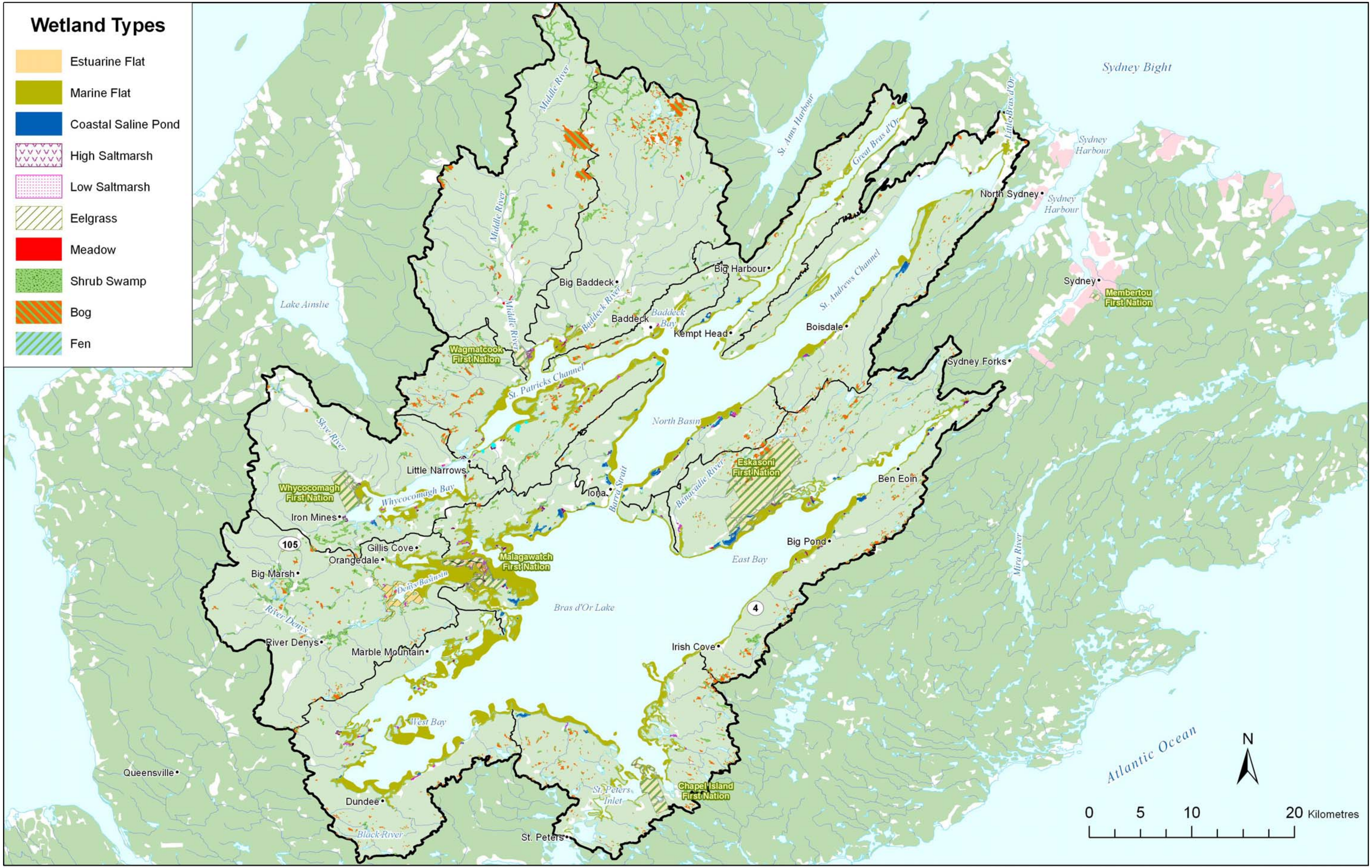


Figure 7. Saline and freshwater wetlands within the Bras d'Or watershed
Data sources: NSDNR (2000); DFO (2003); Basemap (Natural Resources Canada, National Topographic Database 1:250,000 3rd Edition)

13.5.3 Deepwater Habitats

The average depth of the Bras d'Or Lakes is 30 m (Strain and Yeats 2002). However, several basins exist that are much deeper. St. Andrews Channel has the deepest basin at 280 m, while the North Basin (229 m) and Bras d'Or Lake (119 m) also have deepwater areas. The constant cold water temperatures and relatively high salinity found in these locations provide habitat characteristics unique to the Bras d'Or system. These are arguably the most closely related areas of the Bras d'Or Lakes to the oceanographic parameters of the open ocean. The apparent long-term stability of the habitat parameters in these areas is a contributing factor that allows the Arctic relict species to survive within the Bras d'Or over time, while other areas of the Lakes have become less hospitable to these species. It is the unique habitat and unique species that make these areas of the Bras d'Or ecosystem significant.

13.5.4 Intertidal Habitats

Because there is such small tidal amplitude in the Bras d'Or, there is very little intertidal habitat. As well, much of the tidal amplitude is barometrically influenced so the time of exposure lacks consistency between cycles. Furthermore, the lack of large shallow mudflat-type areas that might become exposed during a tidal cycle means that the intertidal zone is significantly limited to 5-10 cm vertical change over the slope of the shoreline in most areas of the Lakes.

Intertidal habitats are not well quantified for the Bras d'Or Lakes, however, the Nova Scotia Department of Natural Resources (2000) has compiled a number of marine marsh characteristics that reflect one component of the intertidal zone. These are the various vegetation communities that separate high and low salt marshes, as well as eelgrass beds (Table 23). The latter are considered here as they have been identified in the past as key spawning areas for herring (Denny et al. 1998), and has a number of other significant biological functions. The herring population in the Lakes crashed because of overfishing in the late 1990s. Eelgrass habitats will likely be a key component of any recovery of the Bras d'Or herring population.

Table 23. Tidal marsh areas as classified by dominant vegetation coverage in each of the Bras d'Or Lakes bay-scale areas

Watershed	High Marsh Veg. (m^2x1000)	Low Marsh Veg. (m^2x1000)	Eelgrass (*Zostera marina*) Veg. (m^2x1000)	Total Coastal Marsh vegetated area (m^2x1000)
Denys Basin	0	21	6050	6071
St. Patricks Channel	36	64	433	533
Bras d'Or Lake	12	49	123	184
East Bay	88	37	0	125
West Bay	31	19	49	99
North Basin	4	46	0	50
Whycocomagh Bay	6	34	0	40
St. Andrews	2	11	0	13
St. Peters Inlet	3	9	0	12
Great Bras d'Or Channel	3	0	0	3
Total	**185**	**290**	**6655**	**7130**

Source: NSDNR 2000

The numbers found in Table 23 are based on interpretation of air photos that are now ten or more years old, and that had minimal ground truthing. September 2005 field surveys of the southern portion of Denys Basin failed to find areas of eelgrass coverage similar to those identified from the air photos (Vandermeulen pers. comm. 2006) bringing the state of current coverage into question. Significant declines in eelgrass coverage have been noted in other areas of Nova Scotia (Chapman 2006) and Atlantic Canada (Hanson 2004).

Elders have observed the decline of eelgrass around the Bras d'Or (CEPI 2006). As late as the 1940s and 1950s, eelgrass would wash ashore in large volumes where it could be collected for use as banking around houses in the fall and during potato planting to help keep potatoes dry (CEPI 2006). The material no longer washes ashore in such quantities. Declines of eelgrass have also been noted by residents at Eskasoni and Manis (West Bay).

Some Elders believe that the plant is not declining but shifting location, at least around Whycocomagh (CEPI 2006). The Elders report that there are still a lot of healthy eelgrass beds where there are islands such as around Chapel Island. Eelgrass has been observed in deeper waters in River Denys, at about 3-4 m depth, and in South Basin, possibly because the water is clearer. Residents say that eelgrass appears healthy near Wagmatcook and Waycobah, and report an increase in eelgrass in St. Peters and West Bay over the last five years, after observing low quantities for decades. Near Baddeck and Little Narrows, eelgrass can die off for a few years but usually returns. It is not observed in muddy or deep water but has been observed growing on sand and hard bottom areas.

13.5.5 Saline Ponds

Saline ponds created behind barrier beaches which are formed of fine-grained materials, are inherently less stable than areas of coarse coastal substrates (Table 24). Natural events that create high winds and wave action can destabilize these habitats. Many of the saline ponds around the Bras d'Or Lakes have been documented as in a state of destabilization or failure (Taylor and Shaw 2002). They are sensitive to anthropogenic impacts, and enclosed saline ponds can become highly eutrophic given accelerated nutrient loads from land based activities.

Table 24. Limited saline pond habitat areas found in the Bras d'Or watershed

Watershed	Total Saline Ponds (m^2 x 1000)
East Bay	201
West Bay	5
Bras d'Or Lake	95
St. Andrews	62
North Basin	60
St. Peters Inlet	30
Great Bras d'Or Channel	160
St. Patricks Channel	38
Denys Basin	0
Whycocomagh Bay	0
Total	**651**

Source: NSDNR 1999

Saline ponds support a diversity of flora and fauna, including fish that will spawn or rear in the ponds (Vieth 1884). Little literature exists that defines the importance of these habitats in the Bras d'Or Lakes.

14. Terrestrial Habitat Components

The Nova Scotia Department of Natural Resources (NSDNR) owns and maintains a GIS database of significant species and habitats that spatially classifies 12 habitat types. These include locations of species at risk, species of conservation concern, deer wintering areas, moose wintering areas, migratory bird habitat, salt marshes, wetlands, freshwater habitats, old forests, rare plant sites, sites identified by the International Biological Program, and other significant wildlife habitats. Regional biologists locate data sources, including knowledgeable naturalists, universities, the Nova Scotia Museum of Natural History and other museums, the Atlantic Canada Conservation Data Centre and other government departments, and confirm accuracy and completeness. The database is not a complete inventory of all significant habitats in the province, although it does provide an indication of what is known. The database was last updated in August of 2004. A summary of a few select classified habitats for each subwatershed in the Bras d'Or is provided in Table 25 and shown in Figures 8 and 9.

Table 25. Classified habitat areas for each subwatershed as defined in the NSDNR significant species and habitats database (NSDNR 2004). These are approximate areas only.

Subwatershed	NSDNR Habitat Classification in hectares (% of watershed if ≥5%)					
	Species at risk	**Species of concern**	**Deer wintering**	**Rare plant**	**Migratory bird**	**Old forest**
East Bay	7757 (23)	422	1759 (5)	19	27	116
River Denys	1,015	132	3825 (13)	162	0	1064
West Bay	761	114	1155 (7)	0	0	0
North Basin	674 (8)	38	794 (9)	7	0	0
Whycocomagh Bay	600	983	267	52	3	0
St. Peters Inlet	322	227	243	0	10	0
Baddeck River	286	1416 (5)	23	19	19	0
St. Patricks Channel	72	160	1519	30	25	0
Great Bras d'Or Channel	25	355	241	7	0	0
St. Andrews Channel	19	101	548	0	64	19
Middle River	0	1532 (5)	16	0	0	0
McKinnon's Harbour	0	301	390 (5)	2	8	0

The NSDNR also maintains a GIS database of forested land cover and habitat classification. Each of the Bras d'Or subwatersheds are highly forested, with Middle River having the highest percentage at 86% (as well as the highest total area) and St. Patricks Channel having the lowest at 74% (Table 26, Figure 10). Percentage of regeneration area for each subwatershed is also similar and ranges between five and ten percent. The percent coverage of areas defined as urban were highest in the Great Bras d'Or Channel, McKinnon's Harbour, and St. Andrews Channel subwatersheds. Areas covered by freshwater, barrens, gravel pits and corridors were all minimal, at less than 5% of each subwatershed area. The low area of freshwater cover directly relates to the few freshwater lakes within the Bras d'Or watershed. It should be noted that gravel pits cover much more area in the River Denys and St. Patricks Channel subwatersheds than all other areas (403 and 355 ha, respectively).

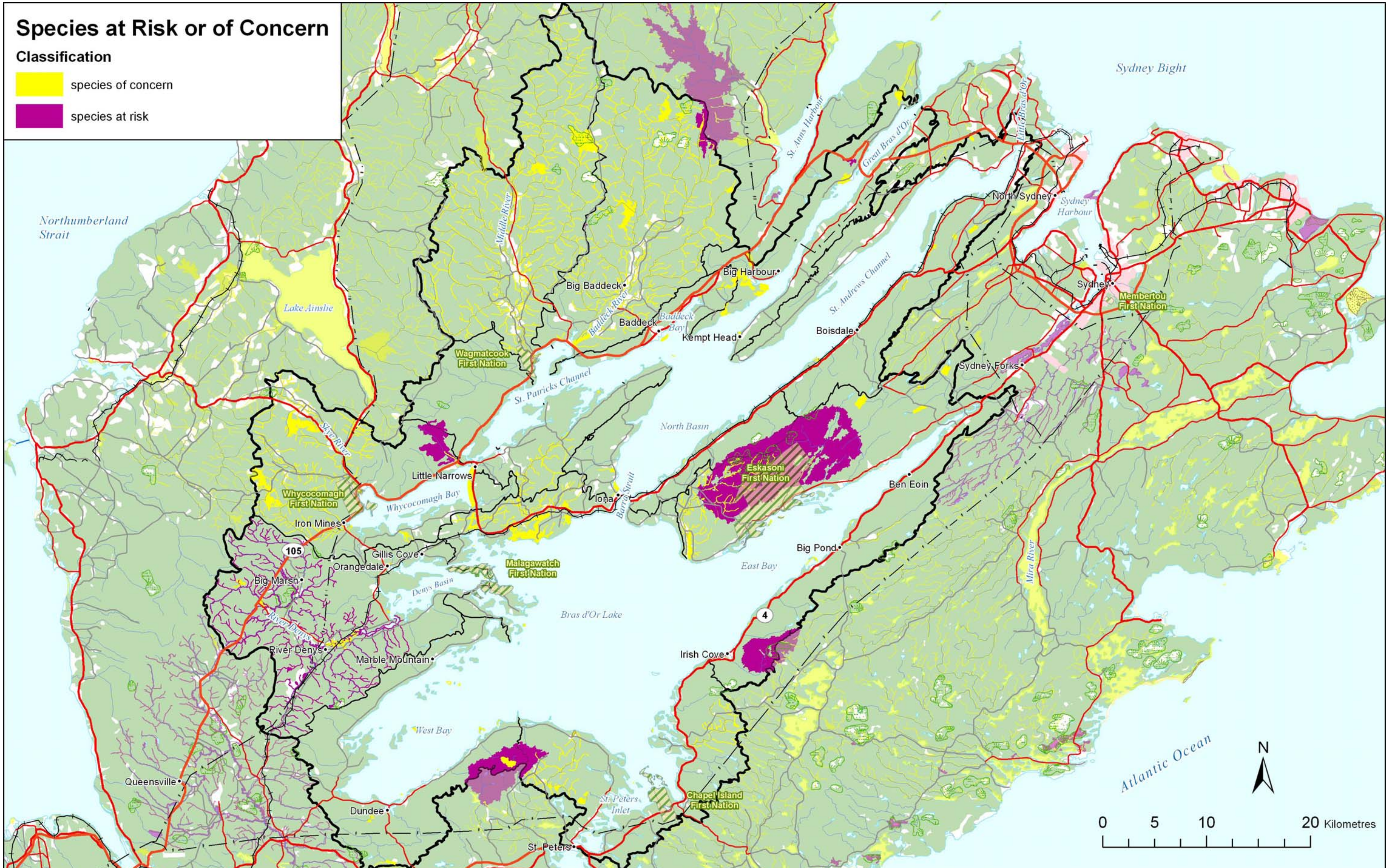


Figure 8. Habitats for species at risk or of concern within the Bras d'Or watershed
Data sources: NSDNR (2004); DFO (2003); Basemap (Natural Resources Canada, National Topographic Database 1:250,000 3rd Edition)

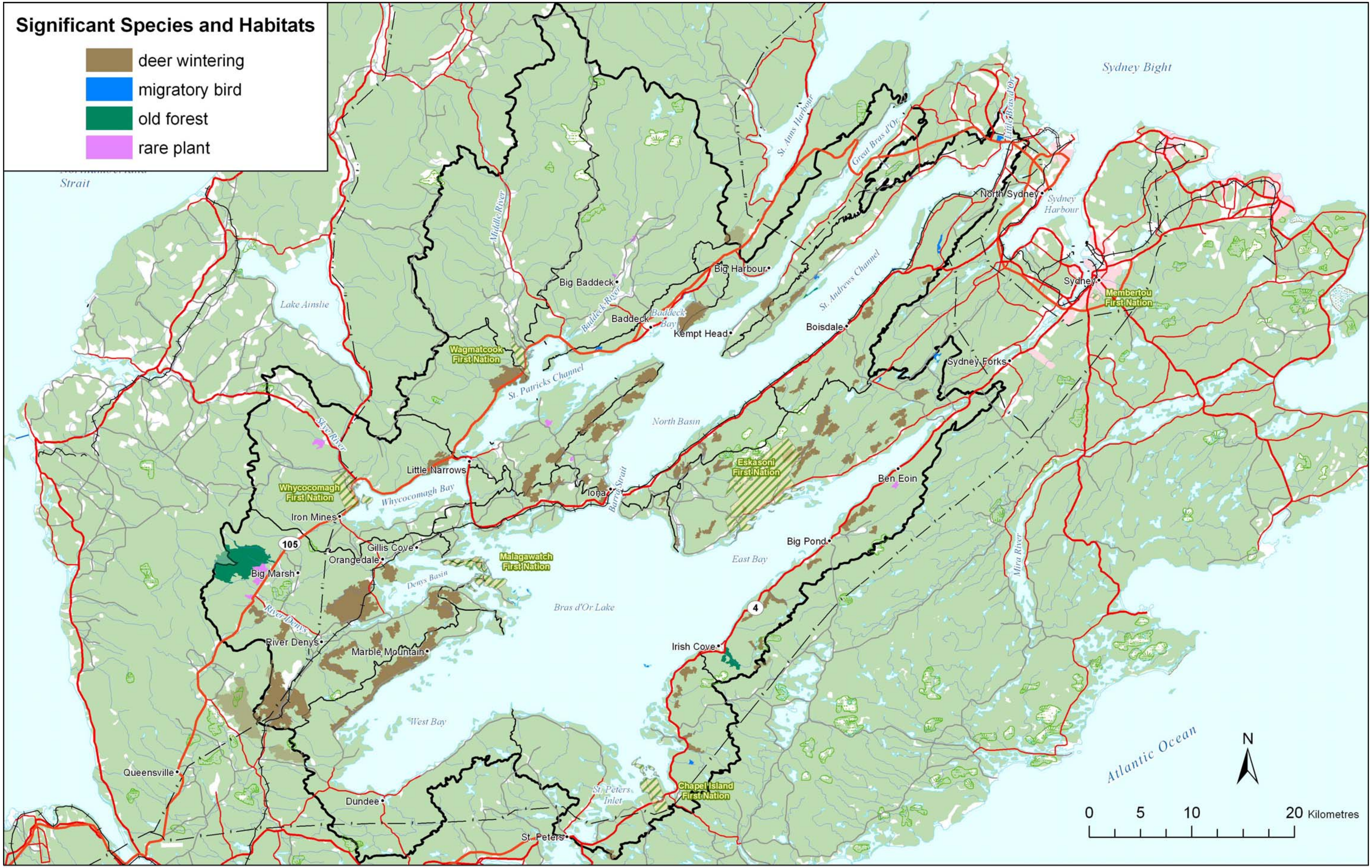


Figure 9. Significant species and habitat classification within the Bras d'Or watershed. Note that lightly shaded areas indicate habitats extending beyond the watershed boundary.
Data sources: NSDNR (2004); DFO (2003); Basemap (Natural Resources Canada, National Topographic Database 1:250,000 3rd Edition)

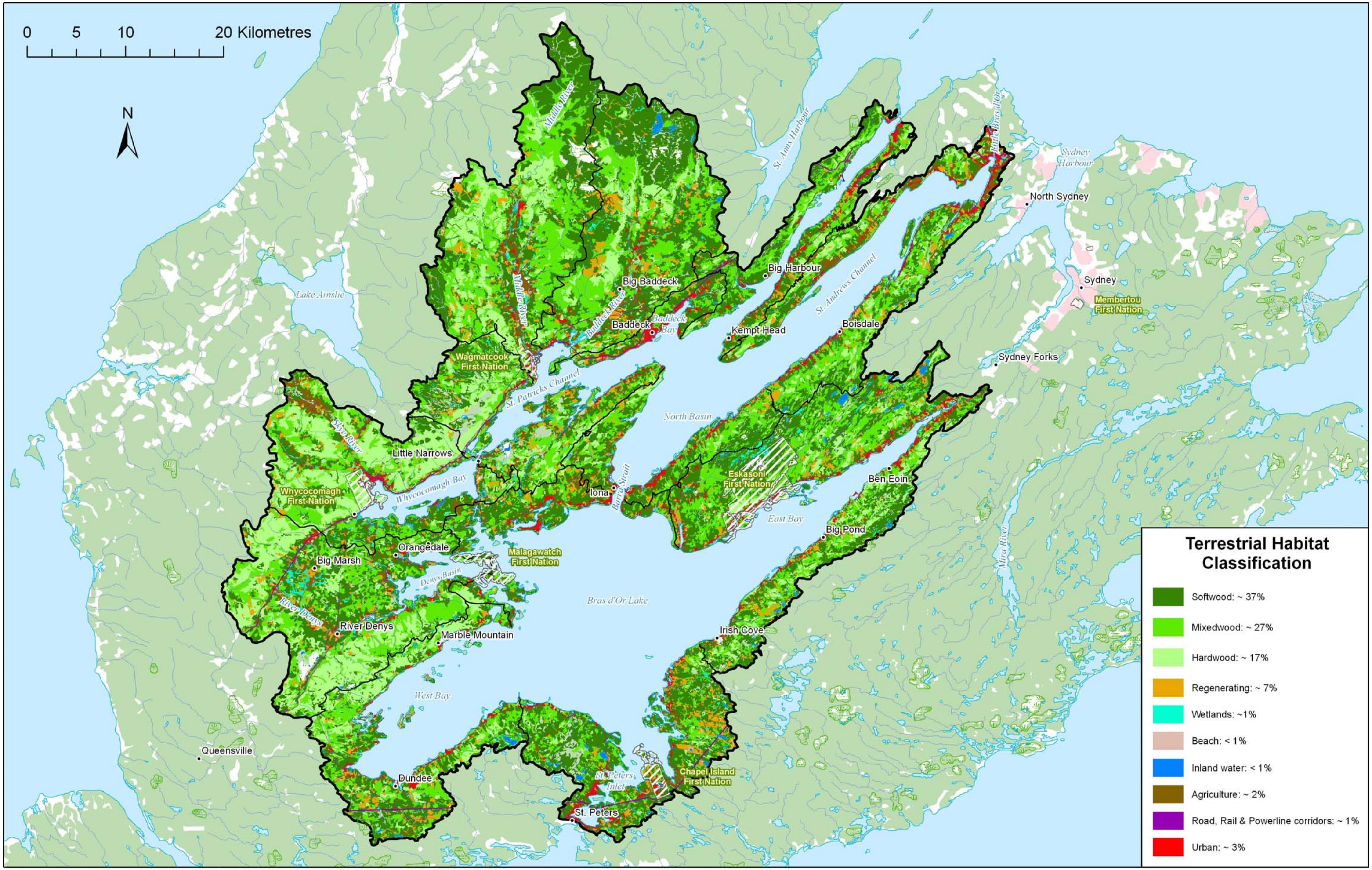


Figure 10. Terrestrial habitat classification within the Bras d'Or watershed
Data sources: Nova Scotia Department of Natural Resources Forested Land Use Database; DFO (2003); Basemap (Natural Resources Canada, National Topographic Database 1:250,000 3rd Edition)

Table 26. Habitat classification coverage for each subwatershed in the Bras d'Or[4]

Subwatershed	NSDNR Habitat Classification in hectares (% of subwatershed if ≥5%)						
	Forest	Regenerating	Urban	Water cover	Barren	Gravel pits	Corridor
Middle River	27 933 (86)	1 545 (5)	284	99	64	27	126
River Denys	24 220 (84)	1 538 (5)	428	110	5	403	355
West Bay	13 897 (83)	1 130 (7)	546	143	4	6	327
Baddeck River	25 229 (83)	1 941 (6)	311	291	73	33	172
Whycocomagh Bay	18 813 (83)	1 194 (5)	342	58	52	41	345
North Basin	7078 (82)	615 (7)	346	14	0	14	109
Great Bras d'Or Channel	8960 (82)	615 (6)	592 (5)	18	10	64	250
East Bay	27 064 (81)	2 069 (6)	1262	174	31	69	186
McKinnon's Harbour	6307 (76)	731 (9)	459 (6)	32	5	4	98
St. Andrews Channel	13 774 (75)	1398 (8)	990 (5)	80	0	43	358
St. Peters Inlet	13 063 (74)	1853 (10)	716	217	422	27	387
St. Patricks Channel	14 520 (74)	1521 (8)	761	96	456	335	438

Along with the significant species and habitats database described above, the NSDNR has created an Ecological Land Classification (ELC) to aid with forest planning and management (Neily et al. 2003). It is a framework of mapped ecosystems that provides an understanding of terrestrial ecosystem form and function by linking physical and biological environments. Each mapped unit represents the interactions of climate, landform, water, soils, and biology at varying scales. At the time of this publication spatial resolution of Ecozones (1:1 000 000), Ecoregions (1:500 000), and Ecodistricts (1:250 000) had been defined. Ecodistricts are a subdivision of the Ecoregions and reflect macro-elements of the physical and biological attributes that will influence biodiversity. There are five Ecodistricts in the Bras d'Or watershed – their characteristics are summarized in Table 27 and arrangement displayed in Figure 11.

[4] Data from the NSDNR forested land cover database. Approximate areas based on 1988-1999 photography and 1999-2000 satellite imagery. Accessed at: http://www.gov.ns.ca/natr/forestry/GIS/downloads.htm.

Table 27. Characteristics of each ecodistrict found in the Bras d'Or watershed, as defined by the Nova Scotia Department of Natural Resources

Ecodistrict	Annual Precipitation (mm)	Mean annual temperature (C)	Soils and Terrain	Dominant Forest
Inverness Lowlands	1377	6.1	Gently undulating to rolling	Sugar maple, white ash, balsam, poplar, American elm, also areas of black spruce
Cape Breton Hills	1470	6.0	Imperfectly drained fine textured tills; high steep-sloped hills and lower gradual hills with karst topography	Tolerant hardwood forest with scattered spruce and fir
Bras d'Or Lowlands	1502	5.8	Well drained, moderately coarse to medium texture; low-lying lands	Black spruce, tolerant hardwoods (sugar maple, yellow birch), red spruce and hemlock
Cape Breton Coastal		5.9	Better drained or imperfectly drained; rolling drumlins	White spruce, balsam fir and black spruce mix
Cape Breton Highlands	1493+	6.0	Sandy loams; unstable steep escarpment, undulating plateau	Balsam fir on plateau, tolerant hardwoods on slopes

The following sections describe terrestrial features at a smaller spatial resolution than Ecodistricts, and provide detail of some of the terrestrial habitat components found within the Bras d'Or Lakes watershed.

14.1 Special Use Terrestrial Areas

The special use terrestrial areas described here are areas of particular congregation of a species or species that appears to occur because of the habitat characteristics present. These are not comprehensive lists of such areas of congregation, nor of a particular habitat type, but instead reflect what is currently recorded in written reports and studies of the Bras d'Or Lakes watershed.

Coastal areas adjacent to shallow waters around Denys Basin and St. Patricks Channel are significant regionally for eagle nesting because of the very high density of nests observed, and significant locally for overwintering of eagles (MacDonald and Austin-Smith 1989). Eagles congregate around the Bras d'Or during winter to feed, likely drawn by accessibility to fish after many strictly freshwater areas begin to freeze over.

The highland area of the watershed west and north of St. Patricks Channel provides key habitats for several large mammals that are either not bothered by, or rely on, the heavier snow loads for a competitive advantage (Parker et al. 1983), and which may seek lower road densities (Beazley et al. 2004) associated with that area. Moose, lynx, and marten are

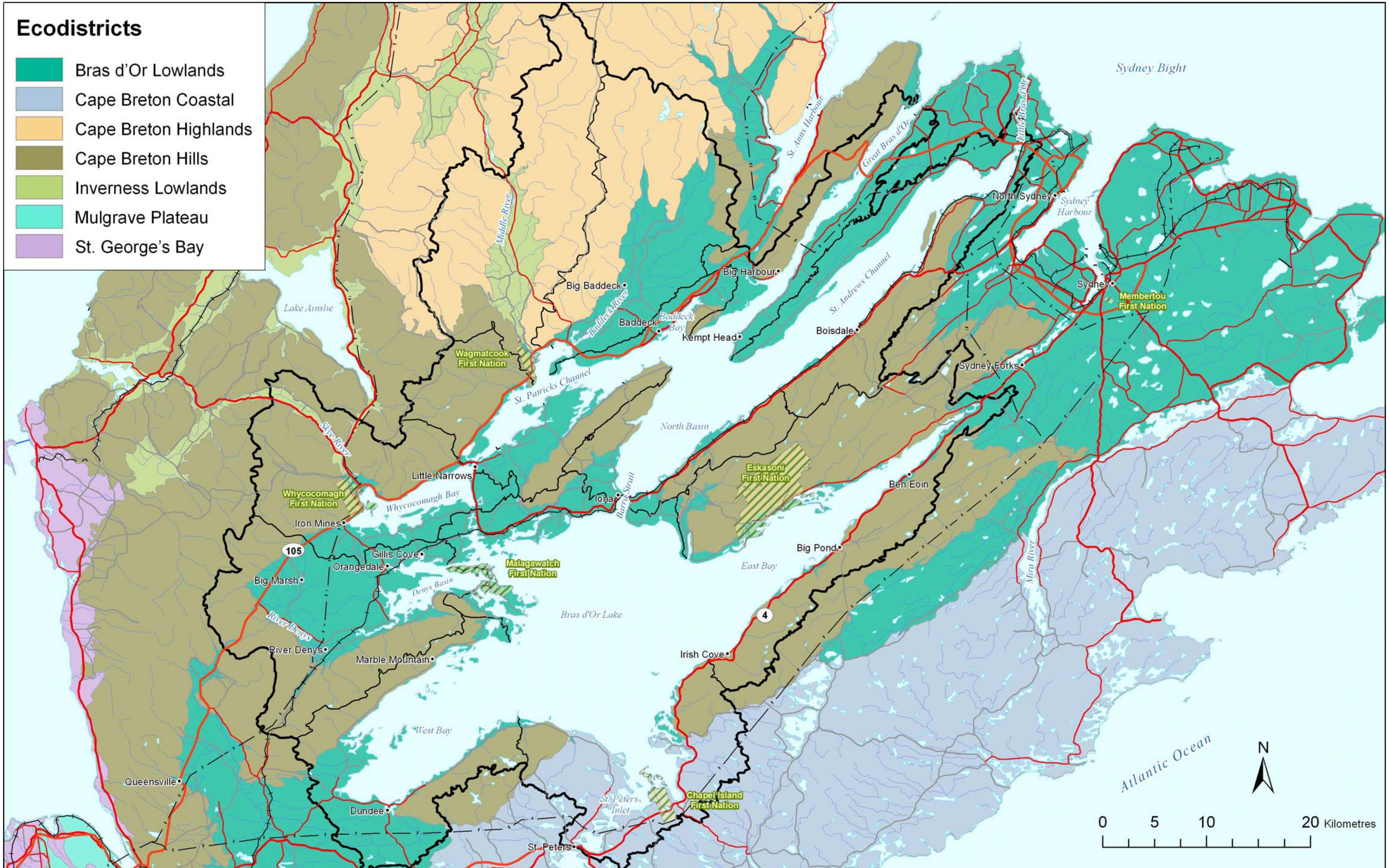


Figure 11. Ecodistricts of the Bras d'Or watershed
Data sources: NSDNR (2005a); DFO (2003); Basemap (Natural Resources Canada, National Topographic Database 1:250,000 3rd Edition)

all found throughout portions of the higher elevations in a variety of habitats, and at much higher densities than other locations around the Bras d'Or watershed. Specific forest types associated with each species have not been discussed as these three species have varied habitat requirements, but do have a common spatial preference for the highland area.

Erskine (1971) noted that the bird communities that used primarily fresh and brackish flowing water habitats could be categorized into two types based on which stream characteristic they were associated with. Mergansers and sandpipers were the dominant species at the more rapidly moving upstream reaches, whereas slow moving downstream reaches were dominated by standing water species. He suggested that a third habitat might be considered for small brooks with heavy alder growth where mergansers are not found and in which Woodcock (*Philohela minor*) occur. This observation could provide a finer spatial resolution for categorizing terrestrial habitats for bird communities.

Within the River Denys Basin is a 24 km^2 deer overwintering area where many of the local deer will congregate during hard winters. Densities of deer have been observed at 9.8 / km^2 in this area, called Eden (Patterson and Messier 2003). Such winter densities are more than six times the average observed on mainland Nova Scotia. Congregation to such densities is relatively unique in Nova Scotia, and likely indicative of the great significance this area has to the survival of the Cape Breton deer population.

14.2 Freshwater River Habitats

Much of the freshwater stream habitats of the watershed are small first and second order streams that flow directly into the Bras d'Or Lakes. A few large rivers, such as the Baddeck, Skye, Denys, and Middle Rivers, occur almost exclusively in the northern half of the Lakes. This characteristic was not lost on Thomas Knight (1867), who nearly 140 years ago wrote:

> *The only rivers of note in the northern division of the Island of Cape Breton are Middle River and Baddeck River, flowing into the Bras d'Or, and the Marguerite, which issues from Ainslie or Marguerite Lake, and runs into the Gulf of St. Lawrence. ….and salmon are still taken in the Middle and Baddeck Rivers; but the Collector at Baddeck writes that they are rapidly becoming exterminated "consequence of their being caught when coming up the rivers to spawn, and spears and nets being mostly used for their capture".*

With the exception of River Denys, the larger river systems of the Bras d'Or watershed all drain the highland area in the northwestern watershed directly into St. Patricks Channel. A notable characteristic of the freshwater systems throughout the Bras d'Or is the lack of significant lake headed rivers, and therefore lake habitat. The lakes that do exist typically have less than 1 km^2 surface area, and enter the Lakes directly through small first or second order streams. This characteristic does not only mean that typical freshwater lake fish assemblages may be limited, but that the river systems, without the storage and moderation capacity that large lakes provide, tend to be more "flashy", responding quickly to precipitation events with a rise and fall in water level. This characteristic was described in 1884 (Vieth 1884):

> *…Baddeck River, a magnificent stream, perfectly clear from its source to the Bras d'Or Lake. In common with the Margarie and Middle Rivers it cannot be dammed, as the freshets rise to a great height, and the vast volume of water which comes surging down with irresistible force and immense rapidity, would sweep mills and dams before it.*

Lower summer low flows and higher peak flows during the wet season relative to lake headed systems might also be expected in most freshwater systems of the Bras d'Or.

Vieth (1884) also noted the importance of tributaries within these systems:

> *The tributaries are in reality the nurseries of these rivers, and they are in deplorable bad condition. It seems as if every possible method was resorted to, to prevent salmon breeding there.*

Vieth (1884) does not suggest why these tributaries may be important. However, recent studies on sea run trout in the watershed have focused on the cold-water refuge these systems offer (MacMillan and Crandlemere 2005b). Other recent assessments have identified potential Atlantic salmon spawning areas in tributaries such as Glen Brook in River Denys watershed (ADI 1999 cited in Barrington 2005).

Cool water summer habitat found in the Middle River, Baddeck River, and River Denys is critical for salmonid populations, particularly trout. During recent thermal classification studies of streams across Nova Scotia, virtually all sites on the Middle and Baddeck Rivers were classified as cool or intermediate streams, whereas 2/3 of the River Denys sites were intermediate to warm water (MacMillan et al. 2005). Water temperature increases and habitat degradation in other Nova Scotian locations have caused the replacement of cold-water salmonid dominated fish assemblages with a greater diversity of warm water and/or tolerant fish species, and fewer salmonids (Kanno and MacMillan 2004). Salmonid fish densities were also observed to be lower on River Denys than the other two systems. Although no competitor species were captured during the fish surveys of these systems, competitors tend to inhabit warmer waters. Therefore land uses and climate changes that increase water temperatures can be expected to have a detrimental effect on native trout and salmon (MacMillan and Crandlemere 2005a). Currently, almost 89% of the 33 sites assessed on the Denys, Middle and Baddeck River systems are cold to intermediate water sites in summer, compared with a Provincial average of only 61%.

The Middle and Baddeck Rivers support the most significant Atlantic salmon numbers not only within the Bras d'Or Lakes watershed but also in much of Eastern Cape Breton. These two rivers have excellent water quality for Atlantic salmon rearing and no significant impediments to fish migration (Robichaud-Leblanc and Amiro 2004). As such they could be considered critical habitat areas for salmon within the Bras d'Or and Cape Breton.

Gaspereau have been reported to have spawned in large numbers in River Denys in the past, but appear to have undergone a significant decline in numbers over the past ten years (Barrington 2005).

Little detail on freshwater stream habitats has been documented in the literature outside of the larger rivers discussed here.

14.3 Significant Forest Stands

Much of the Bras d'Or Lakes watershed has a potential hardwood climax forest that would consist of sugar maple, yellow birch, and beech. Exceptions would be much of Denys Basin, Middle River watershed and the St. Peters Inlet area, where black spruce, balsam fir, red maple, and red oak would be more likely to dominate a climax forest left to grow undisturbed (NSDNR 2003a). In 1995 it was reported that only 1.06% of the total forested land base in

Nova Scotia was significant old forest, and only 0.6% of forests were more than 100 years old. True old growth forests (>150 years old) are very few and are usually small isolated stands of questionable ecological integrity (Lynds and LeDuc 1995). Yet, less than 100 years ago it was estimated that over 40% of Cape Breton forests were in a virgin undisturbed state (Fernow 1912 cited in Lynds 1989). One of the larger provincially protected mature old growth forest stands in the province is found in the Bornish Hills Nature Reserve in the River Denys watershed. A sugar maple – yellow birch stand of some 750 ha grows there. A large tract of immature mixed old growth of 80-100 years exists on Provincial Crown lands in the Middle River watershed (Lynds and LeDuc 1995) as well.

Through interpretation of 1993 air photos, 30 parcels of land owned by Stora Enso Port Hawkesbury forestry were identified as having outstanding old forest features (Miller 2004). Miller (2004) suggests that some of these tracts would be particularly appropriate for reserve planning on private lands in the Bras d'Or watershed, including old forest stands adjacent to the provincially protected Middle River Wilderness Area and Bornish Hills Ecological Reserve, because they could effectively expand the size of existing core reserves. A Stora owned 820 ha parcel of land on the northeastern side of Kluscap (Kelly's) Mountain in the Great Bras d'Or Channel subwatershed includes old growth hardwood forests, old growth mixed forest, old growth hemlock forest, as well as other potentially significant ecological features (Miller 2004).

14.4 Coastal Habitats

A number of terrestrial habitats support both marine and terrestrial fauna because of their proximity to the Bras d'Or Lakes. Some of these habitats are sensitive and some are simply limited in volume. They all add to the diversity of habitat found around the Bras d'Or and thereby support the diversity of flora and fauna of the ecosystem.

14.4.1 Dunes

Dunes are formed of fine grained materials. Natural events that create high winds and wave action can destabilize these habitats. They are also sensitive to anthropogenic uses such as human traffic that can destabilize dunes. Dune habitat areas within the Bras d'Or watershed are outlined in Table 28.

Table 28. Limited dune habitat areas found in the Bras d'Or watershed

Watershed	Total Dunes (m^2 x 1000)
East Bay	147
West Bay	60
Bras d'Or Lake	52
St. Andrews	35
North Basin	31
St. Peters Inlet	19
Great Bras d'Or Channel	5
St. Patricks Channel	5
Denys Basin	1
Whycocomagh Bay	0.3
Total	**355.3**

Source: NSDNR 1999

14.4.2 Cliff Habitats

Although Cape Breton is a reasonably mountainous area with a number of highland relief features constituting watershed boundaries to the Bras d'Or, coastal cliff habitats are quite limited. Through video survey Taylor and Frobel (1998) identified a number of coastal shoreline types around the Bras d'Or Lakes. Most cliff habitat exists along the Great Bras d'Or Channel, St. Andrews Channel, and at the Barra Strait (Taylor and Shaw 2002), although limited shoreline cliffs exist elsewhere, as do some inland rock outcrops. Such cliffs can be an important nesting habitat for a number of seabird species. Locally around the Bras d'Or this habitat is somewhat limited. However, around coastal Cape Breton shoreline cliff habitats are relatively plentiful.

14.4.3 Island Habitats

Island habitats are often areas sought by colonial nesting birds for their lack of predators, and associated shoals that provide feeding areas. Within the Bras d'Or such habitats are quite limited. Although the coastline is a diversity of small bays and inlets, relatively few islands exist. Glacial drumlins form islands in West Bay, and to a lesser extent in Bras d'Or Lake and East Bay. The small numbers of islands within the Bras d'Or Lakes have been used for nesting and rearing by colonial bird species. The islands are biologically significant to the Bras d'Or Lakes ecosystem.

14.5 Freshwater Wetlands

Freshwater wetlands are documented by the Nova Scotia Department of Natural Resources in the Wetlands Database Specifications (NSDNR 1999) and are differentiated by type (Figure 7). For the purposes of this overview, they have been grouped together to provide some indication of the total area covered by freshwater wetlands (Table 29). These freshwater wetlands are ecologically important as they typically can be expected to support more diverse biota, may support some of the species at risk within the Bras d'Or, and serve as a filter mechanism for runoff entering the Bras d'Or Lakes system.

Table 29. Summary of freshwater and total wetlands area identified for the Bras d'Or Lakes watershed in the Nova Scotia Provincial Wetlands Database (NSDNR 1999)

Watershed	Total Freshwater Wetlands (km^2)	Total all wetlands (km^2)
St. Patricks Channel	43.8	64.7
East Bay	16.7	53.4
West Bay	3.6	36.1
Denys Basin	11.5	31.8
Bras d'Or Lake	1.4	29.9
St. Peters Inlet	6.8	20.8
St. Andrews	5.0	17.2
Whycocomagh Bay	6.9	15.4
North Basin	1.7	13.6
Great Bras d'Or Channel	1.5	8.3
Total	**98.9 km^2**	**291.2 km^2**

15. Threats and Stressors

The local threats and stressors described in this section are aquatic invasive species. Other local threats and stressors, including land use practices, siltation, erosion, habitat destruction, and water pollution, are important issues for which there is limited information of potential impacts within the Bras d'Or watershed. On a global scale, climate change, sea level change and air quality are also potential threats to the Bras d'Or Lakes ecosystem, but currently there is little direct study of their potential impacts within the watershed. We have therefore chosen not to extrapolate larger scale results to incorporate in this document, but identify the need to assess such stressors within the information gaps sections of this report. In an attempt to fill the gap, we have included climate change information based on TEK which provides a local context to this global issue. Air quality is discussed in Section 7.2 of this report.

15.1 Aquatic Invasive Species

15.1.1 Green Crab

Green crab (*Carcinus maenas*), native to Europe, has recently been introduced to the Bras d'Or Lakes. The impact of this species is not yet fully understood. Initial trapping surveys for green crab began in August 1999 by DFO and Eskasoni Fish and Wildlife Commission. These surveys included East Bay, West Bay, St Peters Inlet, Denys Basin, Great Bras d'Or Channel, St. Patricks Channel, and Bras d'Or Lake, and distribution was found to be widespread. More recent video and SCUBA surveys have shown the highest densities of green Crab are in West Bay, and lowest in East Bay (Tremblay 2004).

A study of green crab at the mouth of the Benacadie River has been carried out in order to learn more about the population within the Bras d'Or Lakes. It has been noted that the crab at this location, in Benacadie Pond estuary that enters Bras d'Or Lake between East Bay and the Barra Strait, appear to be locally produced. They are unconstrained by the small size and tidal range that is coupled with a shorter development period than other coastal Nova Scotian locations. Green crab larvae from Benacadie, early zoeae stage in particular, did not complete development in waters less than 23 ppt salinity in a laboratory setting (Cameron 2003), a condition that exists at Benacadie and at various locations throughout the Lakes. Furthermore, no later megalopae stage larvae were obtained from Benacadie when salinities were less than 23 ppt. As 23 ppt is more saline than the range typically observed at Benacadie, it is probable that the population is utilizing an offshore development strategy (Cameron 2003), where they rear in deeper more saline lake waters during critical stages of larval development. Study results indicate that females may be producing two broods at Benacadie, as can occur in warmer parts of the green crab's native range (Cameron 2003). Water temperatures tend to be considerably warmer in the Bras d'Or than in other coastal areas of Nova Scotia, making this double brood feasible. Female green crabs are highly reproductive, producing up to 200 000 eggs a year, and as adults, they are tolerant of a wide range of salinities, temperatures, and habitats. During a recent video and SCUBA survey of the Bras d'Or (Tremblay 2004), lobsters and green crab were found at the same depths, but the highest percentage of green crab was observed at depths less than 6 m, whereas lobsters were observed in greatest percentage at 6-10 m. It is not known if the difference in distribution with depth is a result of competitive interaction or differences in habitat preference. It has recently been determined that the *C. maenas* populations of Cape Breton and the southern Gulf of St. Lawrence are of different genetic lineage than those found in southwestern Nova Scotia and the Gulf of Maine (Roman pers. comm. 2003 cited in Cameron 2003), and the Bras d'Or population most likely derives from the Cape Breton population (Cameron 2003).

15.1.2 Tunicates

Tunicates have been found in various areas of the Bras d'Or Lakes. The golden star tunicate (*Botryllus schlosseri*) and sea squirt (*Ciona intestinalis*) have both been identified in the Lakes (Paul pers. comm. 2005). Star tunicates grow in colonies after a free-swimming larval stage. Through division, a colony of genetically identical clones will grow to several centimetres in diameter in the sub-tidal zone, eventually forming thick blankets that cover substrates. The sea squirt interferes with the settlement of oyster and mussel larvae, and competes for food with the young of these two commercially important shellfish of the Bras d'Or Lakes. During a 2003 provincial survey of aquaculture operations, it was determined that the area of Isle Madame, adjacent to St. Peters canal and thereby the Bras d'Or Lakes, was particularly heavily infested with the sea squirt (Clancey and Hinton 2003). Aquaculture operators in the Lakes indicated no *Ciona intestinalis* present at their operations during the same survey.

15.1.3 MSX and SSO

Two new oyster diseases have been found in the Bras d'Or since the fall of 2002. Multinucleated sphere X (MSX) (*Haplosporidium nelsoni*) and SSO (seaside organism) (*Haplosporidium costale*) are microscopic parasites. MSX can tolerate salinities of 15-25 ppt, and cause 90-95% mortality in infected shellfish. Because of their wide salinity tolerance, MSX could likely survive in most of the Bras d'Or and it has been found to date in St. Patricks Channel, Gillis Cove, Eskasoni, Whycocomagh Bay, St. Peters Inlet, the Barra Strait, and the eastern end of East Bay (Paul pers. comm. 2005; Stephenson and Petrie 2005). SSO is less tolerant to low salinities and is typically found in areas where salinity is >25 ppt. This limitation is likely to limit SSO distribution in the Bras d'Or, and currently it is found only in the eastern end of East Bay. SSO can cause shellfish mortalities of 20-40%. It is believed that SSO and MSX use an unknown, intermediate host to spread infection.

15.2 Climate Change

Although currently there is little direct study of potential impacts of climate change within the watershed, TEK indicates that potential impacts and threats of climate change to biological systems are evident (CEPI 2006). Elders have observed fewer jellyfish because of the warmer water. The warmer winters mean less water in the spring because the water sources are receiving less runoff. This results in less flushing such that more bacteria are present in the water. Animals and people get sick more frequently. The smaller brooks are dry and there are less fish in the brooks. The warmer weather brings more illness to potatoes, and makes gardens harder to grow. Insulation of snow during winter is important for berries and the warmer winters affect berry picking. There is an increase in insect populations, such as the moth, due to the earlier spring and later fall. Floating algae appears earlier in the spring and more abundant in inlets.

Climate change is also thought to have played a role in the changes in forests. A lesson has been learned from black ash whose seeds will not germinate unless climate conditions are appropriate (CEPI 2006). Black ash has died away in the Bras d'Or area although some residual black ash seems to be present in hardwood forests in the mountains.

16. Biological System Information Gaps

Biological system information gaps that exist for the Bras d'Or Lakes watershed are primarily related to: (1) habitat use by species and life stage, and (2) having more current information upon which to base decisions. Many other gaps related to species biology exist, but they are ecosystem gaps that involve the understanding of physical biological relationships as well as biological interactions between species. Such relationships are discussed under Section 20: Ecosystem Relationships Data Gaps. Here we focus more on the gaps associated with single species management, and baseline inventories.

Without knowledge of what areas are used by what species for reproduction, rearing, foraging, and migration, it is difficult to understand how changes in a physical habitat component may impact the biological system. Much of the biological data collected on the Bras d'Or to date is based on such factors as when collection is likely to identify the most species, or when collection is best facilitated by weather conditions. The result is that point in time inventories of a group of animals or plants (e.g., fish, seaweeds, or birds) are collected (MacMillan and Crandlemere 2005b; DFO 2004c; Lambert 2002; Tremblay 2002; DFO 1997; DFO 1996; Denny et al. 1998; Stevens 1993; Shih et al. 1988; Erskine 1987; Fournier and Pocklington 1984; Erskine 1971; MacLachlan and Edelstein 1971; MacDonald 1968; Vilks 1967; Black 1958); evaluation of genetic distinctions are made (Austin-Smith and O'Brien 2003; Pogson et al. 2001; Broders et al. 1999; Nelson et al. 1994; Scott 1975); or assessment of the effects of contaminants on biota (Chou et al. 1999; Young 1973a,b) are conducted. However, very few studies make any significant associations with habitat data or determine the spatial distribution of a species by life cycle (Macmillan and Crandlemere 2005a; Robichaud-LeBlanc and Amiro 2004; Tremblay 2004; Cameron 2003; Graf et al. 2003; Jameison et al. 1992; MacDonald and Austin-Smith 1989; Parker et al. 1983; Crawford et al. 1982), and those that do are typically limited to a single species and/or provide only partial geographic coverage within the Bras d'Or. Habitat studies in the Bras d'Or, particularly for marine habitats, have usually been conducted without associating species or life stage uses of those habitats (Myers and Gilbert 1993; Smith and Rushton 1964). Such works are very important for single species or site management but do little to immediately facilitate decision making on an ecosystem scale.

A basic freshwater biological information gap exists in that comprehensive species lists do not exist for freshwater systems of the Bras d'Or. Mammals (Scott and Hebda 2004) and birds (Erksine 1971, 1987) have been inventoried, and broad marine inventories have been completed at various times (Lambert 2002). However, a gap exists in that a similar species inventory for even the major river systems of the Bras d'Or, let alone the diverse barachois habitats, is lacking. Although no freshwater species within the Bras d'Or have been documented as extinct or extirpated, North American extinction rates for freshwater fauna are five times higher than those for terrestrial fauna, and are predicted to continue at a rate of 4% per decade (Ricciardi and Rasmussen 1999). Such species tend to be the smaller and less valued fish. Filling this gap would not only provide record for future comparison, but also help describe associated freshwater habitats within the watershed of the Lakes.

Describing habitats and observing a range of year classes within a species is generally more difficult in aquatic habitats than terrestrial habitats because researchers can not directly see their targeted species or the habitats, but instead must rely on equipment to measure, capture, and describe what exists. Through recent multibeam surveys (Shaw and Potter 2006a-d) biologists can now "see" bottom habitats of the Bras d'Or, so there is a need to describe these areas and classify them for potential species' and life cycle uses.

Terrestrial biology has perhaps fewer gaps than marine. However, the biological gap for the terrestrial Bras d'Or watershed is one of appropriate spatial coverage. Studies have focused either on small areas within the watershed for which there is higher productivity or congregation by the target species, or on much broader geographic scales that cover the Bras d'Or within a provincial or regional study, and therefore provide less detail. Lack of a consistent scale of study, such as the bay-scale, either creates such detailed results that they are difficult to apply to the entire Bras d'Or watershed or such general results that it is difficult to distinguish or describe species use or habitats within the watershed. There is also a strong bias within terrestrial studies towards the western and northern parts of the watershed, as few written studies have examined the eastern portion of the watershed or areas south of the Barra Strait (with the exception of Denys Basin).

A significant biological spatial information gap exists in describing the nearshore (<10m depth) habitats, keystone species and their life stages, and the contributions this fringe makes to primary and secondary production within the Bras d'Or Lakes. Such assessments of the nearshore need to be conducted at a bay-scale resolution, and for more than one bay in order to cover the diversity of habitats present and allow extrapolation to areas that can not be surveyed in detail.

Finally, there is one species in the marine environment that appears linked to many processes and species within the Bras d'Or ecosystem. Because of the lack of current and complete information on this species, interpretation of other study results and prediction of ecosystem changes are inhibited. Eelgrass is linked to the production, and species diversity of the Lakes, and increasing our knowledge of even basic distribution and densities around the Lakes may answer a number of critical questions for resource users and managers. Justification for singling out this species is further provided in Section 20: Ecosystem Relationships Data Gaps.

PART D – ECOSYSTEM RELATIONSHIPS

17. Marine Ecosystem Relationships

The Nova Scotia Department of Natural Resources has developed a process of Ecological Land Classification (Neily et al. 2003) for the Provinces terrestrial ecosystems. All of Nova Scotia falls within the Atlantic Ecozone, the broadest scale of this hierarchical classification. Four Ecoregions are used to define the Bras d'Or watershed, with these same Ecoregions being relabeled and redefined to produce five separate Ecodistricts within the terrestrial portion of the watershed (NSDNR 2005a, Figure 11 in Section 14.0 Terrestrial Habitat Components). There are 39 Ecodistricts within Nova Scotia characterized by distinctive assemblages of relief, geology, landform, soils and vegetation. No similar scale of ecological classification of the Bras d'Or's marine ecosystem has been carried out. Through this document and the preliminary delineation of ten bay-scale areas, a marine equivalent to the terrestrial "Ecodistricts" has been proposed (Figure 1). Like ecodistricts, these bay-scale areas were established based primarily on physical and chemical properties (oceanographic), and topographic (bathymetric) features.

17.1 Physical-Biological Linkages

17.1.1 Basic Cycles and Processes

The following discussion of ecosystem relationships is intended to demonstrate how the biological and physical characteristics of the Bras d'Or Lakes watershed interact at the bay-scale resolution.

17.1.1.1 Nutrient Cycling

Low levels of chlorophyll *a*, inorganic nitrogen, and silicate in the spring suggest that a spring bloom occurs prior to when samples have been collected. The low silicate levels, relative to the known abundant supply from some rivers in St. Patricks Channel and Denys Basin, indicate that diatoms are likely a significant part of the early spring bloom. Silicate levels are then able to rebuild after the bloom to nearly double the spring observed values (Strain and Yeats 2002). Silicate amounts do not determine the size of the spring bloom, but do regulate the significance of the diatom fraction. The silicate comes from limited geological formations, carried by freshwater systems to the Bras d'Or. Most of these watersheds are north of the Barra Strait, which provides spatial variability to the availability of silicate and diatom related bloom in the Lakes.

The spring bloom is driven by nutrient buildup that occurs during winter months when there is limited biological activity. A nutrient increase in the surface layer during winter provides the most fuel to the spring bloom (Petrie and Raymond 2002). These nutrients are derived from inflowing marine waters and mixing between surface and deeper waters within the Lakes. Later season data has sometimes shown a modest fall bloom, followed by an increase in concentration of nutrients in surface waters. This resupply of nutrients in the surface waters results from a variety of interacting processes where surface and deepwater chemistry becomes less stratified and vertical mixing increases. Fall winds deepen the surface mixed layer, and are one of the mechanisms that contribute to higher surface nitrate levels in the fall (Strain and Yeats 2002). Deepwater areas, including the depths of St. Andrews Channel, are periodically renewed, but the frequency and mechanisms of renewal is not known (Petrie and Raymond 2002). Although precipitation levels are not significantly different than those of other coastal Nova Scotia locations, the atmospheric deposition of nutrients through precipitation is a greater percentage of the total nutrient input to the Bras d'Or (Strain and Yeats 2002), and fall rains may contribute to the start of the late season buildup.

Nitrogen sources limit production year-round, and the new production in spring through fall is regulated primarily by the amount of nitrogen becoming available from deepwater sources. The most significant of these deepwater sources appears to be St. Andrews Channel, where 50-70% of new nitrate and ammonia is produced. New production within the Lakes typically accounts for 15-30% of total production (Strain and Yeats 2002).

Geen and Hargrave (1966) hypothesized that excretion of significant quantities of phosphate and ammonium nitrate by copepods may account for much of the nutrient regeneration in the Lakes on a daily basis. These zooplankton rise to the surface to feed during the night and excrete waste that is then available for uptake by phytoplankton in the morning during photosynthesis. Similarly, fish species such as herring, alewife, and salmon are known to contribute significant marine nutrients to freshwater systems (Helfield and Naimon 2000, Bilby et al. 1995, Durbin et al. 1979).

Nutrient cycling in an estuarine system is composed of two primary parts. One part is the sources of nutrients that are available for production. As discussed above, we have a moderate understanding of these within the Bras d'Or Lakes. The second component is the oceanographic process(es) by which nutrients get transported to and held within the photic zone, where they are available for uptake by primary producers. On this topic we know considerably less for the Bras d'Or Lakes.

Tidal jets at Barra Strait may be of crucial importance to the ecology of the Lakes since the associated turbulence seems to be responsible for a very high proportion of the mixing of surface and deeper waters in Bras d'Or. This mixing action draws deeper water up into the surface, thus driving the basic circulation of the Lakes, and at the same time bringing up nutrients needed to promote plant production in the summer and salt to the less saline surface layer.

Key mixing of marine waters occurs in the Great Bras d'Or Channel as well. This area has the strongest mixing within the Lakes. However, more than half of the mixed water is recirculated surface water from the Lakes (Petrie and Bugden 2002), and this water would effectively dilute the levels of marine derived nutrients that are entering the Lakes. Regardless, incoming waters through the Great Bras d'Or Channel remain the most significant source of nutrient to the Lakes.

17.1.1.2 Seal worm Life Cycle

One of the most interesting relationships between habitat and biological process within the Lakes is the heavy infestation of the Bras d'Or cod with seal worm (*Porracaecum decipiens*) in all areas except Whycocomagh Bay. The seal worm has a complex life cycle, requiring numerous invertebrate and vertebrate hosts between its larval stages when it is found in seal scat and its return in adult form to a seal host where it will mature and reproduce.

Scott and Black (1960) observed that mysid shrimp, which did carry seal worm, were the most common item of food found in the stomachs of cod of all ages, except for those fish within Whycocomagh Bay. They suggested that the mysid did not exist or were not being eaten within the Bay. The unique anoxic and low oxygen characteristic of much of Whycocomagh Bay, which appears primarily regulated by the Bay's deep basin morphometry and enclosed nature, has been observed to limit several species of benthic invertebrates, in particular mysid shrimp.

These shrimp are known to be an intermediary host between the free-living seal worm larva and fish hosts, such as cod, in the Bras d'Or. However, being benthic in nature, they do not flourish in the deeper low oxygen waters of Whycocomagh Bay. In this way, the life cycle of the seal worm is broken within Whycocomagh Bay as there are limited adequate hosts (mysid shrimp). Young cod of the Bay feed on other species, and grow largely uninfested by the seal worm. The presence of highly infested cod in the neighbouring St. Patricks Channel suggests a further ecosystem relationship. It appears that the shallow sill and restricted passageway of Little Narrows, which connects Whycocomagh Bay to St. Patricks Channel and the rest of the Bras d'Or, may be limiting cod (Black 1976) and seal (Scott and Black 1960) movement between these bodies. Without significant movement of heavily worm infested cod or seals from other areas of the Lakes across this sill, the cod population within Whycocomagh Bay maintains a uniquely low infestation of seal worm. Although early studies suggested the population in Whycocomagh was worm free, locals suggest that is not currently true, and that fish that come into the area during the fall and stay over winter are infested with the parasite (DFO 2006).

The larvae of seal worm *Porracaecum decipiens*, has also been found in fillets of ten other fish species in the Bras d'Or Lakes (Scott and Black 1960).

17.1.1.3 Freshwater Inputs

The annual cycle of freshwater input is of summer lows in June through August to a sharp rise during autumn. Winter months continue to be high, with a peak in March and April associated with snow and ice melt (Gurbutt and Petrie 1995). Weakest inflows occur between July and September as rainfall drops off and the dry season follows. A secondary peak occurs in November / December corresponding to fall rains. The biological impact of these freshwater inputs on the Bras d'Or system is significant. Given the strong stratification of the Lakes, these inputs markedly change salinities and temperatures in the shallower bays, and provide for the varied salinity character of the Lakes. These wide ranging salinities limit the distribution of many species. This is particularly apparent with shellfish, including lobster and oysters. The freshwater inputs also drive the basic flow structure of the Lakes where the lighter, fresh outflowing surface layer moves over a denser and saline inflowing bottom layer. Spring runoff brings silicates to the Bras d'Or Lakes from the land base, influencing the number of diatoms in the spring bloom.

17.1.1.4 Tidal Influences

The unique tidal character of the Bras d'Or Lakes has many impacts on the ecosystem and the habitats. Two habitat characteristics of the Lakes that are directly related to the small tidal amplitude are coastal barrier evolution and extent of intertidal zone habitats.

The depositional shore features in the Bras d'Or Lakes evolve through a cycle of growth, stabilization, breakdown, and collapse (Petrie and Raymond 2002). Coastal barriers are a prominent feature around the Lakes. These features are both built and destroyed by the physical process of the Lakes such as tides, winds, and currents. Their smaller vertical relief is unique to coastal Nova Scotia, and directly related to the small tidal amplitude in the Lakes (Shaw and Taylor 2002).

The small tidal amplitude within the Bras d'Or Lakes also has biological significance as it greatly limits the intertidal zone area. With a typical tidal range about 5 cm, very little horizontal distance of shoreline habitat gets exposed on each cycle. Typically this transition from the land base to the marine environment, periodically covered with water, houses a very diverse and productive number of flora and fauna. In some areas of the Bras d'Or where a tide is virtually non-existent, so will be the intertidal zone and associated species. Where some tidal magnitude exists the amount of habitat is predictably small, limiting the number of organisms and possibly species that one would expect to find.

17.1.2 High Biodiversity/Productivity Areas

Ocean Science Associates (1972) suggested that production in the Lakes could be categorized into one of five general habitats. Modified slightly, they are as follows:

Open area water column	Characterized by deep open areas of low productivity to a depth of light penetration of about 40 m, sparse plankton populations, and low nutrient levels. Limited productivity in the upper thermal layer of the column.
Deep Benthos	Below the depth of light penetration, productivity comes from surface layers and infrequent vertical mixing, deeper than 40 m.
Shallow Bay Benthos	Areas less than 10 m deep, bottom always within the photic zone, encompassing many of the bays around the Lakes, seasonally high productivity, algal growth, and nutrient supplement from the land base.
Barachois	Areas of shallow fresh or brackish water cut off from the main Lakes by coastal barrier beach formations, wide range of salinity and oxygen content provides a diversity of habitat within this grouping.
Subtidal Region	This habitat is the remaining shallow coastal area that remains within the photic zone; generally includes the small coastal intertidal band and more coarse substrates along the shoreline, inhabited by the marine algae that attach to the substrate.

This resolution is finer than the bay-scale resolution discussed within this document for assessing areas of the Bras d'Or Lakes and depicted in Figure 1. Although much research has been conducted on the Lakes, there does not currently exist adequate coverage across the complete system to complete a comparative evaluation at the scale of productivity categorized by Ocean Science Associates. However, the scale they describe, or some within bay "inlet" scale of knowledge for keystone species, habitats and processes would be desirable for resource management.

Many scientists have noted through the years the low overall productivity in the Bras d'Or Lakes relative to other coastal areas of Nova Scotia (Geen 1965; Geen and Hargrave 1966; Ocean Science Associates Limited 1972; Wright 1976; Strain and Yeats 2002). For the most part, these same scientists have noted that the Bras d'Or is not a homogenous body of water, and the various physical, oceanographic, and biological characteristics do influence productivity on a more local scale. Some of these differences are apparent at the bay-scale resolution, whereas others will only become apparent with a finer resolution assessment of nearshore and inlet areas. At the bay-scale, three areas appear to be higher biodiversity/productivity areas. They are the Great Bras d'Or Channel, North Basin, and St. Andrews Channel. Several broad scale assessments and studies point toward the significance of these three areas.

High productivity areas of the Bras d'Or were mapped (Ocean Science Associates 1972) based on foraminifera (Vilks 1967) distributions. This mapping was based on the belief that the Barra Strait is a high production area because of vertical mixing that occurs, and the foram species composition that existed there should also exist in other areas of higher productivity around the Lakes. This process highlighted larger scale areas such as the Barra Strait in the

North Basin and the southwestern portion of the Great Bras d'Or Channel, as well as a number of smaller "inlet" scale locations.

Based on a number of biological surveys (fish, algae, copepods, polychaetes and foraminifera) conducted in the Bras d'Or prior to 2001, the highest species diversity occurs in the Great Bras d'Or Channel, St. Andrews Channel, and the North Basin (Lambert 2002). These results are likely due to the Great Bras d'Or being a transition between the Lakes' and Atlantic Ocean populations, and St. Andrews Channel and the North Basin having the greatest ranges of depth, temperature, and salinity within the Lakes. Diversity of habitats has led to diversity of species in these areas. Conversely, St. Patricks Channel and Whycocomagh Bay appear to have the least variety of species. These results cannot be too heavily weighted given that not all surveys were carried out in all locations of the Lakes (Lambert 2002), however it is likely that the general rank of each bay-scale area within the range of Lake areas categorized would not change significantly given more complete surveys.

The following discussion presents some additional characteristics we have learned that indicate the significance of St. Andrews Channel, Great Bras d'Or Channel, and North Basin as higher productivity/diversity areas.

St. Andrews Channel

As noted earlier, at 280 m depth, St. Andrews is significantly deeper than any other area of the Lakes. This feature offers cold, stable, and relatively saline waters, as well as significantly higher DO levels than some shallower low oxygen areas of the Lakes. Numerous Arctic relict species have been confirmed in the basin, likely surviving due to these deepwater characteristics. A modern example of this withdrawal tactic appears to be occurring with the American plaice (*Hippoglossoides platessoides*). This species is now found confined to deepwater areas of St. Andrews Channel and Bras d'Or Lake after historically being found widespread and plentiful around the Lakes (Lambert 2002). St. Andrews also accounts for an estimated 50-70% of new nitrate and ammonia found in the photic zone of the Bras d'Or Lakes (Strain and Yeats 2002).

Great Bras d'Or Channel

The Great Bras d'Or Channel is the largest well mixed body of the Bras d'Or Lakes. It is the most saline at its outer limit, and has significant hard bottom and coarse substrate habitats. This channel is the corridor through which virtually all water and aquatic biota must move to enter or exit the Lakes.

The Great Bras d'Or Channel held 42 of the 43 polychaete species identified in the Bras d'Or. Nineteen of those species, which were primarily warm water Virginian enclave species surviving within a unique set of habitat parameters in the Lakes, were found only in this location. Furthermore, the channel contained the greatest abundance of polychaetes found in a 1981 surveys of the Lakes (Fournier and Pocklington 1984). The outer reaches of the Channel are the primary production area for rock crab and lobster, due mainly to preferred salinity and substrates.

North Basin

The North Basin tends to contribute significantly to the primary production of the Bras d'Or Lakes, not because of a single characteristic of this basin, but possibly because it is a meeting place for waters influenced by significant features in adjacent basins. Silicate, critical to the spring bloom and diatom production, is delivered in significant volume to the rivers entering St. Patricks Channel. As fresh surface waters flow out of the Lakes, the silicate passes into the North Basin on the way to the Great Bras d'Or Channel and the Atlantic Ocean. Marine nutrients and cold saline water are brought into the Lakes almost exclusively through the Great Bras d'Or Channel. This dense bottom layer flows in through the Channel, with the first open expanse of Lakes it meets being the North Basin. It has been suggested that this cold dense water layer flows over a sill that exits near Kempt Head, and into the deeper body of the North Basin. This in turn would move waters in the basin, promoting mixing at depth. The North Basin is known to be the location of significant upwelling in the Lakes (Petrie and Bugden 2002), a process that can bring these deep marine nutrient laden waters toward the photic zone where they would be available for production. A similar action occurs at the southern boundary of the North Basin, where water exchanges through the Great Narrows and Barra Strait. This movement is somewhat more dominated by outflowing surface waters, but again promotes mixing in the North Basin. All of the mixing, the supply of incoming nutrients from the marine environment, the storage of nutrients in the deepest body of the Basin, and the supply of silicate could be expected to make the North Basin the mixing pot for Bras d'Or Lakes productivity.

Other

At a finer resolution than the bay-scale evaluation conducted, a few spatial observations on biodiversity and productivity within inlets around the Lakes are of interest.

A deeper basin in St. Peters southern end has cooler and more saline waters than much of the southern portion of the Bras d'Or Lakes (Kenchington and Carruthers 2001). There are also some harder substrate habitats in the inlet. As such it appears to host a different, slightly more marine, community of species than is typically found south of the Barra Strait.

Muhammad (1966 cited in Kenchington and Carruthers 2001) provided almost the only quantitative estimates of the density of benthos in the Lakes, at around 350 cumaceans, 150 amphipods and 30 isopods per square metre in Baddeck Bay.

Historically, the sheltered bays of West Bay and Bras d'Or Lake were critical to the production of herring within the Lakes, which supported one of the more significant commercial fisheries. Although herring numbers have dropped significantly because of overharvest, the potential productivity of these areas must still be considered.

Denys Basin has been a significant producer of oyster for many decades. Temperature and salinity of the shallow basin made it one of the biggest producers by volume on the Atlantic Coast for many years. Loss of hard bottom habitats, and closures because of bacterial contamination have limited production from this area in more recent years, but it continues to be a great producer of oyster spat, and has been the site of numerous aquaculture endeavours.

Important floral and faunal areas based on TEK

At the Bras d'Or Lakes Traditional Ecological Knowledge Workshop (May 3-4, 2006), important areas for plants and animals within the Bras d'Or Lakes watershed were identified by workshop participants (CEPI 2006). Please refer to the workshop proceedings (Appendix A) for more information about these important areas.

17.2 Biological Interactions

Biological interactions are the relationships that exist between one living organism and another. These may be predator prey relationship, symbiotic and asymbiotic relationships, a herbivourous forage relationship of an animal feeding on a plant, or any of a number of other relationships across all the trophic levels that exist in the food web and energy paths of an ecosystem.

17.2.1 Marine Food Webs and Energy Flows

A food web for the Bras d'Or Lakes marine environment has not been described to date. However, many researchers have noted in passing predator prey relationships associated with the species they were assessing. The following is a collection of such observations with no relative importance implied by the inclusion or absence of the many relationships that must exist within the Bras d'Or Lakes ecosystem.

In 1973 and 1974 microflagellates and chromogenic bacteria were observed to dominate the summer plankton. These species would likely act as a food source for oyster spat in the summer (Wright 1976). Mean organic levels were also quite high, possibly representing an important supplementary energy source to adult oysters in suspended culture (Wright 1976).

Copepods are tiny crustaceans that are a food source for many larval fish and even some adult fish. Mysid shrimp are a bottom dwelling shrimp that are a main food source for many bottom feeding fish, and are an important item in the diet of cod that are less than 50 cm long within the Lakes (Black 1958). Although Black (1958) only examined cod in detail, he also noted that within the Bras d'Or, mysids were important to the diet of hake, smelt, mailed sculpin, and plaice as well. Winter flounder, on the other hand, had not consumed any mysid based on his sampling. Crawford *et al.* (1982) noted that winter flounder were feeding on herring spawn in the spring, and most of the 85% of herring eggs that were lost before hatching were predated by winter flounder and to a lesser extent cod (Lambert 2002). North Cove, West Bay had considerable influx of Winter flounder (*Pseudopleuronectes americanus*) onto the spawning bed, and their stomach contents indicated heavy feeding on herring eggs. To a lesser extent, a few cod were also predating heavily on the eggs, and it was suspected that given the shallowness of the spawning beds (<1m), gulls might be another predator (Crawford *et al.* 1982). Among the flatfish, Black (1956) documents that 61% of plaice had an occurrence of bivalves in their stomachs.

The evaluation of why seal worm was so prevalent in Bras d'Or cod has led to the direct documentation of three levels of food web interaction within the Lakes. It was found that the key step in the life cycle of the worm was spent as a parasite inside mysids (Black 1956), a group of small shrimp-like animals. The abundant mysid, which feed around the seals' feces, pick up the larvae of the seal worm. Young Bras d' Or cod then eat the *Mysis*, thus becoming hosts to the worm. Finally, the cod pass the seal worm on to seals when the seals predate the cod. Far from a complete food web around even a single species, this documented case does show three trophic levels from filter feeder to what are likely the top carnivores in the Bras d'Or Lakes.

Cod are one of the more studied fish species in the Lakes, and several researchers have noted their forage choices. In his catches in 1951-52, Black (1956) found cod to have eaten polychaete worms, gammarids, mysids, and shrimp, plus smaller numbers of cumaceans, caprellids, crabs, hermit crabs, isopods, gastropods, and bivalves. More recently it has been noted (based on stomach content analysis) that cod appear to be feeding substantially on the invasive green crab (Lambert pers. comm. 2001 cited in Tremblay 2002). This new food source may positively affect cod. However, green crab may be preying on rock crab, and rock crab are not only an important commercial species, but are an important lobster food source (Tremblay 2004). Thereby, it is possible that lobsters may be negatively affected by this new interaction (Tremblay 2002). This example demonstrates one of the many complexities of the Bras d'Or Lakes food web, and how introduction of a new species can have potentially widespread impacts.

Other noted fish diets include Black's (1956) observation that the smelt in the Lakes ate mostly mysids, while hake had a similar diet to cod (polychaete worms, gammarids, mysids and shrimp, plus smaller amounts of cumaceans, caprellids, crabs, hermit crabs, isopods, gastropods and bivalves) but with a higher dependence on shrimp. Mailed sculpins also ate much the same mixture as cod but emphasized smaller prey sizes than those preferred by the larger fish. Of all of these fish species, the most important in many respects is herring. In the past herring has supported the principal commercial fishery in the Lakes and is probably a major component of the ecosystem, feeding on zooplankton and itself being prey for cod and other larger species (Kenchington and Carruthers 2001).

The sea urchin (*Stronglyocentrotus droebachiensus*) and starfishes are important grazers and predators within the Bras d'Or system for which little is known. Sea urchins have been found throughout the Bras d'Or in non-targeted surveys, dominating the invertebrate catch in the Bras d'Or Lake, including East and West Bays. Likewise, starfish (particularly *Asterias vulgaris*) are found in all areas (Tremblay 2002).

18. Terrestrial Ecosystem Relationships

Terrestrial ecosystem relationships are interesting in that the freshwater relationships are likely to be guided in large part by features found in a watershed boundary such as depicted in Figure 1, whereas larger more mobile species may be more likely to interact with their environment based on geological and climatic variations used to define the ecodistricts shown in Figure 11 in Section 14 Terrestrial Habitat Components. Finally, each of these will then interact with one another as terrestrial and avian species feed or respond to freshwater species and habitats, as well as marine species and coastal habitats. The complexity of these physical and biological linkages provides challenge for both scientific study and resource management.

18.1 Terrestrial Physical – Biological Linkages

The physical landscape influences the biological community in many complex ways. Here we present a few of the linkages that have been noted during recent studies within the Bras d'Or Lakes watershed.

In some areas of Cape Breton, part of the limestone geology creates a karst topography where minerals dissolve, creating pockets and caves in the landscape. Such caves and abandoned mines are recognized as providing hibernacula for a number of bat species found in the province (Garroway 2004), including those within the Bras d'Or watershed (Barrington 2005). Although such habitats have not been quantified or described in the scientific literature, their individual characteristics will influence which, if any, of the provincial bat species and other cave dwelling organisms may be present.

Baddeck has received an average of 298 cm of snow per year for the past 30 years (Environment Canada 2005a). To the west and north of Baddeck, the highlands area of the Bras d'Or watershed can be expected to receive considerably more. The snow load has a number of significant ecological consequences for several terrestrial fauna of the watershed. Snowfall greater than 270 cm/yr is a critical component for predicting the presence of the Canada lynx (Hoving et al. 2005), which may be in part because of reduced competition from the bobcat, whose feet make it less capable of successfully hunting in deep snow (Parker et al. 1983). Snowfall is also the strongest predictor of deer health through body condition (Garroway and Broders 2005), leading to the belief that the existence of the Eden deer wintering yard in Denys Basin is in part due to deer avoiding heavier snowfalls that occur in their summer habitats.

Eagles around the Bras d'Or Lakes nest more frequently near freshwater or marine areas where water depths are <5m and less frequently near water >5m (Macdonald and Austin-Smith 1989). This likely relates to feeding locations where the birds can capture fish that venture into shallow water. Therefore, the bathymetry of standing bodies of water becomes a predictor for eagle nesting location.

As with any fish in a freshwater system, whether anadromous or resident, gradient is a strong predictor of distribution by both species and life stage. Gradients have been used to quantify habitat area for various life cycle requirements of Atlantic salmon in several major rivers of the Bras d'Or watershed (Robichaud-LeBlanc and Amiro 2004).

18.2 Terrestrial Food Webs and Energy Flows

As with the marine environment, food webs and energy flows have not been specifically detailed for the Bras d'Or Lakes watershed or any sub-basin of the watershed. Such a process will in part require the identification of appropriate terrestrial keystone species. The following describes some of the food webs associated with top level predators within the terrestrial faunal community.

A relatively new predator on Cape Breton Island, the coyote has only become part of the island food web since the construction of the Canso causeway in the 1950's. Because they are a new introduction to the fauna of the island, they may compete with other carnivores and upset the balance that may have existed within the ecosystem. However, although coyotes have been confirmed as a predator of deer within the watershed, it is unlikely they regulate the population (Patterson et al. 2002). Coyotes also feed heavily on snowshoe hare. Coyote scat analysis in Nova Scotia, that included sites in River Denys, indicated 35 different prey items including 18 wild animals, 3 reptiles, 1 amphibian, 4 birds, domestic livestock, cats and dogs, 6 species of wild berries, and other vegetation (Patterson et al. 1998). Around the lowlands area of the Lakes, snowshoe hare make up some 57% of the coyote's scat volume in spring before they switch to deer during June and July when heavy predation on fawns may contribute to deer constituting ~50% of the coyote scat volume (Patterson et al. 1998). Traditional ecological knowledge indicates that the coyote population is increasing around the Bras d'Or Lakes area despite a bad winter for coyotes a few of years ago (CEPI 2006). Elders believe that numbers of coyotes are increasing on Chapel Island and more have been sighted around Whycocomagh and Membertou.

Bald Eagles are one of the top avian predators within the Bras d'Or Lakes watershed. Birds from around Cape Breton, and possibly the mainland, converge on the Bras d'Or as a feeding ground during winter. They prey on a number of benthic fish and other birds, and scavenge from the carcasses of larger animals that may have died or been killed (Cash et al. 1985). The eagles' preference for flounder and cod demonstrate the ecosystem links between the terrestrial and aquatic environments.

19. Indicator and Keystone Species

Frameworks for the development of ecosystem monitoring exist (ECA 2003). To create such a system four primary steps need to be completed. One of those steps requires identification of keystone species from each trophic level in each ecotype. In order to select an appropriate cross-section of keystone species, one must consider terrestrial and aquatic, benthic and pelagic, sedentary and motile organisms. As well, it is appropriate to consider a variety of habitats based on anticipated or known impacts. Therefore, an ecosystem monitoring program must focus on a number of species at different trophic levels in different habitat types in order to monitor ecosystem scale changes. It is beyond the scope of this report to identify keystone species of the Bras d'Or. However, the following introduces a number of candidate species at different trophic levels that might be considered keystone for the development of a Bras d'Or Lakes ecosystem management framework.

Flat fish may be an indicator of environmental conditions as they tend to bury themselves in sediments, a location where contaminants emanating from such activities as marine commercial and pleasure boat traffic, industrial works, and agricultural practices are likely to settle. Because of this potential, winter flounder have been sampled and used as biological detectors for metals in the Bras d'Or in the past. Such tests did not produce a clear relationship between metal concentrations in flounder tissues and the sediments of the Bras d'Or (Chou et al. 1999) although a baseline database was established for future comparison. In an examination of liver and kidneys of the winter flounder, of the 21 different elements assessed, it was found that only cadmium (Cd), copper (Cu), and manganese (Mn) levels had good correspondence with local sediment concentrations (Chou et al. 1999). This is an example of an indicator species that targets one habitat component (benthic substrates), and a single trophic level. Ecosystem management must cover a wide array of habitat components and trophic levels using a number of keystone species.

American plaice (*Hippoglossoides platessoides*) is now found confined to deepwater areas of St. Andrews Channel and Bras d'Or Lake after historically being found widespread and plentiful around the Lakes (Lambert 2002). This observation shows the dependence of a higher trophic level organism on some habitat feature or food web relationship that has become spatially limited within the Bras d'Or Lakes ecosystem. Understanding what this limitation is would likely contribute to the establishment of a single parameter boundary for the St. Andrews Channel and Bras d'Or Lake deepwater ecotype.

The most common polychaete worm found in the Bras d'Or Lakes is called *Euchone papillosa*, and it builds a slender clay-walled tube within which it lives. These tubes are important because they are found in dense mats that provide substrate to which a small clam, *Hiatella artica*, attaches. This example demonstrates a reliance of one species on another, but through a non predator-prey relationship. Presumably, some stress might be put on the *H. artica* population if the polychaete numbers were to diminish, reducing this preferred substrate within the Lakes. Understanding the full role of *H. artica* within the Bras d'Or would help determine if it warranted monitoring as a keystone species.

Herring spawning in 2000 was nearly non-existent south of the Barra Strait, unlike in earlier records where this area was the most significant. At the same time, Baddeck Bay, which had not factored significantly in pre-collapse herring population spawning, was one of the more prominent spawning sites (Lambert 2002). Bras d'Or Lakes herring was a large fish stock within the Lakes prior to its collapse. It has been documented as an important food source at several life stages to other species, so it is integral to the food web. Herring is also a fish that migrates in and out of the Bras d'Or, and as such it is potentially significant as a source of marine derived nutrients. The magnitude and impact of this species' decline on the Bras d'Or Lakes ecosystem has not been evaluated. This example demonstrates the need to be aware of both the habitat requirements and trophic relationships of keystone species in order to have confidence that ecosystem management will protect critical components.

Drinnan (1976) noted that Bras d'Or oysters are very long lived, if not harvested when young. He reported known-age animals of up to 20 years old, while extrapolation of shell weights at known ages hinted that many wild-harvested animals were 40-50 years old and some perhaps more than 120. This would make oysters one of the longer lived, yet accessible organisms in the Lakes. Given that oysters are filter feeders that can bioaccumulate various contaminants, tissue sampling could provide an indication of long-term changes to the environment of the nearshores that they inhabit. In fact, this approach was used thirty years ago when Young (1973b, 1976) looked at metal concentrations in oysters in the Lakes and found them to be generally low, although with local variation. These results likely reflect minor pollutant inputs to each cove. Young's (1973b) survey results also showed that different species such as oyster, mussel, snails, and scallops exhibited varying uptakes of different metals when found side-by-side in a sampling location. If information is desired on a particular metal, it may be beneficial to select a particular mollusk for sampling. This example shows potential appropriateness of selecting a longer lived species as indicator for an ecosystem. It also shows that once a critical ecosystem parameter is identified for monitoring, such as a metal level, the indicator species for monitoring that parameter may be different than the species that is to be protected. Tolerance levels and sensitivity of a monitoring organism do not necessarily exist within the same organism.

Eelgrass could be a keystone species in the Bras d'Or Lakes. It has been noted for a number of key positive attributes such as being a prominent spawning habitat for Bras d'Or Lake herring (Power et al. 2003; Denny et al. 1998); a dominant coastal vegetation in areas like St. Patricks Channel, Denys Basin, North Basin, and the upper reaches of East Bay and St. Peters Inlet (MacLachlan and Edelstein 1971); a suitable settling location for oyster spat; a potentially significant but as yet undefined contributor to carbon production in the lakes; the only marine macrophyte in the system capable of forming extensive beds; a structural habitat for fish and invertebrates; a habitat that significantly supports waterfowl species found in and around the Bras d'Or Lakes such as Common and Barrow's Goldeneye, American Brant, Black Duck, and Canada Goose (Hanson 2004); and a habitat that supports rearing of juvenile fish species that are found in the Bras d'Or such as winter flounder, white hake, cunners and cod (Hanson 2004). Traditional ecological knowledge confirms that eelgrass provides important habitat and nurseries for several species (CEPI 2006).

Eelgrass is of further importance given the potential negative impacts of significant volumes of it having been damaged by green crab (which are now widespread in the Lakes) in other Atlantic coastal areas (Davis et al. 1998): the observed collapse of the Bras d'Or herring population and reduction in wild oyster population which rely in part on the eelgrass for reproduction; the apparent reduction, or former overestimation of size of eelgrass beds within Denys Basin (Vandermuelen pers. comm. 2006); and the observed decline of waterfowl with collapse of eelgrass beds in other areas of Nova Scotia (Seymour et al. 2002). Traditional ecological knowledge confirms that green crabs are damaging eelgrass in the Bras d'Or Lakes and that the loss of eelgrass has likely played a role in the decline of herring and oysters (CEPI 2006).

Bald Eagles, being a top avian predator within the food chain of the Bras d'Or Lakes watershed, can be an important indicator of the health of other wildlife species and the environment generally (MacDonald 1994). The eagles, which use the Bras d'Or as a winter feeding ground, prey on a number of benthic fish and other birds, and scavenge from the carcasses of larger animals (Cash et al. 1985). As such, this bird has the potential to bioaccumulate potentially toxic substances through consumption of other animals. In particular, the Bras d'Or eagles appear to rely on benthic fish species of cod and flounder for a large part of their diet. Such benthic fish species may more readily accumulate toxic substances because of their tendencies to feed at the Lakes' bottom where such contaminants tend to settle. Field surveys have confirmed heavy metal content of silt in the rivers flowing into Bras d'Or as being generally low, though somewhat higher in Baddeck and Middle Rivers (Young 1976; Creamer et al. 1973). More recently, sediments in Denys Basin have been found to contain levels of cadmium, zinc, copper, and lead greater than threshold effects levels (but less than probable effects levels) (Yeats pers. comm. 2006). All of these locations that exhibit relatively higher metal levels are areas in which eagles tend to congregate to feed heavily on the benthic fish species (MacDonald and Austin-Smith 1989). However, bioaccumulation of metals to toxic levels does not appear to have occurred in benthic fish species assessed within the Bras d'Or, and evaluation of these substances in eagles has not been reported in the literature.

The Evening Grosbeak (*Hersperiphona vespertina*) and Tennessee Warbler (*Vermivora peregrine*) were noted to be increasing in numbers in Cape Breton during 1966-68, and Erskine (1971) predicted that spruce budworm might be reaching high densities in the area because of the more frequent sightings of these bird species. Shortly thereafter spruce budworm infestations were confirmed and significant tree harvests were undertaken over much of northwestern Cape Breton to try to control its spread. Erskine reports these birds have been used in New Brunswick as a "budworm indicator" species.

For freshwater systems of Nova Scotia, it has been suggested that Atlantic salmon (*Salmo salar*), brook trout (*Salvelinus fontinalis*), and rainbow smelt (*Osmerus mordax*) warrant consideration as focal species for conservation due to their high ecological importance and / or vulnerability (Kanno and Beazley 2004). The proportion of species listed at risk in Nova Scotia that are associated with cold water assemblages is high (56%) in comparison with the proportion of native species in the province that are associated with coldwater assemblages (25%) (Kanno 2002 cited in Kanno and Beazley 2004). These factors may also warrant consideration of one of these species as a keystone species indicative of coldwater habitat conditions.

20. Ecosystem Relationships Data Gaps

Many of the ecosystem relationship data gaps that exist are tied in part to gaps that have been identified in the geological and oceanographic systems of the Bras d'Or. That is because ecosystem relationships include not only biological interactions but also physical biological interactions. Generally both types of ecosystem relationships are poorly defined in the Bras d'Or, but there is a marked lack of physical biological relationships described by the current literature. Very few ecosystem relationships have been studied at any scale within the Bras d'Or Lakes watershed. Even at the bay-scale resolution it has been noted that in Denys Basin, arguably one of the more studied areas of the Lakes, ecological information is fragmented both in time and space (Barrington 2005).

As the gaps in ecosystem relationships are many, only a few of the key areas for which study is needed are discussed. Most gaps relate to food webs and keystone species, or to energy flows through the system. It is important to note that identification of keystone species is critical to addressing ecosystem relationship gaps because the magnitude of the task would practically eliminate studying and defining all relationships. Therefore, focusing on keystone species allows us to learn about those species that establish balance within the ecosystem. To provide a very current example of how having an energy model and a spatial knowledge of habitats critical for life cycle requirements of key species within the Bras d'Or, it would be useful to look at the issues currently being observed regarding eelgrass beds.

There is a need to better understand the role of eelgrass within the Bras d'Or Lakes because of the numerous apparent ecosystem linkages with this species. Eelgrass is a potential source of production within the Lakes, and the nearshore environment. The eelgrass beds in Denys Basin were recently surveyed in the field and found to be much smaller than previously estimated through airphoto interpretation (Vandermuelen pers. comm. 2006). At the same time, eelgrass beds have been estimated to have declined as much as 79% in coastal Nova Scotia over the 1992-2002 period (Chapman and Smith 2004 cited in Hanson 2004). Furthermore, eelgrass in the Bras d'Or Lakes was an important spawning location for the once abundant herring whose population has failed to rebound within the Lakes despite closure of the fishery. West Bay, prior to about 1997, had significant herring spawning aggregations on eelgrass beds (Denny et al. 1998). More recently herring have spatially shifted spawning to north of the Barra Strait, yet the reason for this is not fully understood. During the same time frame, since the 1990's, green crab has become widespread in the Bras d'Or Lakes as an invasive species. In New England (Davis et al. 1998) and Nova Scotia (Garbary et al. 2004 cited in Hanson 2004) green crab have been observed to damage eelgrass in the wild, and cause loss of as much as 39% of transplants in a lab setting within as little as one week where crab densities exceed 4.0 crab / m^2 (Davis et al. 1998). Recent surveys have noted this invasive species was most abundant in West Bay at a density of 0.086 crab / m^2, although these surveys occurred at depths typically deeper than 10m, and green crab appear most common in waters less than 6 m (Tremblay 2004). Although eelgrass beds have not been assessed recently in West Bay, knowledge of relatively dense green crab within the bay warrants evaluation of the current relationship of these two species and potential implications for Bras d'Or herring. Eelgrass may also be significant in Denys Basin where recent field surveys indicate that eelgrass beds are nowhere near as abundant as once reported (Vandermuelen pers. comm. 2006). Eelgrass has been identified as a suitable spat settling substrate for oyster, the wild population of which has undergone significant declines in the Bras d'Or (Lambert 2002). Finally, eelgrass declines in other locations of Nova Scotia have been corresponded to significant declines in presence of both Canada Geese, which feed directly on the grass, and Common Goldeneye, which feed on invertebrates associated with eelgrass (Seymour et al. 2002). As the nearshore area in general remains a biological information gap within the Bras d'Or it is not possible to determine if changes in eelgrass have occurred, or what the ecosystem impacts may be if changes have occurred. Therefore, understanding eelgrass and its role within the Lakes is important to understanding the ecosystem relationships of the Lakes. Examining current status of eelgrass at past key locations, (such as Denys Basin, West Bay, and St. Peters Inlet) and current key locations (St. Patricks Channel), along with densities of green crab, invertebrate species, and waterfowl at these locations would be significant to understanding the current role of these species within the Bras d'Or Lakes ecosystem.

A second general area for which study of ecosystem relationships is needed is the habitat uses by the various species present for different critical life cycle periods such as reproduction, rearing, and foraging. Without knowledge of which areas support key species through important life cycle requirements, it is impossible to identify keystone or indicator species within the broader ecosystem. Also inherent in this is the need to define the food web relationships for potential keystone species in the Bras d'Or to confirm the importance of these species in providing balance in the system, and to allow us to anticipate and manage significant changes. For example, understanding the food web of keystone species might allow us to anticipate and manage the effects of the collapse of the Bras d'Or Lakes herring stock on other species that either prey upon or have been prey for the herring, or might allow us to more readily determine potential causes for species decline, such as has been observed with American plaice in the Lakes.

Ecosystem management requires both knowledge of species and habitats. Beazley et al. (2004) mapped and integrated a network of terrestrial habitats for the Province of Nova Scotia (Figure 12). They identified a series of core areas with suitable buffers and connectivity areas they felt were sufficient to maintain and restore the Province's native species and ecosystems over >100 years.

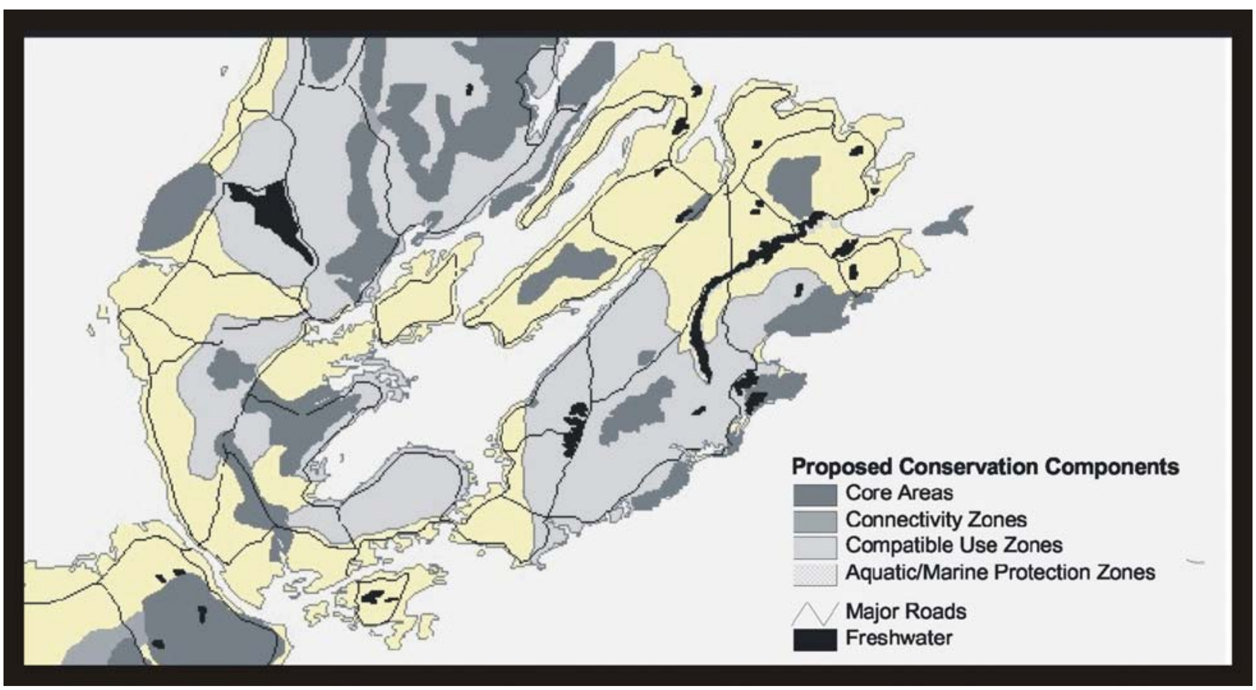


Figure 12. A terrestrial biodiversity conservation map modified from Beazley et al. (2004) depicts a number of management areas aimed to maintain biodiversity of ecosystems

The spatial resolution of this model is provincial in scope, and the marine component that accompanied it categorized all of the Bras d'Or Lakes as a single management unit. Therefore, the terrestrial model depicted in Figure 12 may not meet all ecosystem objectives that may be defined for the Bras d'Or Lakes, and the marine model simply confirms that an ecosystem management approach needs to be developed specifically for the Bras d'Or. However, the work of Beazley et al. (2004) is important to consider when moving forward on both of these tasks as it provides both a model for consideration, and incorporation of broader scale ecological objectives that may not differ significantly from those which may be established for the Lakes ecosystem.

A final broad marine ecosystem gap of critical importance to the future management of the Bras d'Or Lakes ecosystem is the lack of understanding of the role of the nearshore environments on productivity of the larger bay-scale areas of which they are part. Productivity helps define both the number of organisms and diversity of species an area will support. Currently we do not understand the role of the nearshore environment on the energy flows through the ecosystem. As primary and secondary productivity are pillars upon which diversity and abundance are built, we need to fill this gap to ensure we do not disturb critical components of the larger system.

Conducting current research in support of defining ecosystem relationships, and revisiting historic data once energy models are created and spatial life cycle habitat needs are understood, will provide us with understanding of why past trends have occurred and knowledge upon which to base future ecosystem management decisions. Historical context of relationships is particularly important, as we can learn much by the magnitude of change that has occurred from disturbance to the energy model in the past, and thereby better be able to predict the ramifications of current trends and potential impacts to the ecosystem.

PART E – IDENTIFICATION OF ECOLOGICALLY AND BIOLOGICALLY SIGNIFICANT AREAS

The Bras d'Or Lakes Ecosystem Overview and Assessment Report (EOAR) was originally drafted in part to facilitate the process of identifying ecologically and biologically significant areas (EBSAs) within the Lakes ecosystem. In the first draft of the EOAR that was circulated to participants of the November 2005 Regional Advisory Process (RAP), a model for how EBSAs might be identified was included (DFO 2006). The RAP acknowledged the draft model was a good foundation, but noted that a number of model parameters needed modification, that the scoring system needed broader input and evaluation, and that data gaps in the EOAR needed to be addressed in order to create a final version of the Bras d'Or Lakes EBSA model. A number of the EOAR data gaps have been filled in this final version of the document, and outstanding gaps have been identified in the relevant sections. However, the remaining issues with the EBSA process are not yet fully addressed, and therefore EBSAs are not explicitly identified within this report. The intent of this document to support identification of EBSAs warrants some discussion of what EBSAs are and how the process of identification will likely take place.

A national guidance document has been produced that outlines the general considerations and methodologies for identification of EBSAs (DFO 2004b). Although it is not imperative that one understands all details of the process undertaken, several points of the process do need to be presented. The guidance document outlines several key concepts that are central to application of the document to a project area. They are:

- Significance
- Consideration of risks and threats
- Spatial Scale
- Uniqueness, Aggregation, Fitness, Resilience, and Naturalness
- Temporal Scale

Identification of EBSAs requires clear understanding of how the term "significant" is being used. Species, habitat features, areas, etc. that are significant are those that if perturbed severely, would have greater ecological consequences than an equal perturbation of most other species, features, or areas. The term "value" is used to refer to special utility or importance to humans, and is not a major consideration in identifying an area as ecologically or biologically significant. Areas may have high cultural or economic value, and managers may choose to give them enhanced protection to preserve such valued properties, however, this does not make such areas ecologically or biologically significant. The identification of EBSAs also does <u>not</u> consider threats and risks to the site. Instead these concerns are a component of the management decision process for areas that have been identified as ecologically and biologically significant (DFO 2004b).

Unlike in other open ocean areas, physical and biological features are less spatially mobile in the Bras d'Or. Therefore, EBSA boundaries are less likely to shift significant distances with seasonal and inter-annual changes. The spatial scale for evaluation of EBSAs is critical for interpretation of factors such as uniqueness, fitness consequences, and aggregation.

The process of identifying EBSAs is based on information currently available. As such, it is only as good as the scientific knowledge and TEK at hand. Research in the Bras d'Or is ongoing on many fronts. Furthermore, other temporal changes such as climate change, shoreline development, coastal barrier evolution, and fishing efforts are likely to change existing qualities of the ecosystem over time. As changes occur some areas may become more ecologically and biologically significant, while others may become less so. Therefore, temporal variation on the scales of years to decades will best be addressed through periodic review.

PART F – HUMAN ACTIVITIES

21. Governance Structures

21.1. Federal and Provincial Governments

The legislative authorities of the federal and provincial governments are differentiated in Canada's *Constitution Act (Constitution Act, 1982)*. Section 91 of the *Constitution Act* outlines the areas where the federal government has authority to make laws for the "Peace, Order and good Government of Canada". Relevant examples from the twenty-nine areas under federal jurisdiction include:

Sea Coast and Inland Fisheries
Navigation and Shipping
Indians and Lands Reserved for Indians

Section 92 of the *Constitution Act* outlines the areas where provincial legislatures have jurisdiction. Examples of these areas under provincial jurisdiction include:

Municipal Institutions
Property and Civil Rights
Exploration for non-renewable natural resources
Development, conservation and management of non-renewable natural resources and forestry resources
Development, conservation and management of sites and facilities for the generation and production of electrical energy

Various federal and provincial laws have been created to exercise these areas of authority. These laws are administered by federal and provincial departments or agencies, each of which has further developed their respective regulations, policies and programs.

Relevant federal departments in the Bras d'Or and some of their key federal acts include (not exhaustive):

Fisheries and Oceans Canada: (*Oceans Act, Fisheries Act*)
Environment Canada: (*Canadian Environmental Protection Act, Migratory Birds Convention Act, Species at Risk Act, Canadian Environmental Assessment Act*),
Natural Resources Canada: (*Forestry Act, Cape Breton Development Corporation Act, National Energy Board Act*)
Indian and Northern Affairs Canada: (*Indian Act, First Nations Land Management Act, Mi'kmaq Education Act*)
Transport Canada: (*Canada Shipping Act, Navigable Waters Protection Act*)

Relevant provincial departments in the Bras d'Or and some of their key provincial acts include (not exhaustive):

NS Environment and Labour: (*Environment Act, Wilderness Areas Protection Act*)
NS Natural Resources: (*Beaches Act, Forests Act, Mineral Resources Act, Parks Act, Wildlife Act, Endangered Species Act, Crown Lands Act*)
NS Agriculture and Fisheries: (*Fisheries and Coastal Resources Act, Farm Practices Act, Agriculture and Marketing Act*)
Service NS and Municipal Relations: (*Municipal Government Act*)
NS Energy: (*Energy Act* – pending, *Petroleum Resources Act, Energy Resources Conservation Act*)

21.2 Traditional/Aboriginal

The Bras d'Or Lakes is home to several First Nation communities which comprise a large and growing portion of the population in the watershed. These First Nation communities include[5]:

- Chapel Island
- Eskasoni
- Malagawatch
- Wagmatcook
- Wycocomagh

These communities are reserves as defined under the federal *Indian Act* of 1985. As such, the way these communities are governed, including the election and powers of Chiefs and Band Councils, as well as numerous issues associated with the management of the reserves and its people are expressly dictated in various sections of the *Indian Act*. This act, with roots over one hundred years old, is administered by the federal department of Indian and Northern Affairs Canada. The Council of a Band may make bylaws for the reserve in a number of defined areas. Examples of these areas under Band jurisdiction include:

- Regulation of traffic
- Construction and maintenance of watercourses, roads, bridges, ditches, fences, and other local works
- Construction and regulation of the use of public wells, cisterns, reservoirs and other water supplies
- Preservation, protection, and management of fur-bearing animals, fish and other game on the reserve
- Taxation of land for local purposes

There are currently a number of proposed new Acts, including Bill C-7 (*First Nations Governance Act*) that seek to enable bands to achieve independence in the management of their affairs and to reduce the degree of involvement by the Minister in band affairs. In addition, within Nova Scotia, the "*Made in Nova Scotia Process*" has been established to explore, through negotiation rather than litigation, issues of Aboriginal rights and the assertion of Aboriginal title. Within this process the governments of Canada, Nova Scotia and the Mi'kmaq of Nova Scotia will seek agreements and arrangements concerning matters over land, resources and governance. Issues relevant to Mi'kmaq of Nova Scotia that fall outside the scope of Aboriginal and Treaty rights (including issues of culture and heritage, economic development, education, health, justice and social issues) are being addressed in the "*Tripartite Forum*". Information about these latter processes can be attained from the NS Office of Aboriginal Affairs.

In addition to the governance arrangements discussed above, there are a number of Mi'kmaq organizations formed to provide representation, coordination and support to First Nation communities in Nova Scotia. The primary ones relevant to the bands in Cape Breton are described below.

21.2.1 Unama'ki Institute of Natural Resources

The Unama'ki Institute of Natural Resources (UINR) represents the five Cape Breton First Nation communities of Eskasoni, Membertou, Chapel Island, Waycobah, and Wagmatcook. The

[5] The community of Membertou, while physically located outside the Bras d'Or watershed, has joint use of the lands at Malagawatch.

UINR was formed to increase First Nations involvement in the management of natural resources in their traditional territory of Unama'ki. The mandate of UINR is to:

- Promote and contribute to the understanding and protection of the Bras d'Or Lakes marine system and its watershed;
- Assist in the development of monitoring programs, data collection, analysis and other matters essential to the protection of the natural resources;
- Promote and contribute to the understanding and protection of the marine system in and around the traditional territory of the Mi'kmaq people;
- Enter into arrangements with others that will aid UINR in achieving their objectives.

Staff of the UINR are based in the community of Eskasoni.

21.2.2 Atlantic Policy Congress of First Nation Chiefs (APCFNC)

The Atlantic Policy Congress of First Nation Chiefs is a policy, research and advocacy secretariat that analyses and develops culturally relevant alternatives to federal policies that impact on the Mi'kmaq, Maliseet, and Passamaquoddy First Nation communities and people.

21.2.3 Union of Nova Scotia Indians

The Union of Nova Scotia Indians is an organization created in 1970 to provide political leadership and a unified political voice for the Mi'kmaq people of the province. The objectives of the organization include:

- To promote the welfare and well-being of the Indians of Nova Scotia
- To improve the economic and social conditions of the Indians of Nova Scotia
- To promote the rights of Indian people, to inform Indians of their rights and to assist Indians of Nova Scotia in their enforcement of their rights
- To promote discussion of Indian problems
- To seek to promote a better understanding between Indians and other people
- To initiate and carry out programs for the advancement of Indian people
- To cooperate with governmental and private agencies for the promoting of the interests of Indian people
- To do all such things as are incidental or conductive to the attainment of the above objectives

21.2.4 Native Council of Nova Scotia

Established in 1974, the Native Council of Nova Scotia provides a voice for the Mi'kmaq peoples living off-reserve in Nova Scotia. Specific activities of the Native Council of Nova Scotia include:

- Advocate and work with all levels of government, public and private agencies, and industry to improve social, educational, economic and employment opportunities
- Promote, advance, and foster Aboriginal Rights, Treaty Rights and Aboriginal Title
- Aid and assist off-reserve Mi'kmaq peoples in Nova Scotia to organize Community Affiliate Zones for the purpose of advancing their general living conditions
- Develop, negotiate, manage and administer a wide range of programs, services, initiatives, entities, secretariats and directorates to advance the well-being of the Community

21.3 Local and Municipal Government

Municipal (local) levels of government are created under the authority of the provincial government as stated in Section 92 of the *Constitution Act* of 1982. The powers and authority of the municipal governments in Nova Scotia are in turn detailed in the *Municipal Government Act* of 1999, including details concerning the election of councils, mayors and wardens. The functions of municipalities outlined in this act are to:

- Provide good government
- Provide services, facilities and other things that in the opinion of the council are necessary or desirable for all or part of the municipality
- Develop and maintain safe and viable communities

Examples of areas under municipal jurisdiction include:

- Taxation (e.g., property tax)
- Planning and Development
- Subdivisions
- Streets and Highways
- Solid waste resource management
- Sewers

There are four municipal units that are represented within the Bras d'Or watershed, each with their respective Councils and Mayors or Wardens. These include:

- Cape Breton Regional Municipality
- Inverness County
- Richmond County
- Victoria County

21.4 Non-Government Organizations

The main environmental NGO's operating in the Bras d'Or watershed include the following[6]:

<u>21.4.1 The Bras d'Or Stewardship Society</u>

The Bras d'Or Stewardship Society is a membership organization of individuals committed to promote accountable and responsible stewardship of the Bras d'Or Lakes and its watershed (Bras d'Or Stewardship Society 2006). The Society promotes an appropriate strategy to conserve, restore and protect the Bras d'Or Lakes for current and future generations using public meetings, newsletters and educational activities. The society aims to gather ideas and scientific information relating to the Lake and provide a forum for education, co-operation and partnership among interested individuals and communities. As a group, they are better able to voice concerns regarding the safeguarding of the future environmental health of the watershed to government, business and the general public.

[6] For a complete listing of all NGOs (environmental, social, cultural and economic) in the Bras d'Or watershed see Naug (2004).

21.4.2 The Bras d'Or Preservation Society

The Bras d'Or Preservation Society was established in 1993 as a dedicated conservation organization under the Nova Scotia *Conservation Easements Act*. Primary objectives of the organization include:

- Acquisition of conservation easements and fee interests in environmentally important lands; and
- Community education on the need to conserve the Bras d'Or.

Activities of the Bras d'Or Preservation Foundation have been supported to date by funding from the federal government, the province of Nova Scotia, the Foundation itself, and other private sources. Current efforts are underway to establish an endowment fund to provide a long term and dependable source of income to support its staff and its land purchase program. The work of the Preservation Foundation is directed by a volunteer Board of Directors. Staff of the Preservation Society are employed at the Bras d'Or Lakes Interpretive Centre in Baddeck.

21.4.3 Stewards of the River Denys

The primary mandate of the Stewards of the River Denys Watershed Association is to restore fish habitat in the watershed of the River Denys Basin. This is done using various stream restoration techniques. Work of the Stewards Group is supported by in-kind contributions from local industry (mining) as well as grants from environmental foundations (Adopt-a-Stream, Shell Canada Environmental Fund) and a summer youth internship program of the federal government. Activities of participants from the watershed are voluntary.

21.4.4 Middle River Watershed Society

The Middle River Watershed Society, a combination of the Middle River Watershed Association and the Middle River Development Association, is focusing on developing baseline data on the health of the river itself to be used to develop a strategy to enhance the sea trout population. The Department of Fisheries and Oceans, the Nova Scotia Department of Agriculture and Fisheries, the Nova Scotia Department of Natural Resources, and community partners have formed a committee to explore how to maintain the Middle River Valley environment through a comprehensive watershed approach. The Committee will consider all possible aspects of proper watershed development, such as habitat, regulations, stream improvement, trails, and access.

21.5 Co-Management and Integrated Management

A number of partnerships and organizations have been formed in recent years to better address the issues in the Bras d'Or in a more integrated manner. Those with an environmental focus, in whole or part, include:

21.5.1 The Bras d'Or Collaborative Environmental Planning Initiative (CEPI)

Established in 2003, the Bras d'Or Collaborative Environmental Planning Initiative (CEPI) is a partnership between First Nations communities in Cape Breton; federal, provincial and municipal governments; industry; NGOs; academia; and the broader community. Its vision is to achieve a healthy and productive Bras d'Or ecosystem. The CEPI will do this through the development and implementation of an overall management plan for the Bras d'Or Lakes and watershed lands. The First Nations communities in Cape Breton have played a strong role in helping facilitate this process, with a secretariat based at the Unama'ki Institute of Natural Resources, providing support to a Steering Committee and Task Teams. Support for the secretariat (both financial and in-kind) is provided by the various partners involved.

21.5.2 The Pitu'paq Committee

The Pitu'paq Committee was formed in 2001 representing the five First Nation Chiefs and the five Mayors and Wardens in Cape Breton (PPS 2006). This organization was formed to deal with the remediation and prevention of sewage problems around the Bras d'Or Lakes. The Pitu'paq Committee's vision is to:

Restore the Bras d'Or Lakes to their former pristine state free of contaminants from shoreline land use; and,

To manage these waters and the lands around them to maintain the waters so that they will support aquaculture, wild fisheries and tourism.

As sewage management is the primary issue being addressed, there is a specific focus on sewage treatment plants, on-site sewage disposal systems, and sewage from recreational boats and other marine crafts. The Pitu'paq Committee have made ten commitments with regard to the issue of sewage in the Bras d'Or Lakes. Recognizing that they cannot work alone to deal with this issue, ten reciprocal commitments are being sought from other government departments and agencies with a role to play in this area. Additional support for the Committee is provided by NS Environment and Labour, and Environment Canada.

21.5.3 The Sustainable Communities Initiative (SCI)

The Sustainable Communities Initiative (SCI) arose from communities imploring governments to work together in ways that better support communities' priorities. The SCI is an intergovernmental body made up of federal, provincial and municipal government departments and First Nation groups (NSSCI 2005). Its vision, which is for communities and governments to work together for long term sustainability, includes consideration of the relevant social, economic, cultural and environmental dimensions of the issues present. The goals of SCI include:

Designing and implementing horizontal coordination within government.

Supporting sustainable communities through a collaborative approach that integrates social, cultural, economic and environmental policies and programs.

Building community partnerships using new models.

The SCI structure includes two Co-Champions (federal/provincial), a Coordinating Committee, two Field Teams (Annapolis-Fundy and Cape Breton Island) and a three member secretariat. Financial support for the secretariat is cost-shared among the government departments involved.

22. Impacting Activities and Stressors (Socio-Economic Pressures)

22.1 Human Settlements

There are five First Nation Reserves in the Bras d'Or watershed. In order of decreasing population size, they are Eskasoni, Whycocomagh, Wagmatcook, Chapel Island, and Malagawatch. Malagawatch is not occupied on a permanent basis, but is used seasonally for hunting and fishing.

The watershed is dotted with towns (mostly coastal) between 400-3000 residents in size (Figure 13). All four of the First Nation reserves are increasing in population, particularly Whycocomagh and Chapel Island which almost doubled in a decade (Table 30). All other settlements except for Big Pond and Grand Narrows, which maintained their populations, have seen outmigration in the past decade (particularly of youth), a problem common to all of rural Nova Scotia.

The total population of the watershed is approximately 22 000 people (Statistics Canada, 2004a) and is spread out in many small communities. The bulk of the population (roughly 20-25%) is found in the East Bay watershed, and the next most populated areas are the St. Andrews Channel and Baddeck watersheds with both having roughly 15% of the total population.

Cape Breton Island as a whole is home to over 154 000 people, and has undergone dramatic changes recently. More than 20 000 jobs have been lost in the past 40 years as a result of coal and steel industry shut-downs. In 1961, 24% of the workforce was employed in these two sectors and today that percentage is zero (ECBC and CBGFC 2006).

Table 30. Population, dwelling and education statistics for the larger settlements in the Bras d'Or Lakes watershed

Place Name	Total population 2001	% Population change 1991-2001	Total occupied dwellings in 2001	% Change in occupied dwellings 1991-2001	Value of dwellings in 2001 (Avg in $)	% with less than high school	% with high school	% with College/Trades certificate or diploma	% with University
Baddeck	2377	-4	921	4	87, 817	34	9	34	22
Wagmatcook IR	445	19	130	30	n/a	54	4	27	15
Whycocomagh	825	-7	323	5	78 ,495	39	10	35	18
Whycocomagh IR	635	49	165	65	n/a	35	16	27	24
Dundee	1041	-2	408	17	79,099	34	14	36	16
St. Peters	1717	-16	692	0	69 170	43	10	35	11
Chapel Island IR	420	45	120	60	n/a	38	5	36	21
Big Pond	520	1	196	14	86,040	32	10	31	27
East Bay	1200	-1	427	12	94,589	28	12	37	23
Eskasoni IR	2740	24	730	54	n/a	34	6	34	26
Grand Narrows	553	1	218	11	63,028	32	9	38	20
Little Narrows	555	-12	230	-2	64,914	39	19	29	13
Bras d'Or	2856	-8	1020	7	79,349	41	9	35	16

Source: Province of Nova Scotia 2005

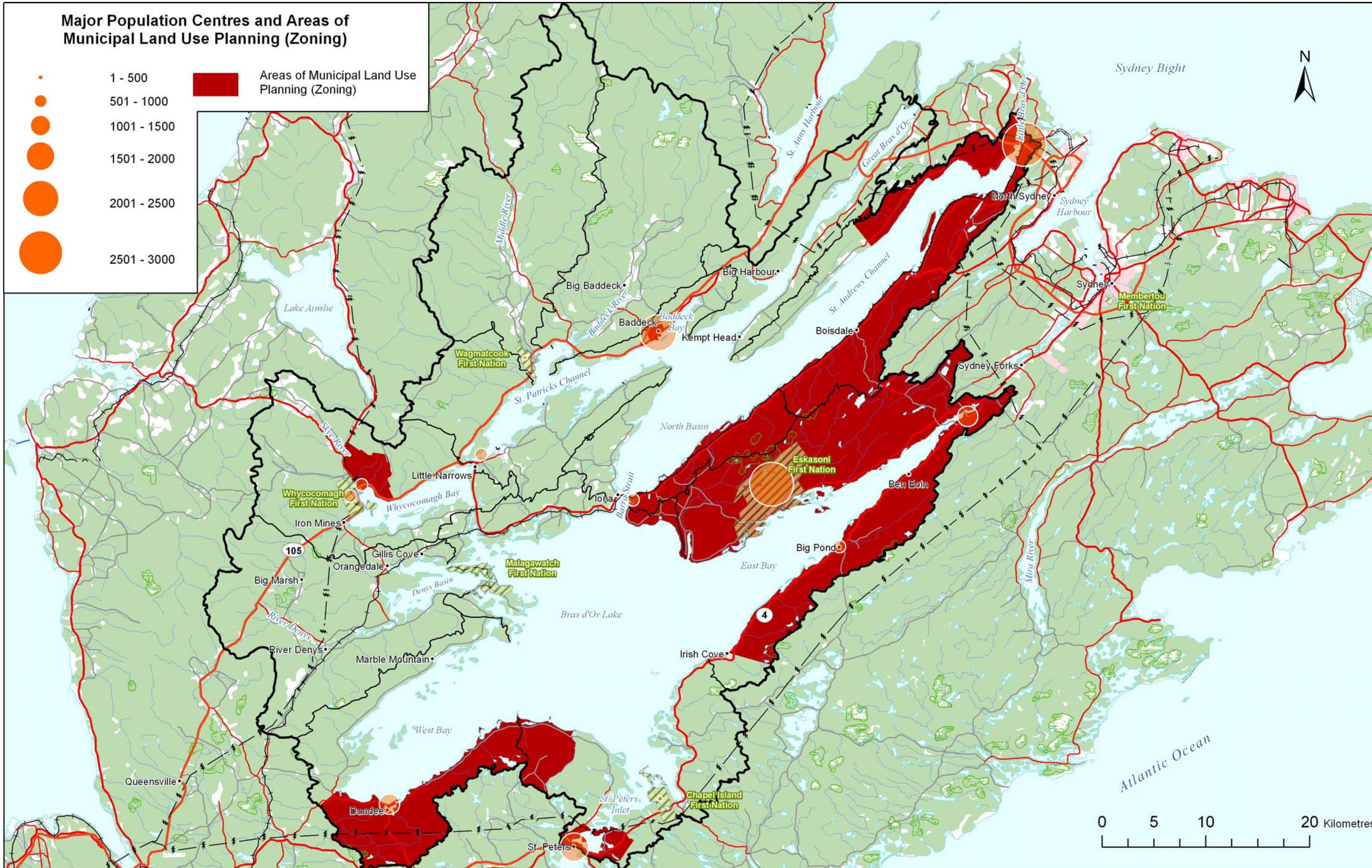


Figure 13. Major population centres and areas of municipal land use planning (zoning) within the Bras d'Or watershed
Data sources: Province of Nova Scotia (2005); DFO (2003); Planning areas (Eastern District Planning Commission, Port Hawkesbury, Nova Scotia and Cape Breton Regional Municipality, Sydney, Nova Scotia); Basemap (Natural Resources Canada, National Topographic Database 1:250,000 3rd Edition)

22.2 Agriculture

Compared to other areas of Nova Scotia, such as the Annapolis Valley, there is relatively little agriculture in the Bras d'Or watershed. The agricultural activity in the watershed is variable, however generally the western side of the Lakes tends to have beef and dairy production while the northern side (Boularderie Island area) has mainly horticulture with some beef and dairy (McCabe pers. comm. 2005). Most operations are located in Middle River, St. Andrews Channel, and Whycocomagh Bay subwatersheds (Table 31, Figure 14). The eastern and southern side of the Lakes has very little agricultural activity.

Table 31. Agricultural activity in the Bras d'Or Lakes watershed, broken down by subwatershed[7]

Subwatershed	Total area of agricultural land (ha)	# of parcels of agricultural land
Middle River	1528	182
St. Andrews Channel	1192	145
Whycocomagh Bay	941	127
River Denys	600	99
Baddeck River	584	68
McKinnons Harbour	320	71
East Bay	315	67
West Bay	259	48
North Basin	240	36
St. Peters Inlet	224	48
St. Patricks Channel	181	36
Great Bras dOr Channel	169	26
TOTAL	**6553**	**953**

22.3 Forestry

The Nova Scotia Department of Natural Resources (NSDNR) has overall responsibility for forest management on all Crown lands in the province. Water protection measures called for in the provincial Wildlife Habitat and Watercourse Protection Regulations have applied on all crown lands since 1988, although recently (since January 2002) they have been updated and now apply to all land ownership types including private land. Under these Regulations, regular inspections of both private and Crown land forestry operations are conducted to ensure compliance. Specific watercourse protection measures include the mandatory provision for 20 m minimum "special management" zones along both sides of streams and rivers wider than 50 cm, and all lakes and marshes with permanent open water. Connectivity management zones (also known as corridors) are required between ecologically significant areas (Stora Enso 2002a) which allow wildlife to move between stands of treed areas. On a provincial level, the Nova Scotia *Wilderness Areas Protection Act* protects 19% of all provincial crown land.

NSDNR monitors forest products acquired and produced in the province. Table 32 summarizes the total Cape Breton harvest for 2004.

[7] Data provided by the NS Department of Agriculture and Fisheries

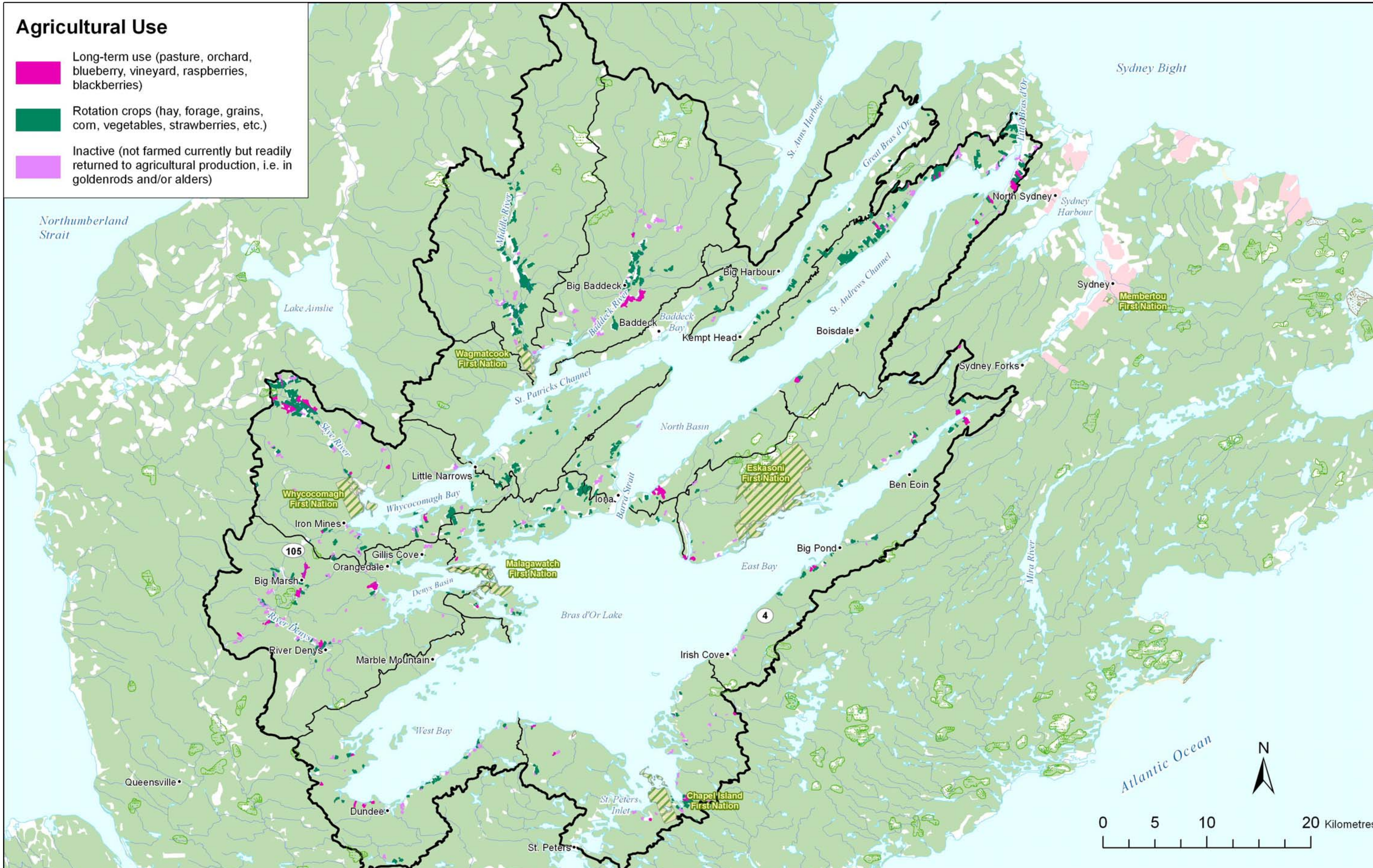


Figure 14. Agricultural activity within the Bras d'Or watershed
Data sources: Nova Scotia Department of Agriculture and Fisheries, Agricultural Land Use Classification; DFO (2003); Basemap (Natural Resources Canada, National Topographic Database 1:250,000 3rd Edition)

Table 32. Total Cape Breton harvest for 2004. Represents all land tenures (crown, industrial and private) by county of origin, species (S=softwood, H=hardwood) and use

County		Provincial m³ solid	Export m³ solid	Total m³ solid
Cape Breton	S	101 472	88 032	189 504
	H	5 924	2712	8 636
Inverness	S	232 675	9 161	241 836
	H	15 465	18 597	34 062
Richmond	S	51 634	8 403	60 037
	H	1 456	1 711	3 167
Victoria	S	82 642	8 334	90 976
	H	3 602	366	3 968
Total		**494 870**	**137 316**	**632 186**

Source: NSDNR 2005c

Stora Enso Port Hawkesbury Limited (SEPH) holds a forest management licence agreement with the provincial government for some 607 000 ha of crown land contained within the seven eastern counties of Nova Scotia, and is one of the largest commercial forestry operations in the watershed. Under the terms of this agreement SEPH is responsible for forest management planning (long-term and annual), road building, wood harvesting and silviculture practices. Day to day operations are controlled and independently verified according to an International Standards Organization (ISO 14001) environmental management system. Overall sustainable forest management (SFM) has been certified by the Canadian Standards Association (CSA Z809) and Sustainable Forestry Initiative standards. Various measures aimed at protecting water quality and ecological integrity are imbedded within the environmental management system and SFM systems. These measures include water quality monitoring, strict operating procedures around streams, steep slope (> 30% slope) reservation from regular harvesting, limited harvesting in key identified watersheds (at least 80% in non clearcut condition), provision for at least 8% old forest reserves and 15% of management area in protected areas.

Of most importance, however, is the reality that private woodlots are not adequately tracked or monitored for overall harvesting levels. Only Crown land and lands under the management of Stora Enso can be effectively characterized for wood harvesting levels. As 62% of the land in the watershed is privately owned, this presents challenges in both monitoring and regulating harvest levels so that cumulative effects can be kept in check.

22.3.1 UINR/Stora Enso agreement

In January of 2002, an agreement was signed between Stora Enso and Unama'ki Institute of Natural Resources (UINR), which outlined provisions for forestry management services to be carried out by UINR on the Cape Breton crown lands. Thus, UINR acts as a full services contractor for Stora Enso. Activities include aspects of forest planning, harvesting and silviculture. The two parties also agreed to establish a joint UINR/Stora Enso forest planning committee made up of two individuals from each party. This committee reviews and makes recommendations to Stora Enso on their long-term forest management plan.

The contract signed allowed UINR to harvest 10% of the annual allowable cut (AAC) on Cape Breton (i.e. UINR was responsible for harvesting 8000 cords of softwood). A Forestry Manager and Forest Technician were hired to help generate and implement a sustainable forest management program. A forestry advisory council (FAC) was developed consisting of a representative from each of the five First Nation bands to aid in developing the management plan by representing communities' concerns.

22.3.2 Stora Enso's Long Term Plan – 2002

Stora Enso's 180-page Long Term Plan (Stora Enso 2002b) came into effect in January of 2002. Its development relied heavily on input from various stakeholders such as citizens and government departments. The document directs forest operations according to a series of landscape-scale plans that strive to balance forest resource use with protection measures. The company has developed a vision, mission, a set of 14 guiding principals, and 11 standard practices of sustainable forest management, all of which are used to aid forest planning and management.

Stora Enso's planning is also tightly linked to NSDNR's Integrated Resource Management (IRM) process and is based on their management categories as well as the Ecodistrict level of NSDNR's ecological land classification. As well, many of Stora Enso's Long Term Plan indicators are directly relevant to IRM objectives. All Stora Enso's plans must be submitted to NSDNR for review.

Stora Enso has seven indicator species it uses to assess their activities. These are the Barred Owl (*Strix varia*), White-winged Crossbill (*Loxia leucoptera*), Black-backed Woodpecker (*Picoides articus*), Red Breasted Nuthatch (*Sitta canadensis*), Bicknell's Thrush (*Catharus bicknelli*), Pileated Woodpecker (*Drycocopus pileatus*), and Canada lynx (*Lyns canadensis*). Stora also has three "emphasis species", which are also used for forest management planning. These are Moose (*Alces alces*), Ruffed Grouse (*Bonasa umbellus*), and White Tailed Deer (*Odocoileus virginianus*). Stora also has activity-related targets that are closely monitored such as no regular harvesting in identified steep slope areas, meet or exceed provincial riparian zone management regulations, and maintain 8% of forest area in old forest condition, to name a few examples. In total, Stora has identified 41 indicators to aid management and regulation of activities – 9 of these are under development and 32 are currently in use (Stora Enso 2005).

A comprehensive summary of Stora Enso's harvesting and management activities broken down by subwatershed is provided in Table 33. There are also specially managed areas in Stora Enso's management plans that include riparian zones, recreation areas, old forest areas, lynx habitat, deer wintering areas, etc., which are provided in Appendix C. Steep slope areas (>30% slope) are also typically not harvested, making them a type of protected area.

In total, Stora Enso has access to and manages approximately 30% of the Bras d'Or Lakes watershed, the bulk of which is located in the Baddeck and Middle River subwatersheds (Figure 15). Of the watershed area managed by Stora Enso, less than 1% is in clearcut condition (any clearcut less than five years of age), less than 1% is in partial cut condition, and approximately 7% is in recent cut condition (any clearcut less than 15 years of age) (Table 33).

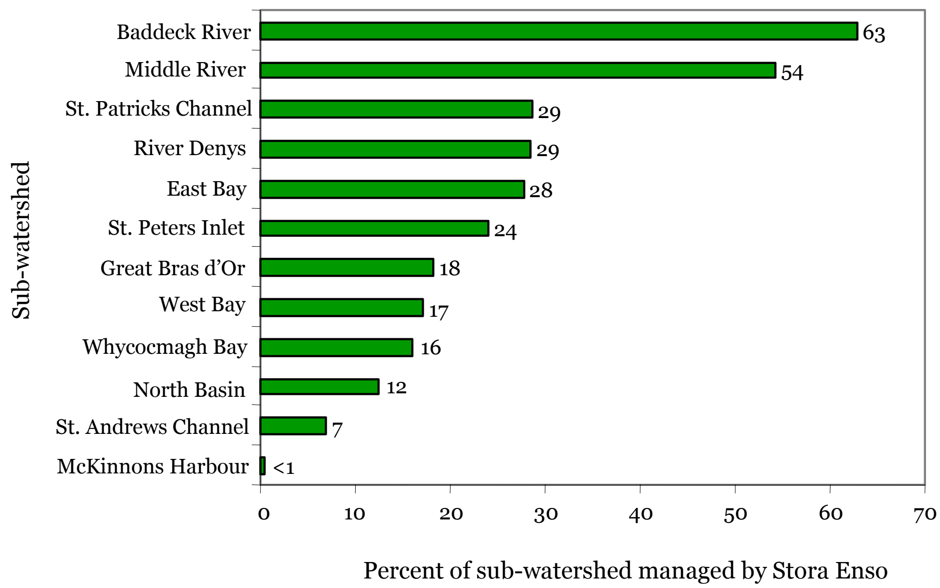


Figure 15. Amount of land in each Bras d'Or Lakes subwatershed managed by Stora Enso Port Hawkesbury. Data provided by Stora Enso Port Hawkesbury.

Table 33. Stora Enso Port Hawkesbury (SEPH) forestry areas and treatments broken down by subwatershed from 2001-2004[8]

Subwatershed	Area in watershed managed by SEPH (ha)	Subwatershed managed by SEPH (%)	Steep slope reserve (ha)	Area of clearcut (ha)	Area of partial cut* (ha)	Area of recent cut** (ha,% of subwatershed)	Protected areas (ha)
Baddeck River	18 999	63	1755	269	397	1426 (8%)	0
Middle River	17 582	54	1588	518	903	2402 (14%)	72
East Bay	9267	28	250	154	19	216 (2%)	0
River Denys	8270	29	543	73	100	336 (4%)	281
St. Patricks Channel	5591	29	152	13	259	625 (11%)	0
St. Peters Inlet	4269	24	17	31	12	577 (14%)	0
Whycocomagh Bay	3631	16	559	52	0	103 (3%)	55
West Bay	2879	17	27	24	1	299 (10%)	0
Great Bras dOr Channel	1992	18	344	85	0	88 (4%)	261
St. Andrews Channel	1281	7	16	20	0	25 (2%)	0
North Basin	1078	12	17	0	0	0	0
McKinnons Harbour	38	0.5	0	0	0	18 (48%)	18
TOTAL	**74 876 30% of wshed**	**n/a**	**5267 7% of wshed**	**1239 <1% of wshed**	**1692 <1% of wshed**	**6115 8% of wshed**	**987 1% of wshed**

* Partial cut: Moderate overstory removal in one pass with retention of 'stump sprouting' species
** Recent cut: Any clearcut less than 15 years of age (includes clearcuts)

[8] Data provided by Stora Enso Port Hawkesbury

22.4 Development and Land Use Planning

In East Bay alone, 63 groynes, 44 seawalls and 19 rip rap structures were observed along the shores during a 1996 aerial video survey (Taylor and Frobel 1998 cited in Taylor and Shaw 2002). Approximately 20 km (<2%) of the Bras d'Or shoreline have been modified and stabilized by anthropogenic activity (Taylor and Shaw 2002). Of a subset of barrier beaches surveyed, nearly 44 were classed as in breakdown and collapse phases of barrier evolution. As such they are particularly sensitive to human activities (Taylor and Shaw 2002). However, these structures are predominantly a result of activities conducted prior to 1988.

Since 1988, the Nova Scotia Department of Natural Resources (NSDNR) has administered all activities below the ordinary mean high water mark (OMHM) in the Bras d'Or, with the exception of some cases on First Nations Lands. The Inland and Coastal Waters Policy was developed in consultation with all federal and provincial departments and serves as a guide for all approvals. The authority for this administration is the *Crown Lands Act* and the *Beaches Act*. No infills are permitted below the OMHM unless they pass a full IRM review and are proven to be for the public good. Personal groynes or infills are not permitted and illegal activities are strictly enforced. Bank protection is allowed if it does not extend below the OMHM. Almost all of the man made structures along the coastal area of the Bras d'Or Lakes have been inventoried, measured, photographed and GPS measured by NSDNR staff, and entered into a NSDNR GIS database.

Land use planning is a complex process involving an array of legislation, documents, and people. The *Constitution Act* gives the province authority over property rights, which is then delegated to municipalities via the *Municipal Government Act*. The Municipal Planning Strategy is a document that establishes the framework and sets the context and direction under which planning occurs. It also provides the authority for regulation. Within the strategy the Land Use Bylaw outlines zoning, and details what is permitted where and under what conditions. A planner typically writes these documents for approval by municipal council, and provides advice to council on various land use issues. A development officer is responsible for interpreting the Land Use Bylaw, approves subdivision and issues development permits. Larger scale industrial developments are subject to provincial approval under the *Environment Act*. Some cases require both municipal and provincial approval, and some cases only require provincial approval (e.g. regulating gravel pits and quarries). The province also reviews Municipal Planning Strategies and occasionally creates "Statements of Provincial Interest" when conflicts arise.

Outside of the First Nations communities which are under Federal government jurisdiction, land development is regulated by four municipal governments. These are Cape Breton Regional Municipality (CBRM), Inverness County, Richmond County, and Victoria County. Development is regulated by Subdivision Bylaws, Municipal Planning Strategies and Land Use Bylaws adopted and administered by each municipal council. Planning staff carry out daily administration of the bylaws and strategies.

The Rural Cape Breton District Planning Commission is responsible for providing planning, subdivision and building inspection services for the "planned areas" of three counties (Inverness, Richmond and Victoria). Within Inverness County planned areas include Whycocomagh; within Richmond County planned areas include St. Peters and Sporting Mountain; within Victoria County planned areas include Baddeck (Figure 13). Outside of these planned areas there is no overall land use plan, only use-specific plans such as those developed by various industries in conjunction with the Planning Commission or other regulating bodies or government departments. The Planning Commission is jointly funded by the three municipalities. All four of the municipalities, together with the Province of Nova Scotia and the

First Nation communities, share a responsibility to protect the drainage basin of the Bras D'Or Lake from pollution.

Cape Breton Regional Municipality has its own Planning Department. CBRM is the only county in the watershed which is entirely covered by a Municipal Planning Strategy and Land Use Bylaw (adopted by Council in September of 2004). Within the Municipal Planning Strategy is a policy stating that "the CBRM continues to support the concept of an inter-municipal plan for the Bras D'Or Lake focused on its environmental remediation by continuing to participate in the joint planning endeavours of the three levels of government and the First Nations Reserves, and the Bras d'Or Lakes Stewardship Society." Also within the Planning Strategy is a policy of Council to "consider the drainage basin of the Bras D'Or Lake as a potential wastewater management district when developing a wastewater management strategy for the entire Regional Municipality".

Development statistics for the Cape Breton Regional Municipality for residential building permits are accessible as far back as 1986, and further if one goes to the paper records. Overall in CBRM, building permit issuance declined over the past decade, and when viewed on a map there are no development 'hot spots' that can be seen. Most of these developments are along the coastline.

22.4.1 Residential Development in the Cape Breton Regional Municipality portion of the Bras d'Or watershed 1987-2004

Section 22.4.1 contributed by Rick McCready, CBRM Planning Department

Three hundred and ninety-eight new residential dwellings were built between January 1, 1987 and December 31, 2004 in the portion of the Bras d'Or watershed that is within the Cape Breton Regional Municipality. Of this number, 100 were located on waterfront lots. The average lot size for these new dwellings was 4.08 ha, and the average waterfront lot size was somewhat smaller at 2.76 ha. It is interesting to note that the minimum lot size currently required by the Nova Scotia Department of the Environment for *new* building lots (that is, lots being subdivided today) is 0.28 ha. Of the 100 lakefront lots for which permits were issued in CBRM over the nineteen-year period, only five were less than 0.28 ha.

The trend in recent years has been toward less residential development in the watershed (Figure 16). For example, since 1996 there have been fewer than 20 permits issued in every year except one; prior to 1996 more than 20 permits were issued each year.

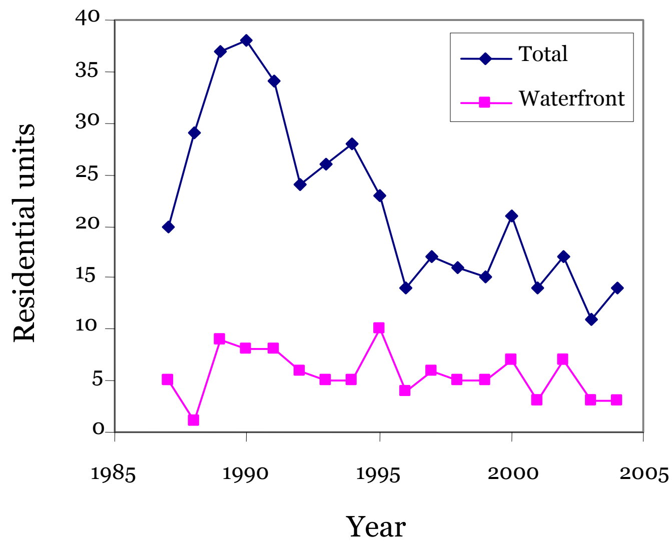


Figure 16. Summary of residential building permits issued in Cape Breton Regional Municipality within the Bras d'Or watershed from 1987-2004

Unfortunately, equivalent information on residential development in the other three municipalities within the watershed (Inverness, Richmond and Victoria) is not available at this time. It should also be noted that municipalities do not regulate residential development on First Nations lands, and as a result the statistics presented here do not include those communities.

Land Use Information for all four counties within the Bras d'Or watershed

In 2003 there were 22 431 parcels of land in the Bras d'Or watershed. Of these, 14 850 were vacant (no structures had been built on them) and 7581 were occupied by some form of development[9]. As some lots have more than one development (i.e. two dwellings or a dwelling and a business on the same lot) there were actually a total of 9863 developments in the watershed in 2003 (Table 34).

Table 34. Summary of developed lots in the Bras d'Or watershed as of 2003

Developed lot type	CBRM	Victoria	Inverness	Richmond	Entire Watershed
Developments with central sewer	910	657	368	480	2415
Developments with no central sewer	3065	2225	1251	907	7448
Total developments	**3975 (40%)**	**2882 (29%)**	**1619 (16%)**	**1387 (14%)**	**9863 (100%)**

Source: CBRM Planning Department with information from the NS Geomatics Centre. Watershed boundary created by Pitu'paq mapping project, 2004.

Of the developments in the watershed, only 2415 (25% of the total) are located in communities served by a central sewer system. The remaining developments are in areas where domestic sewage is disposed of by some form of on-site system. Areas with sewer systems are Little Bras d'Or, St. Peters, Baddeck, Whycocomagh, Eskasoni, Wagmatcook, and Chapel Island, although a few developments in these areas may not be connected.

[9] Developments are structures with civic addresses. Approximately 90% are residential with the remainder being used for commercial, agricultural, industrial and other purposes.

Land Ownership in the Bras d'Or watershed, 2005

Most lands within the watershed are owned privately by companies or individuals (62%), or the Province of Nova Scotia (33%) (Figure 17). Less than 3% of all watershed lands are owned by the federal, municipal and First Nations governments combined (Table 35).

Table 35. Summary of land ownership in the Bras d'Or watershed

Owner	Number of parcels	Size (ha)	% of the Bras d'Or watershed lands
Federal government	149	4689	2
Provincial government	1285	83 012	33
Municipalities/village commissions	59	819	<1
Band councils	32	1310	<1
Private	19 229	154 699	62
Road/rail segments	1677	4129	2
TOTAL	**22 431**	**248 658**	**100**

Source: CBRM Planning Department with information from the NS Geomatics Centre. Watershed boundary created by Pitu'paq mapping project, 2004.

It is worth noting that although the provincial government owns a great deal of land in the watershed very little of this land borders directly on the lake. Nearly all waterfront land is owned by private companies or individuals.

22.4.2 Nonresident Land Ownership

In 2001 a provincial analysis of non-resident land ownership was released (Voluntary Planning Task Force 2001). Nova Scotia ranks second lowest in Canada in terms of the amount of land owned by the Crown, at 25%. Non-resident is defined as anyone living in the province for less than 183 days in any given calendar year, and may therefore include Canadians as well as those from other countries. The analysis is summarized in Table 36. Most of the non-resident ownership in each county is by Canadians, followed by Americans and very small percentages of Germans, Swiss and 'other'.

Table 36. Non-resident property ownership in Cape Breton by county

County	Total non-resident properties	% of total county properties	Total area of nonresident properties (ha)	% of total county area
Cape Breton	2335	4	18 203	7
Inverness	2394	12	34 372	9
Richmond	1444	12	13 444	10
Victoria	1072	12	17 316	6

Source: Voluntary Planning Task Force 2001

Figure 17. Land ownership within the Bras d'Or watershed
Data sources: NSGC (no date); DFO (2003); Basemap (Natural Resources Canada, National Topographic Database 1:250,000 3rd Edition)

22.4.3 Road Density

Roads can impact the connectivity of ecosystems, and ecosystem connectivity influences the dispersal of plants and animals. Sometimes roads restrict dispersal, as in the case of animals that are unable to cross roads, and sometimes they enhance it, as in the case of plant species that spread along disturbed roadsides. The influence of any road extends for some distance, depending on factors such as road size, traffic volume, and type of use. Direct effects of roads includes road kills, avoidance behaviour, population fragmentation and isolation, pollution, and impacts on hydrology by way of increased runoff and increased sedimentation[10].

Road densities for each subwatershed (Table 37) were calculated and include primary and secondary paved, tertiary, old roads, inactive trails and wood roads[11]. As all road types such as old roads and inactive trails are included here the road density is likely very high compared to other studies that might have looked at this issue with respect to environmental impact analysis. Road densities above 2.0 km/km^2 are found in McKinnons Harbour, St. Peters Inlet, Great Bras d'Or Channel, St. Andrews Channel, and West Bay.

Table 37. Road density for each subwatershed[12]

Subwatershed	Length of road (km)	Road density (km/km^2)
McKinnons Harbour	83	2.56
St. Peters Inlet	178	2.28
Great Bras dOr Channel	109	2.18
St. Andrews Channel	184	2.04
West Bay	168	2.02
East Bay	332	1.84
Whycocomagh Bay	226	1.81
North Basin	87	1.73
St. Patricks Channel	195	1.72
River Denys	290	1.50
Baddeck River	302	1.45
Middle River	324	1.40

Road densities appear to be an appropriate indicator for predicting presence of moose and some other wildlife populations in Nova Scotia (Beazley et al. 2004). A road density threshold of 0.6 km/km2 has been shown to be correlated with a decline in some large vertebrate populations (Foreman et al. 1997 cited in Beazley et al. 2004). Many areas of mainland Nova Scotia exceed this threshold as do each of the subwatersheds within the Bras d'Or. Habitat fragmentation and human disturbance facilitated by roadways may have a significant impact on Cape Breton Island, which is in part naturally fragmented by the Bras d'Or Lakes themselves. Similar road densities to the threshold for wildlife are also shown to have hydrological impacts at the watershed scale and sediment delivery consequences to freshwater systems (Anonymous 1995).

[10] http://www.epa.gov/maia/html/road.html
[11] Data provided by Stora Enso Port Hawkesbury
[12] Calculated by Stora Enso Port Hawkesbury

22.4.4 Sewage Treatment

The NS Department of Environment and Labour regulates all development that is intended to be serviced by on-site sewage disposal systems. Most of the development in this category excluding First Nations communities, occurs at Baddeck and St. Peters where there are central sewer systems. Sewage treatment plants also exist at Whycocomagh and Evanston.

By population, 45% of Nova Scotians have their sewage treated and disposed of with home sewage disposal systems (on-site or septic), 25% have their sewage treated at a central facility, and 30% of the population has their sewage collected and disposed of raw into coastal waters (NS DEL 2001).

Sewage management is a complex legal issue that overlaps jurisdictions at all levels of government. Federally, eight acts and one set of regulations are relevant to the issue of water and wastewater. Relevant at the provincial level, Nova Scotia has four acts, three approval processes, two sets of regulations, two certifications, and one licensing requirement.

Rural land owners that are not hooked up to a central sewage collection system are entirely responsible for proper installation and maintenance of their septic systems. Although the Nova Scotia Department of Environment and Labour inspects new systems when they are installed, there is no legislation or regulation which requires regular inspections (however the Department recommends pumping every three to five years for proper functioning). On-site septic systems are expensive, ranging from $7,500 to $15,000, and local geology is not always appropriate for their installation and functioning (Malcolm 2003).

In the mid 1960s Nova Scotia prohibited the construction of new outfall pipes discharging raw sewage, but existing ‘straight pipes’ were not addressed at that time.

Some central community collection systems are outdated, although upgrades have been funded for St. Peters, Baddeck, Whycocomagh, and Eskasoni in the order of $10 million over the last 10 years (Malcolm 2003). Baddeck received $2.2 million for upgrading funding in 2001, started construction in 2002, and as of 2003 was 90% operational. The costs of installation and maintenance of central sewage systems have increased rapidly. In 1969, the average cost per connection was $1,500; in 2002, the average cost per connection was $20,000. Operating and maintenance costs have also risen similarly (Service Nova Scotia and Municipal Relations 2003).

Non-Discharge Designation

On July 6, 2006, regulations to prevent the discharge of sewage by all recreational and commercial vessels operating in Bras d’Or Lake, Nova Scotia, were announced. These regulations amending the Pleasure Craft Sewage Pollution Prevention Regulations add the Bras d’Or Lake to the Schedule. This includes “all connected waters inside a line joining Carey Point to Noir Point in Great Bras d’Or, southwards of Alder Point in Little Bras d’Or and northwards of the seaward end of St. Peters Canal” (Canada Gazette Part II 2006). Ultimately, this means that no craft will be allowed to discharge sewage, and holding tanks aboard all boats will be required to empty at marinas with pump-out stations.

Summary of the Non-Discharge Regulations

1. Every owner of a pleasure craft and a non-pleasure craft shall comply with these regulations while in a body of water designated.

2. No pleasure craft and non-pleasure craft shall discharge sewage into any body of water designated on schedule and no person shall discharge or permit the discharge of sewage from a pleasure craft or into designated waters.
3. Sewage may be discharged from a pleasure craft or non-pleasure craft into any body of water only for the purposes to ensure safety of the craft or any person on board or from result of damage to the craft or its equipment.
4. A pleasure craft that is fitted with a toilet shall be fitted with a holding tank (up to code) and if not fitted with a holding tank must have the discharge system visibly disconnected and closed so as to prevent the possible discharge of sewage from the craft.

Marinas with pump-out stations available include Baddeck, Grand Narrows, Dundee, St. Peters and the SS Marion Sailing Society Wharf in Whycocomagh.

22.5 Harvesting of Renewable Resources

In 1990, the UMA Group attempted a description of the Bras d'Or fisheries (UMA 1990). They suggested that there were 169 full and part-time commercial fishermen in the region (including licensed boat-owning fishermen and their helpers) – 79 in Big Bras d'Or, New Campbellton and Seal Island; 20 at Iona; 15 at Baddeck; 15 at Orangedale; ten at Little Narrows; and up to six at many other communities. This breakdown has likely changed dramatically since that time, but no recent statistics are available. Species fished in 1990 included cod, herring, mackerel, eel, and lobster (Kenchington and Carruthers 2001), and at that time, any individual in possession of a lobster license could fish for herring in the Lakes.

22.5.1 Lobster

The area south of Barra Strait makes up Lobster Fishing Area (LFA) 28, and the area north of Barra Strait is a part of LFA 27. Up until 1947, landings were recorded by county and after that, recorded by Statistical District. LFA 28 was not recorded separately from other LFAs until the mid 1980s. The portion of the Lakes in LFA 27 is fished only by a few fishermen, but landings for this part of the Lakes are not compiled separately from those of the entire LFA 27 area. The fishing season in LFA 28 is from early May to early July; in LFA 27 the season is from mid-May to mid-July (Tremblay and Reeves 2004). Of all landings in LFAs 27-30, 90% are from LFA 27 (mostly outside of the Bras d'Or) and less than 1% is from LFA 28 (Tremblay and Eagles 1998).

The management of all Maritime lobster fisheries are based on effort controls such as trap limits, limits on the total number of licences and restricted seasons, as well as protection of lobsters below minimum legal size and egg-bearing (berried) females.

Reported landings in LFA 28 were lower in 2001 than in 1997, whereas LFAs 27, 29 and 30 all reported increases as much as 30% (Tremblay and Reeves 2004). Yearly landings for LFA 28 are displayed in Figure 18.

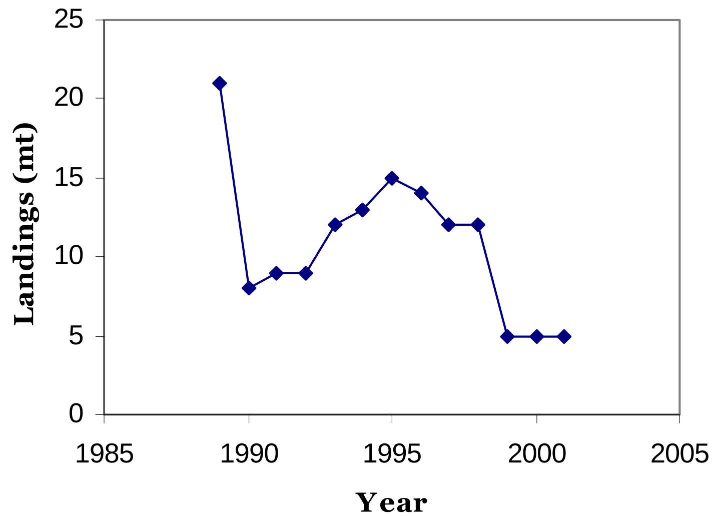


Figure 18. Lobster landings for LFA 28, the Bras d'Or Lakes area south of Barra Strait, from 1990 to 2002 (data from Tremblay and Reeves 2004)

In 1997 there were 18 lobster licences in LFA 28, each with a 275 trap limit and a minimum legal size of 81 mm. In 2003 there were 17 lobster licences, each with a 250 trap limit and a minimum legal size of 84 mm. The number of licences in LFA 27 that are fished in the upper Lakes is thought to be small (less than ten) and several license holders only fish part of their gear in this area (Tremblay pers. comm. 2005).

Conservation Measures

Conservation measures that were announced for LFA 28 in 1998 and put in place by 2002 include an increase in minimum legal size of 84 mm (carapace length) from 81 mm, and an increase in hoop size from 127 mm to 153 mm (Tremblay and Reeves 2004). For LFA 27 the minimum legal size increased from 70 mm to 76 mm.

Resource Status

Landings in LFA 28 decreased from 1997 to 2001, and landings were also down compared to the ten year mean (Tremblay and Reeves 2004). The lack of reliable indicators for LFA 28 clouds the picture of the stock status (DFO 2004c).

As a whole, landings in LFA 27 were higher in 2001 than in 1997 (the year before management changes were introduced). Coincident with the increase in minimum legal size in LFA 27, there were improvements in indicators for egg-bearing females and market lobsters in the north of LFA 27 (Tremblay and Reeves 2004)

22.5.2 Herring

The Bras d'Or herring are believed to be separate from the Gulf of St. Lawrence (4T) and the other spawning populations along the Atlantic coast stocks, and there is still some debate as to whether these fish move into the Lakes to spawn and then move out, or if they remain in the Lakes throughout their life cycle (Lambert 2002). Although the Bras d'Or spawning population is separate from other groups at the time of spawning, they are not completely isolated from other populations and some exchange may occur outside of the spawning season (Kenchington and Carruthers 2001).

The Lakes herring population should not be thought of as one group, as it includes sub-stocks (i.e., 'runs' of fish) which often intermingle. Herring likely return to the same spawning grounds year after year, and therefore intense localized fishing could deplete some sub-stocks while not impacting the rest of the population (Kenchington and Carruthers 2001). For example, fishers targeting a small spawning group could essentially overexploit that group to depletion without affecting other nearby spawning groups. This could, however, have long-term consequences on the sustainability of the spawning group by decreasing recruitment and lowering spawning stock biomass to a level from which future recruitment cannot recover. While homing of herring to natal spawning grounds is expected, there is evidence that herring have spawned in other areas when environmental conditions are optimal. Spawning grounds have varying degrees of intensities in different years, which is largely dependent on the length to which ice remains on the lake and in the spawning coves.

After spawning it is assumed that the herring migrate out to Sydney Bight in the late summer or fall and return in late winter or early spring. It is possible that much of the Bras d'Or stock is incidentally caught by purse seiners on the overwintering area of the Bight, where the Gulf of St. Lawrence and southwest Nova Scotia herring populations also overwinter (Kenchington and Carruthers 2001). Herring however are found in the Bras d'Or Lakes year round and in different stages of maturity.

Until 1999 there was a commercial gillnet spring fishery targeting the spawning herring groups. Fishing generally started after the breakup of the ice and lasted for 3-4 weeks. The primary spawning areas were along the western shore of West Bay, Denys Basin, St. Peters Inlet and near Eskasoni (Lambert 2002). In the last few years of the fishery it was noted that aside from an area near Malagawatch, the herring had stopped spawning south of the Barra Strait, and the only substantial egg deposition was found in Baddeck Bay (Denny et al. 1998). Other smaller pockets of spawning grounds can be found in East Bay. According to TEK, there used to be 32 spawning grounds for herring in the Bras d'Or Lakes but now there are few (CEPI 2006). TEK indicates that herring still spawn on sand bars along the shore in East Bay. Spawning has also been observed near Malagawatch and Johnson's Harbour, although there are only a few spawners at this location (CEPI 2006).

Mackerel, mostly used for lobster bait, increased in price in recent years which raised demand for herring (also used for bait), which was much cheaper (Lambert 2002). The timing of herring spawning just prior to the start of the lobster fishery made the capture of herring even more desirable. The sudden surge of fishing effort focused on the already declining herring stock brought the population to the point of collapse and the fishery was ordered closed in 1999.

Little is known about the Bras d'Or herring, including life history and population estimates. It has been suggested that there is a strong need to improve our knowledge of the Bras d'Or Lakes spawning areas (Melvin et al. 2003). Recent discoveries using elemental fingerprinting of herring otoliths suggests that Bras d'Or Lakes herring spend enough time separate from other groups to acquire a different environmental fingerprint incorporated into their otoliths (Denny pers. comm. 2005). This suggests that herring do not immediately leave the Bras d'Or Lakes nor do they enter just prior to spawning. Herring have been found under the ice in pre-spawning condition in Eskasoni in February. Herring that spawn in the fall have also been found and continue to be found until December when sampling ceased. These fish were found at different stages of maturity.

Management Overview

The herring fishery was the primary commercial fishery in the Lakes and is likely a major ecosystem component (Kenchington and Carruthers 2001). The winter flounder fishery ended in 1992 with the banning of commercial draggers from the Lakes, so possible damage from fishing gear is no longer a major concern (MacIsaac 2001). Signs of seriously reduced numbers of the population were noted in 1997 (Denny et al. 1998), a suspected result of overfishing (Lambert 2002) and a full closure was announced in 1999 (DFO 2000).

DFO and the industry attempted to reduce the fishing effort in 1998 and 1999 by keeping fishing activity away from areas where herring spawn, and closing the "choke points" (areas in the Lakes where fish are forced to pass through a narrow channel where they are easily targeted by fishermen) to fishing activity in 1999. Fishermen also increased the mesh size of their nets and limited the effort to fewer nets. Those measures did not achieve the conservation goals desired, so the Lakes remain closed to herring fishing to this day. As an indirect result, the use of nets to capture mackerel is prohibited due to the probability that mackerel nets may capture herring as well.

Recent trends

Six statistical districts cover the Bras d'Or Lakes and each of them include areas that are outside of the watershed (i.e. Atlantic coast/Southern Gulf of St. Lawrence ports are also included). This makes statistical analysis of fishery landings trends difficult, however Denny et al. (1998) managed to separate the Bras d'Or herring catches to show the long-term trend (Figure 19). They suggest that low landings in the early 1970s might be from lack of reporting, with an average of 181 t from 1978-1997.

Spawning is still absent from some traditional areas in the Lakes and the observed spring spawning biomass is very low (Power et al. 2003).

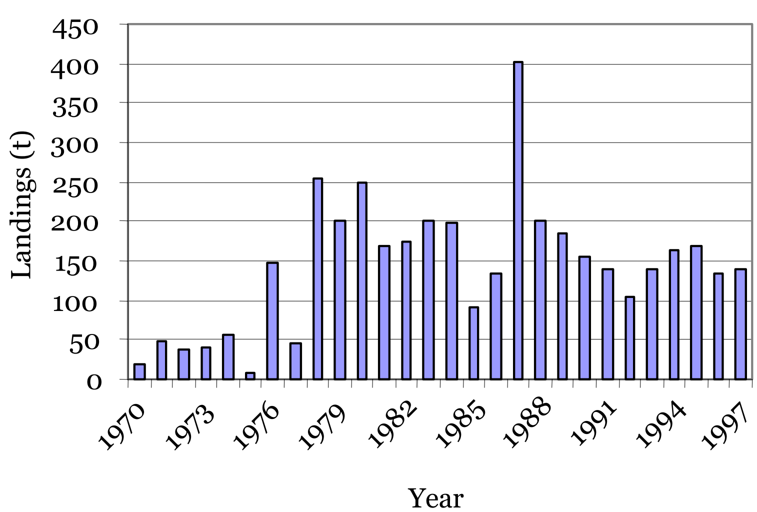


Figure 19. Recorded landings for the Bras d'Or spring herring fishery from 1970 to 1997 (from Denny et al. 1998). There has been no commercial fishery in the Lakes since.

22.5.3 Oyster

At present, oysters are the only species harvested through aquaculture in the Bras d'Or. Finfish species have been reared in the past within the Lakes, and finfish licenses have been issued by the Nova Scotia Department of Agriculture and Fisheries (NSDAF), however these leases are not active. All currently active aquaculture leases are for oyster.

The American oyster, *Crassostrea virginica*, is restricted to warmer estuaries primarily due to reproductive requirements, and the Nova Scotia area is the most northern limit of the species. The only major predator in Cape Breton is the starfish *Asterias vulgaris* (Rowell 1975). Historically, the oyster fishery has been executed by members of local Aboriginal communities, however there has been increasing interest by aquaculturists and other commercial harvesters in recent years. Long handled tongs or rakes are the main gear used for harvesting (DFO 1996). SCUBA, snorkeling and hand picking are only permitted on an aquaculture lease by the lease holder and cannot be employed during commercial fisheries. First Nation fisheries tend to occur on public beds and leases with year round harvesting because of historical treaty rights (DFO 1996).

Currently, oysters are harvested from both public grounds and private leases. There are three types of oyster fisheries that occur in the Lakes, each described in detail below:

- The lease (aquaculture) fishery: Harvesting occurs only on leased grounds or beds by SCUBA, snorkeling or hand-picking. This fishery is administered by the Nova Scotia Department of Agriculture and Fisheries (NS DAF).
- The relay fishery: Harvesting occurs on public beds that have been classified as closed by Environment Canada's (EC) Shellfish Sanitation Program. Oysters are harvested from contaminated areas for natural relay into areas approved by EC for the growing of shellfish. Harvesting occurs during the spring months prior to spat fall. This fishery is administered by Fisheries and Oceans (DFO).
- The commercial and recreational fishery on public beds: Oyster fisheries occur in areas deemed open or approved by EC. Harvesting may also occur in areas classified as conditional if environmental and physical conditions are acceptable. This fishery is administered by DFO.

The Lease/Aquaculture Fishery

The first private aquaculture leases were issued in 1865, and some are considered family heirlooms. Although there is a grand total of 409 ha of leased area allocated to 121 issued leases for aquaculture activity in the Bras d'Or Lakes, only 77 ha (19% of the total) reported any activity for the years 2000 to 2004. Oysters are currently the only organism grown and harvested under these aquaculture licences, and they may be harvested year-round. The geographic breakdown of oyster aquaculture activity is summarized in Table 38. Not included in Table 38 are 37 inactive oyster leases in other areas of the Lakes.

To establish a commercial aquatic farm, a licence and lease from the Nova Scotia Department of Agriculture and Fisheries is required. To apply for a licence/lease, proponents must pay a fee and submit an application with a detailed farm development plan. If the application is accepted, it undergoes a comprehensive review involving up to 12 provincial and federal agencies. All applications (except for shellfish grown directly on the bottom) must undergo an environmental assessment under the *Canadian Environmental Assessment Act*. The review process can take 12-36 months and can cost up to tens of thousands of dollars (paid by the proponent), with no certainty of success. This process also applies to expansions of existing operations.

Table 38. Summary of active oyster aquaculture leases in the Bras d'Or Lakes at the bay-scale[13]

Area (bay-scale)	Total number of leases issued in area	Number of active leases (as of 2004)	Total area of active leases (ha)	Percentage of total active lease area in the Bras d'Or Lakes
McKinnons Harbour	14	4	19.4	25
St. Patricks Channel	14	2	18.7	25
East Bay	13	4	18.5	24
Denys Basin	25	5	15.5	20
Whycocomagh Bay	18	3	4.5	6
St. Peters Inlet	35	0	0	0
Great Bras d'Or	2	0	0	0
North Basin	0	0	0	0
St. Andrews Channel	0	0	0	0
West Bay	0	0	0	0
TOTAL	**121**	**18**	**76.6**	**100**

Many lease holders collect spat (juvenile oysters) in other areas of the Lakes, for grow-out on their leases. A lease holder must apply to DFO for a spat collection permit as well as a transfer permit, which allows them to collect and transfer spat. All transfer permit applications are reviewed and approved by the Nova Scotia Introductions and Transfers Committee before they are issued.

Unfortunately, NS DAF landings statistics are not available for the Bras d'Or coast. Lease holders report their annual production to the Department, but the records are organized on a county basis and cannot be broken down further.

The Relay Fishery

There are a maximum of 14 relay licences awarded on an annual basis. These must be applied for each year, and the applicant must have a lease in an open area in which the oysters may depurate, or cleanse themselves of contaminants (e.g., fecal coliform). Lease holders with DFO relay permits collect oysters from public beds that have been classified as closed by Environment Canada's Shellfish Sanitation Program, and "re-lay" them onto their lease for depuration (a minimum of 30 days, or 14 days with testing). This fishery occurs during the spring months prior to spat fall. Only market sized oysters may be harvested (76 - 125 mm in shell height). Once the oysters are clean they are sent to market.

The Commercial and Recreational Fishery

The commercial fishery became a licenced fishery in 1998, however harvesting had been taking place for many years before this. Public grounds, or areas not under a lease, are a common property resource and anyone holding a licence (commercial or recreational) is allowed to fish them. Commercial and recreational harvesting is permitted from mid-September to the end of November. Tongs and rakes operated by hand are the only devices allowed for harvesting oysters in public beds, whereas snorkeling and SCUBA may be used on an aquaculture lease by the lease holder.

[13] Data from Nova Scotia Department of Agriculture and Fisheries

Approximately 240 commercial and 53 recreational licenses (limit of 25 oysters per day) have been issued in the Bras d'Or. However, the recreational fishery was closed in the fall of 2002 and only 172 of the commercial licences were renewed in 2003 (Figure 20). All of these licenses were first issued for the 1998 fishery and were available to eligible historical users.

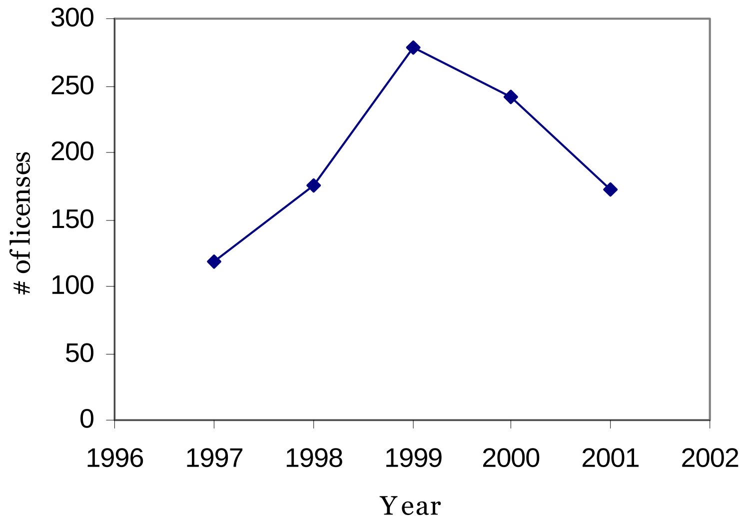


Figure 20. Number of commercial oyster licences issued for the Bras d'Or Lakes from 1997-2001. These licence holders are permitted to harvest oysters from any open public bed. Data provided by Lorne Penny, Fisheries and Oceans Canada.

DFO data on landings is very limited, but the 2001 season yielded 36 016 kg from the relay fishery by 14 harvesters and 17 638 kg from the commercial fishery by 56 harvesters. Stocks were depleted as a result of heavy harvesting of wild oyster stocks in 1999 and 2000, and the confirmation of MSX in 2002 closed the Lakes between 2002 and 2003. In 2002 a small relay fishery took place, which landed 11 886 kg. There was a small relay and commercial harvest in 2004 yielding 20 500 kg, and there is also a small harvest expected for 2005.

Regulations apply to all public beds, and are summarized as follows:

- To harvest, one must have a commercial or recreational licence issued by DFO (commercial or recreational), and harvesting may only be from open shellfish beds (as deemed by Environment Canada's Shellfish Sanitation Program)
- The minimum harvest size is 76 mm (shell height), maximum 125 mm
- The commercial harvest season is from mid-September to the end of November

Oyster Resource Status

The most recent comprehensive population survey was completed in the summer of 1990 using a combination of direct field observations and leaseholder interviews. The 1997 total standing crop of harvestable oysters was estimated to be between 340 000 and 1 million organisms, with 85% located on leases and 15% on public beds. Only 6.8% of oysters were found in closed areas (DFO 1996).

In 2001, the Unima'ki Institute of Natural Resources conducted research on the stocks in public beds and initiated some enhancement projects. Also, industry conducts annual science studies and enhancement projects in various areas of the Lakes. Unfortunately the data is not comprehensive in nature so cannot be compared to the 1990 data. Oyster sanctuaries have been established to assist in the rebuilding of the Bras d'Or oyster population. These closed areas were established by DFO in October of 2004 and include a 10 ha site in Denys Basin and two sites in St. Patricks Channel, one of 4 ha in Nyanza Bay and one of 3 ha at Morrisons Cove. The sanctuaries were established to protect transplanted oyster seed, and provide appropriate locations for disease and growth monitoring.

22.5.4 Salmon

Within the Bras d'Or Lakes watershed there are five rivers having historically reported Atlantic salmon angling: Baddeck River, Middle River, Indian Brook, River Denys and Skye River. Salmon stocks are assessed annually in the Middle and Baddeck Rivers (Robichaud-Leblanc and Amiro 2004). These two rivers have excellent water quality for Atlantic salmon rearing and no significant impediments to fish migration.

Commercial Fishery

In Eastern Cape Breton (Salmon Fishing Area 19) which encompasses the majority of the Bras d'Or watershed, the commercial salmon fishery was shortened in 1984 and has remained closed since 1985 (Robichaud-Leblanc and Amiro 2004). No commercial salmon fishing licenses remain in SFA 19.

Recreational Fishery

With the exception of Indian Brook which was closed all year, the recreational salmon angling season for rivers within the watershed was open for catch-and-release fly fishing only from June 1 to July 15 and September 1 to October 31 in 2003 (Robichaud-Leblanc and Amiro 2004). The daily catch-and-release limit in 2003 was two fish of any combination of small salmon (grilse) (<63 cm) or large salmon (≥63.0 cm). Recreational catch and effort for Atlantic salmon is estimated from Nova Scotia Salmon Angling License stubs returned by anglers.

In 2003, anglers spent an estimated 1328 rod days on Cape Breton Island's eastern rivers (Robichaud-Leblanc and Amiro 2004). Of this total, 554 rod days were spent in the Baddeck and Middle rivers (Table 39), accounting for 42% of the total recreational fishing effort exerted in the 15 Eastern Cape Breton rivers reported fished for salmon in 2003. Middle River had the highest catch per effort (0.51 fish/day) of salmon of all the Eastern Cape Breton rivers in 2003 and Baddeck had the second highest (0.5 fish/day) within the Bras d'Or watershed. There were no salmon reported caught from the Skye River or River Denys. Despite the closure of Indian Brook to recreational fishing in 2003 a few salmon were caught.

Table 39. Recreational catch and effort for Atlantic salmon on rivers within the Bras d'Or Lakes watershed in 2003

River	Observed number of anglers	Numbers caught (including releases)						Effort (rod days)		Catch per effort (Fish/day)
		Grilse		Salmon		Total				
		Obs	Est	Obs	Est	Obs	Est	Obs	Est	
Baddeck	49	17	24	55	77	72	101	145	220	0.5
Middle	73	16	24	95	144	111	168	220	334	0.51
Indian Brook	4	0	0	2	4	2	4	6	9	0.33
Skye	0	0	0	0	0	0	0	0	0	0
River Denys	0	0	0	0	0	0	0	0	0	0

Source: Robichaud-Leblanc and Amiro 2004

Aboriginal Fisheries and Harvest

Within the Bras d'Or watershed, an allocation of 220 salmon (small or large) was given to a maximum of 22 harvesters of the Native Council of Nova Scotia (Robichaud-Leblanc and Amiro 2004). The fishing of salmon by angling, snaring, spearing and dip netting were permitted methods of achieving quotas. An estimated 30 salmon (20 large and 10 small) were taken from a trap set in the approaches of the Middle River with another 10 large and 10 small salmon angled from the Middle River by Wagmatcook, Membertou and Eskasoni First Nations in late March and April. None were reported taken by First Nations on the Baddeck River.

Unlicensed removals of salmon

Fishery officers estimated unreported Atlantic salmon removals from all Eastern Cape Breton rivers in 2003 at 79 small and 109 large salmon for a total of 188 fish (Robichaud-Leblanc and Amiro 2004). It is not known whether these were taken from rivers within the Bras d'Or watershed.

Resource status

Conservation requirements for the Baddeck River are 2.0 million eggs which are expected from 450 large and 80 small salmon (Marshall et al. 1999). Estimated returns to the Baddeck River in 2003 were 305 large and 36 small salmon (Robichaud-Leblanc and Amiro 2004) (Figure 21). Population assessments for the Baddeck River in 2003 suggest that small salmon escapement (the number of salmon surviving to spawn) was 44% of the conservation requirement and large salmon was 67% of requirement. Although up 384% from 2002, large salmon escapement on the Baddeck River remained below the conservation requirement. Population estimates for the Baddeck River are low relative to other rivers in the area (e.g., Middle River and North River). Escapement to the Baddeck River has not met conservation requirements since at least 1994.

Conservation requirements for the Middle River are 2.07 million eggs which are expected from 470 large and 80 small salmon (Marshall et al. 1999). Estimated returns to the Middle River in 2003 were 554 large and 61 small salmon (Robichaud-Leblanc and Amiro 2004) (Figure 22). Population assessments for Middle River suggest that small salmon escapement was approximately 75% of the conservation requirement. Large salmon escapement was about 117%

of conservation requirement and up 561% since 2002, the highest since 1989. With the exception of 1996, conservation requirements had not been met on the Middle River since 1989. However, in 2003 conservation requirements were met.

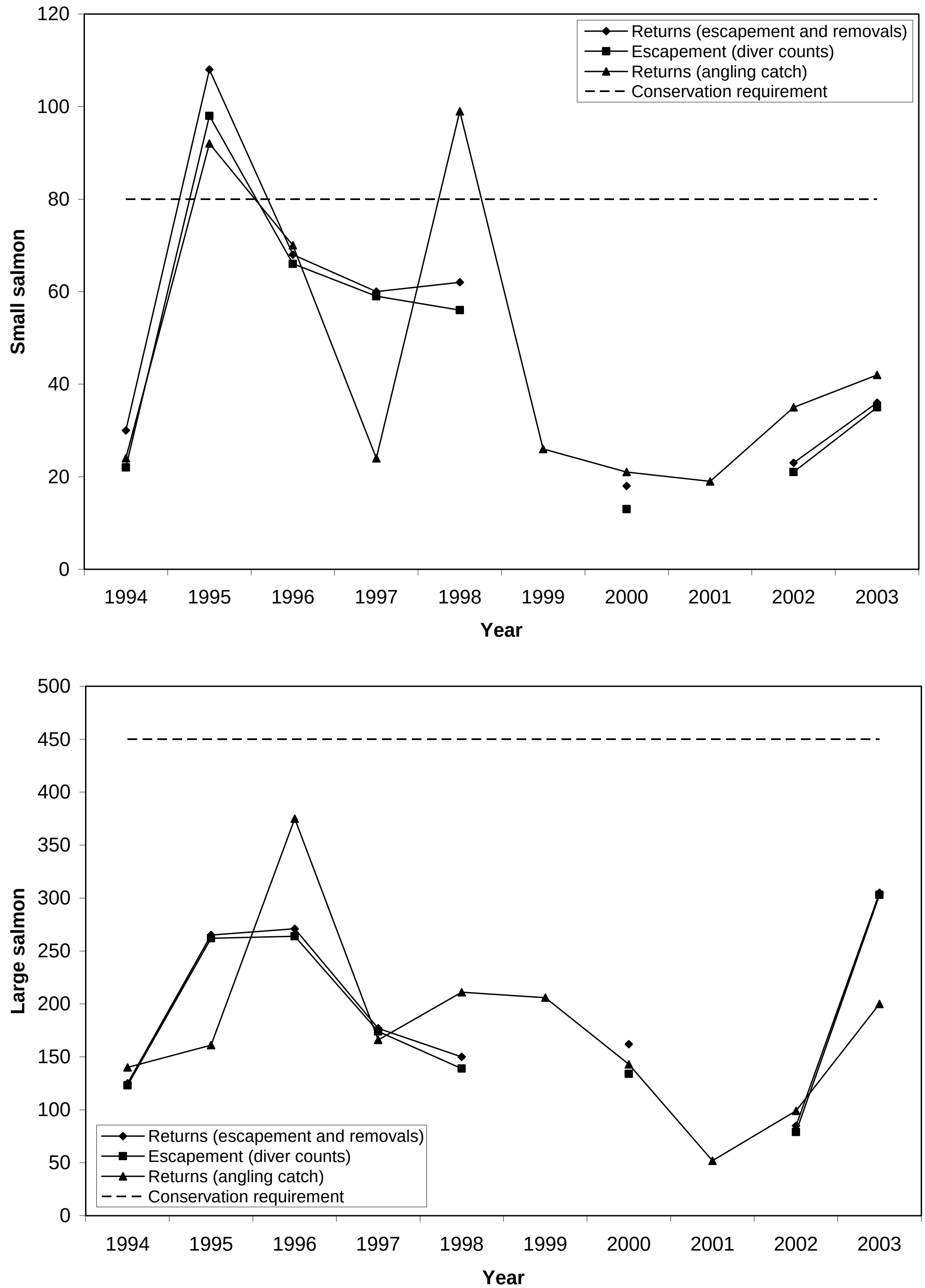


Figure 21. Annual estimates of small and large salmon returns and escapement to Baddeck River, 1994-2003 (based on data from Robichaud-Leblanc and Amiro 2004)

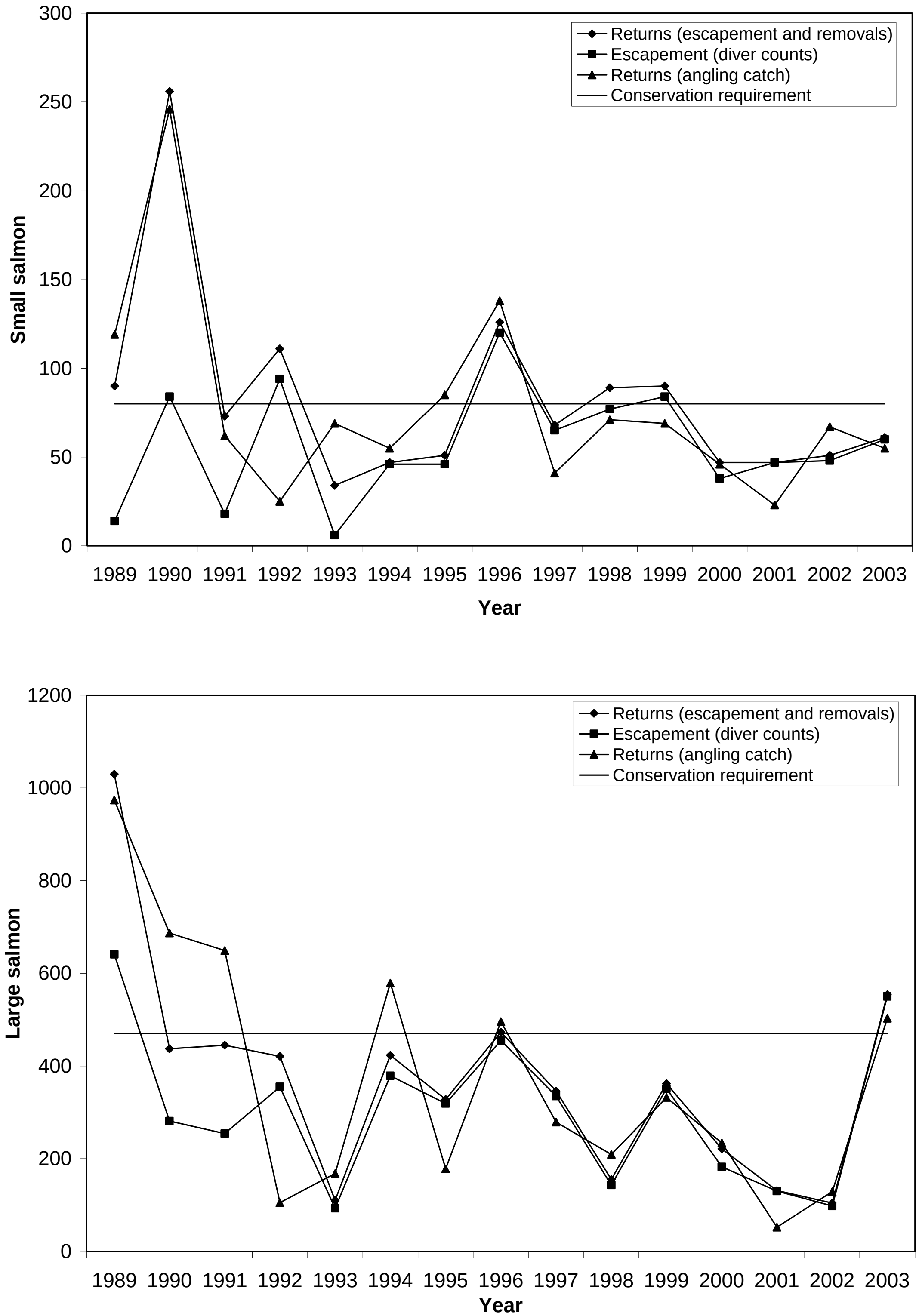


Figure 22. Annual estimates of small and large salmon returns and escapement to Middle River, 1989-2003 (based on data from Robichaud-Leblanc and Amiro 2004)

22.5.5 Hunting

Hunting statistics are not kept by watershed, and are instead compiled either by hunting zone or county. Generally speaking, though, moose hunting occurs annually from roughly the end of September to mid-October. Moose management zones 3 and 4 are located in the watershed (Figure 23), in Inverness and Victoria counties. Only 25 permits are issued for each of zones 3 and 4, out of 300-500+ applicants. The moose population on mainland Nova Scotia has been officially listed "endangered" under the Nova Scotia *Endangered Species Act*. Therefore, hunting is currently permitted only for the population on Cape Breton Island. Since 1986, the annual harvest for all zones combined in Cape Breton has ranged from 113 to 281 moose (NSDNR 2006b). Between 2003 and 2005, the annual harvest in zones 3 and 4 has ranged from 64-78 moose.

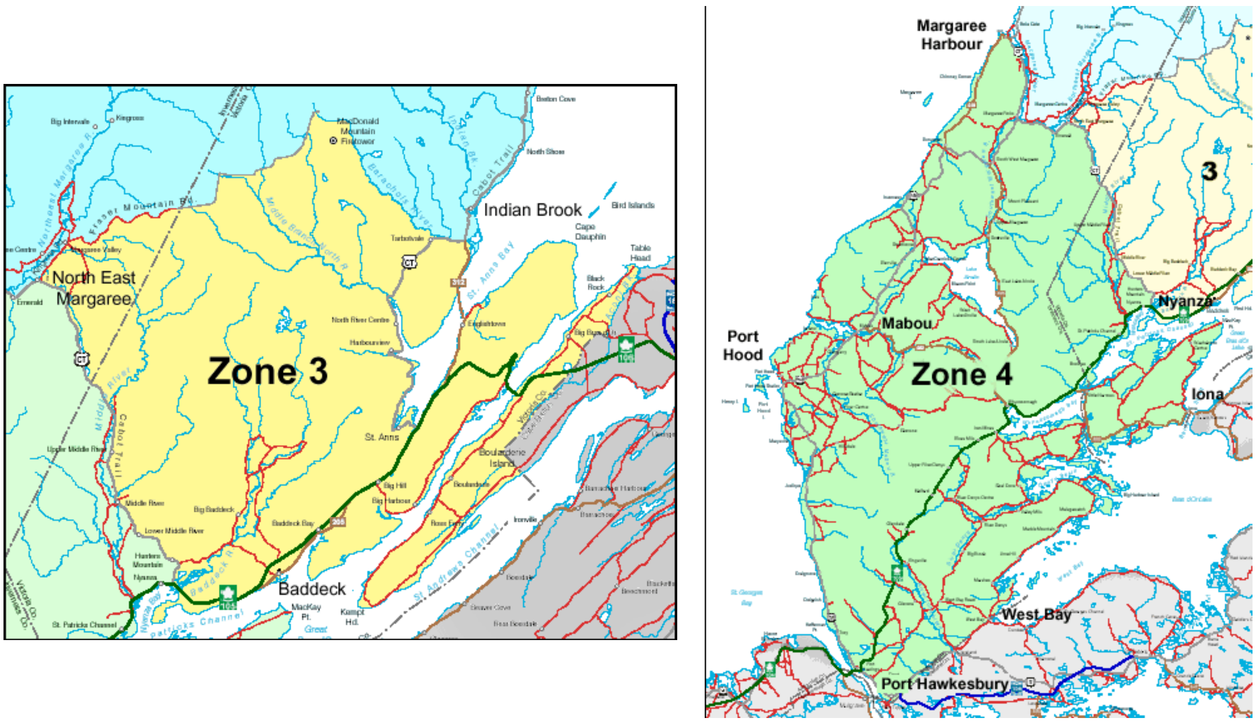


Figure 23. Location of moose management zones located in the Bras d'Or watershed[14]

Deer management zones 6 and 7 cover the entire Island (Figure 24). Deer hunting occurs in all four counties in Cape Breton, and a drastic decline has been seen since 2002 as a result of a harsh winter the previous year. For example, over 500 deer were harvested in Inverness and Richmond counties alone in the late 1990s and less than 25 were harvested in each of those counties in 2005; in 2005 a total of 151 deer were reported killed for zones 6 and 7 combined, compared to a total of over 7150 for the entire province of Nova Scotia (NSDNR 2006c).

[14] Figures from http://www.gov.ns.ca/natr/draws/moosedraw/mmzones.asp

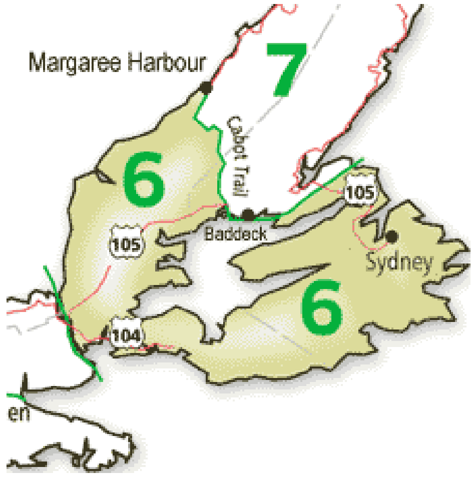


Figure 24. Deer management zones in the Bras d'Or watershed[15]

In Nova Scotia, bears can only legally be hunted, or snared using an Aldrich foot snare in the fall. Bear statistics are kept only for the entire province, not by hunting zone. Although not considered management units, data can be extracted and presented at the county level. Between 1993 and 2002, the annual provincial harvest (includes hunter and snaring harvest) ranged from 171 (1993) to 280 (2002) bears (NSDNR 2006a). The number of harvested bears appears to have increased in recent years (2003: 432, 2004: 842, 2005: 654), however, there is low confidence in these harvest estimate numbers because of the dismally low return of bear hunter report forms from which harvest statistics are derived.

There are also animals harvested for fur in each of the four Cape Breton counties; these include animals such as beaver, muskrat, otter, mink, bobcat, fox, racoon, weasel, and coyote. Harvesting of upland game (snowshoe hare, ruffed grouse and pheasant) also occurs in each of the four counties.

22.5.6 Plants

According to TEK, many plants and berries within the Bras d'Or Lakes watershed are harvested for food, ceremonial purposes and medicines (Table 40) (CEPI 2006). In recent years, gooseberries, cranberries, raspberries, wild strawberries and blackberries, all of which were once abundant, have noticeably declined. Potential reasons for the decline in berries include climate change, acid rain and development of houses. Mint leaves, hazelnuts and Indian Pipe have also disappeared, and the mayflower and black-eyed susies are now harder to find. The decline of plants around the Bras d'Or area has had an impact on the Aboriginal community because it has become difficult to find the plants needed to make certain traditional medicines.

[15] Figure from http://www.gov.ns.ca/natr/draws/deerdraw/ddZones.asp

Table 40. Plants harvested within the Bras d'Or Lakes watershed (modified from CEPI 2006)

Common name	Mi'kmaq name	Use
Sweetgrass	Wjinsiku'l	Ceremonial purposes, opening prayers
Peppermint leaves	Plamuipkl	Cold medicine, tea, food, stomach medicine
Blackberries and root	Najoqjemin	Stomach medicine
Golden theath	Wisawtaqjijkewe'l	Cold medicine, high blood pressure, tea, salve cures anything
Tea berries		
Pepsin plants		
Crow berries	Kaqauejuman	
Cranberries	K'lu'n	
Gooseberries	Apaqtejkl	
Foxberries		
Flagroot	Ki'kwesuskl	
Wild turnip	Pakosi	Good for flu
	Jikmueyey Pakosi	
	Melkamu'kowey	
Buttercups	Jipaqteskewe'l	Used as tea and can be crushed and wrapped around knees
Caraway seeds	Pqajkkjij	
Oak tree	Mimkom	Diarrhea
Wild cherry tree	Mujiwimanaqsi	Take off bark, boil, add sugar and use as a cough syrup
Service berry or Saskatoon berry	Pituiskijijik	Used to make pies
Dandelions		Jam and wine
Blueberries	Mkwiman	
Sugar berries	Knijijk	
Mint leaves	Plamuipkl	Tea
Hazelnuts	Maliqumjil	
Fern (eggs)	Npiktuniej	
Flagroot	Kikwasusk	
Spruce Gum	Wisapeklow	Used as a gum and the bark (Jikmuutp) was used as medicine for a sore throat
Punchberries	Kaqawejmin	
Fiddleheads	Mteskmwaqsil	
Hot parsnips	Eptekewe'l	
Wild rosebush	Kesipalka'luajijik	Diarrhea
Mayflower	Amaltaqiaqewe'l	
Black Eye Susies		
Violet	Temkuetotimkewel	Medicine
Yellow flower		
	Tuklijuimis	Salve cures anything
Poison ivy		
Indian Pipe	Tamaqn	

22.6 Extraction of Non-Renewable Resources

22.6.1 Mining

Cape Breton has a long mining history, with coal mining beginning over 250 years ago. In the early 1700's, coal was extracted from exposed seams along the cliffs. In 1720 the first coal mine was officially opened at Cow Bay, now known as Port Morien (CBMM 2006). In the 1800's, many company houses could be found at Morien, along with hundreds of miners. In 1873, there were eight coal companies operating in Cape Breton. Currently there are no coal mines in operation within the watershed.

Within the Bras d'Or watershed, most of the historic quarrying would have been for gypsum and limestone. According to historical geological maps, several gypsum deposits had been surveyed near Plaister Mines and the Big Harbour area (near Baddeck), Little Narrows, south side Whycocomagh Bay, McKinnon Intervale, and the Big Harbour Centre area by 1884 (GSC 1884). The Plaister Mines were active in the late 1800's. Several limestone deposits were surveyed at Irish Cove, north of Whycocomagh, near Salt Mountain, along McCuish Brook, Lime Hill, and Clarke Cove. In 1884, five quarries existed between Lime Hill and Clarke Cove. There was also a marble quarry near George Pond (GSC 1899). Gypsum and limestone deposits were also identified in the Middle River area and along the River Denys (GSC 1884). Copper and iron deposits were identified within the watershed but they were not as numerous as the gypsum and limestone deposits.

Currently, the only active mining operations in the watershed are for industrial minerals. Nova Scotia accounts for 81% of Canada's production of natural gypsum and for almost all of its exports. The majority of gypsum is shipped raw by ocean freighter to East Coast ports in the United States. Two gypsum mining companies operate in the watershed, Georgia-Pacific Canada Inc. in Melford and Little Narrows Gypsum Company in Little Narrows, accounting for 31% of the province's production in 2004 (NSDNR 2006d). There is also a small active red marble quarry owned and operated by MacLeod Resources near River Denys, and a limestone quarry owned and operated by Scotia Limestone Limited. Figure 25 illustrates the approximate locations of the current mining activities, inactive open pits, mines and quarries, and abandoned mine openings[16] within the Bras d'Or watershed.

Melford Gypsum

Owned and operated by Georgia-Pacific Canada Inc., the Melford mine was developed to replace the company's nearby Sugar Camp mine in 2002 when the latter was expected to be mined out. The company later decided to bring Melford on stream and to continue operating the Sugar Camp mine as well, but at a reduced level of output. The old Sugar Camp mine is outside of the Bras d'Or Lakes watershed, and the Melford mine falls within it. Together both mines employ a staff of 121 people (NSDNR 2006d).

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[16] The locations of abandoned mine openings are from a database of published abandoned mine openings for the province of Nova Scotia, created and maintained by the Nova Scotia Department of Natural Resources, Mineral Resources Branch (NSDNR 2006e). This information should not be considered a complete record of all abandoned mine openings in the Province. Other abandoned mine openings exist which have not been identified. The location of identified abandoned mine openings as shown may not be precise. The abandoned mine openings data does not include quarry or open pit mining sites nor is it a record of underground mining activity.

The Melford mine, approximately 250 ha in size (Hennick pers. comm. 2006), is located in the River Denys subwatershed, and is approximately 20 km upstream from Bras d'Or Lake. The site is operational 24 hours a day, seven days a week. Mined gypsum is crushed on-site and transported to the Point Tupper ship loading facility by transport truck. Ten trucks are used to haul the gypsum from Melford to Point Tupper, a distance of 40 km, and each can be loaded, weighed and dispatched in approximately six minutes. This results in approximately 42 100 truckloads shipped annually via Highway 105 and through Port Hastings and Port Hawkesbury to the Point Tupper marine terminal (KPMG LLP 2003). The Melford mine produced 1 363 769 tonnes of gypsum in 2004 (NSDNR 2006d).

According to a consultant's report (ADI 1999), the life of the Melford mine is estimated to be approximately 20 years. All water pumped from excavation and runoff water is directed to settling ponds which are eventually discharged into Beaver Brook. Water needed for mining operations is supplied by a pipeline from North Brook and/or a well in the Glen Brook Valley.

Little Narrows Gypsum

Operated by Little Narrows Gypsum, a division of United States Gypsum, this surface mine near the settlement of Little Narrows (Victoria County) exports raw gypsum and anhydrite. It falls within the St. Patricks Channel watershed, and has been producing gypsum since 1935, under two different owners. United States Gypsum (USG) has owned the company since 1954. Today, the mine and plant cover an area of approximately 809 ha.

From docking facilities on the Bras d'Or Lakes adjacent to the quarry, Little Narrows Gypsum ships approximately one million tonnes of quarried gypsum yearly by vessel to several destinations in the United States, including Baltimore, Maryland and Florida. Water depths in the Bras d'Or Lakes limit outgoing tonnage to 40 000 despite a vessel capacity of 60 000 tonnes (KPMG LLP 2003). As the loading facility is closed from January to March, this amounts to roughly 30 vessels per year from April to December.

Little Narrows Gypsum Company's anhydrite quarry produced 71 441 tonnes in 2004 (NSDNR 2006d). Gypsum production for the same year was 1 105 480 tonnes. The company employs 99 people.

Kennedy's Big Brook Red Marble Quarry

MacLeod Resources Limited was founded in 2000, and after receiving a mining permit in 2002, developed Atlantic Canada's only red marble quarry, located along North Mountain in the Rivers Denys subwatershed, 6.4 km from the settlement of River Denys (MacLeod Resources Ltd. 2006). This rare deposit of red marble is believed to be one of the few of its kind in the Western Hemisphere. There is an estimated volume of more than one million cubic metres of marble on site and recoverable, with 56% being pale-pink to red (rare and most valuable). The total quarry area expected to be utilized over a 12-15 year operational lifespan is 1.1 ha. The Kennedy's Big Brook Marble Quarry operates year round. Production was 16 326 tonnes of red marble in 2004 (NSDNR 2006d).

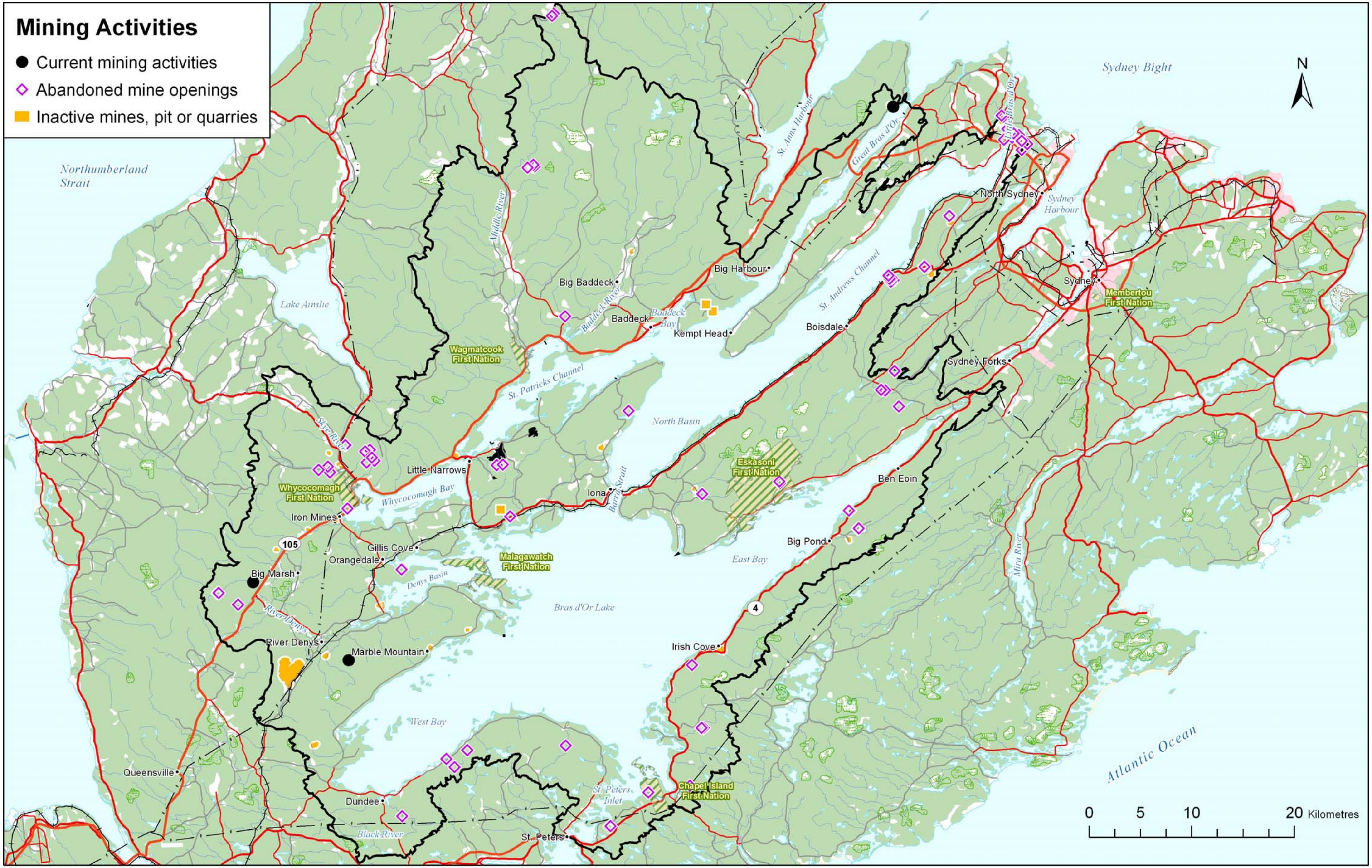

Figure 25. Approximate locations of current mining activities, inactive open-pit mines, pits and quarries, and abandoned mine openings in the Bras d'Or watershed
Data sources: NSDNR (2006d, e); DFO (2003); Adams (1991); Operational Open Pit (Mines, Pits, Quarries), Natural Resources Canada (NRCan), National Topographic Database (NTDB) 1:50,000; Basemap: NRCan, NTDB 1: 250,000.

Scotia Limestone Mine

Scotia Limestone Limited owns and operates a limestone quarry and plant in Kelly's Cove near New Campbellton. The plant produces an agricultural grade dolomite for domestic sale and dolomite products for the offshore steel industry (NSDNR 2003b). Production was 773 tonnes of dolomitic limestone in 2004 (NSDNR 2006d). The company employees a staff of two.

Marble Mountain

Although inactive since 1991, Marble Mountain is worthy of mention. Marble Mountain was mined for limestone for over 100 years beginning in 1869, and at one point employed over 700. Most of the limestone was not of high enough quality or strength to be considered marble for use as building material, so lower-grade limestone was extracted and shipped to coal and steel factories in the Sydney area. In total, approximately five million tonnes of limestone were removed from the site (Dickie pers. comm. 2005).

22.6.2 Onshore Petroleum Activity

Section 22.6.2 contributed by Jack MacDonald, Nova Scotia Department of Energy

Historical

Drilling for oil and natural gas in Nova Scotia dates back to at least 1869. Provincially, some 116 wells have been drilled specifically looking for oil and gas, while another 69 drilled as mineral exploration holes encountered some indication of oil and natural gas. In Cape Breton there have been 64 wells drilled for petroleum since 1869, many of which were located in the vicinity of Lake Ainslie (Figure 26). The last well drilled on the Island was in 1988 and was in the vicinity of Mull River.

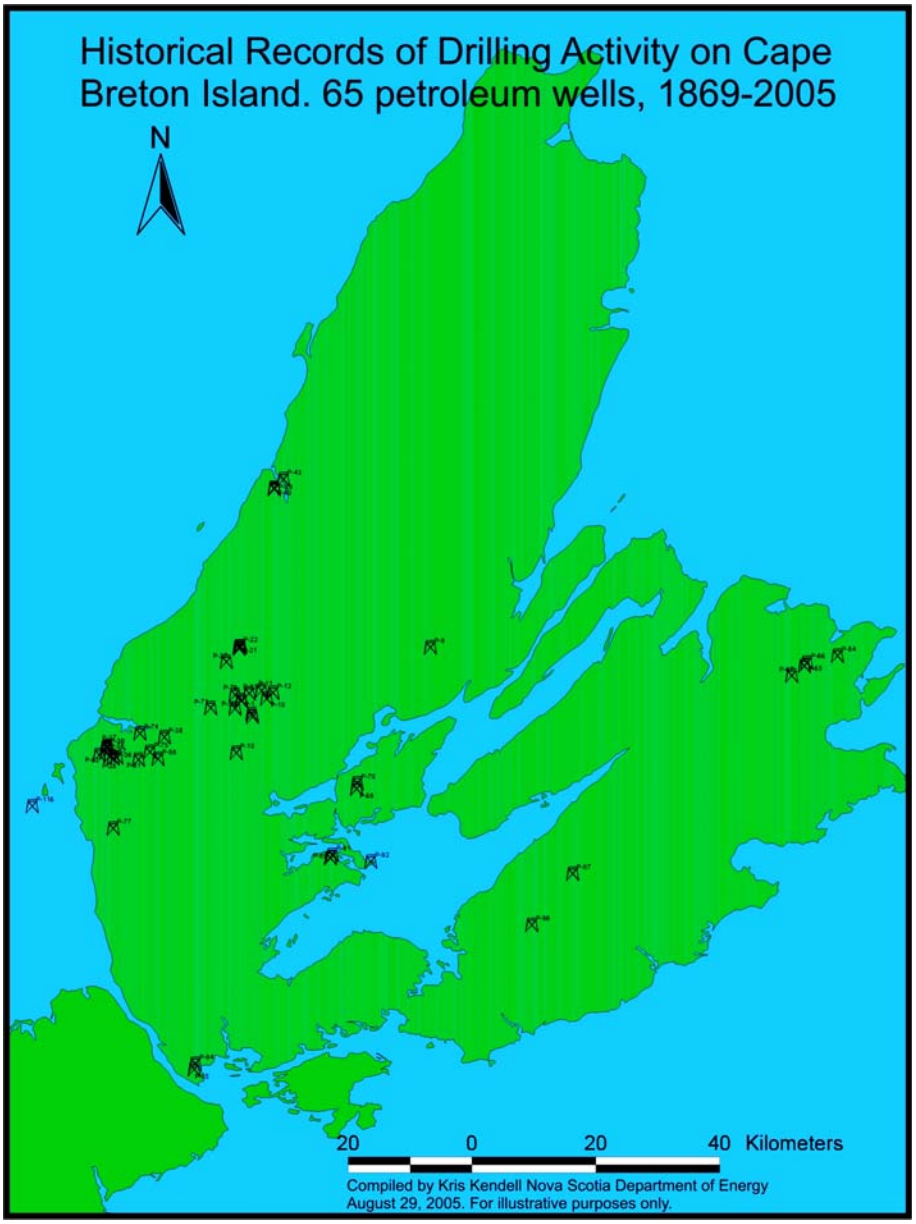

Figure 26. Location and concentration of petroleum drilling on Cape Breton Island from 1869-2005

Seismic surveying which generally precedes drilling, is a more modern development when compared to drilling. There were two small programs acquired in the Sydney area in mid-1960. One survey of interest was conducted over the Bras d'Or Lakes using a ship-towed low energy air gun source (Figure 27). This program was acquired for Chevron Canada during the summer of 1980.

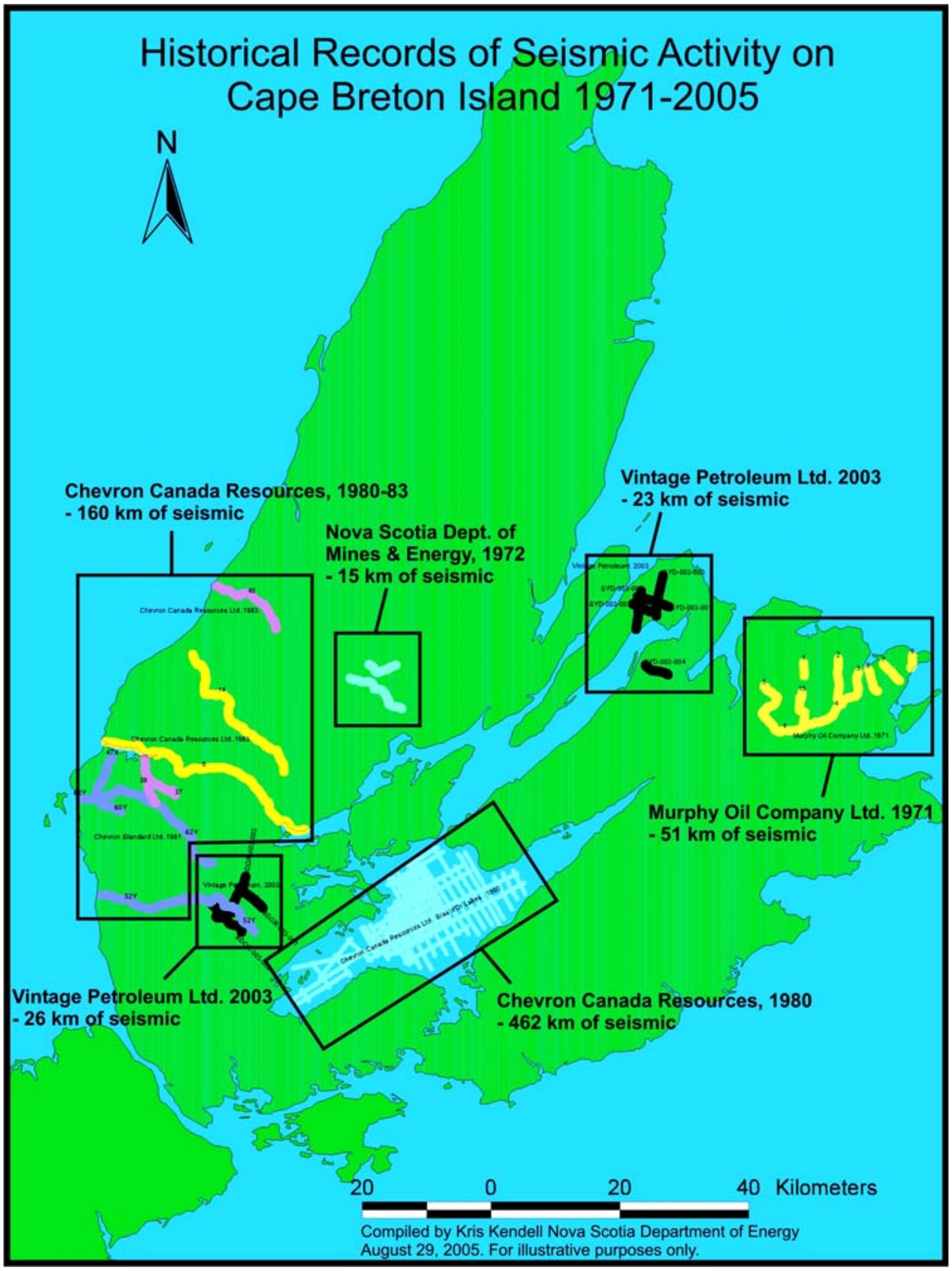

Figure 27. All seismic activity on Cape Breton Island from 1971-2005

Operational

On-land seismic utilizes one of two methods. The first is "Vibroseis" which uses specialized trucks that travel existing roadways, stopping at frequent intervals to lift partially off the ground and vibrate to send sound waves into the earth. The second method surveys across areas where there are no tracks or roadways. Typically, industry will drill small diameter holes with a portable drill to depths of approximately 6 m and then load them with one kilogram charges of dynamite. The hole is backfilled and the charge set off sends sound waves into the earth. In both cases 'geophones' (microphones) are placed on the ground at set intervals to detect the sound waves as they are reflected back to the surface from the various rock layers at depth. The waves take different times to arrive back at the surface which are what produces the seismic profiles that industry uses to predict structures and traps where hydrocarbons might be found.

Drilling will often occur in the field season that follows the year that the seismic data was acquired. The drilling program lays out the details of what rock layers are expected at what depths and the type of drilling procedures that will be used. The drill site normally occupies an area that measures approximately 90 by 90 m. The length of time it takes to drill the well depends upon its depth. Typically, wells can be as deep as 3000-4000 m and take four to eight weeks to drill.

Approvals

No activity is permitted unless approved by the Nova Scotia Department of Energy. The approval process requires a number of things, many by the company and a number of approvals from other affected government agencies who have direct responsibility for various aspects. The company's work plan (seismic or drilling) must:

- be reviewed directly with other government departments and agencies (Natural Resources, Transportation, Environment & Labour), and in some cases both federal and provincial agencies who share jurisdiction may be involved,
- be shared with the general public at an Open House,
- have landowner permission,
- address any cautions and/or concerns raised by any of the above, and
- be approved by the Department of Energy (with or without conditions).

Inspections by responsible agencies can (and do) occur at any time during the programs and work stoppage or prohibitions can be issued at any time. The company must be released from the program following final inspections and approvals. The company must also file security bonds to guarantee the performance of all obligations under the *Petroleum Resources Act*, Regulations, and Approvals granted.

Current Activity

No applications were received in 2005 or 2006 for any on-the-ground work to be conducted on the petroleum licence blocks on Cape Breton Island as shown in Figure 28. Should an application be received to conduct work it would follow the above process.

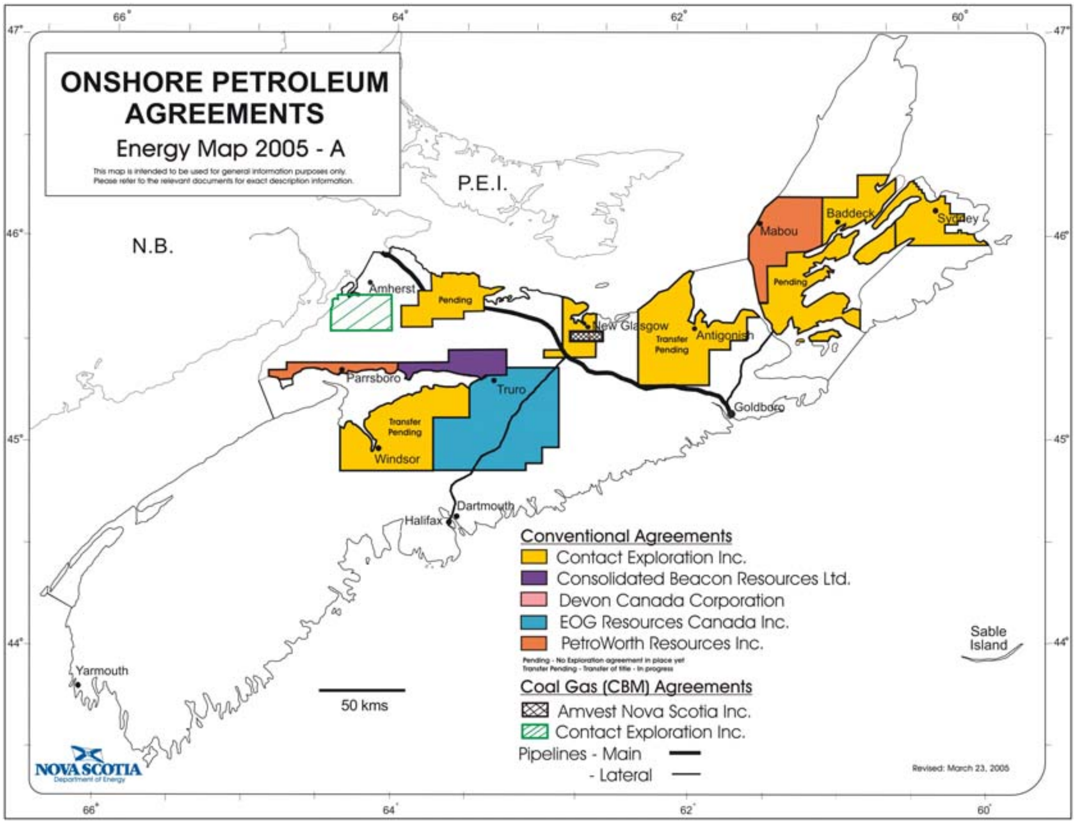

Figure 28. Onshore petroleum agreements in Nova Scotia as of 2005[17]

22.7 Transportation

22.7.1 Industrial Shipping

The Bras d'Or Lakes can be accessed through its three channels although traffic through the Little Bras d'Or Channel is limited to local boats familiar with the narrow passage. The majority of marine traffic travels through the Big Bras d'Or Channel and the St. Peter's Canal (Malcolm 2003). Commercial activity in the Lakes occurs from May to December. The majority of recreational boating activities are from May to October.

Table 41 provides an overview of vessel movements and cargo tonnage transported at ports in the Bras d'Or Lakes.

[17] Figure from http://www.gov.ns.ca/energy/

Table 41. Number of movements, vessel capacity, and tonnage transported by port for domestic and international shipping (2002) (Statistics Canada 2004b)[18]

Port	Ballast			Cargo			Total tonnage handled ('000t)
	# of movements	Gross tonnage ('000t)	Net tonnage ('000t)	# of movements	Gross tonnage ('000t)	Net tonnage ('000t)	
International							
Baddeck	8	41.0	12.4	0	0.0	0.0	0.0
Little Narrows	32	693.5	236.1	32	693.5	236.1	797.2
Domestic							
Little Narrows	12	252.7	154.2	12	252.7	154.2	371.5

The majority of industrial shipping in the Lakes is the transport of gypsum from Little Narrows Gypsum Company, in Little Narrows. This is a loading facility only, meaning the ships come in empty and leave full of cargo. The facility is typically closed from the beginning of January to the end of April (weather dependent). The number of vessels docking varies (Figure 29), but on average 45 vessels per year are entering and exiting the Lakes. During the busier times (May to December), about two ships per week enter and leave the facility. Gypsum vessels come from either Baltimore, Maryland or Jacksonville, Florida (Hemphill pers. comm. 2005).

[18] Statistics Canada (2004) derives its statistics from two surveys: the Coastwise Shipping Survey and the Marine International Freight Origin Destination Survey. The Coastwise Shipping Survey population consists of ships engaged in domestic shipping at Canadian ports, with the exception of: i. cargo vessels less than 15 net register tons (NRT); ii. tugs or other vessels under 15 gross register tons (GRT); iii. Canadian naval ships; iv. fishing vessels; v. research vessels; vi. ballast movements for towboat and ferry operators on the West Coast ports; vii. cargo carried in trucks and rail cars on domestic vehicle ferries.

The survey population for the Marine International Freight Origin Destination Survey includes vessels engaged in international shipping at Canadian ports with the exception of (i) fishing boats registered in Canada or abroad, (ii) maintenance and service ships such as icebreakers, (iii) research vessels and (iv) other non-commercial vessels such as hospital ships.

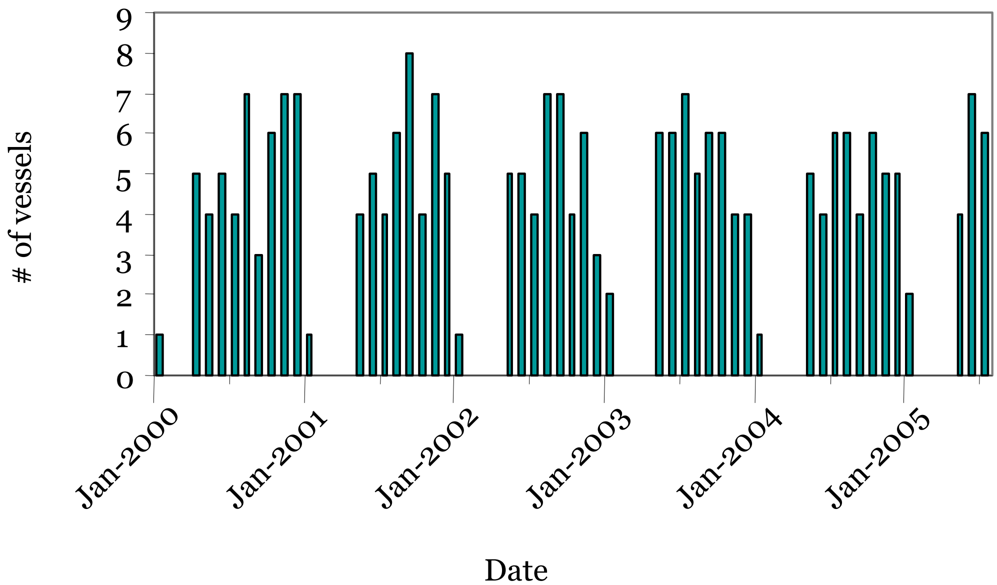

Figure 29. Total number of gypsum vessels per month which enter and leave the Bras d'Or Lakes via the Great Bras d'Or Channel. Each vessel enters empty, is loaded with gypsum at the Little Narrows Gypsum facility, and leaves the Lakes full.[19]

22.7.2 Cruise Ships and Ferries

Smaller cruise ships such as the 100 passenger Nantucket Clipper and the 90 passenger Le Levant (both approximately 100 m long, 14 m wide) occasionally cruise into the Lakes and dock overnight at Baddeck, however it is not a common occurrence.

A small vehicle and passenger cable ferry crosses the small channel of Little Narrows (less than 0.5 km). It is operated by the Department of Transportation and Public Works and runs year round. The ferry holds 12 average sized cars.

22.7.3 Harbours and Facilities

22.7.3.1 Boat Ramps

There are 13 boat ramps available around the Bras d'Or Lakes for launching and removing personal recreational boats (Table 42). Responsibility for maintenance of these facilities varies from provincial departments to community groups. Boat ramps that are truly "public" are those operated and maintained by NSDNR. As they are public facilities, boat ramps in the Bras d'Or may be used by anyone at any time with the exception of Baddeck, which is privately owned. In addition to the public ramps, there are many private ramps in existence which are administered by the group operating them and may offer restricted use by the public for a fee or under certain rules.

[19] Data from Mark Hemphill, Plant Manager, Little Narrows Gypsum Company

Table 42. Boat ramp facilities on the Bras d'Or coastline[20]

Location	Watershed	Width (feet)	Responsibility
Head of East Bay	East Bay	?	NSDNR
Ben Eoin	East Bay	12	NSDNR
Big Pond	East Bay	12	NSDNR
Dundee	West Bay	29	NSDNR
Marble Mountain	West Bay	12	Marble Mountain Wharf Preservation Society
Big Bras d'Or	Great Bras d'Or	16	Harbour Authority of Big Bras d'Or
Ross Ferry	Great Bras d'Or	9	NS Department of Natural Resources
Orangedale	Denys Basin	20	NS DAF
Whycocomagh	Whycocomagh	14	NS DAF
Baddeck	St. Patricks Channel	19	Bras d'Or Yacht Club
Tip of St. Andrews Channel	St. Andrews Channel	10	Bras d'Or Boat Club/NSDNR
Grand Narrows	North Basin	12	Grand Narrows Preservation Society
St. Peters Canal	St. Peters Inlet	10	Parks Canada

22.7.4 Recreational Boating

The recreational boating season generally runs from May to October. No statistics are kept on recreational boating activities in the Lakes, however staff at the Bras d'Or Yacht Club in Baddeck suggest that vessel traffic has been declining during the past five years. All recreational boating facilities available in the Lakes are summarized in Table 43.

Table 43. Recreational boating facilities in the Bras d'Or Lakes

'Bay'	Marina	Slips	Moorings
St. Patricks Channel	Baddeck	17	15
St. Patricks Channel	Cape Breton Boat Yard	25	6
West Bay	Dundee	?	?
Bras d'Or Lake	Barra Strait	9	6
Outside of Lakes, but many boats travel into the Lakes via St. Peters inlet	St. Peters	57	10

22.7.5 Boating Activity

There is no single definitive information source for the number of boats within the Bras d'Or Lakes region. In addition, the number of boats on the lake can vary greatly depending on the season, weather conditions, etc. Malcolm (2003) reports that approximately 445 local power and sailboats with fixed heads occur within the Bras d'Or Lakes, based on the number of private and public slips and moorings within the Lakes (Table 44). Although Sydney is not within the Bras d'Or Lakes watershed, it has many recreational boats that move into the Lakes during the summer season.

[20] data from http://www.gov.ns.ca/nsaf/marine/ramps/

Table 44. Boats in the Bras d'Or Lakes (Malcolm 2003)

Area	Estimated # of boats
Sydney – North Sydney	204
Baddeck	51
St. Peters – West Bay	50
Dundee	33
Alders Point – MacNeils Cove	32
Iona	18
Big Bras d'Or	8
Marble Mountain	8
East Bay	7
Orangedale	7
Whycocomagh	6
Others	20

Data from the marinas on the Lake provide another source of boating activity information. The Baddeck Marina reported 106 visitors in 2002 (Malcolm 2003). The Dundee Marina reported that 360 to 450 transient boats visit the marina throughout the season, 50% of which are local. The Grand Narrows Marina reports seasonal occupancy of 3 sailboats and 5 powerboats with additional transient boating traffic of 3-4 boats per day. St. Peter's Marina accommodates 20 permanent seasonal boaters.

Boat traffic movements at the Barra Strait Bridge have been logged since 1991, and have consistently ranged between 1700 and 2100, with a peak of 2100 recorded for 2002 (Malcolm 2003). Of these movements, an estimated 2% are commercial activity, 8% are government and 90% are recreational. It is estimated that 30 local boats represent a substantial portion of this traffic. Boating traffic entering the Lake by the Great Bras d'Or Channel and not moving through the Barra Strait Bridge, such as Gypsum carrier movements, is not accounted for in the above estimate.

Approximately 625 boats traverse St. Peter's Canal annually with an estimated 12% (75 boats) commercial vessels, 2.4% (15 boats) government vessels and 80% (500 boats) pleasure craft (Malcolm 2003).

22.7.6 Ballast Water

In recent years, the transport of non-indigenous species in ballast water has raised concerns. However, until recently ballast water reporting was neither comprehensive nor coordinated. In 1998 (CEF Consultants Ltd. 2000), 2000 (Balaban 2001) and 2002 (Statistics Canada 2004b), 100% of ships arriving at Little Narrows from foreign origins were in ballast, thus they released their ballast water in the Bras d'Or Lakes. Table 41 indicates ballast water exchange at ports in the Bras d'Or Lakes.

Carver and Mallet (2004) assessed the risk of introducing non-indigenous phytoplankton and zooplankton taxa via ballast water from Chesapeake Bay to the Little Narrows gypsum port in the Bras d'Or Lakes. In September 2003, they collected ballast water samples on a voyage from Baltimore, Maryland to Little Narrows. Ballast water tanks were exchanged at various locations en route to evaluate the impact of this procedure on the original port community. Carver and Mallet estimated that 31% to 61% of original Baltimore taxa remained, indicating a ballast water exchange effectiveness of 39 to 69%.

A survey of the foreign ship traffic docking at Little Narrows in 2003 indicated that a total of 130 840 m^3 of ballast water was discharged directly from six US ports: Portsmouth, New Hampshire; Brayton Point, Massachusetts; Perth Amboy, New York; Stony Point, New York; Baltimore, Maryland; and Norfolk, Virginia (Carver and Mallet 2004). Given that the salinity in many of these source ports is similar to the Bras d'Or Lakes (15-25‰), Carver and Mallet (2004) argue that the potential for the translocation and subsequent survival of non-indigenous species is relatively high, particularly during the summer and fall. Although ballast water exchange did not completely eliminate the original suite of Chesapeake Bay taxa, in most instances it did substantially reduce their abundance.

Ballast Water Control and Management Regulations were published in Part II of the *Canada Gazette* (Vol. 140, No. 13) in June 2006. These Regulations apply to ships in waters under Canadian jurisdiction that are designed or constructed to carry ballast water. However, ships operating exclusively between ports, offshore terminals or anchorage areas on the east coast of North America north of Cape Cod and ports, offshore terminals or anchorage areas on the east coast of Nova Scotia are not required to manage their ballast water (i.e., exchange). Vessels operating between the east coast of Nova Scotia and south of Cape Cod must exchange their ballast water prior to entering Canadian waters. If this is not possible the Regulations indicate that these vessels may exchange their ballast water in an area south of 43°30' north latitude where the water depth is at least 1000 m. These Regulations decrease the risk of transport of non-indigenous species into the Bras d'Or Lakes by industrial shipping (i.e., transport of gypsum). However, given that vessels operating exclusively north of Cape Cod are not required to manage their ballast water and that ballast water exchange is not 100% effective in eliminating the transport of non-indigenous species, there remains concern about their transport into the Bras d'Or Lakes.

22.8 Recreation

22.8.1 Diving

The Cape Breton Nervous Wrecks Dive Club operates the only substantial SCUBA operation in the Lakes (through SCUBA Tech Limited operating in Sydney). With a membership of approximately 75, the dive club remains active almost year round, and three to four trips per week during the summer tourist season is standard, however not all of these are in the Bras d'Or Lakes. The most popular diving sites in the Lakes are around Long Island (in St. Andrews Channel) and Barra Strait. According to the Nervous Wrecks web site[21], there are approximately 19 ship wrecks in the Bras d'Or Lakes: three in West Bay, three in St. Peters Inlet, four in Bras d'Or Lake, two in East Bay, one in McKinnons Harbour, five in North Basin and one in St. Patricks Channel.

22.8.2 Golfing

Golfing on Cape Breton Island is a popular tourist attraction. Cape Breton was ranked 29th by Golf Digest's Top 50 Golf Destinations in the World rating (CBFF 2006). Within the Bras d'Or Lakes watershed, there are three golf courses (Table 45).

[21] http:www.geocities.com/cbdive1/scat.html

Table 45. Golf courses in the Bras d'Or Lakes watershed

Golf Course	Location	Holes	Yardage	Season
Baddeck Forks Golf Club	Baddeck	9	3778	May to November
Bell Bay Golf Course	Baddeck	18	7037	May 15 to October 31
Dundee Resort and Golf Club	Dundee	18	5940	May to October

Sources: CBIR 2006a, 2006b; WWT 2006

22.8.3 Tourism

The province of Nova Scotia has approximately 2.2 million visitors a year from out-of-province. About 1 million person trips are made annually to Cape Breton (including tourist trips by residents of Cape Breton), 70% of these trips involve overnight stays and some 340 000 are by non-Nova Scotians (Economic Planning Groups of Canada 2004).

The tourism sector in Cape Breton as a whole employs over 6800 people and generates $230 million in revenues each year (Economic Growth Solutions 2003). A detailed summary of the levels of tourism explicitly in the Bras d'Or watershed could not be found, nor could one be produced for this report.

22.8.4 Parks and Protected Areas

There are various types of parks and protected areas within the Bras d'Or watershed. Areas of provincial protection cover about 7430 ha within the watershed (Table 46, Figure 30). The two largest protected areas are the Bornish Hills Nature Reserve and the Middle River Wilderness Area. The Spectacle Island Game Sanctuary is the only game sanctuary within the watershed.

Bornish Hills Nature Reserve: Originally identified in the 1970s, the 960 ha Bornish Hills Nature Reserve is the largest nature reserve within the Bras d'Or watershed. It contains steeply sloping hills, ravines and several bogs. It also protects an example of the once-characteristic, old growth sugar maple, beech, and yellow birch hardwood forests in the region (NS DEL no date). Part of the Big Ridge of the Creignish Hills in the River Denys watershed, it is likely the best and largest remaining example of this characteristic forest type in the region. Only pre-approved non-destructive scientific research and some educational programs are allowed in the area (ADI Limited 1999).

Middle River Wilderness Area: Protecting 5620 ha, the Middle River Wilderness Area is the largest wilderness area within the Bras d'Or watershed. Typical regional features are steep talus-covered slopes, well-developed deciduous forests, deep faults, undulating valleys, canyon complexes and river systems. The area includes some of the oldest rocks in the province and is located next to the agricultural lowlands of the Middle River valley.

Spectacle Island Game Sanctuary: A small game sanctuary intended to protect birds and their habitat, it encompasses 13 ha (some of which is covered by water). Activities prohibited include hunting of wildlife or eggs, or destroying or disturbing wildlife species or nesting sites. No person is allowed within the limits of the Sanctuary from April 15th to August 15th with some exceptions.

There are five designated provincial parks in the Bras d'Or Watershed (Table 46), all of which are along the coast. There are 62 camping sites and lake access at Whycocomagh Provincial Park. There are several operational but non-designated parks and reserves, and two national historic sites/parks within the watershed (Table 47). There are also many hiking and multi-use trails in the watershed (Table 48).

Table 46. Areas of provincial protection by subwatershed (NSDNR 2002)[22]

Subwatershed	Name	Approximate area within watershed (ha)
Middle River	Middle River Wilderness Area	5340
Baddeck River	North River Wilderness Area	468
Rivers Denys	Bornish Hills Nature Reserve	845
St. Patricks Channel	Trout Brook Wilderness Area Washabuck River Nature Reserve* Spectacle Island Game Sanctuary	275 67 13
North Basin	Iona Protected Beach Shenacadie Protected Beach	5 2
Whycocomagh Bay	Whycocomagh Provincial Park	192
St. Andrews Channel	Barachois Provincial Park Groves Point Provincial Park	117 5
East Bay	Ben Eoin Provincial Park	90
West Bay	Malcolm Cove Protected Beach	< 1
St. Peters Inlet	Battery Provincial Park	12

*The Washabuck River Nature Reserve is the only private land protected through legislation within the watershed.

[22] data compiled by querying the NS Restricted Land Use database for designated provincial parks and reserves, protected beaches, special places act lands, wilderness areas and game sanctuaries.

Table 47. National sites and non-designated parks and reserves within the Bras d'Or watershed (NSDNR 2002)[23]

Subwatershed	Name	Approximate area within watershed (ha)
Rivers Denys	Marble Mountain Melford Orangedale	55 5.5 19
St. Patricks Channel	Alexander Graham Bell National Historic Park Baddeck Inlet	2 < 1
North Basin	Barra Forest McNeil Vale MacCormack Park Grass Cove	267 183 4 < 1
East Bay	Castle Bay	< 1
Baddeck	Uisge Ban Falls	-
St. Andrews Channel	Irish Cove	-
West Bay	Marble Mountain Dundee	71 < 1
St. Peters Inlet	Hay Cove St. Peters Canal National Historic Site	169 4
Great Bras d'Or	Ross Ferry Big Harbour Beach Bras d'Or Dalem Lake	2 < 1 < 1 -

Table 48. Summary of hiking and multi-use trails in the Bras d'Or watershed[24]

Name	Subwatershed	Trail length (km)	Activities permitted	Ownership
Pringle Mountain Trail	St. Peters Inlet	14	Foot, bike, ATV, snowmobile, skiing	Crown land
Uisge Ban Falls	Baddeck	3.5	Hiking only, part of provincial park	Provincial
Dalem Lake	Great Bras d'Or	2.7	Hiking only, part of provincial park	Provincial
Salt Mountain Trail	Whycocomagh	2.5	Hiking only, part of provincial park	Provincial
Ben Eoin	East Bay	1.1	Hiking only, part of provincial park	Provincial

[23] data compiled by querying the NS Restricted Land Use database for operational/non-designated parks and reserves, and national historic sites and parks.
[24] data from http://trails.gov.ns.ca., list may not be comprehensive

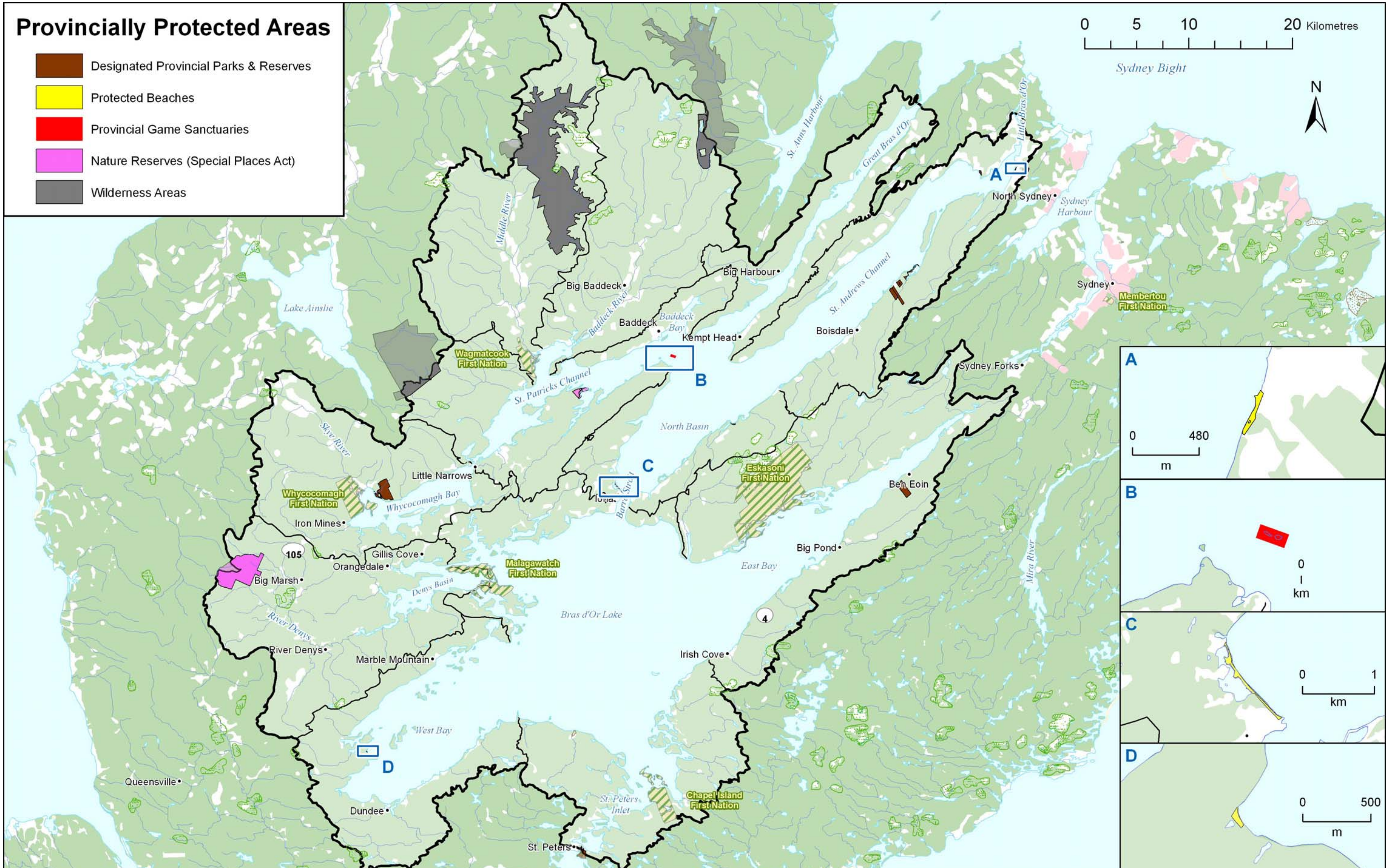

Figure 30. Areas of provincial protection within the Bras d'Or watershed. Note that lightly shaded areas indicate protected areas extending beyond the watershed boundary.
Data sources: NSDNR (2002); DFO (2003); Basemap (Natural Resources Canada, National Topographic Database 1:250,000 3rd Edition)

22.9 Other Activities

22.9.1 Navigation Aids

According to the Nova Scotia Lighthouse Preservation Society, there are eight navigation aids still standing in and around the Bras d'Or Lakes (Table 49).

Table 49. Navigation aids still standing in the Bras d'Or Lakes[25]

Lighthouse	Location (watershed)	Year Established	Year Automated
Little Narrows	Little Narrows, on Curlew Point (St. Patricks Channel)	1881	1982
Kidston Island (aka Baddeck)*	Northeast point of island (St. Patricks Channel)	1872	1960
Gillis Point	At Gillis Point (St. Patricks Channel)	1895	1973
Cameron Island	Northeast end of Cameron Island (West Bay)	1977	1993
McNeil Beach (aka Boularderie)	Eastern shore of Great Bras d'Or (Great Bras dÒr Channel)	1884	1962 (and decommissioned)
Carey Point	End of cape, east entrance to St. Marys Bay (Great Bras dÒr Channel)	1972	1972
Great Bras d'Or	On Noir Point, entrance to Great Bras d'Or (Great Bras dÒr Channel)	1903	1993
Gregory Island	West point of island, north entrance to St. Peters Inlet (St. Peters Inlet)	1882	1951
Cape George*	End of point, west entrance to St. George's Bay (St. Peters Inlet)	1861	1993

* lighthouse grounds are open to the public

22.9.2 Ocean Dumping

It has been suggested that there is an old munitions dump off of Bouladerie Island, near Kempt Head, however this could not be confirmed (Kehoe pers. comm. 2005). No dredging or dumping occurs regularly in the Lakes.

[25] data from http://www.nslps.com

23. Receptors and Key Issues – Impacts on Ecosystem Components and Properties

23.1 Water/Sediment Quality, Pollutants and Toxicity

Whycocomagh Bay and the deeper portions of St. Andrews Channel and North Basin have very low flushing rates making them sensitive to water borne pollutants and contaminants that could not be quickly dispersed by water movement. However, with the exception of this caution, examination at the larger bay-scale resolution shows little evidence of human impact. However, it is important to note that impacts and indicators of impact exist in several locations around the Lakes, albeit at a more localized scale. This section of the EOAR is intended to highlight such situations and is not intended to be a comprehensive documentation of known or anticipated impacts, but simply an overview of conditions that exist.

23.1.1 Environment Canada's (EC) Shellfish Growing Area Classification

The objective of EC's surveys is to determine if the water quality is acceptable for the harvesting of shellfish. From a public health standpoint, the principal purpose is to detect the occurrence of disease-causing organisms that may be accumulated by shellfish if domestic sewage or animal wastes reach their environment. The public health safety of shellfish and shellfish harvesting waters in Canada is presently judged by bacteriological standards. It should be emphasized that bacteriological examination of shellfish growing waters is used only as an adjunct to a sanitary survey to show the extent of fecal pollution affecting an area.

Fecal contamination is often intermittent and may not be revealed by the bacteriological examination of a single water sample. The most a bacteriological report can prove is that, at the time of examination, bacteria indicating fecal pollution did or did not grow under laboratory conditions from a sample of water. Therefore, if a sanitary survey shows that the waters in a shellfish growing area are obviously subject to contamination from direct fecal wastes, radionuclides or harmful industrial wastes, the shellfish area should be closed regardless of the results of bacteriological analyses.

In 1995 there were approximately 490 km^2 of classified shellfish growing area within the Bras d'Or (93.4% approved, 5.3% closed, and 1.3% conditionally approved). By 2003, the total classified area had increased to 560 km^2 (94.2% approved, 5.1% closed and 0.7% conditional). Based on the percentages of closed areas, conditions had improved only slightly between 1995 and 2003. Overall, shellfish classification area trends have not shown a great deal of change in the past decade. According to the most recent Environment Canada shellfish classification maps, St. Peters Inlet, St. Patricks Channel, Denys Basin and East Bay contain the bulk of the closed areas which are mostly found in close proximity to clusters of houses[26]. It should be noted, however, that areas are not always closed as a result of human activity (improper septic systems and agricultural operations) – wild animal populations such as bird colonies or terrestrial animals can also render areas unsafe.

[26] From http://www.atl.ec.gc.ca/epb/sfish/maps/ns/area7.html

23.2 Integrity of Coastal Landscapes and Bottomscapes

In 1992, concern over the possible disturbance of bottom habitats resulted in the closure of the mobile gear fishery in the Bras d'Or. Of particular concern were impacts from the groundfish trawlers and Danish seiners involved in the winter flounder fishery that centred on East Bay in August of each year (Myers and Gilbert 1993). During a survey by (Myers and Gilbert 1993) some 240 linear kilometres were covered with a sidescan survey, primarily in East Bay, St. Andrews Channel, and the Great Bras d'Or Channel. Heavily trawled areas were generally confined to the soft bottom habitats, which often were the areas parallel to the shoreline and bound by coarser wave exposed shoreline sediments on one side and coarser steep slopes dropping to deeper water on the other. Of the three primary areas examined, no trawl marks were observed in the Great Bras d'Or Channel, the most widespread impact was in the East Bay area and its approaches, and heavily impacted areas included sections of St. Andrews Channel near the outlet to Little Bras d'Or Channel and off the Cross Point area at the southwestern opening of the Channel. Although not confirmed by the sidescan sonar surveys, the authors suggested that heavy impact was likely in some areas of West Bay, Malagawatch, and near Chapel Island (Myers and Gilbert 1993).

Dredging has occurred in the area of Middle Shoal at the ocean side entrance to the Great Bras d'Or Channel in order to facilitate ship passage associated with the removal of gypsum from a mine at Little Narrows. In 1996, approximately 350 000 m^3 of materials were removed from a 2.25 km long channel and disposed at three marine sites (Nicholls 1997). Middle Shoal is relatively shallow, generally not exceeding about 10 m depth. Although the impact to fisheries resources were largely unquantified by monitoring works, there did not appear to be any significant changes in channel currents, flow exchange, tidal events, water salinity and temperature, and wind-induced surge events to the Bras d'Or Lakes. Increased turbidity during dredging was reasonably localized and did not exceed levels associated with local natural events of shoreline erosion and storm induced disturbances.

24. Human Activity in the Bras d'Or Watershed

Approximately 80% of the watershed area is forested area. The bulk of the forestry occurs in the lands feeding into St. Patricks Channel (the Middle and Baddeck River subwatersheds). The Middle River subwatershed has the largest amount of area in clearcut condition (518 ha), however this only amounts to 3% of the subwatershed area managed by Stora Enso Port Hawkesbury, or 1.6% of the entire Middle River subwatershed.

The greatest percentage of areas classified as urban are found in the Great Bras d'Or Channel, McKinnons Harbour and St. Andrews Channel subwatersheds. The largest human settlements in the area are found in the East Bay, St. Andrews Channel and Baddeck subwatersheds. The disparity between the subwatersheds listed for high urban area and population centres (except the Bras d'Or Channel) is likely a result of the small size of both McKinnons Harbour and St. Andrews Channel subwatersheds.

Most of the mining activity (gravel pits, gypsum, marble) occurs in the Denys Basin subwatershed, with a large gypsum operation also active in the St. Patricks Channel subwatershed. Agricultural activity occurs mostly in the Middle River, St. Andrews Channel, and Whycocomagh subwatersheds.

Land ownership is mostly private (62%), most of which is waterfront, followed by provincial (33%), most of which is inland. Foreign ownership is minimal. Land development has been decreasing since the early 1990s. Most of the existing developments are in the Cape Breton Regional Municipality (40%) and Victoria County (29%). Only 25% of all existing development is served by central sewer systems, all others have private septic systems. The number of shellfish closures resulting from fecal contamination (not always a result of human waste) has improved slightly since 1995.

Fishing activity in the lakes is now minimal. Lobster has declined since the mid-1990s and the herring fishery has been closed since 1999. The aquaculture industry, once thriving, was hit by MSX and SSO, resulting in only 15% of all aquaculture leases active today. These leases are evenly spread between McKinnons Harbour, St. Patricks Channel, East Bay and Denys Basin.

An example of a human activity matrix that attempts to quantify the level of human activities and resulting pressures occurring in each subwatershed is presented in Appendix D.

PART G - CONCLUSIONS

Future studies within the Bras d'Or Lakes should be based on three basic premises to support ecosystem management:

1. Studies should focus on ecological linkages (physical biological, or biological interactions) and move away from inventories and species specific study. This will facilitate the move from species management to ecosystem management.
2. Studies should generally be undertaken at the bay-scale watershed resolution. More localized scale does not allow for adequate comparison between sample sites to support management decision making for the benefit of the Bras d'Or watershed, and larger scales may not provide adequate detail to support management.
3. Studies should be designed in part using Environmental Effects Monitoring Program approaches to research (McMaster and Courtenay 2005). This approach evaluates relationships between biota and their environment, and as such would support not only current study objectives but facilitate the effectiveness of future EEM Programs that may be necessary given as yet unforeseen development within the Bras d'Or watershed.

As a management tool, the EOAR needs to be periodically reviewed and updated. This will ensure that the basis upon which decision making is conducted remains current, and best management will be supported. It was recommended at the Regional Advisory Process meeting regarding the first draft of this report (DFO 2006), that the EOAR document should be reviewed and updated at least one year before the Collaborative Environmental Planning Initiative (CEPI) Management Plan is reviewed, and not later than 2010. Ongoing tracking, in a central location, of any new Bras d'Or Lakes research that it is in process along with the anticipated completion dates would greatly facilitate updates, making them achievable, not onerous.

The most impacted area of the Lakes appears to be the nearshore fringe where science has documented conditions of coliform pollution, sedimentation, metals, isolated areas of anoxia and hypoxia, and other stressors such as road development, shoreline development, and various resource use and extraction. This shoreline fringe is also where significant population changes have been observed at herring spawning and oyster grounds, along with other species. However, there is still a lack of current and comprehensive evaluation of the nearshore habitats, species, energy flows, and conditions that allow us to determine the state and trend of the ecosystem interactions in this area.

LITERATURE CITED

Acadia University. 2006. Nova Scotia Herptofaunal Atlas project website. Accessed at: Landscape.acadiau.ca/herpatlas. February 2006.

ACCDC (Atlantic Canada Conservation Data Centre). 2006. Atlantic Canada Conservation Data Centre Species at Risk. Accessed at: http://www.accdc.com/index2.html.

Adams, J. 1995. An Evaluation of Wood Turtle Distribution in Nova Scotia through public Surveys. BSc. Honors Thesis Report. Acadia University. Wolfville, Nova Scotia. 48pp.

Adams, G.C. 1991. Gypsum and Anhydrite Resources in Nova Scotia. Nova Scotia Department of Natural Resources, Mines and Energy Branches, Economic Geology Series 91-1. 293p.

ADI Ltd. 2006. State of the Environment Bras d'Or Lakes: Fresh Water Resources. Prepared for Collaborative Environmental Planning Initiative (CEPI). DRAFT.

ADI Ltd. 1999. Report on Registration of Undertaking for Environmental Assessment for Proposed Gypsum Mine. Melford, Cape Breton, Nova Scotia. Prepared for Georgia Pacific Canada Inc. February, 1999.

Alexander, D.R., J.J. Kerekes and B.C. Sabean. 1986. Description of selected lake characteristics and occurrence of fish species in 781 Nova Scotia Lakes. Proc. N.S. Inst. Sci. 36(2): 63-106.

Anonymous. 1995. Interior Watershed Assessment Proceedure Guidebook: Level 1 Analysis. British Columbia Ministry of Environment. ISBN 0-7726-2612-X. 82p.

Anonymous. 2003. The NS Herp Atlas Project Newsletter. Acadia University Biology Department. Vol. 6. No. 2. December 2003.

Arseneau, D.F., A.J. Arseneau and C. Rogers. 1977. The waters of East Bay, Cape Breton: A study of their physical and chemical nature. Bras d'Or Institute Technical Bulletin 2: ii+78p.

Austin-Smith, P. Jr. and M. O'Brien. 2003. Determining the genetic distinctiveness of the Cape Breton Marten (*Martes Americana*). Nature's Resources 6(2):8-9. Nova Scotia Department of Natural Resources.

Baird, R. and G. Corbett. 2003. Peskowesk Brook 2003 Field Report. Parks Canada. Kejimkujik National Park.

Balaban, M. 2001. Vessel Traffic/Vessel Shipping Patterns on the East Coast of Canada: 2000 Shipping Season. Prepared for Transport Canada, Marine Safety, Dartmouth, NS.

Banks, D. 1994. Elusive ghosts of the deep forest. Conservation 18(4). Nova Scotia Department of Natural Resources. 2pp.

Banks, J. 2006. Season Creep: How global warming is already affecting the world around us. Accessed at: www.cleartheair.org. March 22, 2006. Washington, DC. 16pp.

Barlow, J. and R. Gentry. 2004. Report of the NOAA Workshop on Anthropogenic Sound and Marine Mammals. NOAA Technical Memorandum: NMFS SWFSC 361. 28p.

Barrington, S. 2005. Developing a Strategic Action Plan for the Denys Basin Watershed, Nova Scotia. Dalhousie University. Masters of Environmental Studies thesis report. 157p.

Basquille, S. and R. Thompson. 1997. Moose (*Alces alces*) browse availability and utilization in Cape Breton Highlands National Park. Parks Canada Technical Report in Ecosyst. Sci. 10: 1-37.

Beazley, K., T. Snaith, F. Mackinnon and D. Colville. 2004. Road density and potential impacts on wildlife species such as American Moose in Mainland Nova Scotia. Proc. N. S. Inst. Sci. 42(2): 339-357.

Bilby, R., B. Fransen, and P. Bission. 1995. Role of salmon carcasses in maintaining stream productivity: ecological significance and management considerations. In: Abstracts for the Annual Meeting of the North Pacific International Chapter of the American Fisheries Society. Vancouver, British Columbia.

Black, W.F. 1976. Aspects of the marine biology of the Great Bras d'Or. In: The Proceedings of the Bras d'Or Lakes Aquaculture Conference, Sydney, Nova Scotia. Ed. G. McKay. College of Cape Breton Press, Sydney, NS. p. 44-53.

Black, W.F. 1958. Biology of Mysids of the Great Bras d'Or: 1. Station list, occurrence, mysids as fish food, vertical distribution. Fish. Res. Board Can. Manus. Rep. Ser. (Biological) 671: 37 p.

Black, W.F. 1956. The Mysidacea of the Bras d'Or Lakes. PhD thesis, McGill University, Montreal.

Bousfield, E. and M. Thomas. 1975. Postglacial changes in distribution of littoral marine invertebrates in the Canadian Atlantic region. Proc. N.S. Inst. Sci. 27, Suppl. 3: 47-60.

Bowyer, P. J. (Ed.) 1995. Where the Wind Blows: A guide to marine weather in Atlantic Canada. Environment Canada. ISBN 1-55081-119-3. 178 p.

Bras d'Or Stewardship Society. 2006. What is the Bras d'Or Lake Stewardship Society? Accessed at: http://baddeck.com/bss/what.html. October 6, 2006.

Brimley, B. and B. Thomas. 1999. River ice trends of coastal rivers in Atlantic Canada. In: Proceedings of the CWRA (Canadian Water Resources Association) 52nd Annual Conference. Nova Scotia – June 1999. p. 15-29.

Broders, H. S. Mahoney, W. Montevecchi, and W. Davidson. 1999. Population genetic structure and the effect of founder events on the genetic variability of moose, *Alces alces*, in Canada. Molecular Ecology 8: 1309-1315.

Calder, J.H. 1998. The Carboniferous evolution of Nova Scotia. In Lyell: The Past is the Key to the Present. Eds. D. J. Blundell and A.C. Scott. Geological Society, London, Special Publication, 143: 261-302.

Cameron, E.H. 2003. Recruitment of the Invasive Green Crab, *Carcinus maenas*, in Nova Scotia. Masters of Science thesis report. Dalhousie University, Halifax, Nova Scotia. April 2003. 93 p.

Canada Gazette Part II. 2006. Regulations Amending the Pleasure Craft Sewage Pollution Prevention Regulations. Canada Gazette Part II, Vol. 140, No. 13. SOR/2006-133. June 28, 2006.

Carver, C.E. and A.L. Mallet. 2004. Investigating Potential Ballast Water Management Strategies for Ships Travelling from Chesapeake Bay to Ports in Nova Scotia. Prepared for Transport Canada, Marine Safety, Dartmouth, NS.

Cash, K., P. Ausitn-Smith, D. Banks, D. Harris and P. Smith. 1985. Food remains from bald eagle nest sites on Cape Breton Island, Nova Scotia. J. Wildl. Manage. 49(1):223-225.

CBFF (Cape Breton's Fabulous Foursome). Fab 4 News. Accessed at: http://www.golfcapebreton.com/fab4news.html. June 13, 2006.

CBIR (Cape Breton Island Resorts). 2006a. Golf – Bell Bay. Accessed at: http://www.capebretonresorts.com/golf_bellbay.asp. June 13, 2006.

CBIR (Cape Breton Island Resorts). 2006b. Golf – Dundee. Accessed at: http://www.capebretonresorts.com/golf_dundee.asp. June 13, 2006.

CBMM (Cape Breton Miners' Museum). 2006. The History of Mining in Cape Breton. Accessed at: http://www.minersmuseum.com/hof_mining_in_region.htm. December 15, 2006.

CEF Consultants Ltd. 2000. Vessel Traffic/Vessel Shipping Patterns on the East Coast of Canada. Prepared for Transport Canada, Marine Safety, Dartmouth, NS.

CEPI (Collaborative Environmental Planning Initiative). 2006. Bras d'Or Lakes Traditional Ecological Knowledge Workshop Proceedings, May 3-4, 2006. Prepared for the Collaborative Environmental Planning Initiative by Penny Doherty and Jason Naug.

Chapman, A. S. 2006. Quantifying the rapid decline of eelgrass beds on the Eastern Shore of Nova Scotia: 1992 vs. 2002. Presentation at the January 16th – 19th, 2006 Workshop on the Inshore Ecosystem and Significant Areas of the Scotian Shelf, Bedford Institute of Oceanography, Dartmouth, NS.

Chapman, A. and J. Smith. 2004. Quantifying the rapid decline of eelgrass beds on the Eastern Shore of Nova Scotia. In: Hanson, A. R. 2004. Status and conservation of eelgrass (*Zostera marina*) in Eastern Canada: summary from a workshop held 17-18 December 2003, Sackville, NB. Technical Report Series (Canadian Wildlife Service). CW69-5/412E. vii. 40p.

Chapman, C.J. and A.D. Hawkins. 1969. The importance of sound in fish behaviour in relation to capture by trawls. p 717-729 In: Proceedings of the FAO Conference on Fish Behaviour in Relation to Fishing Techniques and Tactics. 19-27 October 1967. Eds. A. Ben-Tuvia and W. Dickson. FAO Fisheries Report No. 62, Vol 3, Rome.

Clarke, A.H. 1981. The Freshwater Molluscs of Canada. National Museum of Canada, Ottawa, ON. 449p.

Chou, C.L., B.M. Zwicker, J.D. Moffatt and L. Paon. 1999. Elemental Concentrations in the Livers and Kidneys of Winter Flounder (*Pseudopleurectes americanus*) and Associated Sediments from Various Locations in the Bras d'Or Lake, Nova Scotia, Canada. Can. Tech. Rep. Fish. Aquat. Sci. 284: 116p.

Clancey, L. and R. Hinton. 2003. Distribution of the Tunicate, *Ciona intestinalis*, in Nova Scotia. Nova Scotia Department of Fisheries and Agriculture. Halifax, Nova Scotia. 24 April 2003. 6 p.

Cohrs, J. (ed). 1991. Birding Nova Scotia. Nova Scotia Museum. Halifax. 3rd Edition. 86pp.

COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2006. Wood turtle, *Glyptemys insculpta*. Accessed at: www.cosewic.gc.ca. December 12, 2006.

Crawford, R., D. Webber, and G. Boutlier. 1982. The Biology of Herring from Bras d'Or Lake, Cape Breton, Nova Scotia. MS and Tech. Rept. N. S. Dept. Fish. 82-04. 66 p.

Creamer, R., M. Giles, J.H. MacDonald and J.C.O'C. Young. 1973. Metals contents of silt samples from Bras d'Or Lake and influent rivers. Bound in Silt, Water, and Miscellaneous Molluscs. August 1973. SMU ESG Report 73-04: iv+29 p.

Dalziel, J., P. Yeats and B. Amirault. 1998. Inorganic Chemical Analysis of Major Rivers Flowing into the Bay of Fundy, Scotian Shelf and Bras d'Or Lakes. Department of Fisheries and Oceans. Can. Tech. Rep. Fish. Aquat. Sci. 2226. 8p.

Davis, D. and S. Browne. Eds. 1996a. Natural History of Nova Scotia: Volume one, topics and habitats. Rev. ed. Nimbus Publishing. 518 p.

Davis, D.S. and S. Brown, Eds. 1996b. The Natural History of Nova Scotia: Volume two, theme regions. Rev. ed. Nimbus Publishing. 304 p.

Davis, R. C., F. T. Short and D. M. Burdick. 1998. Quantifying the effects of Green crab damage to eelgrass transplants. Restoration Ecology 6(3):297-302.

Denny, S. 2005. Biologist, Unama'ki Institute of Natural Resources, Eskasoni, Nova Scotia. Personal communication.

Denny, S. 2004. Biologist, Unama'ki Institute of Natural Resources, Eskasoni, Nova Scotia. Personal communication.

Denny, S., K.J. Clark, M.J. Power, and R.L. Stephenson. 1998. The Status of the Herring in the Bras d'Or Lakes in 1996-1997. Can. Stock Assess. Sec. Res. Doc. 98/80. 32 p.

DFO (Department of Fisheries and Oceans). 2006. Proceedings of the Maritimes Regional Advisory Process: Evaluation of the Ecosystem Overview and Assessment Report for the Bras d'Or Lakes, Nova Scotia; 2-3 November 2005. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2006/007.

DFO (Department of Fisheries and Oceans). 2004a. Review of Scientific Information on Impacts of Seismic Sound on Fish, Invertebrates, Marine Turtles and Marine Mammals. Canadian Science Advisory Secretariat. National Capital Region. Habitat Status Report. 2004/002 15p.

DFO (Department of Fisheries and Oceans). 2004b. Identification of Ecologically and Biologically Significant Areas. DFO Can. Sci. Advis. Sec. Ecosystem Status Rep. 2004/006.

DFO (Department of Fisheries and Oceans). 2004c. Eastern Cape Breton Lobster (LFAs 27-30). DFO Science Stock Status Report 2004/032.

DFO (Department of Fisheries and Oceans). 2003. Bras d'Or Watershed. Watersheds were delineated by the Oceans and Coastal Management Division, Maritimes Region, based on the slope; aspect and hill-shaded relief composite (merge) of the 1:10,000 (20m) digital elevation model and 1:150,000 lakes and rivers provided by the Nova Scotia Geomatics Centre (1999).

DFO (Department of Fisheries and Oceans). 2000. Press release. DFO Closes the Bras d'Or Lakes to Herring Fishing. NR-MAR-00-03E. May 1, 2000.

DFO (Department of Fisheries and Oceans). 1997. Middle Shoal Channel Improvement Project – Scientific advice regarding the reconsideration of the July 15, 1996 Screening Report Assessment decision. Department of Fisheries and Oceans Regional Habitat Status Report 97/1 E. 5p.

DFO (Department of Fisheries and Oceans). 1996. Cape Breton American Oyster. DFO Atlantic Fisheries Stock Status Report 96/124E.

Dickie, Gordon. General Manager, Shaw Resources. Personal communication. July 22, 2005.

Drinnan, R.E. 1976. Oysters - Disease, predation, parasites and competitors. In: The Proceedings of the Bras d'Or Lakes Aquaculture Conference. Ed. M.G. McKay. College of Cape Breton Press, Sydney. p. 125-129.

Dupont, F., B. Petrie and J. Chaffey. 2003. Modeling the Tides of the Bras d'Or Lakes. Can. Tech. Rep. Hydrogr. Ocean Sci. ISSN 0711-6721. viii+53 p.

Durbin, A., S. Nixon and C. Oviatt. 1979. Effects of the spawning migrations of the alewife in freshwater ecosystems. Ecology 60: 8-17.

ECA (East Coast Aquatics Inc.) 2003. Musquash Ecosystem Framework Development. Prepared for Fisheries and Oceans Canada. Marine Protected Areas and Coastal Management. St. Andrews, New Brunswick. 37p.

ECA (East Coast Aquatics Inc.). 2001. River Denys Integrated Management Report. Prepared for Department of Fisheries and Oceans. Bedford Institute of Oceanography. Dartmouth, NS. 49 p.

ECBC (Enterprise Cape Breton Corporation) and CBGFC (Cape Breton Growth Fund Corporation). 2006. Advertising Supplement. We Rise Again: An Image of Cape Breton Island. Accessed at: http://www.ecbc.ca/e/PDFs/CapeBreton_Eng6pg_v9.pdf. October 5, 2005.

Economic Growth Solutions. 2003. Cape Breton "Tourism Road Map" Destination Development Plan. Final report prepared for the Cape Breton Growth Fund Corporation by Economic Growth Solutions in association with Market Access International Canada Inc. and Dan White and Associates Ltd.

Economic Planning Group of Canada. 2003. A "Trails for Tourism" Strategy for Cape Breton, Executive Summary Report. 36 p.

Economic Planning Group of Canada. 2004. Cape Breton Accommodation Needs Assessment Study, Executive Summary. 103 p.

Edwards, M. and Richardson, A. 2004. Impact of climate change on marine pelagic phenology and trophic mismatch. Nature 430:881-884.

Elner, R. W. 1981. Diet of green crab *Carcinus maenas* (L.) from Port Hebert, southwestern Nova Scotia. J. Shellfish Res. 1:89-94.

Environment Canada. 2006a. Atlantic cod, Maritimes Population. Accessed at: http://www.speciesatrisk.gc.ca/search/speciesDetails_e.cfm?SpeciesID=763. December 12, 2006.

Environment Canada. 2006b. Winter skate, Eastern Scotian Shelf Population. Accessed at: http://www.speciesatrisk.gc.ca/search/speciesDetails_e.cfm?SpeciesID=855. December 12, 2006.

Environment Canada. 2006c. Piping Plover melodus subspecies. Accessed at: http://www.speciesatrisk.gc.ca/search/speciesDetails_e.cfm?SpeciesID=687. December 12, 2006.

Environment Canada. 2006d. Yellow Lampmussel. Accessed at: http://www.speciesatrisk.gc.ca/search/speciesDetails_e.cfm?SpeciesID=811. December 12, 2006.

Environment Canada. 2005a. Canadian Climate Normals. Accessed at: http://climate.weatheroffice.ec.gc.ca/climate_normals/index_e.html. March 14, 2005.

Environment Canada. 2005b. Atlantic Regional Historical Air Quality Data. Accessed at: http://www.atl.ec.gc.ca/airquality/query/. April 20, 2006.

Environment Canada. 2004. Species at Risk Web Mapping Application. Canadian Wildlife Service. Accessed at: http://www.sis.ec.gc.ca/ec_species/ec_species_e.phtml. May 16th, 2005.

Environment Canada. 2003. What is the Air Quality Index? Accessed at: http://www.atl.ec.gc.ca/airquality/whatis_index_e.html. April 20, 2006.

Environment Canada. 2002a. Species at Risk Act. Bill C-5 as passed by the House of Commons. June 11, 2002.

Environment Canada. 2002b. Seabird Colony Database. Environment Canada. Sackville, New Brunswick.

Erskine, A. J. 1971. Bird communities in and around Cape Breton wetlands. Canadian Field-Naturalist. 85:129-140.

Erskine, A. J. 1987. Cape Breton Island waterfowl breeding populations, 1960-63. In: Waterfowl Breeding in the Atlantic Provinces. p. 18-25.

Erskine, A. J. 1992. Atlas of Breeding Birds of the Maritimes Provinces. Province of Nova Scotia and Nova Scotia Museum. 270p.

Ford, W.L. 1976. Environmental parameters of Bras d'Or: Summary report of the panel. In: The Proceedings of the Bras d'Or Lakes Aquaculture Conference. Ed. M.G. McKay. College of Cape Breton Press, Sydney. p. 67.

Forman, R.T.T. and A.M. Hersperger. 1996. Road ecology and road density in different landscapes, with international planning and mitigation solutions. In: Highways and Movement of Wildlife: Improving habitat connections and wildlife passageways across highway corridors. Proceedings of the Florida Department of Transportation/Federal Highway Administration Transportation-related Wildlife Mortality Seminar. Orlando, Florida. April 30-May 2, 1996. Eds. G. Evink, D. Ziegler, P. Garrett and J. Berry. U.S. Dept. of Transport. Orlando, Fl. pp. 1-23.

Forman, R.T.T., D.S. Friedman, D. Fitzhenry, J.D. Martin, A.S. Chen and L.E. Alexander. 1997. Ecological effects of roads: toward three summary indices and an overview of North America. In: Habitat Fragmentation and Infrastructure. Minister of Transport and Public Works and Water Management, Delft, Netherlands. pp. 40-54.

Fournier, J and P. Pocklington. 1984. The sub littoral polychaete fauna of the Bras d'Or Lakes, Nova Scotia Canada. In: Proc. First Int. Polychaete Conf., Sydney. Ed. P. Hutchings. Linnean Soc. NS. Wales. p. 254-278.

Garbary, D., A. Miller, N. Seymour and J. Williams. 2004. Destruction of eelgrass beds in Nova Scotia by the invasive green crab, *Carcinus maenus*. In: Hanson, A. R. 2004. Status and conservation of eelgrass (*Zostera marina*) in Eastern Canada: summary from a workshop held 17-18 December 2003, Sackville, NB. Technical Report Series (Canadian Wildlife Service). CW69-5/412E. vii. 40p.

Garroway, C.J. 2004. Inter and Intraspecific Temporal Variation in the Activity of Bats at Two Nova Scotia Hibernacula. BSc. Thesis. St. Mary's University. Halifax, Nova Scotia.34p +.

Garroway, C. J. and H. G. Broders. 2005. The quantitative effects of population density and winter weather on the body condition of white-tailed deer (*Odocoileus virginianus*) in Nova Scotia, Canada. Can. J. Zool. 83: 1246-1256.

Geen, G.H. 1965. Primary Production in Bras d'Or Lake and Other Inland Waters of Cape Breton Island, Nova Scotia. Ph.D. thesis, Dalhousie University, Halifax, Nova Scotia. 187p.

Geen, G.H. and Hargrave, B.T. 1966. Primary and secondary production in Bras d'Or Lake, Nova Scotia, Canada. Verh. Internat. Limnol. 16: 333-340.

Gilhen, J. 1984. Amphibians and Reptiles of Nova Scotia. Nova Scotia Museum, Halifax, Nova Scotia. 162p.

Gilhen, J. and B. Grantmyre. 1973. The Wood turtle, *Clemmys insculpta* (LeConte): An addition to the Herpetofauna of Cape Breton Island, Nova Scotia. Canadian Field-Naturalist 87: 308-310.

Graf, A., J. Gilhen and J. Adams. 2003. The Wood turtle, *Glyptemys insculpta*, at River Denys: A second population for Cape Breton Island, Nova Scotia. Canadian Field-Naturalist 117(3):415-418.

Grant, D.R. 1994. Quaternary geology, Cape Breton, Nova Scotia. Geological Survey of Canada Bulletin 482: 159p.

Gregory, R. S. 2004. Eelgrass as nursery habitat for juvenile fish in the coastal marine environment. In: Hanson, A. R. 2004. Status and conservation of eelgrass (*Zostera marina*) in Eastern Canada: summary from a workshop held 17-18 December 2003, Sackville, NB. Technical Report Series (Canadian Wildlife Service). CW69-5/412E. vii. 40p.

GSC. 1899. Province of Nova Scotia and Cape Breton Counties (Sydney sheet). Compiled from Sydney – Coal field sheets 1874-1876. Faribault-Fletcher Map No. 134. Geological Survey of Canada.

GSC. 1884. Geological and Natural History Survey of Canada. Complied and drawn by Hugh Fletcher from plans made by the Admiralty, the Department of Crown Lands, Nova Scotia and the Geological Survey. Faribault-Fletcher Maps No. 12, 13, 15, 17, 18. Geological Survey of Canada.

Gurbutt, P. and B. Petrie. 1995. Circulation in the Bras d'Or Lakes. Estuarine, Coastal and Shelf Science 41: 611-630.

Gurbutt, P., B. Petrie and F. Jordan. 1993. The Physical Oceanography of the Bras d'Or Lakes: Data analysis and modeling. Can. Tech. Rep. Hydro. Ocean Sci. No. 147. 61p.

Hanson, A. R. 2004. Status and Conservation of Eelgrass (*Zostera marina*) in Eastern Canada: summary from a workshop held 17-18 December 2003, Sackville, NB. Technical Report Series (Canadian Wildlife Service) CW69-5/412E. vii. 40p.

Hargrave, B.T. and G.H. Geen. 1970. Effects of copepod grazing on two natural phytoplankton populations. J. Fish. Res. Board Can. 27: 1395-1403.

Helfield, J. and R. Naimon. 2000. Effects of salmon derived nitrogen on riparian forest growth and implications for stream productivity. Ecology 82(9): 2403-2409.

Hemphill, M. 2005. Plant Manager, Little Narrows Gypsum Company, Little Narrows, Nova Scotia. Personal communication.

Hennick, E. 2006. Mining Technician, Nova Scotia Department of Natural Resources. Personal communication via email. December 6, 2006.

Hoving, C., D. Harrison, W. Krohn, R. Joseph and M. O'Brien. 2005. Broad-scale predictors of Canada lynx occurrence in Eastern North America. J. Wildl. Manage. 69(2): 739-751.

Hurley Fisheries Consulting. 1989. Enhancing the Recreational Salmonid Fishery in the Bras d'Or Lakes: Feasibility study. Prepared for Bras d'Or Lakes Recreational Fisheries Ltd. Sydney, Nova Scotia. iii+89p.

Jamieson, I.G., D.M. Blouw and P.W. Colgan. 1992. Field observations on the reproductive biology of a newly discovered stickleback (*Gasterosteus*). Can. J. Zoology 70: 1057-1063.

Johnston, S. 2006. GIS Technician, Fisheries and Oceans Canada, Bedford Institute of Oceanography, Oceans and Coastal Management Division, Dartmouth, Nova Scotia. Personal communication.

Jones, K. 1990. Horizontal Interpolation of Sound Speed using Density Surfaces. Royal Roads Military College. Victoria, BC. Thesis (MSc.). 132p.

Joseph, V. A. Locke and J-G. Godin. 2004. Characterization and habitat use of eelgrass in Kouchibouguac estuary, New Brunswick. In: Hanson, A. R. 2004. Status and conservation of eelgrass (*Zostera marina*) in Eastern Canada: summary from a workshop held 17-18 December 2003, Sackville, NB. Technical Report Series (Canadian Wildlife Service) CW69-5/412E. vii. 40p.

Kanno, Y. 2002. Fish Community Changes in River Philip, Nova Scotia, and an Index of Sustainable Coldwater Streams (ISCS). MES thesis. Dalhousie University, Halifax, Nova Scotia.

Kanno, Y. and K. Beazley. 2004. Freshwater fish considerations for aquatic conservation systems planning in Nova Scotia. Proc. N.S. Inst. Sci. 42(2): 375-391.

Kanno, Y. and J. MacMillan. 2004. Developing an index of sustainable coldwater streams using fish community attributes in River Philip, Nova Scotia. Proc. N. S. Inst. Sci. 42(2): 319-338.

Kehoe, M. Personal communication. July 28, 2005.

Kenchington, T.J., and E. Carruthers. 2001. Unamapaqt – A Description of the Bras d'Or Marine Environment. Version 0.2.2. Gadus Associates, Musquidoboit Harbour, NS. For the Unama'ki Environmental Committee of the Union of Nova Scotia Indians. 130p.

Knight, T. F. 1867. Pamphlets on the Fishes and Fisheries of Nova Scotia. No: III River Fisheries. CIHM/ICMH Microfiche series No: 12842. ISBN 0665128428. 71pp.

Krauel, D.P. 1976. A summary of the physical oceanography of the Bras d'Or Lake system. In: The Proceedings of the Bras d'Or Lakes Aquaculture Conference. Ed. G. McKay. College of Cape Breton Press, Sydney. p. 29-43.

Krauel, D.P. 1975. The Physical Oceanography of the Bras d'Or Lakes 1972-1974. Fisheries & Marine Service, Resource Development Technical Report 570: xiii+357p.

KPMG LLP. 2003. Cape Breton Island Transportation Services and Infrastructure Market Analysis Final Report. 136 p.

Lambert, T.C. 2005. Department of Fisheries and Oceans. Bedford Institute of Oceanography. Personal communication in writing July 2005.

Lambert, T.C. 2002. Overview of the ecology of the Bras d'Or Lakes with Emphasis on the Fish. Proc. of the N.S. Inst. Sci. 42: 65-98.

Lambert, T.C. 2001. Department of Fisheries and Oceans. Bedford Institute of Oceanography. Personal communication.

Leggat, L., H. Merklinger and J. Kennedy. 1981. LNG Carrier Underwater Noise Study for Baffin Bay. Department of National Defence. Research and Development Branch. Defence Research Establishment Atlantic. Dartmouth, Nova Scotia. DREA Report 81/3. 24p.

LGL Ltd. 2001. Assessment of Noise Issues Relevant to Key Cetacean Species in the Sable Gully Area of Interest. LGL report TA2446-2.

Lynds, A. and J. LeDuc. 1995. Old Forests of Nova Scotia: Background and ecological characteristics. Natural Resources Occasional Papers. No: 1. 18pp.

Lynds, J. A. 1989. Nova Scotia's old-growth forests. Conservation 13(2): 4-6.

MacDonald, B. A. 1996. Deer Wintering Habitat Models for Two Regions of Nova Scotia. MSc. Thesis report. Acadia University. Wolfville, Nova Scotia. 119pp.

MacDonald, K. F. 1968. Fish Population Assessment, Bras d'Or Lake, Cape Breton Island. N.S. Dept. Fish. Resource Development Div., Pictou. 16p.

MacDonald, P. 1994. Bald Eagles: An update on population status. Conservation 8(4). Nova Scotia Department of Natural Resources. 3pp.

MacDonald, P. and P. Austin-Smith. 1989. Bald eagle *Haliaeetus leucocephalus*, nest distribution on Cape Breton Island, Nova Scotia. Canadian Field-Naturalist 103(2): 293-296.

MacLeod Resources Ltd. 2006. Company profile. Accessed at: http://www.canadasmarble.com/home.htm. December 12, 2006.

MacMillan, J., D. Caissie, J. LeBlanc and T. Crandlemere. 2005. Characterization of Summer Water Temperatures for 312 Selected Sites in Nova Scotia. Can. Tech. Rep. Fish. Aquat. Sci. 2582: 43p.

MacMillan, J., and T. Crandlemere. 2005a. Thermal Classification of Salmonid Streams and Summer Distribution of Fishes in Nova Scotia with Potential Implication of Climate Change. Nova Scotia Department of Agriculture and Fisheries. Pictou, Nova Scotia. Unpublished. 24pp.

MacMillan, J. and T. Crandlemere. 2005b. Population Parameters of Cape Breton Brook Trout Populations in River Denys, Lake O'Law Brook of Margaree River, and Cold Brook of Middle River. Nova Scotia Department of Agriculture and Fisheries. Pictou, NS. Unpublished. Interim Draft data report. 10p

MacMillan, J. 2006. Nova Scotia Department of Fisheries and Aquaculture. Pictou, Nova Scotia. Personal communication via email. March 8, 2006.

Magnuson, J.J., D. M. Robertson, B. J. Benson, R. H. Wynne, D. M. Livingstone, T. Arai, R. A. Assel, R. G. Barry, V. Card, E. Kuusisto, N. G. Granin, T. D. Prowse, K. M. Stewart, and V. S. Vuglinski. 2000. Historical trends in lake and river ice cover in the Northern Hemisphere. Science 289: 1743-1746.

Malcolm, K. 2003. Proposed Designation of the Bras d'Or Lake as a Non-discharge Zone for Boating Sewage under the Canada Shipping Act. Prepared for the Pitu'paq Partnership. Submitted to Transport Canada, Marine Safety, Dartmouth, NS.

Marshall, T.L., Rutherford, K., LeBlanc, P. and Jones, R. 1999. Follow-up to the Assessment of Atlantic Salmon in Selected Rivers of Cape Breton Island, 1998. Can. Stock Assess. Sec. Res. Doc. 99/108.

Marshall, T.L., R. Jones, P. LeBlanc and L. Forsyth. 1996. Status of Atlantic Salmon Stocks in Selected Rivers of Cape Breton, 1995. DFO Atl. Fish. Res. Doc. 96/142.

McCabe, J. 2005. Personal communication via email. August 17, 2005.

McCorquodale, D. B. and R. W. Knapton. 2003. Changes in numbers of wintering American Black duck and Mallards in urban Cape Breton Island, Nova Scotia. Northeastern Naturalist 10(3): 297-304.

McLachlan, J. and T. Edelstein. 1971. Investigations of the marine algae of Nova Scotia. IX. A preliminary survey of the flora of Bras d'Or Lake, Cape Breton Island. Proc. N.S. Inst. Sci. 27: 11-22.

McLean's Magazine. Year unknown. We Rise Again: An Image of Cape Breton Island. Advertising Supplement. 6 p.

McMaster, M. and S. Courtenay (eds.) 2005. Theme Issue: Environmental Effects Monitoring. Water Quality Research Journal of Canada 40(3). 387 pp.

Medcof, J.C. 1955. Day and night characteristics of spatfall and of behaviour of oyster larvae. J. Fish. Res. Board Can. 12: 270-286.

Medcof, J.C. 1940. Oyster investigations in 1940. Fisheries Research Board of Canada, Manuscript Report 184: iii+103p.

Medcof, J.C. 1938a. Oyster investigations in Bras d'Or Lakes, 1938. Fisheries Research Board of Canada, Manuscript Report 159: iii+64p.

Melvin, G.D., L.M. Annis, M.J. Power, K.J. Clark, F.J. Fife and R.L. Stephenson. 2003. Herring Acoustic Surveys for 2002 in NAFO Divisions 4WX. Can. Sci. Advis. Sec. Res. Doc. 2003/034.

Miller, C. A. 2004. Reserve Planning on private land holdings of the forestry company, Stora Port Hawkesbury Limited: Cape Breton Island and Eastern Mainland Nova Scotia. Proc. N.S. Inst. Sci. 42(2): 393-408.

Milton, R. 2005. Manager, Wildlife Resources. Nova Scotia Department of Natural Resources (NSDNR), Kentville, Nova Scotia. Personal communication regarding data from NSDNR Colonial Bird Database.

Misund, O.A. 1997. Underwater acoustics in marine fisheries and fisheries research. Rev. Fish. Biol. Fisheries 7:1-34.

Morin, G. 2005. Climate Technician. Meteorological Service of Canada - Atlantic Region. Atlantic Climate Centre. Fredericton, New Brunswick. Personal communication via email. May 27th, 2005.

Muhammad, M.B. 1966. Spatial Distribution and Energy Requirements of Some Benthic Crustaceans in Baddeck Bay, Bras d'Or Lake, Nova Scotia. M.Sc. thesis. Dalhousie University, Halifax, Nova Scotia. iv+69p.

Murrant, D. 2005. Hatchery Manager. Nova Scotia Department of Agriculture & Fisheries. Fraser's Mills Fish Hatchery. St. Andrews. Nova Scotia. Personal communication via email. June 27th, 2005.

Myers, R. and G. Gilbert. 1993. Fishing-related Bottom Disturbance Study Bras d'Or Lakes. By Canadian Seabed Research Ltd. for Department of Fisheries and Oceans. Industry Services and Native Fisheries Branch. Halifax, NS. 22 pp.

Naug, J. 2004. Summary of Groups within the Bras d'Or Lakes Watershed. Oceans and Coastal Management Division, Department of Fisheries and Oceans, Dartmouth, Nova Scotia.

Needler, A.W.H. 1934. Oysters in the Bras d'Or Lakes, Cape Breton. Fish. Res. Board Can. Manus. Rep. 15313: 6 p.

Needler, A.W.H. 1936. Proposals for an Oyster Culture Policy in Cape Breton. Fish. Res. Board Can. Manus. Rep. 153A: 8 p.

Neily, P. D., E. Quigley, L. Benjamin, B. Stewart and T. Duke. 2003. Ecological Land Classification for Nova Scotia Volume 1 – Mapping Nova Scotia's Terrestrial Ecosystems. Nova Scotia Department of Natural Resources Renewable Resources Branch. Report DNR 2003-2. 83pp.

Nelson, J.A., Y. Tang and R.G. Boutiller. 1994. Differences in exercise physiology between two Atlantic cod (*Gadus morhua*) populations from different environments. Physiological Zoology 67(2): 330-354.

Nette, A. 2006. Nova Scotia Department of Natural Resources, Kentville, NS. Personal communication via email. September 5, 2006.

Nicholls, H. B. 1997. Middle Shoal Channel Improvement Project- Environmental Effects Monitoring. Department of Fisheries and Oceans. Can. Stock Assess. Sec. Res. Doc. 97/90. 11pp.

NS DEL (Nova Scotia Department of Environment and Labour). No date. Nature Reserves of Nova Scotia: Protecting special natural places. Four page brochure produced by the Environmental and Natural Areas Management Division, Protected Areas Branch.

NS DEL (Nova Scotia Department of Environment and Labour). 2001. We All Have a Part to Play. A sewage management discussion paper for the province of Nova Scotia. 13 p.

Nova Scotia Museum. 2006. Nova Scotia Salamanders. Accessed at: http://museum.gov.ns.ca/mnh/nature/salamand/bspotd.htm. March 14, 2006.

Nova Scotia Museum. 2005. Nova Scotia Turtles. Accessed at: http://museum.gov.ns.ca/mnh/nature/index.htm. March 14, 2005.

NSDNR (Nova Scotia Department of Natural Resources). 2006a. Bear Management Update 2005. Accessed at: http://www.gov.ns.ca/natr/wildlife/LGMAMS/lgmambear.htm. October 4, 2006.

NSDNR (Nova Scotia Department of Natural Resources). 2006b. Moose Management Update 2005. Accessed at: http://www.gov.ns.ca/natr/wildlife/LGMAMS/lgmammoose.htm. October 4, 2006.

NSDNR (Nova Scotia Department of Natural Resources). 2006c. Deer Management Update 2005. Accessed at: http://www.gov.ns.ca/natr/wildlife/LGMAMS/lgmamdeer.htm#Figure2. October 4, 2006.

NSDNR (Nova Scotia Department of Natural Resources). 2006d. Active Mining Operations in Nova Scotia. Open File Illustration ME 2006-3. Poster produced by the NSDNR, Graphing and Mapping Services.

NSDNR (Nova Scotia Department of Natural Resources). 2006e. Nova Scotia Abandoned Mine Openings Database. DP ME 10, Version 3, 2006. Digital product compiled by B. E. Fisher and E. W. Hennick. Accessed at: http://www.gov.ns.ca/natr/MEB/download/dp010.htm. November 26th, 2006.

NSDNR (Nova Scotia Department of Natural Resources). 2005a. Ecological Land Classification Map and Database. Accessed at: www.gov.ns.ca/natr/forestry/ecosystem/elcpg3.htm. May 26th, 2005.

NSDNR (Nova Scotia Department of Natural Resources). 2005b. GeoFacts: Anhydrite in Nova Scotia. Mineral Resources Branch Information Circular ME31. Accessed at: http://www.gov.ns.ca/natr/meb/ic/ic31.htm#06. September 2005.

NSDNR (Nova Scotia Department of Natural Resources). 2005c. Report on Primary Forest Products Acquired, Secondary Forest Products Produced and Wood Acquisition Plan Program. Registry of Buyers, 2004 Calendar Year.

NSDNR (Nova Scotia Department of Natural Resources). 2004. Significant Species and Habitats database. Wildlife Division. Accessed at: http://www.gov.ns.ca/natr/wildlife/Thp/disclaim.htm.

NSDNR (Nova Scotia Department of Natural Resources). 2003a. Selected Nova Scotia old-growth forests: Age, ecology, structure, scoring. The Forestry Chronicle 79(3): 632-644.

NSDNR (Nova Scotia Department of Natural Resources). 2003b. Mining Industry Activity in Nova Scotia, 2003. Accessed at: http://www.gov.ns.ca/natr/meb/pdf/06re01/Appendix01.pdf. January 26, 2007.

NSDNR (Nova Scotia Department of Natural Resources). 2002. Restricted and Limited Use Land Database. Accessed at: http://gov.ns.ca/natr/meb/download/rlul.htm.

NSDNR (Nova Scotia Department of Natural Resources). 2000. Nova Scotia Wetlands and Coastal Habitats Inventory. Computer database. Renewable Resources Branch. Wildlife Division. Kentville, Nova Scotia.

NSDNR (Nova Scotia Department of Natural Resources). 1999. Wetlands Database Specifications. Draft at September 03, 1999. Renewable Resources Branch. Wildlife Division. Kentville, Nova Scotia. 16 p.

NSDNR (Nova Scotia Department of Natural Resources). 1998. Endangered Species Act. 1998, c. 11, s. 1.

NSGC (Nova Scotia Geomatics Centre). 1999. 1:10,000 (20m) digital elevation model. NSGC, Service Nova Scotia and Municipal Relations.

NSGC (Nova Scotia Geomatics Centre). no date. Property ownership data from the Digital Property Series and Property Online, NSGC, Service Nova Scotia and Municipal Relations. Accessed at: http://www.gov.ns.ca/snsmr/land/products/property1.asp.

NSSCI (Nova Scotia Sustainable Communities Initiative). 2005. Welcome to NSSCI. Accessed at: http://www.nssci.net/about_nssci. October 2005.

Ocean Science Associates Ltd. & Atlantic Mariculture Ltd. 1972. An Evaluation of Environmental Factors in the Bras d' Or Lake and Approaches with Respect to a Potential Oyster Culture Industry. Report to the Cape Breton Development Corporation: v+58p.

Paul, K. 2005. Eskasoni Fish and Wildlife Commission. Personal communication.

Parker, G. R., J. W. Maxwell, L. D. Morton and G.E. J. Smith. 1983. The ecology of the lynx (*Lynx canadensis*) on Cape Breton Island. Can. J. Zoology 61: 770-786.

Parkes, G. and J.M. Gray. 1992. Scotia/Fundy Marine Weather Guide. Environment Canada Atlantic Region. Catalogue No. En 56-90/1992 E, 100 p.

Patterson, B., L. Benjamin and F. Messier. 1998. Prey switching and feeding habits of eastern coyotes in relation to snowshoe hare and white-tailed deer densities. Can. J. Zoology 76(10): 1885-1897.

Patterson, B. , S. Bondrup-Nielsen, and F. Messier. 1999. Activity patterns and daily movements of the Eastern Coyote, *Canis latrans*, in Nova Sotia. Canadian Field Naturalist 113 (2): 251-257.

Patterson, B. and V. Power. 2002. Contributions of forage competition, harvest, and climate fluctuations to changes in population growth of northern white-tailed deer. Oecologia 130:62-71.

Patterson, B., B. MacDonald, B. Lock, D. Anderson and L. Benjamin. 2002. Proximate factors limiting population growth of white-tailed deer in Nova Scotia. J. Wildl. Manage. 66(2): 511-521.

Patterson, B. and F. Messier. 2003. Age and condition of deer killed by coyotes in Nova Scotia. Can. J. Zoology 81: 1894-1898.

Petrie, B. 1999. Sea level variability in the Bras d'Or Lakes. Atmosphere-Ocean 37(2):221-239.

Petrie, Brian. 2006. Fisheries and Oceans Canada. Personal communication. Written comments on draft Bras d'Or ecosystem overview report.

Petrie, B. and G. Bugden. 2002. The physical oceanography of the Bras d'Or Lakes. Proc. N.S. Inst. Sci. 42 (1): 9-36.

Petrie, B. and J. Raymond. 2002. The oceanography of the Bras d'Or Lakes: General introduction. Proc. N.S. Inst. Sci. 42 (1):1-8.

Petrie, B., P. Yeats and P. Strain. 1999. Nitrate, Silicate and Phosphate Atlas for the Scotian Shelf and Gulf of Maine. Can. Tech. Rep. Hydrog. Ocean Sci. 203: vii+ 96pp.

PPS (Pitu'paq Partnership Society). 2006. The Pitu'paq Partnership Society. Accessed at: http://pitupaq.ca/. October 12, 2005.

Pogson, G.H., C.T. Taggart, K. A. Mesa and R. G. Boutilier. 2001. Isolation by distance in the Atlantic cod, *Gadus morhua*, at large and small geographic scales. Evolution 55(1): 131-146.

Power, M.J., R. L. Stephenson, L.M. Annis, F.J. Fife, K.J.Clark and G. D. Melvin. 2003. 2003 Evaluation of 4VWX Herring. Can. Sci. Advis. Secret. Res. Doc. 2003/035. Fisheries and Oceans Canada. 104pp.

Province of Nova Scotia. 2005. Nova Scotia Community Counts. Accessed at: http://www.gov.ns.ca/finance/communitycounts/. September 2005.

Province of Nova Scotia. 1994. Nova Scotia Geology Map. 1:640,000. Nova Scotia Department of Natural Resources. Nimbus Publishing.

Pulsifer, M. 1995. Moose herd perseveres. Conservation 19(3). Nova Scotia Department of Natural Resources.

Pulsifer, M., J. MacEachern and L. Allen. 2004. St. Mary's River Wood turtles a species at risk, a population in decline? Nova Scotia Department of Natural Resources. Natures Resources 7(1):15-17.

Pulsifer, M. and T. Nette. 1995. History, status and present distribution of moose in Nova Scotia. Alces 31: 209-219. Co-editors: M. Lankester and H. Timmermann.

Pulsifer, M., P. Tufts and A. Nette. No date. When Black Bears Become a Nuisance. Nova Scotia Department of Natural Resources.

Rankin, D. and R. Hyndman. 1971. Shallow water heat flow measurements in Bras d'Or Lake, Nova Scotia. Can. J. Earth Sci. 8:96-101.

Ricciardi, A. and J. B. Rasmussen. 1999. Extinction rates of North American freshwater fauna. Conservation Biology 13(5): 1220-1222.

Robichaud-LeBlanc, K. and P. Amiro. 2004. Assessments of Atlantic Salmon Stocks in Selected Rivers of Eastern Cape Breton, SFA 19, to 2003. Can. Sci. Advis. Sec. Res. Doc. 2004/017. 66p.

Roman, J. 2003. Harvard University. Personal communication.

Rowell, T. W. 1975. Maritime oyster culture development potentials & limitations. In: The Proceedings of the Bras d'Or Lakes Aquaculture Conference. June, 1975. Ed. G. Mackay. College of Cape Breton Press, Sydney, Cape Breton Island. p. 130-139.

Sabean, B.C. 1983. Bras d'Or Lake Rainbow Trout Fishery. Nova Scotia Department of Lands and forests, Technical Note No. 17. 10p.

Schwarz, A.L. and G.L. Greer. 1984. Responses of Pacific herring, *Clupea harengus pallasi* to some underwater sounds. Can. J. Fish. Aquat. Sci. 41: 1183-1192.

Scott, D.M. and W.F. Black. 1960. Studies on the life-history of the Ascarid *Porrocaecum decipiens* in the Bras d'Or Lakes, Nova Scotia, Canada. J. Fish. Res. Board Can. 17(6): 763-774.

Scott, D.M. and H.D. Fisher. 1958. Incidence of the ascarid *Porrocaecum decipiens* in the stomachs of three species of seals along the southern Canadian Atlantic mainland. Journal of the Fisheries Researhc Board of Canada 15: 495-516.

Scott, F. W. and A. J. Hebda. 2004. Annotated list of the mammals of Nova Scotia. Proc. N. S. Inst. Sci. 42(2): 189-208.

Scott, J. S. 1975. Meristics of Herring (*Clupea harengus L.*) from the Canadian Maritimes Area. Fish. Mar. Serv. Tech. Rep. 599: 24 p.

Service Nova Scotia and Municipal Relations. 2003. Wastewater Management Districts - An Alternative for Sewage Disposal in Small Communities. Local Resource Government Handbook, Section 5.10.

Seymour, N. R., A. G. Miller, and D. J. Garbary. 2002. Decline of Canada geese (*Branta Canadensis*) and common goldeneye (*Bucephala clangula*) associated with a collapse of eelgrass (*Zostera marina*) in a Nova Scotia estuary. Helgol. Mar. Res. 56: 198-202.

Shaw, J. and D. P. Potter. 2006a. Sun Illuminated Sea Floor Topography, Bras d'Or (South) Nova Scotia. Geological Survey of Canada. A-Series Map XXXX-A2. Scale 1:50000. In Press. Map one of a three-map series for the southern part of the Bras d' Or Lakes, Nova Scotia. (90%).

Shaw, J. and D. P. Potter. 2006b. Sun Illuminated Sea Floor Topography, Bras d'Or (North) Nova Scotia. Geological Survey of Canada. A-Series Map XXXX-A2. Scale 1:50000. In Press. Map one of a three-map series for the northern part of the Bras d' Or Lakes, Nova Scotia. (90%).

Shaw, J., and D. P. Potter. 2006c. Backscatter Strength Bras d'Or Lakes (South), Nova Scotia. Geological Survey of Canada. A-Series Map XXXX-A1. Scale 1:50000. In Press. Map one of a three-map series for the southern part of the Bras d' Or Lakes, Nova Scotia. (90%).

Shaw, J. and D. P. Potter. 2006d. Backscatter Strength Bras d'Or Lakes (North), Nova Scotia. Geological Survey of Canada. A-Series Map XXXX-A2. Scale 1:50000. In Press.

Shaw, J., D.J.W. Piper and R.B. Taylor. 2002. The geology of the Bras d'Or Lakes, Nova Scotia. Proc. N.S. Inst. Sci. 42 (1): 127-147.

Shih, C., L. Marhue, N. Barrett and R. Munro. 1988. Planktonic copepods of the Bras d'Or Lakes system, Nova Scotia, Canada. Hydrobiologica 167/168: 319-324.

Simpson, F.J. (Chair). 1976. Seaweeds. In: The Proceedings of the Bras d'Or Lakes Aquaculture Conference, Sydney, Cape Breton. Ed. M.G. McKay. College of Cape Breton Press, Sydney, N.S.

Sirota, G.R., J.F. Uthe, D.G. Robinson and C.J. Musial. 1984. Polycyclic Aromatic Hydrocarbons in American Lobster (*Homarus americanus*) and Blue Mussels (*Mytilus edulis*) Collected in the Area of Sydney Harbour, Nova Scotia. Can. MS Rep. Fish. Aquat. Sci. 1758: vi+22p

Smith, G.F.M. 1936. Oyster Investigations at Bras d'Or Lakes, Cape Breton: Report for 1936. Fish. Res. Board Can. Manus. Rep. 164A: 9p.

Smith, M.W. and D.K. Rushton. 1964. A study of barachois ponds in the Bras d'Or Lake area of Cape Breton, Nova Scotia. Proc. N. S. Inst. Sci. 26(1): 3-17.

Snaith, T. and K. Beazley. 2004. The distribution, status and habitat associations of moose in Mainland Nova Scotia. Proc. N. S. Inst. Sci. 42(2): 263-317.

Statistics Canada. 2004a. Census information based on 2001 census data and the Census Dissemination Area Boundaries that approximate the watershed.

Statistics Canada. 2004b. Shipping in Canada 2002. Transportation Division, Multimodal Transport Section, Statistics Canada. Minister of Industry, Ottawa, Ontario.

Stephenson, M. and B. Petrie. 2005. Oceanographic influences on the management of MSX disease of American oysters (*Crassostrea virginica*) in Atlantic Canada. Bull. Aquacul. Assoc. Canada 105(1): 67-78.

Stevens, S. 1993. Bras d'Or Lakes Lobster Population Study. Mi'kmaq Aboriginal Fisheries Service, Eskasoni, N.S.: ii+63p.

Stevens, S. and E. Denny. 1993. Lobster Study. Un ama' kik Aboriginal Fisheries Services. East Bay, Nova Scotia. Pp.12.

Stora Enso. 2005. Stora Enso Port Hawkesbury – Indicators of Sustainable Forest Management. April 18th, 2005. 9 pp.

Stora Enso. 2002a. SFM Indicator Status. Stora Enso Port Hawkesbury Woodlands Unit. 69 pp.

Stora Enso. 2002b. Stora Enso Port Hawkesbury Woodlands Unit Long Term Plan – 2002. 180 pp. Accessed at: http://www.storaenso.com. October 15, 2005.

Strain, P.M. and P.A. Yeats. 2002. The chemical oceanography of the Bras d'Or Lakes. Proc. N.S. Inst. Sci. 42 (1): 37-64.

Strain, P.M., G. Bugden, M. Brylinsky and S. Denny. 2001. Nutrient, Dissolved Oxygen, Trace Metal and Related Measurements in the Bras d'Or Lakes, 1995-1997. Can. Data Rep. Fish. Aquat. Sci. 1073: 52p.

Strain, P.M. and P.A. Yeats. 1999. The relationships between chemical measures and potential predictors of the eutrophication status of inlets. Mar. Poll. Bull. 38: 1163-1170.

Taylor, R.B. and J. Shaw. 2002. Coastal character and coastal barrier evolution in the Bras d'Or Lakes, Nova Scotia. Proc. N.S. Inst. Sci. 42(1): 148-181.

Taylor, R. B. and D. Frobel. 1998. Aerial Video Surveys: The Bras d'Or Lakes Shoreline, Nova Scotia. Geological Survey of Canada Open File Report 3656. 58p.

TEC Ltd. (Thaumas Environmental Consultants Ltd.). 2005. Chapters 11, 12, 13. In: Gulf of St. Lawrence Integrated Management Ecosystem Assessment. Department of Fisheries and Oceans. In Press.

Tremblay, M.J. 2005. Fisheries and Oceans Canada. Bedford Institute of Oceanography. Dartmouth, Nova Scotia. Personal communication

Tremblay, M. J. 2004. Lobsters and other invertebrates in relation to bottom habitat in the Bras d'Or Lakes: Application of video and SCUBA transects. Report on the 2002-03 and 2003-04 Joint Project Agreement between Eskasoni Fish and Wildlife Commission and Fisheries and Oceans Canada. Sept. 2004. Fisheries and Oceans Canada. Invertebrate Fisheries Division. Bedford Institute of Oceanography. 53p.

Tremblay, M.J. 2002. Large epibenthic invertebrates in the Bras d'Or Lakes. Proc. N.S. Inst. Sci. 42(1): 101-126.

Tremblay, M.J. and A. Reeves. 2004. Eastern Cape Breton Lobster (LFAs 27-30): Stock status and biological effects of the increase in minimum legal size. Can. Sci. Advis. Sec. Res. Doc. 2004/021.

Tremblay, M.J. and M.D. Eagles. 1998. Eastern Cape Breton Lobster (LFAs 27-30): Stock status and egg per recruit estimates. Can. Sci. Advis. Sec. Res. Doc. 1998/124.

Turnpenny, A.W.H. and J.R. Nedwell 1994. The Effects on Marine Fish, Diving Mammals and Birds of Underwater Sound Generated by Seismic Surveys. Report by Fawley Aquatic Research Laboratories Ltd. for United Kingdom Offshore Operators Association Limited, London. 40 p.

UMA Group. 1989. Bras d'Or Lake Watershed Integrated Resource Management Plan Study. Bras d'Or Institute. Dec. 1989. 142 +App.

Vandermeulen, H. 2006. Department of Fisheries and Oceans. Bedford Institute of Oceanography. Personal communication. February 10, 2006.

Vieth, F. 1884. Report upon the Condition of the Rivers in Nova Scotia in Connection with the Fisheries in that Province. Canadian Department of the Secretary of State. Sessional Papers No. 134. Published by MacLean, Roger and Co. Ottawa, Ontario. 76pp.

Vilks, G. 1967. Quantitative Analysis of Foraminifera in the Bras d'Or Lakes. Report of Bedford Institute of Oceanography. 67-1, 84 p.

Voluntary Planning Task Force. 2001. Non-resident Land Ownership in Nova Scotia. Final report – December 2001. Accessed at http://www.gov.ns.ca/vp/nonres/fr.pdf.

Warner, J.M. and J.L. Warner. 1996. Middle Shoal Channel Improvement Project: Physical oceanography and sediment dispersion monitoring programs. [Draft] Martec Report TR-96-44, prepared for Little Narrows Gypsum Company, pag.var.

Westhead, M. 2004. Overview of the herring fishery in the Bras d'Or Lakes. In: Bras d'Or Lakes Workshop 2004 Proceedings. Viii+86 pp.

WWT (World Web Technologies Ltd). 2006. Cape Breton Golf Courses. Accessed at: http://www.capebreton.worldweb.com/ToursActivitiesAdventures/GolfCourses/. June 7, 2006.

Wright, R.A. 1976. Some production parameters at selected Bras d'Or sites. In: The Proceedings of the Bras d'Or Lakes Aquaculture Conference, Sydney, Cape Breton. Ed. M.G. McKay. College of Cape Breton Press, Sydney, N.S. p. 54-66.

Yeats, P. 2006. Head, Marine Chemistry Section. Fisheries and Oceans Canada. Bedford Institute of Oceanography. Dartmouth, Nova Scotia. Personal communication.

Yeats, P. 2005. Head, Marine Chemistry Section. Fisheries and Oceans Canada. Bedford Institute of Oceanography. Dartmouth, Nova Scotia. Personal communication via email. May 19th, 2005.

Young, J.C. O'C. 1973a. Metal content of oysters found in Cape Breton Island waters. In: Rocks, Phytoplankton and Oysters. Environmental Studies Group, St. Mary's University, Halifax, Nova Scotia. St. Mary's University ESG Rep. 73-03.

Young, J.C. O'C. 1973b. Metal content of miscellaneous molluscs found in Cape Breton Island waters. In: Silt, Water and Miscellaneous Mollusks. Environmental Studies Group, St. Mary's University, Halifax, Nova Scotia. St. Mary's University. October 1973. ESG Rep. 73-06.18pp.

Young, J.C.O'C. 1973c. Phytoplankton Chlorophyll Levels and Oyster Growth in Cape Breton Island Waters. Applied Science Associates Limited report. Prepared for the Cape Breton Development Corporation. January 1973. Report no. ASA-73-01-11. 54pp.

Young, J. C. O'C. 1973d. Analysis of water samples from the Bras d'Or Lake system and influent rivers. In: Silt, Water and Miscellaneous Mollusks. Environmental Studies Group, St. Mary's University, Halifax, Nova Scotia. September 1973. St. Mary's University ESG Rep. 73-05. 106pp.

Young, J. C.O'C. 1974. Further studies of chlorophyll determination as an index of primary production. SMU ESG Report 74-08: iv+29p. [Bound in: Trout, Chlorophyll & Shells: A report prepared for the Cape Breton Development Corporation by the Environmental Studies Group of the Department of Chemistry, Saint Mary's University.]

Young, J. C.O'C. 1976. Aquaculture and chemistry of Bras d'Or. In: The Proceedings of the Bras d'Or Lakes Aquaculture Conference, Sydney, Cape Breton. Ed. M.G. McKay. College of Cape Breton Press, Sydney, NS. p. 17-28.

APPENDIX A: BRAS D'OR LAKES TRADITIONAL ECOLOGICAL KNOWLEDGE WORKSHOP PROCEEDINGS

APPENDIX B: SUMMARY OF SPECIES AT RISK IN THE BRAS D'OR WATERSHED

Table B1. Summary of species assessed and reported through the Atlantic Canada Conservation Data Centre for the Bras d'Or Lake watershed sub-basins in 2005, and sorted first by provincial (SPROT) and national (NPROT) protected species, followed by provincial ranking (SRANK). Further explanation of ranks follows this table.

01BaddeckR	02UpMiddleR	03GBrasdOr	05StPetersI	06aStPatricks	06bStAndrews	06cRiverDenys	08Whycocomagh	10aWestBay	10bEastBay	12NorthBasin	15unnamed	GNAME	GCOMNAME	GRANK	NPROT	SRANK	SPROT
X		X		X	X			X	X			*Lynx canadensis*	Lynx	G5	**NAR**	S1	**Endangered**
								X				*Floerkea proserpinacoides*	False Mermaid-Weed	G5	**NAR**	S2S3	
						X					X	*Ammodramus nelsoni*	Nelson's Sharp-tailed Sparrow	G5	**NAR**	S2S3B	
X		X		X								*Hemidactylium scutatum*	Four-toed Salamander	G5	**NAR**	S3	
		X										*Accipiter gentilis*	Northern Goshawk	G5	**NAR**	S3B	
X	X	X	X	X	X	X	X	X	X	X	X	*Sterna hirundo*	Common Tern	G5	**NAR**	S3B	
		X										*Falco columbarius*	Merlin	G5	**NAR**	S3S4B	
				X			X					*Catharus bicknelli*	Bicknell's Thrush	G4	**SC**	S1S2B	**Vulnerable**
X	X	X		X	X	X	X					*Glyptemys insculpta*	Wood Turtle	G4	**SC**	S3	**Vulnerable**
X	X			X								*Sorex gaspensis*	GaspÄ Shrew	G3	**SC**	S2	
X			X	X						X	X	*Isoetes prototypus*	Prototype Quillwort	G2?	**SC**	S2	
X												*Martes americana*	American Marten	G5		S1	**Endangered**
X												*Ophiogomphus aspersus*	Brook Snaketail	G3G4		S1	
							X					*Gomphaeschna furcillata*	Harlequin Darner	G5		S1	
X		X	X	X			X	X		X		*Somatochlora septentrionalis*	Muskeg Emerald	G5		S1	
			X		X	X	X		X		X	*Somatochlora williamsoni*	Williamson's Emerald	G5		S1	
					X							*Coenagrion interrogatum*	Subarctic Bluet	G5		S1	
X												*Enallagma carunculatum*	Tule Bluet	G5		S1	
						X						*Paludella squarrosa*	a Moss	G3G5		S1	
						X		X				*Sanicula odorata*	Black Snake-Root	G5		S1	
X						X	X					*Hypericum majus*	Larger Canadian St. John's Wort	G5		S1	
							X					*Polygonum viviparum*	Viviparous Knotweed	G5		S1	
		X					X					*Rhynchospora capillacea*	Horned Beakrush	G5		S1	
	X			X								*Listera australis*	Southern Twayblade	G4		S1	
X												*Stuckenia vaginata*	Sheathed Pondweed	G5		S1	
	X											*Schoenoplectus robustus*	Saltmarsh Bulrush	G5		S1?	
				X			X					*Triglochin gaspensis*	Gaspe Peninsula Arrow-Grass	G3		S1?	
				X			X					*Cystopteris laurentiana*	Laurentian Bladder Fern	G3		S1?	
				X			X					*Asio otus*	Long-eared Owl	G5		S1S2	
						X						*Arabis hirsuta var. pycnocarpa*	Hairy Rock-Cress	G5T5		S1S2	

Table B1. Summary of species assessed and reported through the Atlantic Canada Conservation Data Centre for the Bras d'Or Lake watershed sub-basins in 2005 *continued*

01BaddeckR	02UpMiddleR	03GBrasdOr	05StPetersI	06aStPatricks	06bStAndrews	06cRiverDenys	08Whycocomagh	10aWestBay	10bEastBay	12NorthBasin	15unnamed	GNAME	GCOMNAME	GRANK	NPROT	SRANK	SPROT
						X						*Lobelia kalmii*	Kalm's Lobelia	G5		S1S2	
						X						*Anemone virginiana var. alba*	River Anemone	G5T4T5		S1S2	
						X						*Carex bebbii*	Bebb's Sedge	G5		S1S2	
						X						*Carex viridula ssp. oedocarpa*	A Sedge	G5T?		S1S2	
						X						*Juncus alpinoarticulatus*	A Rush	G5		S1S2	
						X	X					*Juncus alpinoarticulatus ssp. nodulosus*	Richardson's Rush	G5T5?		S1S2	
							X				X	*Calamagrostis stricta* ssp. stricta	Northern Reedgrass	G5T5		S1S2	
						X						*Cryptogramma stelleri*	Fragile Rockbrake	G5		S1S2	
						X						*Woodsia alpina*	Northern Woodsia	G4		S1S2	
						X						*Picoides tridactylus dorsalis*	American Three-toed Woodpecker	G5TU		S2	
X				X		X						*Salmo salar*	Atlantic Salmon	G5		S2	
X		X		X		X						*Microtus chrotorrhinus*	Rock Vole	G4		S2	
X	X			X		X				X		*Gomphus borealis*	Beaverpond Clubtail	G4		S2	
X	X			X						X		*Gomphus descriptus*	Harpoon Clubtail	G4		S2	
X	X	X		X								*Gomphus spicatus*	Dusky Clubtail	G5		S2	
X	X	X		X								*Gomphus adelphus*	Mustached Clubtail	G4		S2	
X	X			X						X		*Lanthus parvulus*	Northern Pygmy Clubtail	G4		S2	
X	X					X						*Aeshna sitchensis*	Zigzag Darner	G5		S2	
X				X								*Dorocordulia libera*	Racket-Tailed Emerald	G5		S2	
X	X											*Somatochlora cingulata*	Lake Emerald	G5		S2	
X				X						X		*Somatochlora forcipata*	Forcipate Emerald	G5		S2	
X	X					X						*Somatochlora minor*	Ocellated Emerald	G5		S2	
						X						*Somatochlora tenebrosa*	Clamp-Tipped Emerald	G5		S2	
						X						*Sympetrum danae*	Black Meadowhawk	G5		S2	
X		X		X			X			X		*Lestes forcipatus*	Sweetflag Spreadwing	G5		S2	
				X	X	X				X	X	*Lestes eurinus*	Amber-Winged Spreadwing	G4		S2	
					X							*Lestes unguiculatus*	Lyre-Tipped Spreadwing	G5		S2	
				X		X	X			X		*Enallagma vernale*	a Bluet Damselfly	G4Q		S2	
					X		X					*Enallagma aspersum*	Azure Bluet	G5		S2	
X	X	X		X			X					*Amphiagrion saucium*	Eastern Red Damsel	G5		S2	
	X											*Osmorhiza longistylis*	Smoother Sweet-Cicely	G5		S2	
		X										*Erigeron philadelphicus*	Philadelphia Fleabane	G5		S2	
		X										*Senecio pseudoarnica*	Seabeach Groundsel	G5		S2	
X							X					*Impatiens pallida*	Pale Jewel-Weed	G5		S2	

Table B1. Summary of species assessed and reported through the Atlantic Canada Conservation Data Centre for the Bras d'Or Lake watershed sub-basins in 2005 *continued*

01BaddeckR	02UpMiddleR	03GBrasdOr	05StPetersI	06aStPatricks	06bStAndrews	06cRiverDenys	08Whycocomagh	10aWestBay	10bEastBay	12NorthBasin	15unnamed	GNAME	GCOMNAME	GRANK	NPROT	SRANK	SPROT
						X	X					*Caulophyllum thalictroides*	Blue Cohosh	G4G5		S2	
							X		X			*Arabis drummondii*	Drummond Rockcress	G5		S2	
X				X	X				X	X		*Draba arabisans*	Rock Whitlow-Grass	G4		S2	
X												*Triosteum aurantiacum*	Coffee Tinker's-Weed	G5		S2	
X	X											*Shepherdia canadensis*	Canada Buffalo-Berry	G5		S2	
				X		X	X			X		*Vaccinium boreale*	Northern Blueberry	G4		S2	
X												*Vaccinium caespitosum*	Dwarf Blueberry	G5		S2	
						X	X				X	*Rumex salicifolius*	Willow Dock	G5		S2	
					X							*Pyrola minor*	Lesser Wintergreen	G5		S2	
		X			X		X					*Anemone quinquefolia*	Wood Anemone	G5		S2	
							X					*Galium labradoricum*	Bog Bedstraw	G5		S2	
X												*Comandra umbellata*	Umbellate Bastard Toad-Flax	G5		S2	
X		X										*Parnassia palustris var. parviflora*	a Marsh Grass-of-Parnassus	G4		S2	
						X	X				X	*Saxifraga paniculata ssp. neogaea*	a White Mountain Saxifrage	G5T?		S2	
						X						*Viola nephrophylla*	Northern Bog Violet	G5		S2	
X							X					*Carex atratiformis*	Black Sedge	G5		S2	
	X			X	X		X		X	X		*Eleocharis quinqueflora*	Few-Flower Spikerush	G5		S2	
							X					*Juncus trifidus*	Highland Rush	G5		S2	
X			X	X						X		*Cypripedium reginae*	Showy Lady's-Slipper	G4		S2	
					X				X			*Potamogeton obtusifolius*	Blunt-Leaf Pondweed	G5		S2	
X												*Asplenium trichomanes*	Maidenhair Spleenwort	G5		S2	
X		X		X		X	X	X			X	*Asplenium trichomanes-ramosum*	Green Spleenwort	G4		S2	
			X			X	X					*Polystichum lonchitis*	Northern Holly-Fern	G5		S2	
		X		X	X	X				X	X	*Woodsia glabella*	Smooth Woodsia	G5		S2	
					X							*Botrychium lanceolatum var. angustisegmentum*	Lance-Leaf Grape-Fern	G5T4		S2	
							X					*Hieracium umbellatum*	Umbellate Hawkweed	G5?		S2?	
							X					*Symphyotrichum boreale*	Boreal American-Aster	G5		S2?	
							X					*Amelanchier fernaldii*	Fernald Serviceberry	G2G4		S2?	
				X		X	X					*Bucephala clangula*	Common Goldeneye	G5		S2B	
				X								*Vireo gilvus*	Warbling Vireo	G5		S2B	
X												*Vireo philadelphicus*	Philadelphia Vireo	G5		S2B	
		X		X						X	X	*Tringa melanoleuca*	Greater Yellowlegs	G5		S2B,S5M	
		X			X			X				*Asclepias incarnata ssp. pulchra*	Swamp Milkweed	G5T5		S2S3	
			X									*Erigeron hyssopifolius*	Daisy Fleabane	G5		S2S3	

Table B1. Summary of species assessed and reported through the Atlantic Canada Conservation Data Centre for the Bras d'Or Lake watershed sub-basins in 2005 *continued*

01BaddeckR	02UpMiddleR	03GBrasdOr	05StPetersl	06aStPatricks	06bStAndrews	06cRiverDenys	08Whycocomagh	10aWestBay	10bEastBay	12NorthBasin	15unnamed	GNAME	GCOMNAME	GRANK	NPROT	SRANK	SPROT
											X	*Decodon verticillatus*	Hairy Swamp Loosestrife	G5		S2S3	
		X							X			*Lilium canadense*	Canada Lily	G5		S2S3	
			X						X			*Cypripedium parviflorum*	Small Yellow Lady's-Slipper	G5		S2S3	
X				X					X	X	X	*Goodyera repens*	Dwarf Rattlesnake-Plantain	G5		S2S3	
				X		X	X					*Poa glauca*	White Bluegrass	G5		S2S3	
	X			X								*Poa glauca ssp. glauca*	White Bluegrass	G5T5?		S2S3	
X	X											*Stuckenia filiformis*	Slender Pondweed	G5		S2S3	
X				X						X		*Potamogeton zosteriformis*	Flatstem Pondweed	G5		S2S3	
X				X						X		*Ophioglossum pusillum*	Adder's Tongue	G5		S2S3	
X	X			X		X				X		*Mergus serrator*	Red-breasted Merganser	G5		S2S3B	
						X						*Sayornis phoebe*	Eastern Phoebe	G5		S2S3B	
X	X	X		X								*Polygonum raii*	Pondshore Knotweed	G2G4Q		S2S3SE	
X	X	X		X		X	X			X		*Cordulegaster diastatops*	Delta-Spotted Spiketail	G5		S3	
X		X		X		X	X			X		*Cordulegaster maculata*	Twin-Spotted Spiketail	G5		S3	
						X						*Gomphus exilis*	Lancet Clubtail	G5		S3	
X	X	X		X			X			X		*Ophiogomphus carolus*	Riffle Snaketail	G5		S3	
X	X	X	X	X		X				X	X	*Aeshna canadensis*	Canada Darner	G5		S3	
X	X	X		X		X	X	X	X	X		*Aeshna eremita*	Lake Darner	G5		S3	
						X	X					*Aeshna subarctica*	Subarctic Darner	G5		S3	
					X	X		X				*Aeshna tuberculifera*	Black-Tipped Darner	G4		S3	
X	X	X		X		X	X					*Anax junius*	Common Green Darner	G5		S3	
X	X			X						X		*Basiaeschna janata*	Springtime Darner	G5		S3	
X												*Boyeria vinosa*	Fawn Darner	G5		S3	
X	X	X		X		X		X	X	X		*Cordulia shurtleffii*	American Emerald	G5		S3	
X	X	X		X		X	X					*Epitheca canis*	Beaverpond Baskettail	G5		S3	
X	X											*Epitheca spinigera*	Spiny Baskettail	G5		S3	
X	X			X								*Helocordulia uhleri*	Uhler's Sundragon	G5		S3	
X	X			X		X				X		*Somatochlora elongata*	Ski-Tailed Emerald	G5		S3	
X	X											*Somatochlora elongata*	Ski-Tailed Emerald	G5		S3	
X	X	X		X								*Somatochlora walshii*	Brush-Tipped Emerald	G5		S3	
X				X						X		*Leucorrhinia frigida*	Frosted Whiteface	G5		S3	
X				X		X				X		*Leucorrhinia glacialis*	Crimson-Ringed Whiteface	G5		S3	
X		X		X		X						*Leucorrhinia hudsonica*	Hudsonian Whiteface	G5		S3	
X		X		X								*Leucorrhinia intacta*	Dot-Tailed Whiteface	G5		S3	
X	X	X		X	X	X		X		X	X	*Leucorrhinia proxima*	Red-Waisted Whiteface	G5		S3	
X	X			X				X				*Plathemis lydia*	Common Whitetail	G5		S3	

Table B1. Summary of species assessed and reported through the Atlantic Canada Conservation Data Centre for the Bras d'Or Lake watershed sub-basins in 2005 *continued*

01BaddeckR	02UpMiddleR	03GBrasdOr	05StPetersI	06aStPatricks	06bStAndrews	06cRiverDenys	08Whycocomagh	10aWestBay	10bEastBay	12NorthBasin	15unnamed	GNAME	GCOMNAME	GRANK	NPROT	SRANK	SPROT
X	X	X		X		X	X		X	X	X	*Ladona julia*	Chalk-Fronted Corporal	G5		S3	
X	X	X		X		X				X	X	*Sympetrum costiferum*	Saffron-Winged Meadowhawk	G5		S3	
X						X						*Sympetrum obtrusum*	White-Faced Meadowhawk	G5		S3	
						X						*Sympetrum semicinctum*	Band-Winged Meadowhawk	G5		S3	
X	X					X	X					*Sympetrum vicinum*	Yellow-Legged Meadowhawk	G5		S3	
X	X			X		X				X		*Calopteryx aequabilis*	River Jewelwing	G5		S3	
X		X		X		X				X		*Calopteryx amata*	Superb Jewelwing	G4		S3	
X	X	X		X		X				X		*Lestes dryas*	Emerald Spreadwing	G5		S3	
X				X		X				X		*Lestes congener*	Spotted Spreadwing	G5		S3	
X												*Lestes rectangularis*	Slender Spreadwing	G5		S3	
X	X			X		X			X	X		*Argia fumipennis violacea*	Variable Dancer	G5T5		S3	
						X		X				*Argia moesta*	Powdered Dancer	G5		S3	
X	X			X		X				X		*Enallagma boreale*	Boreal Bluet	G5		S3	
X	X	X		X		X		X		X		*Enallagma civile*	Familiar Bluet	G5		S3	
X	X	X		X		X		X		X		*Enallagma ebrium*	Marsh Bluet	G5		S3	
X	X	X		X		X	X	X				*Enallagma hageni*	Hagen's Bluet	G5		S3	
X	X		X	X		X	X	X			X	*Ischnura posita*	Fragile Forktail	G5		S3	
X	X	X		X		X	X					*Nehalennia irene*	Sedge Sprite	G5		S3	
X	X	X		X		X	X	X				*Chromagrion conditum*	Aurora Damsel	G5		S3	
					X		X				X	*Asclepias incarnata*	Swamp Milkweed	G5		S3	
					X							*Bartonia virginica*	Yellow Screwstem	G5		S3	
					X							*Fraxinus nigra*	Black Ash	G5		S3	
	X						X					*Epilobium strictum*	Downy Willow-Herb	G5?		S3	
									X			*Polygonum pensylvanicum*	Pennsylvania Smartweed	G5		S3	
					X							*Primula laurentiana*	Bird's-Eye Primrose	G5		S3	
				X			X	X				*Rhamnus alnifolia*	Alderleaf Buckthorn	G5		S3	
	X								X			*Galium kamtschaticum*	Boreal Bedstraw	G5		S3	
					X							*Verbena hastata*	Blue Vervain	G5		S3	
					X	X		X	X			*Carex eburnea*	Ebony Sedge	G5		S3	
							X					*Luzula parviflora*	Small-Flowered Wood-Rush	G5		S3	
X	X	X										*Corallorhiza trifida*	Early Coralroot	G5		S3	
X	X											*Listera convallarioides*	Broad-Leaved Twayblade	G5		S3	
			X					X				*Platanthera grandiflora*	Large Purple-Fringe Orchis	G5		S3	
			X					X				*Platanthera orbiculata*	Large Roundleaf Orchid	G5?		S3	
			X									*Sparganium natans*	Small Bur-Reed	G5		S3	
			X			X						*Dryopteris filix-mas*	Male Fern	G5		S3	
								X				*Botrychium dissectum*	Cutleaf Grape-Fern	G5		S3	

Table B1. Summary of species assessed and reported through the Atlantic Canada Conservation Data Centre for the Bras d'Or Lake watershed sub-basins in 2005 *continued*

01BaddeckR	02UpMiddleR	03GBrasdOr	05StPetersl	06aStPatricks	06bStAndrews	06cRiverDenys	08Whycocomagh	10aWestBay	10bEastBay	12NorthBasin	15unnamed	GNAME	GCOMNAME	GRANK	NPROT	SRANK	SPROT
X				X						X		*Campanula aparinoides*	Marsh Bellflower	G5		S3?	
						X		X			X	*Potamogeton praelongus*	White-Stem Pondweed	G5		S3?	
			X						X			*Cystopteris tenuis*	A Bladderfern	G4G5		S3?	
	X	X		X					X			*Isoetes lacustris*	Lake Quillwort	G5		S3?	
					X				X			*Lycopodium complanatum*	Trailing Clubmoss	G5		S3?	
			X					X				*Lycopodium sabinifolium*	Ground-Fir	G4		S3?	
			X						X			*Lycopodium sitchense*	Alaskan Clubmoss	G5		S3?	
X	X			X					X	X		*Sterna paradisaea*	Arctic Tern	G5		S3B	
					X				X			*Coccyzus erythropthalmus*	Black-billed Cuckoo	G5		S3B	
		X			X							*Mimus polyglottos*	Northern Mockingbird	G5		S3B	
X		X		X	X		X		X	X	X	*Dolichonyx oryzivorus*	Bobolink	G5		S3B	
X	X	X	X	X	X	X	X	X	X		X	*Poecile hudsonica*	Boreal Chickadee	G5		S3S4	
											X	*Loxia curvirostra*	Red Crossbill	G5		S3S4	
						X		X				*Synaptomys cooperi*	Southern Bog Lemming	G5		S3S4	
			X			X		X	X		X	*Liparis loeselii*	Loesel's Twayblade	G5		S3S4	
	X			X					X			*Spiranthes romanzoffiana*	Hooded Ladies'-Tresses	G5		S3S4	
X		X										*Sphenopholis intermedia*	Slender Wedge Grass	G5		S3S4	
									X			*Cystopteris bulbifera*	Bulblet Fern	G5		S3S4	

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2004 Edition

Part I. Conservation Data Centre Subnational Rarity Ranks

Biological diversity or biodiversity can be described at a number of levels, from molecules to ecosystems. Biodiversity is a combination of species diversity (the variety of species), genetic diversity (the genetic variability among individuals of that species), and ecological diversity (the variety of ecosystems/habitats in which they live). Conservation Data Centres (CDCs), as part of The NatureServe[27] international network, track biodiversity at two levels: species and ecological communities. Species and ecological communities are referred to as **elements** of biodiversity.

[27] Formerly known as The Nature Conservancy (TNC)

Elements are ranked in each jurisdiction (province or state) and at global and national levels in order to help prioritise conservation efforts.

NatureServe and all CDCs (called Heritage Programs in the US) use a standardised element ranking system that has evolved over some 30 years, with input from hundreds of scientists, managers and conservationists. The following material describes this element ranking system at the subnational (S) or provincial level and explains how ranks are assigned for species elements of biodiversity. (The community ranking process is slightly different.)

Definitions of Provincial (subnational) ranks - SRANKS

S1 Extremely rare throughout its range in the province (typically 5 or fewer occurrences or very few remaining individuals). May be especially vulnerable to extirpation.

S2 Rare throughout its range in the province (6 to 20 occurrences or few remaining individuals). May be vulnerable to extirpation due to rarity or other factors.

S3 Uncommon throughout its range in the province, or found only in a restricted range, even if abundant in at some locations. (21 to 100 occurrences).

S4 Usually widespread, fairly common throughout its range in the province, and apparently secure with many occurrences, but the Element is of long-term concern (e.g. watch list). (100+ occurrences).

S5 Demonstrably widespread, abundant, and secure throughout its range in the province, and essentially ineradicable under present conditions.

S#S# Numeric range rank: A range between two consecutive numeric ranks. Denotes range of uncertainty about the exact rarity of the Element (e.g., S1S2).

SH Historical: Element occurred historically throughout its range in the province (with expectation that it may be rediscovered), perhaps having not been verified in the past 20 - 70 years (depending on the species), and suspected to be still extant.

SU Unrankable: Possibly in peril throughout its range in the province, but status uncertain; need more information.

SX Extinct/Extirpated: Element is believed to be extirpated within the province.

S? Unranked: Element is not yet ranked.

SA Accidental: Accidental or casual in the province (i.e., infrequent and far outside usual range). Includes species (usually birds or butterflies) recorded once or twice or only at very great intervals, hundreds or even thousands of miles outside their usual range; a few of these species may even have bred on the one or two occasions they were recorded.

SE Exotic: An exotic established in the province (e.g., Purple Loosestrife or Coltsfoot); may be native in nearby regions.

SE# Exotic numeric: An exotic established in the province that has been assigned a numeric rank.

SP Potential: Potential that Element occurs in the province, but no occurrences reported.

SR Reported: Element reported in the province but without persuasive documentation which would provide a basis for either accepting or rejecting (e.g., misidentified specimen) the report.

SRF Reported falsely: Element erroneously reported in the province and the error has persisted in the literature.

SZ Zero occurrences: Not of practical conservation concern in the province, because there are no definable occurrences, although the species is native and appears regularly. An NZ rank will generally be used for long distance migrants whose occurrences during their migrations are too irregular (in terms of repeated visitation to the same locations) or transitory. In other words, the migrant regularly passes through the province, but enduring, mappable Element Occurrences cannot be defined.

Qualifiers

Breeding Status

B Breeding: Basic rank refers to the breeding population of the element in the province.

N Non-breeding: Basic rank refers to the non-breeding (usually wintering) population of the element in the province.

M Migratory: Basic rank refers to the migratory stopover population in the province.

Other Qualifiers:

? Inexact or uncertain: for numeric ranks, denotes inexactness, e.g., SE? denotes uncertainty of exotic status. (The "?" qualifies the character immediately preceding it in the SRANK)

C Captive or cultivated: Element is presently extant in the country or province only in captivity or cultivation.

RARITY STATUS

GRANK	TXT 5	Global Rank of taxon*
NRANK	TXT 5	National Rank of taxon (in Canada)*
NPROT	TXT+	National Protection Status of taxon (= COSEWIC in Canada)
SRANK.**	TXT 5	Subnational (Provincial) Rank of taxon*
SRNUM	DEC 3,1	SRANK rendered as number (S2S3 = 2.5 etc)
SPROT.**	TXT+	Provincial rank/status of taxon

Appendix C: Stora Enso Special Management Areas

Table C1. Stora Enso special management areas listed by subwatershed presented in hectares and percentage of Stora Enso managed lands in each subwatershed). Note that overlap occurs (e.g., significant habitat areas may also be deer wintering areas) so areas within subwatershed cannot be totaled. Descriptions for each special management treatment are described below. Data provided by Stora Enso Port Hawkesbury.

Subwatershed	Viewshed management	Significant habitat	Riparian zones	Recreation	Old forest	Connectivity management zone	Marten management zone	Lynx habitat	Boreal felt lichen	Deer wintering
Baddeck River	1443 (8)	280 (1)	1003 (5)	0	948 (5)	106 (1)	14 036 (74)	2155 (11)	2 (0)	7 (0)
East Bay	4355 (47)	4114 (44)	528 (6)	0	807 (9)	91 (1)	0	2227 (24)	28 (0)	657 (7)
Great Bras dOr Channel	1704 (86)	243 (12)	96 (5)	276 (14)	0	0	0	0	1 (0)	29 (1)
McKinnons Harbour	13 (35)	0	0	0	0	0	0	0	0	11 (28)
Middle River	1076 (6)	7 (0)	852 (5)	0	228 (1)	1162 (7)	3460 (20)	1482 (8)	0	0
North Basin	605 (56)	617 (57)	59 (5)	0	100 (9)	0	0	287 (27)	11 (1)	0
River Denys	2282 (28)	954 (12)	440 (5)	0	1709 (21)	33 (0)	0	0	0	986 (12)
St. Andrews Channel	38 (3)	62 (5)	81 (6)	0	38 (3)	0	0	193 (15)	9 (1)	87 (7)
St. Patricks Channel	387 (7)	64 (1)	381 (7)	0	1069 (19)	756 (14)	2816 (50)	0	10 (0)	142 (3)
St. Peters Inlet	6 (0)	204 (5)	262 (6)	0	332 (8)	0	0	120 (3)	1 (0)	9 (0)
West Bay	0 (0)	361 (13)	169 (6)	0	161 (6)	0	0	0	3 (0)	48 (2)
Whycocomagh Bay	1458 (40)	419 (12)	217 (6)	0	138 (4)	0	0	0	1 (0)	0

- **Viewshed Management**: Highly visible, aesthetically important areas managed to minimize impacts to viewscapes as a result of harvesting. Harvest operations carefully planned in viewshed areas to maintain aesthetic quality.
- **Significant Habitat**: Significant wildlife habitat areas defined by NSDNR. Species listed as endangered or threatened (provincial and/or national) are automatically protected by Stora Enso from harvest. Forest management activities will be modified for all other listings to minimize impacts.
- **Riparian Zones**: Riparian zone management adheres to provincial regulations on watercourses. Riparian zones will be maintained a minimum of 20 m wide on either side of all watercourses, including lakes, streams, bogs, and fens within the total forest management area. Municipal watershed areas will have buffers of at least 30 m.
- **Recreation**: Recreation areas identified in the provincial Integrated Resource Management process managed to minimize impacts to recreational opportunities in the area.
- **Old Forest**: Areas defined by Stora Enso and NSDNR as old forests. SE will strive to have 8% of its total forest management area by ecoregion identified and maintained in an old forest condition.
- **Connectivity Management**: These zones are at least 500 m wide and explicitly managed for connectivity between ecologically important areas. The overriding objective for each of these zones is to provide spatially and temporally continuous connectivity between the ecologically important areas of forest.
- **Marten**, **lynx**, **felt lichen** and **deer wintering** areas are all under special management objectives. Sufficient habitats will be maintained for each species, based on habitat levels specified by the NSDNR.

Appendix D: Matrix of Human Activity and Pressures

Table D1. Matrix of human activity and pressures

Subwatershed	Oyster Aquaculture	Mining	Shipping	Forestry (clear + recent)	Agriculture	Development	Parks and Trails	Population density (approx)	Road density	Shellfish Closures	TOTAL SCORE
St. Peters Inlet	0	0	0	S3R3FP(6)	S1R3F1P1(6)	S1R3F0P(4)	S2R0F2P0(4)	S1R3F3P3(10)	S3R3FP(6)	11sm2med(28)	**64**
Denys Basin	S1R1F1P1(4)	S2R3F3P1(9)	0	S3R3FP(6)	S2R3F1P2(8)	S1R3F0P(4)	0	S2R3F3P3(11)	S1R3FP(4)	cond4sm1lg(17)	**63**
East Bay	S1R1F1P1(4)	0	0	S4R3FP(7)	S1R3F1P1(6)	S3R3F0P(6)	S1R0F1P1(3)	S4R3F3P3(13)	S2R3FP(5)	2sm2med1lg(14)	**58**
St. Patricks Channel	S1R1F1P1(4)	S2R3F3P0 (8)	S0R0F2P0 (2)	S3R3FP(6)	S1R3F1P1(6)	S2R3F0P(5)	0	S1R3F3P3(10)	S1R3FP(4)	3sm1lg(10)	**55**
St. Andrews Channel	0	0	0	S2R3FP(5)	S3R3F1P2(9)	S3R3F0P(6)	S1R0F1P1(3)	S2R3F3P3(11)	S2R3FP(5)	3med(9)	**48**
Whycocomagh Bay	S0R1F1P1(3)	0	0	S3R3FP(6)	S2R3F1P2(8)	S1R3F0P(4)	S1R0F1P1(3)	S2R3F3P3(11)	S2R3FP(5)	1sm2med(8)	**48**
Baddeck River	0	0	0	S7R3FP(10)	S2R3F1P1(7)	S2R3F0P(5)	S1R0F1P1(3)	S3R3F3P3(12)	S1R3FP(4)	1lg(4)	**45**
Middle River	0	0	0	S9R3FP(12)	S3R3F1P3(10)	S2R3F0P(5)	0	S1R3F3P3(10)	S1R3FP(4)	1lg(4)	**45**
Great Bras d'Or	0	0	S0R0F2P0 (2)	S3R3FP(6)	S1R3F1P1(6)	S2R3F0P(5)	S1R0F1P1(3)	S1R3F3P3(10)	S2R3FP(5)	2sm1med(7)	**44**
McKinnons Harbour	S1R1F1P1(4)	0	0	S1R3FP(4)	S1R3F1P1(6)	S1R3F0P(4)	0	S1R3F3P3(10)	S3R3FP(6)	3med(9)	**43**
West Bay	0	0	0	S2R3FP(5)	S1R3F1P1(6)	S1R3F0P(4)	0	S1R3F3P3(10)	S2R3FP(5)	1sm2med(7)	**37**
North Basin	0	0	0	0	S1R3F1P1(6)	S3R3F0P(6)	0	S1R3F3P3(10)	S1R3FP(4)	2med(6)	**32**
Activity Total	**19**	**17**	**4**	**73**	**84**	**58**	**18**	**119**	**57**		

Ranking factors:*
S = size of disturbance. Generally ranked from 0 (smallest) to 4 (largest). For example, total area of agriculture in each subwatershed was assigned a 1 if there were 0-500 ha, a 2 for 500-1000 ha, and a 3 for 1000+ ha.
R = ability of an area to recover after a disturbance. Generally ranked from 0 (no recovery time) to 3 (years to decades). For example, hiking trail use was ranked 0 and mining was ranked 3.
F = frequency of disturbance. Generally ranked from 0 (infrequent) to 3 (daily). For example, road density was ranked 0 and mining was ranked 3.
P = patchiness of disturbance. Generally ranked from 0 (one location) to 3 (several locations). For example, oyster aquaculture was ranked 1 and population density was ranked 3.
*If there is no number beside a ranking factor, not enough information was available to reasonably assign a number.

Shellfish closures were assigned a special ranking scheme. Open areas were ranked 0, any conditional areas in a given bay were ranked 1, each small closure was given 2 points, each medium closure was given 3 points, and each large closure was given 4 points.

Note: The relative size of each subwatershed has not been considered in this ranking scheme.