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Proceedings of the Maritimes Regional Advisory Process

Compte rendu du Processus consultatif régional des Maritimes

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

Rapport d'aperçu et d'évaluation de l'écosystème du lac Bras d'Or, Nouvelle-Écosse

2 – 3 November 2005

Les 2 et 3 novembre 2005

Wagmatcook Cultural Centre
Wagmatcook, Cape Breton, Nova Scotia

Wagmatcook Cultural Centre
Wagmatcook, Cap-Breton Nouvelle-Écosse

T. Worcester (Chair)

T. Worcester (président)

Fisheries and Oceans Canada / Pêches et Océans Canada
Bedford Institute of Oceanography / Institute océanographique de Bedford
Dartmouth, Nova Scotia / Dartmouth, N.-É.
B2Y 4A2 Canada

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Foreword

The purpose of these proceedings is to archive the activities and discussions of the meeting, including research recommendations, uncertainties, and to provide a place to formally archive official minority opinions. As such, interpretations and opinions presented in this report may be factually incorrect or mis-leading, but are included to record as faithfully as possible what transpired at the meeting. No statements are to be taken as reflecting the consensus of the meeting unless they are clearly identified as such. Moreover, additional information and further review may result in a change of decision where tentative agreement had been reached.

Avant-propos

Le présent compte rendu fait état des activités et des discussions qui ont eu lieu à la réunion, notamment en ce qui concerne les recommandations de recherche et les incertitudes; il sert aussi à consigner en bonne et due forme les opinions minoritaires officielles. Les interprétations et opinions qui y sont présentées peuvent être incorrectes sur le plan des faits ou trompeuses, mais elles sont intégrées au document pour que celui-ci reflète le plus fidèlement possible ce qui s’est dit à la réunion. Aucune déclaration ne doit être considérée comme une expression du consensus des participants, sauf s’il est clairement indiqué qu’elle l’est effectivement. En outre, des renseignements supplémentaires et un plus ample examen peuvent avoir pour effet de modifier une décision qui avait fait l'objet d'un accord préliminaire.

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200, rue Kent Street
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CSAS@DFO-MPO.GC.CA

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SUMMARY

On 2-3 November 2005, approximately 40 scientists, managers, First Nations, and community stakeholders met at the Wagmatcook Cultural Centre in Cape Breton, Nova Scotia, to review the Ecosystem Overview and Assessment Report (EOAR) for the Bras d'Or Lakes as prepared by the Oceans and Coastal Management Division of DFO Maritimes. The intent of this meeting was to review the document provided for accuracy and completeness, to identify information gaps, and to review the proposed methodology for selection of Ecologically and Biologically Significant Areas (EBSA). Presentations were made on management context, physical and biological systems, ecosystem relationships, human activities and EBSA within the Bras d'Or Lakes. After each presentation, discussion ensued. There was also time set aside to discuss how to better incorporate local and traditional knowledge into this report. In general, the EOAR was thought to be a good compilation of published scientific information and represented a useful snapshot of current conditions in the Lakes; however, it was agreed that some additional work was needed. In particular, it was felt that additional information was needed on the nearshore and terrestrial environments, as well as on smaller-scale features that may be exceptions to general trends. Incorporation of community data sources and knowledge was seen as an important next step. A few of the ecological assumptions were also questioned, such as the assumption that nutrients and primary production was limited within the Lakes, and it was suggested that new scientific information was being produced that might help to resolve these outstanding questions. Participants appreciated the effort that had gone in to developing a methodology for identification of Bras d'Or Lakes EBSA in the absence of national or regional guidance. The development of a relative scoring system and use of an accompanying narrative were of particular interest. However, participants had difficulties with some of the parameters that were evaluated, such as temperature and salinity, in terms of their role in determining significance. It was suggested that the evaluation and scoring of EBSA should be conducted by a group of people rather than by a single individual. Participants made a series of recommendations on next steps for the EOAR and EBSA. Suggestions made at this meeting will be incorporated into a revised EOAR, which will be produced by the Ocean and Coastal Management Division over the coming year.

SOMMAIRE

Les 2 et 3 novembre 2005, une quarantaine de scientifiques, de gestionnaires, de membres des Premières nations et de personnes concernées de la collectivité étaient réunis au Wagmatcook Cultural Centre au Cap Breton, en Nouvelle Écosse, pour examiner le Rapport d'aperçu et d'évaluation de l'écosystème du lac Bras d'Or rédigé par la Division de la gestion côtière et des océans du MPO, Région des Maritimes. Cette réunion avait pour but de vérifier l'exactitude et l'exhaustivité du document, d'en détecter les lacunes en matière d'information et d'examiner la méthode proposée pour la sélection des zones d'importance écologique et biologique (ZIEB). Des exposés ont été présentés sur le contexte de gestion, les systèmes physiques et biologiques, les relations entre les écosystèmes, les activités anthropiques et les ZIEB du lac Bras d'Or, chaque exposé étant suivi d'une discussion. On a également étudié les meilleures façons d'inclure dans le rapport les données provenant du savoir local et traditionnel. Globalement, le Rapport d'aperçu et d'évaluation de l'écosystème était perçu comme une bonne synthèse des données scientifiques publiées sur le sujet et comme une représentation utile des conditions existantes dans le lac. Les participants ont toutefois convenu qu'il était nécessaire de l'étoffer, notamment en y incluant des informations supplémentaires sur les écosystèmes littoraux et terrestres ainsi que sur les systèmes à plus petite échelle qui pourraient faire exception à la tendance générale. L'inclusion des sources de données et des connaissances locales a été considérée comme une prochaine étape importante. Quelques unes des hypothèses sur le plan écologique ont été remises en question, notamment l'hypothèse selon laquelle la teneur en nutriments et la production primaire sont limitées dans le lac, et on a indiqué que de nouvelles données scientifiques en cours de production pourraient contribuer à lever les incertitudes qui subsistent. Les participants ont salué les efforts qui ont été déployés pour élaborer une méthode de désignation des ZIEB du lac Bras d'Or malgré l'absence de lignes directrices nationales ou régionales. La mise au point d'un système de notation relative et l'utilisation en parallèle d'une évaluation narrative ont suscité un intérêt certain. Les participants ont toutefois eu des difficultés à comprendre le rôle de certains des paramètres évalués dans la désignation de l'importance écologique et biologique, notamment la température et la salinité. On a suggéré que l'évaluation et la notation des ZIEB soit effectuées par un groupe de personnes plutôt que par une seule personne. Les participants ont fait une série de recommandations pour les prochaines étapes concernant le Rapport d'aperçu et d'évaluation et les ZIEB. La Division de la gestion côtière et des océans tiendra compte des suggestions qui ont été faites lors de cette réunion pour la rédaction, au cours de l'année à venir, d'un Rapport d'aperçu et d'évaluation révisé.

INTRODUCTION

Tana Worcester, the meeting chair, welcomed participants (Appendix 1) and provided some background to the meeting. She explained that the primary purpose of the meeting was to review the draft Ecosystem Overview and Assessment Report for the Bras d'Or Lakes. Specifically, the meeting objectives as presented in the remit (Appendix 2) were:

- To review material contained in the Ecosystem Overview and Assessment Report for the Bras d'Or Lakes prepared by the Oceans and Coastal Management Division for accuracy and completeness. Any gaps in information are to be identified.
- To review the methodology for selection of Ecologically and Biologically Significant Areas (EBSA) in the Bras d'Or Lakes.

The chair then reviewed the agenda (Appendix 3). The first day was to focus on the evaluation of material contained within the draft Ecosystem Overview and Assessment Report. The first part of the second day was to focus on the discussion of the methodology for identification of EBSA for the Bras d'Or Lakes. The major conclusions and recommendations of the meeting were to be discussed after lunch on the second day. The chair noted that comments could also be submitted after the meeting (Appendix 4). Products from the workshop were to consist of a DFO Science Advisory Report, Proceedings, and a revised Ecosystem Overview and Assessment Report (Appendix 5).

Background materials for the meeting included National guidance on the identification and assessment of marine areas with ecological and biological significance (DFO, 2004) and National guidance on evaluating ecosystem overview and assessments (DFO, 2005).

MANAGEMENT OVERVIEW AND CONEXT

Jason Naug

Jason Naug from the Oceans and Coastal Management Division (DFO Maritimes) set the context for the Ecosystem Overview and Assessment Report by describing how it fits within broader efforts to develop an overall management plan for the Bras d'Or Lakes and watershed.

Presentation

DFO has been working in partnership with other federal, provincial, municipal, and First Nation governments and other organizations to support the development of an overall management plan for the Bras d'Or Lakes, which was identified as a Coastal Management Area under the Oceans Program. Efforts to develop this management plan originated from a request from the First Nation Chiefs in Cape Breton who noted that issues in the Lakes were not improving despite the various organizations working there.

Activities within the lakes and watershed include traditional and recreational fisheries, boating, aquaculture, forestry, mining, cottage development, and marine transportation. Threats include land and marine based sewage, destruction of wildlife habitats, invasive species, erosion and siltation from land-based development, declining fish stocks, etc. There are also a range of management issues, such as establishing a sound governance process, increasing communications, education and awareness, integrating traditional ecological knowledge, and ensuring broad participation from a diversity of stakeholders.

A great diversity of people live within the Bras d'Or Lakes watershed and a range of approaches will be required to engage, communicate and work together. Twenty percent of residents are First Nation. There are also a number of seasonal residents and visitors that have an interest in the management of the area.

Previous efforts to develop management plans for the Lakes were challenged by the complexity of jurisdictions, a lack of high-level buy-in and an inability to transfer legislative authority to new management bodies.

Since 2003, approximately 250 people have been engaged in the planning process through two large planning workshops (Oct. 2003, 2004). Senior government, First Nation leaders, and the broader community provided direction for moving forward. The Unama'ki Institute of Natural Resources was identified as an organization to play a lead role in coordinating these efforts. The Collaborative Environmental Planning Initiative (CEPI) has been formed to develop an overall management plan and facilitate its implementation by government and other relevant stakeholders.

The management plan is intended to prioritize issues and develop specific goals, objectives, action plans, monitoring and funding strategies. Priorities and action plans are to be based on a sound understanding of environmental conditions and the ecology of the lakes and surrounding watershed. The identification of significant habitats and species (marine and terrestrial), ecological processes, threats and impacts will also need to be analysed and communicated to the broader community. It is hoped that the Ecosystem Overview and Assessment Report once finalized will provide much of this background information required for management.

ECOSYSTEM OVERVIEW AND ASSESSMENT REPORT (EOAR)

PHYSICAL SYSTEMS
Mike Parker

Mike Parker, a consultant (East Coast Aquatics) hired by DFO to assist with compilation of published information related to the physical, chemical and biological environment of the Bras d'Or Lakes, presented a summary of this information at the meeting and identified important factors for consideration. The summary was meant to be reflective of what was included in the Ecosystem Overview and Assessment Report; however, the presentation of important factors for consideration was new and was not summarized as such within the draft EOAR.

Presentation

Geology
The Bras d'Or Lakes were scoured glacially during the Wisconsinan glaciation about ten thousand years ago, and the Lakes have only existed in their current state for about 4-5000 years. There is a diverse upland geology but a relatively uniform shoreline of erodible sandstones and siltstones. Only a small percentage of the shoreline is rock; the remainder is unconsolidated material. The greatest geological upland diversity is along St. Patricks Channel. This contributes some unique metal signatures in the smaller bays, as well as a significant silicate load that is deposited by larger rivers that drain this area.

Coastal barriers line some 150km of shoreline. These can be very old and are unique in their vertical scale because of tidal range of the Lakes. Nearly 44% of the larger barriers evaluated are in a state of breakdown or collapse. On average the Lakes are 30m deep; however, there are some much deeper areas (up to 280m). There are also a number of sills. These appear to be important in defining the oceanographic and biological character of the lakes.

Atmospheric Conditions

There is only weather station in the Bras d'Or Lakes watershed that meets the World Meteorological Organizations standards for preparing 30-year normals for temperature and precipitation. The average temperature in July/August is 18 ^{o}C and the average temperature in Nov/Dec is – 4.5^{o}C. February is the coldest month (– 6^{o}C). In the early 1970s, precipitation was highest in November. However, the last 30-year dataset shows December as having the highest precipitation. Minimum precipitation is in July. All snow is gone by the end of April. Winds in winter are about 20 knots and twice as strong as averages for the summer. The winds effect on the Lakes is limited by the short fetch.

Physical Oceanography

Lunar tidal amplitude is impeded by the constriction of the Great Bras d'Or Channel. In contrast, barometric tides retain as much as 85% of their amplitude as found outside the Lakes. This character greatly limits the amount of intertidal zone habitats, and marine water influence of temperature, salinity, and nutrient. Tidal currents are typically about 0.1m/s, but are as little as 0.03m/s in areas like Denys Basin, and up to 3m/s in the Great Bras d'Or Channel. Whycocomagh Bay flushes once every two years and St. Andrews Channel about every 260 days – the average is around a couple of weeks.

Six of the largest rivers entering the Bras d'Or Lakes account for 42% of all flow, and four of these enter the northern bay areas of Whycocomagh Bay and St. Patricks Channel. Approximately 140 m^3/sec of freshwater flows into the Lakes, but this only amounts to about 14% of the total lake volume annually. This still has significant influence on circulation by establishing a two layer system.

Constrictions such as Great Bras d'Or Channel and Barra Strait are the areas of greatest mixing as huge volumes of water try to squeeze through on the tidal cycle. The Great Bras d'Or Channel is the only area of significant downwelling. Upwelling in the North Basin is estimated to provide 5-10 times greater nitrate flux from depth to surface layers than south of the Barra Strait.

Ice typically covers as much as 70% of the Lakes and can be 1.5m thick. Ice influences stratification by cooling and freshening of the surface layer. Ice influences circulation by inhibiting atmospheric forcing.

Below the halocline (10-20m), salinity increases with depth throughout the Lakes; however, it is reasonably stable below 100m. Salinity also changes on a horizontal scale.

Chemical Oceanography

At depths over 200m, the Lakes have dissolved oxygen levels of 55-95% saturation, although the mechanism for replenishment is not fully understood. On a larger 'bay scale' area, only Whycocomagh Bay has significantly reduced oxygen levels. Some smaller enclosed bays may have depressed oxygen levels associated with nutrient inputs. A few of the protected barachois ponds are also anoxic. Overall, dissolved oxygen does not appear to be a problem within the Lakes.

Suspended particulate matter (SPM) does not appear elevated, even in the St. Patricks Channel area where large rivers enter the Lakes. Precipitation (11 mg/m^2/day) appears to rival the rivers (5-12 mg/m^2/day) in contribution of SPM.

50-70% of total new production in the Lakes occurs in the St. Andrews Channel where nitrate and ammonia from the deep waters gets brought to the surface through upwelling.

Nutrients build over winter as a result of ice cover that limits biological activity and photosynthesis, and increased mixing with marine and deep waters as stratification weakens. However, nutrients are quickly consumed in the spring bloom and the system remains nitrogen limited much of the year. Although marine and deep water mixing are extremely limited, these sources remain the most significant source of both nitrogen and phosphorous in the Lakes. The Barra Strait has a large influence on nutrients south of the strait. Five to ten times more nitrate mixes to the surface north of the strait than south, making the south particularly poor in production.

Highest silicate levels are found in the Lakes in February and March, and this is followed by a significant springtime drop.

Contamination from heavy metals and organic contaminants within the Lakes is not significant. Baddeck and Middle Rivers transport metals into the Lakes. Denys Basin and East Bay have some metals, such as copper, zinc, cadmium and lead. Of these, only localized lead results in East Bay appear above probable effects levels. Dissolved metals in the Bras d'Or Lakes are consistently below those found in the more industrial harbours of Nova Scotia and are comparable with relatively pristine harbours.

Important factors related to the physical environment of the Bras d'Or Lakes include:

- The Bras d'Or Lakes is a relatively young marine system
- Shallow sills create compartments
- Small lunar tide
- Strong stratification
- Weak mixing
- Low levels of nutrients and nitrate limited
- Low substrate complexity
- Little contamination
- Good dissolved oxygen

Discussion

<u>Scale</u>

The need to provide information at a scale appropriate for management was identified. Generalizations are useful for broad-scale strategic planning, but we don't want to lose useful information on the local scale. The EOAR should point to where more localized information is available or provide examples of exceptions to the general rule, e.g., Bras d'Or Lakes are generally well oxygenated, but there are locations that are anoxic – these should be identified. Not all rivers have similar sedimentation. Shellfish closure areas should be identified as areas with localized impacts. Generalizations for the Bras d'Or Lakes give the impression that everything is fine when there may be local issues.

<u>Historic Context</u>

The draft EOAR provides a good snapshot of current conditions; however, it doesn't provide a good sense of how current conditions compare to historic baseline. Historic documents, e.g., Fisheries Research Board of Canada Report Series, and local and traditional knowledge could help to inform and validate this baseline.

<u>Inclusion of New Information</u>
Scientific understanding is always improving, e.g., collection of new multibeam imagery. The EOAR must be a "living document." How will "State of the Environment" Reporting be incorporated?

<u>Understanding of Major Features</u>
Evolution of system from freshwater to marine is consistent with archeological evidence of human occupation.

<u>Information Gaps</u>
A number of information gaps were identified. These included:

- Streams and Rivers:
    - flow
    - water chemistry and bacteria
    - sediment geochemistry
    - metals (Natural Resources Canada database)

- Groundwater
    - through bottom of lake (e.g., salt domes underneath lake)
- Climate change and sea level rise
- Winter conditions – date may be available from industry, e.g., aquaculture
- Terrestrial ecology
- Better understand of benthic habitat (bottom type)

<u>Trends</u>
Temporal scale is important. For example, precipitation trends over the past 30 years show an increase, while trends over the last 10 years show a decrease. How will trends affect future conditions, e.g., what effects would there be from changes in ice cover, potential impacts of climate change and seal level rise? How has the system become disturbed?

BIOLOGICAL SYSTEMS

Presentation

The Bras d'Or Lakes have quite clear waters with a large photic zone. Strong stratification helps keep phytoplankton near the surface. However, low nutrients, particularly nitrogen, limit phytoplankton production. The abundance of silicate in the system ensures diatoms are a large part of the spring bloom. Flagellates dominate essentially all times of the year. There is substantially higher production in well mixed shallow areas as compared to the open lake areas.

Herbivorous copepods may consume phytoplankton at a rate exceeding mid-summer daily production. This consumption may limit production of large rotifer and ciliate populations. Limits on zooplankton communities may affect higher level consumers and the number of trophic levels present in the Lakes. This may influence overall population sizes but not diversity. Diversity of zooplankton is less in Whycocomagh Bay and south of Barra Strait. Whycocomagh Bay has poor oxygen characteristics, and nutrients are even less in the southern Lakes. Shallow sills at these areas may prevent the dispersion of some deeper water species of copepod.

With few areas of substrate coarse enough for anchoring, many species of macrophyte within the Lakes are limited to the narrow intertidal zone and near shore where wave action exposes appropriate substrates. Ninety-four species have been identified, most at 3-4m depth. Low salinity may limit some species. Eelgrass has been a significant spawning habitat for herring in areas like St. Patricks Channel, Denys Basin and historically West Bay. During recent lobster surveys, drift kelp has been noted at greater depths (16m) in St. Patricks Channel, North Bay, and East Bay.

Low salinity in the Lakes limits the distribution of lobster, crab, oyster, scallops and other invertebrates. Larval stages are particularly sensitive. Hard bottom habitats may also be a limiting factor. However, a recent lobster study showed that habitat was not a likely limit to lobster production in West Bay. Temperature is another limiting factor for species such as oysters that prefer to spawn at 20°C. These temperatures occur in shallow bays where fresh water inputs bring them toward their salinity tolerance. Low primary production may inhibit the growth of filter feeders. Sea urchin and starfish are both important, widespread predators, and they dominate the invertebrate catch throughout the lakes.

Polychaete, Foraminifera, and mysid studies have primarily been inventories and have not discussed the relative significance of communities within the Bras d'Or Lakes to other coastal areas. A unique combination of Virginian and boreal/arctic boreal polychaete species was noted in Great Bras d'Or Channel, which appears to be regionally significant. Foraminifera were similar to those found in other coastal Nova Scotia areas and are generally boreal in nature. Mysids were boreal and arctic in nature. Mysids are key prey for young cod but are absent from Whycocomagh Bay due to low oxygen levels.

Green crab was noted as an invasive species around 1992-95, and it is now widespread in the Bras d'Or Lakes. Tunicates and the oyster diseases MSX and SSO (microscopic parasites) both exist in the Lakes and can cause significant mortalities in affected shellfish. Salinities will likely limit distribution of SSO, but MSX could become widespread.

Forty-six species of fish are found in the Lakes, most of which are benthic. The most abundant groundfish is winter flounder; the most abundant pelagic fish is cod. A white stickleback was identified in the Bras d'Or Lakes that appears to be a new species. Total fish biomass seems to be about three times more abundant in 2000 then in 1967. One significant exception is the American plaice, which has decreased significantly. The other significant decline is in herring, which has not recovered since the closure of the fishery in 1999. Bras d'Or herring spawn in the spring instead of the fall. The Bras d'Or cod population, like Bras d'Or herring, typically spawns earlier than populations outside of the Lakes (February instead of March.)

Both harbour and grey seals are commonly observed in the Lakes, particularly through the winter months and mostly north of Barra Strait. These likely feed on cod.

There is limited colonial sea bird nesting within the Lakes, although there are a few islands that have locally significant populations in West Bay and St. Patricks Channel.

Within the Bras d'Or ecosystem, species at risk are primarily terrestrial. COSEWIC lists four species of special concern. The most widely distributed is the wood turtle. Nova Scotia lists two endangered species -- marten and lynx. The greatest number of listed species occurs in the watersheds of St. Patricks Channel. Species that are not listed but may be of local concern include the Bras d'Or Lakes population of herring and American plaice. A rare and sparse marine algae (*Nemalion helminthoides*) found throughout the Atlantic Provinces is found at several sites in the Bras d'Or Lakes.

There are several habitats that appear relatively limited within the Bras d'Or area relative to other coastal Nova Scotian areas. These include cliffs, islands, rocky substrates, wetlands, deep water areas, the intertidal zone, dunes and saline ponds.

Important factors related to the biological environment of the Bras d'Or Lakes include:

- Production at the base of the food web is limited.
- Diversity is spatially varied within the Lakes at the larger "bay scale."
- Fish abundance is generally increasing.
- Newer invasive species that may impact the food web through invertebrates exist.
- Aquatic species of concern and not "listed" species.
- Habitats are reasonably well defined, yet habitat use is not well documented.

Discussion

Understanding Major Features
The suggestion was made that a number of ecological relationships needed to be explored in more detail. For example, we need to better understand the role of eelgrass and the nearshore environment in primary production. A better understanding of this relationship might influence the current conclusion that productivity is low in the Bras d'Or Lakes. This question may be addressed in current research. Another relationship that should be explored further is the relationship between nutrients and productivity – are nutrients really the most important factor? The relationship between eelgrass, green crab and herring spawning was of some interest to participants. Further exploration of the role of sills in "communication" between northern and southern Lakes was also encouraged.

Historic Context
Incremental damage and habitat loss, e.g., of wetlands, don't seem to have been adequately captured in the draft EOAR. For example, there have been substantial changes to the number of known herring spawning locations (30-40 down to 1, "Fiddlehead").

Trends
Not all participants were convinced that overall fish abundance is increasing in the Bras d'Or Lakes. It was noted that key experts in this area were not present but that their input would be solicited after the meeting. Participants requested that, when describing status and trends, there should be some reference made to other areas, i.e. some comparison should be made with other coastal environments.

Scale
It was noted that there is a mismatch between the timelines required to conduct science and disseminate research results, and the timelines required for management.

It was noted that the geographic scale at which conclusions are developed will influence the overall message related to the state of the Bras d'Or Lakes system. For example, the conclusion that the Bras d'Or Lakes *overall* are not an ideal location for oysters discounts the fact there are specific locations within the Bras d'Or Lakes that *are* good for oysters. These places should be identified.

Information Gaps
A number of information gaps were identified. These included:

- Energy flow model (how does y effect x? how does energy flow through the system?)
- Bottom habitat
- Secondary production
- Food web relationships

Upcoming initiatives and future references include:

- John Shaw's benthic maps
- Shallow water habitat mapping
- Paper on particle dynamics
- Numeric circulation model
- Remote sensing techniques for nearshore waters
- Zooplankton counts

Terminology

There was some discussion about the best way to describe species of concern. For example, how would you describe species that appear to be in a state of decline but that have not been identified by a regulatory authority as "at-risk"? It was suggested that, at a minimum, there should be consistency with relevant federal and provincial legislation, e.g. the Species-at-Risk Act. Further thought should be given to this issue. It was also recommended that the difference between "sensitivity" and "significance" be clarified. Some concern was expressed over the use of the term "limited."

LOCAL AND TRADITIONAL KNOWLEDGE

Tana Worcester

There was no formal presentation on local and traditional knowledge. It was recognized that this was an area that needed to be addressed within a revised EOAR. Participants were asked for suggestions on how local and traditional knowledge might be more fully integrated into the EOAR.

Discussion

One suggestion was that the "State of Environment Report," and other relevant papers, should be attached as an Appendix to the EOAR. Another suggestion was that traditional ecological knowledge (TEK) should be incorporated wherever it fits throughout the document, possibly using a narrative or story format. However, it was suggested that the proprietary nature of some TEK, e.g., medicinal plants, might need to be taken into consideration. A suggestion was made to only include information that would be suitable for publication and planning purposes and to defer to First Nations to establish guidelines for collection and dissemination of TEK. Participants tended to agree that local and traditional knowledge should not be separated (i.e., placed in a separate section) from published, scientific information. One participant asked how First Nations elders might compile and display ecological information. It was suggested that First Nations elders might use a medicine wheel instead of tables to present this information. There was some discussion on how best to gather local and traditional knowledge from the community. One suggestion was to host an open workshop or small working groups, using previous workshops that have been held as examples. Use of industry data was encouraged.

ECOSYSTEM RELATIONSHIPS

Mike Parker

Presentation

Nutrients are the foundation of the biological community since they support primary productivity; therefore, physical features that affect how nutrients cycle in the Bras d'Or Lakes also directly affect biological response. The primary source of nutrients for the Bras d'Or Lakes is marine waters that enter the Lakes through an inflowing bottom layer. Physical factors that influence vertical mixing and horizontal distribution of nutrients throughout the lakes are also likely to affect biology. Two physical characteristics that play an important role are constrictions and shallow sills. These physical characteristics affect many processes and biological responses either directly or indirectly.

Sills and constrictions help to physically define areas like St. Andrews Channel, which brings 50-70% of the new ammonia and nitrate from deep water areas, Great Bras d'Or Channel where constriction creates intense mixing and weakens stratification, St. Patricks Channel, where heavy silicate loads enter, and North Basin, through which all exchange with the southern portion of the lakes must pass.

The constriction and shallow sill of the Barra Strait limits the flow of the bottom marine (and nutrient rich) layer to the southern portion of the lakes. This sill also controls exchange of silicate rich waters to the southern portion of the Lakes (where less silicate comes off the land base) and thus affects the distribution of diatoms in the Lakes. Shallow sills may limit deepwater species of marine copepod from entry in the Lakes, and the sill at Barra Strait further limits distribution of those found in the bottom marine layer of the north from entering the southern portion of the Lakes.

Seal Worm Relationship with Cod

The sill at Little Narrows greatly limits the tidal exchange of water, giving the Whycocomagh Bay the slowest turnover rate in the Lakes (two years). This is believed to be a key factor in the anoxic and hypoxic character that is created and has long existed in the deep east and west basins within Whycocomagh Bay. Low oxygen limits presence of a bottom living mysid shrimp that are not found in Whycocomagh Bay. In other areas of the Lakes, these shrimp feed on seal scat that carries the seal worm. The shrimp become infected by the parasite as an intermediate host. The shrimp are then eaten by young cod that become infested. The cod are eventually eaten by seals. In Whycocomagh Bay, the lack of mysid shrimp means that cod feed on other things and do not become infested.

Food Web Relationships

Very little information exists on food web relationships within the Bras d'Or Lakes. However, there have been two relatively recent large scale population changes that may have influenced these relationships. One is the decline in herring and the other is the reduction in distribution and numbers of American plaice. Both reproduce in the Lakes and, as such, were predators as larval fish at the base of the food chain and as adult fish. They also were prey at many if not all of these life stages. The large change in herring numbers observed over a short time scale may have affected predator-prey relationships within the Lakes. These fish, moving from a marine environment in such large numbers, could also be a source of marine derived nutrients to the lakes as has been shown with several *Alosa* species such as alewife, herring and shad, as well as salmon. Learning more about the food web interactions of American plaice may show that its primary prey has changed in numbers or become otherwise unacceptable.

Invasive Species

Green crab is a relatively new species to the Lakes. It is known to feed on rock crab and bivalves within the Lakes, and in addition to the economic importance of these species, they also are important food source for lobster. The competition between green crab and lobster for food source (and potentially hard bottom habitats) means there could be a negative impact on lobster. It has also been noted that cod seem to be feeding heavily on the green crab, and therefore the cod may benefit from the presence of the crab. Will invasive species alter the balance and interactions of a food web by competing as a predator and becoming a source of prey?

Three areas emerged from this review as being of particular interest.

<u>St. Andrews Channel</u>
Known to have great overall species diversity, arctic relict species, supplies 50-70% of the new nitrate found in the photic zone of the Lakes, deepest area of the Lakes with good water quality characteristics, one of the last areas for American plaice, spawning and wintering ground for cod, higher percent of rock shores and cliff habitats as well as underwater rock shelves.

<u>Great Bras d'Or Channel</u>
Most significant mixing, most saline body, significant hard bottom habitats, warm water Virginian enclave species of polychaete and greatest polychaete diversity, rock crab and lobster at outer reach that are found in limited numbers elsewhere, shortest flushing time, weak stratification, three terrestrial species at risk, cliff habitats, and high overall species diversity. These characteristics make it the most marine of the Bras d'Or Lakes areas and contribute to its productivity and diversity.

<u>North Basin</u>
The North Basin is an area of high biodiversity and productivity, not so much because of characteristics unique to that area, but because it is a meeting place for waters from a number of different areas and it has several mechanisms to mix these "ingredients" into a productive zone. Freshwaters from major rivers with significant silicates come from St. Patricks Channel, well mixed nutrient rich waters enter from the Great Bras d'Or Channel, nutrient rich waters from St. Andrews move into North Bay, and strong upwelling on either side of the Barra Strait brings more nutrient waters toward the surface in North Bay. It is not the most productive area of the Lakes, nor does it have the greatest species diversity, but it is relatively strong in both of these characteristics and therefore is the third area considered for high biodiversity/production in the Bras d'Or Lakes.

Together these three areas have the greatest species diversity within the Lakes when all surveys are considered (fish, foraminifera, polychaete, mysid, algae, copepods etc.). The suggestion that these areas are significant also is supported by an evaluation of foraminifera. The species mix of Barra Strait, believed to be of high productivity because of mixing characteristics, was noted and wherever this mix was found within the Lakes is believed to also be a productive area. North Basin and Great Bras d'Or Channel emerged as likely productive areas.

When evaluating the Lakes for ecosystem relationships, it is important to note the link to the physical structure of the Lakes. Sills and constrictions ultimately affect the biological processes within the Lakes by influencing the physical and chemical oceanography of the Lakes. It is also important to note that there is some good species inventories and information on interactions with physical and chemical habitat; however, there is a lack of information with regards to biological interaction with other species within the Lakes.

Discussion

A summary of the important ecosystem components and linkages in the Bras d'Or Lakes was developed in discussion, a summary of which is provided in Table 1.

Table 1. Summary of Major Bras d'Or Lakes Ecosystem Components and Linkages

Sills	role in water movement, separation between north and south
Channels (Constrictions)	role in water movement
Sediment	role in distribution of benthic organisms (invertebrates/fish)
Circulation	upwellings, downwellings, "jets"
Rivers	role in source of freshwater, silicate, heavy metals, suspended sediment
Temperature	stratification, presence of arctic species (diversity)
Salinity	distribution of invertebrates
Precipitation	source of freshwater, role in salinity, atmospheric deposition
Wind	role in nutrient mixing in the fall
Nutrients	role in primary production
Ice Cover	relationship to mixing, primary production, and seal distribution
Phytoplankton	role in secondary production
Eelgrass	role as habitat and contribution to primary production nearshore
Zooplankton	role in food web [limited information]
Invertebrates	impact of green crab on macrophytes, role in food web, dominance of benthic biomass by urchins and starfish (echinoderms)
Fish	habitat dependence, population isolation, role as source of nutrients
Seals	impact on cod (seal worm)
Birds	influence on other ecosystem components?
Wetlands	regional significance, species diversity, functional role
Islands, Barriers, Ponds	role at smaller scales, sensitivity
Nearshore Environments	role in primary productivity, etc.
Sinkholes	role unknown
Groundwater	influence on salinity of lakes, relationship to sink holes unknown
Climate Change	impact on stream flow, sea level, groundwater, flooding leading to increased sediment input
Suspended particulates or water clarity	role on macrophyte distribution and primary production
Coliforms	indicator of water quality, links to suspended matter
pH	acid rain less of a concern due to buffering capacity of environment, but may be other impacts
Linkages with other Ecosystems	water movement, migration, etc.

HUMAN ACTIVITIES

Maxine Westhead

Maxine Westhead of the Ocean and Coastal Management Division (DFO Maritimes) presented a summary of information on human activities within the Bras d'Or Lakes and surrounding watershed.

Presentation Highlights

The availability of data on a watershed-level was very difficult to find, as information for most human activities is compiled by county or statistical district. If data is not compiled in a GIS-based system then it's not possible to search by watershed or sub-watershed.

There are 22,000 residents in the Bras d'Or watershed (20-25% in the East Bay sub-watershed), and aside from the First Nation reserves, outmigration is the dominant trend. As of 2003, 66% of all parcels of land in the entire watershed were vacant and 34% had some form of development. Approximately 62% of land within the watershed is privately owned, and 33% is owned by the province. Almost all waterfront land is privately owned.

Sub-watershed forest cover ranges between 74 and 86%, with Middle River and Denys Basin being the highest. Sixty-three percent of the Baddeck River and 54% of the Middle River sub-watersheds are managed by Stora Enso Port Hawkesbury. Eight percent of the Lakes watershed is in recent cut condition (any clearcut less than 15 years old). The largest area of recent cut is in Middle River (14% of the sub-watershed). Less than 1% of the Lakes watershed is in clearcut condition (less than 5 years old).

The lobster fishery is small. Less than 10 fishermen operate north of the Barra Strait and less than 20 fishermen fish the southern area. The herring fishery was the primary commercial fishery until it was closed in 1999. There is still concern about spawning being absent in traditional areas and low spawning biomass. Oyster aquaculture is still operational in the Lakes, although at a reduced level since the devastation due to MSX and SSO. Active lease areas are evenly distributed between McKinnon's Harbour, St. Patricks Channel, East Bay and Denys Basin.

There are two large gypsum mines in the watershed – Little Narrows in the St. Patricks Channel sub-watershed and Melford in the Denys Basin sub-watershed. There is also a small marble mine in the Denys Basin sub-watershed. On-land and in-lakes petroleum exploration activity has been inactive for several years, and no undertakings are expected.

Shipping from Little Narrows Gypsum is the only industrial shipping in the Lakes and it's a loading facility only. An average of 45 vessels per year enters and exits the Lakes, and vessels come from either Baltimore, Maryland or Jacksonville.

There are four Provincial Parks in the watershed plus three small picnic parks along highways. Whycocomagh Provincial Park has a 62-site campground and lake access. There are also four areas set aside for ecosystem protection rather than human use. These are the Bornish Hills Nature Reserve, the Middle River Wilderness Area, Washabuck Conservation Easement, and the Spectacle Island Game Sanctuary. The Nova Scotia Department of Natural Resources also has various types of protected areas with differing levels of protection. The greatest area of protected lands are in the sub-watersheds of Middle River (5300 ha), River Denys (843 ha), Baddeck (467 ha) and North Basin (459 ha). There are no protected areas in McKinnons Harbour or the Great Bras d'Or Channel.

A matrix of human activity was presented in an initial attempt to quantify human pressures on the environment, and results can be found on page 152 of the draft EOAR (Appendix 5). The primary consideration was the quantification of environmental disturbance. Factors considered in the analysis include size of disturbance (small to large), recoverability of the ecosystem post-disturbance (no time to decades), frequency of disturbance (infrequent to daily) and patchiness of disturbance (one location to several). Improvements to the analysis to increase robustness and scientific defensibility will be made in the future.

Discussion

It was felt that the human use matrix should be better incorporated into the text of the EOAR. It was also suggested that this matrix be used to target management activities, i.e., as measure of numbers of people impacted or measure of resistance you might face. It was noted that shellfish closures seemed to drive the ranking. Was there consistency of information for each area? Several participants asked how the matrix might be used for management.

<u>Information Gaps</u>
The following data gaps were identified:
- Ballast water
- Contaminants, e.g., pesticides, fertilizers
- Golf courses – impacts and operations
- Incorporation of future activities, e.g., finfish aquaculture
- Airshed (long-range transport), e.g., Nova Scotia Power's air emissions
- Relationship between activities and impacts – use of activity-stressor matrix
- Maps

<u>Report Organization</u>
It was felt that information on disease and parasites should be moved to the Biological Systems section of the EOAR.

<u>Additional Information Sources</u>
A number of additional information sources were suggested. These included:
- Navigational aides: Coast Guard "list of lights"
- Forestry: Registry of buyers, by county, which keeps track of wood supply.
- Road density: Department of Natural Resources model
- MSX and SSO: info from lease holders or province Annual report of operations.
- Air photos
- Habitat Management (DFO): information on habitat impacts.
- Shipping:
    - Lock records
    - Bridge records
    - Government wharf records
    - Marinas: records of overnight birthing

ECOLOGICALLY AND BIOLOGICALLY SIGNIFICANT AREAS

Mike Parker

Mike Parker provided some background on a DFO initiative to develop criteria for the identification of ecologically and biologically significant areas (EBSA) within the marine environment. He then presented a proposed methodology for the identification of EBSA within the Bras d'Or Lakes.

Presentation

DFO has produced a guidance document on identifying EBSA (DFO, 2004). Some important points to consider include:

1) "Significant" means that if species, habitat features, or areas were to be severely perturbed, the ecological consequences would be greater than an equal perturbation of most other similar species, features or areas.

2) "Value" is used to refer to the importance of something to humans, and it is not to be a major consideration when evaluating areas.

3) EBSA ranking does not consider imminent threats or risks to an area. Risks and threats drive management if an area is identified as an EBSA, but it does not weigh into an area being ranked.

4) Evaluation must be carried out relative to some area, globally, nationally, regionally, locally. The guidance document suggests a regional evaluation. For the Bras d'Or Lakes, EBSA identification was primarily a local evaluation. This was done because that is the information we had on hand upon completion of the Bras d'Or Lakes Overview. EBSA as a process can be applied at virtually any scale, and the results are only functional at that scale and not directly comparable to other locations or other geographical scales.

In total, there were twelve separately defined watersheds flowing into ten Bay Scale areas. Although twelve watersheds are shown, we actually amalgamated the results for those flowing into St. Patricks Channel and treated them as one larger watershed.

It is understood that the EBSA process is only as complete as the information upon which it is based. This is part of the reason why a finer resolution scale was not used, i.e., the scale of evaluation was based on the scale of information available. However, it is expected that new information may necessitate additional evaluation of EBSA, and other temporal changes like climate change, shoreline development, or fishing effort may alter what we currently know. Therefore, temporal variation on the scale of years to decades will need to be addressed through periodic review.

The last point of guidance that the DFO document provides is the concept of evaluating EBSA using five criteria. The three primary criteria for evaluation are Uniqueness, Aggregation and Fitness Consequences. Two secondary criteria included Resilience and

Naturalness
Uniqueness of an area should be measured relative to others in a regional national and even global scale. Aggregation is how individuals aggregate in the area relative to other areas, and for what functions, or (because it is not just biota) what ecological process or structural feature is concentrated in the area. Fitness Consequences refers to how important the area is to fitness of a species, focuses on reproduction and survival, but considers both species and features that support a species that may be found in the area being evaluated. Resilience is how sensitive or resilient a species or structure/function is likely to be to perturbation. Naturalness is how pristine or native versus highly perturbed or anthropogenically influenced are species or features. Further definition of each of these is provided in the guidance document.

Our challenge in identifying EBSA was to take this basic framework and develop it in a manner that would allow some form of quantitative scoring and ultimately ranking of the ten "bay scale" areas of the Bras d'Or Lakes. Information from the overview work was categorized under one of 25 feature headings for each of the 10 bay scale areas. This was just a narrative, but it would be used to support the scores that were later applied in the ranking system. The first three categories were used for EBSA scoring, whereas the Resource Use/Risk Factors category were items that were noted for management consideration, but were not to be used for EBSA ranking.

Table 2. Categories for evaluation of Bras d'Or Lakes EBSA.

Species Use						
Periodic / Historic	Forage Area	Rearing Area	Key Breeding	At Risk Status		
Physical and Chemical Character						
Biodiversity	Ecosystem Function	Nutrients	Anoxia	Mixing/ Stratification	Temperature / Salinity	Minerals and Metals
Sensitive Habitats						
Hard Substrates	Barachois Ponds	Wetlands	Shoreline	Other Limited Habitat Type	Mature forest	
Resource Use / Risk Factors						
Other Industrial	Land Clearing / Development	Shellfish Closures	Invasive Species	Rec. Use	Aquaculture	Commercial Harvest

Numeric ranges that could be used to evaluate each of the five criteria provided by DFO needed to be developed, and it was unclear how these would be applied in a consistent manner. As the primary ranking was to be done on the local scale, the first three criteria were weighted from "not significant" to "significant" locally on a 0-3 scale. Slightly higher scores were given for regional or national significance. Fitness was a straight scale locally, with no Regional or National significance. Resilience and Naturalness were secondary criteria but were still considered for each of the 18 feature headings.

The result was a large scoring matrix with all 18 feature headings across the top and all the 10 Bay Scale areas down the side. This was summed with scores for each of the eighteen feature headings. If new information were to be added, it would be done in the narrative under one of the feature headings. There would then be discussion of whether the scoring should be adjusted based on the new information for that feature heading.

The results for all are summarized to provide a final scoring that creates the ranks from 1-10 for ecological and biological significance for each of the Bay Scale areas of the Bras d'Or Lakes. The final scores mean nothing in an absolute term. There is no passing or failing mark, the scores I gave each feature and area may be different than you may have used; however, the important part is the relative scoring. The ranking is essentially non-numeric. They could be called A-J rankings.

It should be recognized that identifying the relative ecological and biological significance of an area does not give it any special legal status, protection etc. Identification of an EBSA merely provides guidance on the standard of management that is to be considered appropriate for an area to maintain the ecological integrity of a larger ecosystem.

Discussion

<u>General Comments</u>
In general, participants seemed to feel that this approach was a good attempt at working through a process that was not yet well defined. However, it was felt that there might be some value in going through this exercise again with a group of stakeholders. In particular, it was felt that First Nations elders should be invited to participate in this process.

<u>Application</u>
There were a number of questions asking for clarification of the role of EBSA in management. For example, how would EBSA identification impact oyster restoration activities? It was suggested that identification of EBSA didn't mean that other areas aren't also going to require management activity. It was unclear whether DFO was trying to define large management areas or very specific areas for protection.

There was some confusion over whether this was meant to be a conceptual exercise or a practical exercise. If it was meant to be a conceptual exercise, we could investigate the consistency of application. If it was a practical application, we would need to see areas important for various life-history stages identified as EBSA. One small spawning area may be significant. Practical things such as spawning beds and wintering areas should be identified in such a process.

It was asked how EBSA identified in the Bras d'Or Lakes compared to EBSA identified in other areas. The response was that not many other regions have completed their EBSA identification processes; however, this method is somewhat different than what was imagined for the Scotian Shelf offshore environment.

National EBSA Criteria

There was some concern expressed about the exclusion of "threat" from the determination of significance. The definition of disturbance was discussed. Disturbance was expected to include perturbation, e.g., development, which is not a point source. The rationale for trying to determine the significance of an area without knowing exactly what any future threat to it might be was explained.

Scale of Bras d'Or Lakes EBSA Boundaries

Participants commented on the fact that EBSA boundaries were identified at the beginning of the process rather than after criteria had been applied. It was suggested that different EBSA boundaries might emerge using a different approach. For example, the coastal interface might have been identified separately or might not have been identified at all (limited information). Properties that make an area significant might not conform to boundaries as they were initially defined.

The fact that EBSA boundaries may change over time was stressed. Some suggested that exactly where we draw the boundaries of each EBSA may be of interest to those who have to manage them but may be of limited importance to others.

There was much concern expressed over the fact that small scale features didn't emerge from this EBSA identification exercise. Small areas of high significance seem to have been missed. This is an important limitation of this approach.

Categories and Features Evaluated for the Bras d'Or Lakes

Concern was expressed that the variables selected for evaluation favored the north end of the lakes, which is why this part of the Lakes was identified as the most significant.

The evaluation of temperature and salinity was questioned. It was not clear how you would score a warmer or colder temperature regime. Why would warmer temperatures be more significant than colder temperatures, for example? Perhaps temperature and salinity could be translated into impacts to a particular species or process, i.e., the impact or effect of temperature and salinity.

It was suggested that the first six categories (forage areas, rearing areas, breeding areas, at risk status, biodiversity) should receive more weighting. However, there was some confusion on how you might integrate information on 46 different fish species for each of these categories. If you did this for each species and process, however, this would allow for more transparency. You would need an expert on each species and process. It might be useful to include information on the use of areas for plants and plankton. Migration areas may also be of interest.

Inclusion of sensitive habitats was questioned. It was unclear what the relationship between these and "significant" areas was. It was explained that what were called "sensitive habitats" were actually more like rare habitats.

It was suggested that physical processes such as erosion should be included. For example, one might want to describe the significance of erosion or sedimentation in each of the areas.

Data Sources

Some of the information used in the evaluation was considered to be outdated. The need to update information was identified. The use of species distribution maps put together by elders and communities was suggested.

Scoring

A number of comments and suggestions were made on the proposed approach for EBSA scoring. For example, it was suggested that you could produce a ranking across multiple axes, i.e., for each category, and then also across categories. It was also suggested that areas important from a traditional and ecological knowledge perspective should be weighted higher than other types of information. It was suggested that detailed scoring may not be required if you are only trying to achieve major groupings of areas. However, you won't know what the separation is between sites until you've gone through exercise. It was noted that two different sites could get the same score for different reasons; thus, it would be important to include the descriptive information behind the scoring to identify what those differences are. It was suggested that Uniqueness be scored from local to regional to global – a site can't have "national" uniqueness since ecosystems don't have political boundaries. One person was surprised by all the "3"s for naturalness, i.e., that so many sites were considered very natural when we don't really know what the un-impacted system looked like. This demonstrated how sites were scored relative to each other rather than to some historic baseline or absolute ideal.

Some discussion then ensued on how to deal with areas for which we don't have any information. At present, no information is indicated as a 0 score. Several alternate suggestions were provided: 1) insert an average or mid-range score or 2) insert the highest possible score (precautionary approach). It was suggested that the social science literature may provide useful techniques for dealing with the subjectivities of scoring.

Finally, a suggestion was made that it may be useful to translate the narrative table into some geo-referenced format. This could potentially enable you to redo scoring quickly as information changes. However, such an approach would depend upon the availability of geo-referenced EBSA information.

Results

Since this review was of the methodology used to develop EBSA for the Bras d'Or Lakes, there was only limited discussion on its final results. Comments included that the ranking seemed to reflect the connectivity of different areas and that it was hard to discuss the results without knowing the rationale for scoring.

Nearshore Environment

Several people suggested that the nearshore environment as a whole might be a separate area for evaluation with potential for inclusion as an EBSA. However, others suggested that you wouldn't want or expect to see the same level of risk aversion for the entire Bras d'Or Lakes coastline. Examples of how ecologically significant the nearshore environment is relative to the offshore environment were provided. For example, a one hectare bay can fix 100 times more nitrogen than one hectare of offshore environment. A 5m strip of macrophytes can influence

5km out into offshore environment. This is not due to the sensitivity of eelgrass but to its ecosystem function. The question was asked whether the nearshore environment should be evaluated as a continuous zone or in pieces. It was suggested that you could evaluate the coastline within the larger Bay Scale Area. It was also suggested that nesting boundaries may play an important role.

Terrestrial Environment

It was recognized that the EBSA exercise did not take into account the terrestrial environment, which will also include significance areas. For example, the Department of Natural Resources has information on wetlands as potential significant areas. It was recommended that the need to incorporate terrestrial EBSA should be brought forward to CEPI.

Other Considerations

- Connectivity, that is, the degree to which processes that operate within any given EBSA depend on or have impacts upon the processes in adjacent EBSA, was not considered in this exercise. The degree of connectivity, to the extent that it is possible to determine this, should be considered in the next iteration of the Bras D'Or EBSA. Given the fluid, three-dimensional, and relatively connected nature of marine ecosystems, the concept of connectivity is particularly important.
- This process was seen a way of addressing something that is already being discussed by First Nations.
- It may be difficult to change something once it has been written down.
- Allow time to pass before adopting anything.
- This approach didn't seem to have relevance to stakeholders. Categories are useful but may not be relevant. Lack of relevance may lead to lack of credibility.
- Should use common language.
- Can apply slightly different approach to this region (i.e., don't need to follow National Guidelines entirely).
- This is a first step – not a final version.
- Support was expressed for a team approach, but National DFO should be involved in the discussion so that they can understand the requirements.
- Can we identify areas that need to be restored?
- How will EBSA affect stakeholders? This needs to be communicated.

REVIEW OF MAJOR CONCLUSIONS AND RECOMMENDATIONS

General Comments

In general, the EOAR was thought to be a good compilation of published scientific information; however, it was agreed that traditional knowledge was not well represented. The EOAR is currently focused on the open water environments, less on the nearshore and terrestrial environment. It represents a good snapshot of current conditions, though some information needs to be updated. Historic information is important to provide a baseline for how the system used to function, but this information should be clearly separated from our understanding of the current conditions. Oral traditions are important and should be incorporated. A historic perspective at the beginning of the EOAR would help to provide context. Finally, it was felt that the Bras d'Or Lakes system is not a pristine system and this should be clearly acknowledged.

In terms of organization and structure, it was suggested that main conclusions should be included at the end of each section of the report and then summarized in the "Conclusions" section. A number of inconsistencies were identified within the draft EOAR, which should be corrected with the help of people with specific expertise, e.g., biologists and ecologists. It was felt that the EOAR needed to be a "living document," and it was suggested that the EOAR be updated by DFO at least one year before the CEPI management plan is reviewed, but no later than 2010. Ongoing tracking of new information would assist this process.

First Nations have a fiduciary responsibility for the watershed and will play an active role in its conservation and management.

Physical Systems

<u>Scope</u>
For the coastal environment of Bras d'Or Lakes, it was recommended that the scope of the EOAR be expanded to include more information on:

- Nearshore environment
- Streams and rivers
- Climate change (e.g., changes in rainfall, water level, ice cover)
- Winter conditions – suggestions that industry data may be available, e.g., aquaculture
- Benthic habitat (bottom type)
- Groundwater, particularly through seabed
- Terrestrial ecology

<u>Spatial Scale</u>
Generalizations presented in the draft EOAR are useful for broad-scale strategic planning, but we should not lose information that is important at the local scale. Small scale features may have large scale implications. Generalizations for the Bras d'Or Lakes give the impression that everything is fine, when there may be local issues. The recommendation was to include local information that is available or provide examples of exceptions to the general rule. Examples might include:

- anoxic locations
- river sedimentation
- shellfish contamination
- quality of environment for oysters

<u>Understanding of Major Features</u>
There was not significant disagreement with the presentation of information on physical systems. For example, evolution of the system from freshwater to marine was thought to be consistent with archeological evidence of human occupation.

<u>Trends</u>
Temporal scale is important when describing trends. For example, precipitation trends over the past 30 years show an increase, while trends over the last 10 years show a decrease. Information on trends will be data dependant, so use the longest data series possible but note more recent changes.

<u>Other Considerations</u>
Consistency of units was encouraged.

Biological Systems

Scale

Issues related to the scale of biological processes were similar to those discussed for physical systems. For example, the Bras d'Or Lakes *overall* may not be an ideal location for oysters, but there are specific locations that *are* good for oysters.

Understanding Major Features

It was felt that we needed a better understanding of the role of eelgrass and the nearshore environment in primary production. In addition, the role of oysters within the ecosystem should be expanded upon. The assumption that productivity in the Lakes was low was questioned, and it was felt that upcoming research may help to address this issue. Similarly, the assumption that nutrients were the most important factor in productivity was also questioned. Recommendations for additional analysis included: the role of sills in separating the northern and southern Lakes, and the relationship between eelgrass, green crab, oyster settlement and herring spawning.

Trends

It was felt that this EOAR did not adequately capture incremental damage to the Bras d'Or Lakes, e.g., loss of wetlands and loss of known herring spawning sites. Also, the need to capture both overall trends while still highlighting the exceptions to these trends was noted. For example, while total fish abundance appeared to be higher in 2002 as compared to 1967, there are several key species that have declined, e.g., American plaice, herring, lobster, and oyster. When describing status and trends, it would be useful to include references to other areas such as other coastal environments. Finally, natural variability should be distinguished from ecosystem shifts or regime changes where possible.

Data Gaps

The following biological data gaps were identified:

- Role of nearshore (e.g., <10m depth) environment
- Energy flow modeling
- Bottom habitat (dominant species)
- Primary and secondary production
- Food web relationships
- Spatial use by life-cycle

Other Considerations

It was noted that there will always be a time lag between conducting the science and having it available for management.

Local and Traditional Ecological Knowledge

Suggestions for incorporation of local and traditional knowledge into the EAOR were to include TEK wherever it fits throughout the document, perhaps using a narrative, and to use industry and community data where available. It was suggested that First Nations should be consulted for guidelines on the collection and dissemination of their TEK. It was recommended that open workshops or small working groups should be used to gather additional information from the community, using previous workshops as examples.

Human Activities

<u>Human Activities Matrix</u>
The human activities matrix was considered useful and it was suggested that it be included in the EOAR. However, the role of shellfish closures in the ranking scheme should be revisited.

<u>Scope</u>
To better describe the human environment of the Bras d'Or Lakes, it was recommended that the scope of the EOAR be expanded to include more information on:

- Ballast water
- Contaminants, e.g., pesticides, fertilizers
- Golf courses
- Airshed (long-range transport)
- Relationship between activities and impacts (use of activity-stressor matrix)

It was felt that disease and parasites should be moved to the Biological Systems section. Also, better use should be made of maps.

EBSA

The major conclusions of the EBSA discussion were as follows:

- Proposed approach is a good first step.
- Need some revisions to the establishment of EBSA boundaries and the selection of categories for evaluation.
- It may be useful to re-evaluate the national criteria, e.g., inclusion of connectivity.
- Use caution in evaluating EBSA based on old information.
- Additional efforts should be made to ensure use of best available information, including traditional and community knowledge. Not all these sources have been utilized in the current document.
- Areas that we might intuitively/historically expect to be identified as significant have not yet been identified through the process described within the draft EOAR. This might be used as a test of the approach.
- Reproducibility of approach (e.g., relative scoring) may be another test of the approach.
- A team approach is strongly supported.
- The significance of the nearshore environment has not been adequately captured within the current framework.
- Transparency in how the approach is applied is important. It is essential to include the narrative describing how areas are scored.
- The national framework does not currently allow for identification of terrestrial EBSA. The management plan for the Bras d'Or Lakes and surrounding watershed will need to take these into account.
- Where there is no or limited information, scoring shouldn't lead to the assumption that the area is not significant. Gaps in knowledge should be flagged. Methodologies for dealing with data gaps should be explored further.
- Outcomes and management implications should be clear to share/stakeholders – this should be another test of the approach. DFO will ensure that this occurs.

NEXT STEPS

Participants should send comments on the draft EOAR to Maxine Westhead (westheadm@mar.dfo-mpo.gc.ca) by the end of month.

Proceedings will be published and circulated to participants. It was suggested that the draft EOAR be included as an Appendix to the proceedings.

A Science Advisory Report will be formatted by an editorial committee and circulated to participants for comment.

A meeting will be held in the near future to discuss the next steps related to identification of EBSA within the Bras d'Or Lakes. It was suggested that discussions of Bras d'Or Lakes EBSA be included within the larger Eastern Scotian Shelf Integrated Management Initiative (ESSIM) EBSA discussions.

REFERENCES

DFO, 2004. Identification of Ecologically and Biologically Significant Areas. DFO Canadian Science Advisory Secretariat Ecosystem Status Report. 2004/06.

DFO, 2005. Guidelines on Evaluating Ecosystem Overviews and Assessments: Necessary Documentation. DFO Canadian Science Advisory Secretariat Science Advisory Report. 2005/026.

Note: References for information contained within presentations can be found in the bibliography of the draft Ecosystem Overview and Assessment Report (Appendix 5).

APPENDICES

Appendix 1. List of Participants

Participant	Affiliation	Telephone (902)	E-mail
Stephanie Astephen	DFO / Habitat Management	564-7708	AstephenS@mar.dfo-mpo.gc.ca
Fred Baechler	ADI Limited		fbaechler@adisydney.ca
Lynn Baechler	ADI Limited		lynn.baechler@ns.sympatico.ca
John Bain	Rural Cape Breton District Planning Commission		jdbain@rcbplan.ns.ca
Toby Balch	NS Agriculture and Fisheries		balchto@gov.ns.ca
Rod Beresford	Cape Breton University	563-1609	rod_beresford@capebretonu.ca
Gary Bugden	DFO / Ocean Science Division	426-5745	BugdenG@mar.dfo-mpo.gc.ca
Pauline Campbell	Mackinnon HBR Survival Society		piuscampbell@ns.sympatico.ca
Sharron Carter	NS Environment		cartersh@gov.ns.ca
James Crawford		756-3556	
Charlie Dennis	Unama'ki Institute of Natural Resources		charlie@uinr.ca
Diana Denny	Eskasoni	379-2723	
Penny Doherty	DFO / Ocean and Coastal Management Division	426-6533	DohertyP@mar.dfo-mpo.gc.ca
Dave Duggan	DFO / Ocean and Coastal Management Division	426-6183	DugganD@mar.dfo-mpo.gc.ca
Lucia Fanning	Environment Canada		FanningLuciaEC@dfo-mpo.gc.ca
Jim Foulds	ADI Limited		jim@ecoboy.ca
Mark Hemphill			mhemphill@usg.ca
Darren Hiltz	DFO / Habitat Management	426-3622	HiltzD@mar.dfo-mpo.gc.ca
Diane Ingraham	Cape Breton University		diane_ingraham@capebretonu.ca
Rene Lavoie	DFO Emeritus		lavoieR@mar.dfo-mpo.gc.ca
Mudena Marshall	Eskasoni	379-2508	
Alison MacIsaac	Eskasoni Fish and Wildlife Service		allison@efwc.ca
Brian MacSween	NS Natural Resources		macswebh@gov.ns.ca
Albert Marshall	Elder, Eskasoni First Nation		albert@uinr.ca
Denise McCullough	DFO / Ocean and Coastal Management Division	426-4274	McCulloughD@mar.dfo-mpo.gc.ca
David Millar	DFO / Ocean and Coastal Management Division	426-9926	millarDC@mar.dfo-mpo.gc.ca
Jason Naug	DFO / Ocean and Coastal Management Division	426-2574	NaugJ@mar.dfo-mpo.gc.ca
Mike Parker	East Coast Aquatics	665-4682	msrparker@ns.sympatico.ca
Lorne Penny	DFO / Shellfish Sanitation Program Officer	564-2574	pennyL@mar.dfo-mpo.gc.ca
Vera Pierro	DFO / Aboriginal Program Co-ordinator	564-2976	PierroV@mar.dfo-mpo.gc.ca

Participant	Affiliation	Telephone (902)	E-mail
Tammy Rose	DFO / Habitat Management	426-0379	roseT@mar.dfo-mpo.gc.ca
Kevin Squires		674-2634	ksquires@dal.ca
Robin Stuart	Ocean Stuarts		robinstuart@ns.sympatico.ca
John Tremblay	DFO / Population Ecology Division	426-3986	TremblayJ@mar.dfo-mpo.gc.ca
Herb Vandermeulen	DFO / Ecosystem Research Division	426-8202	VandermeulenH@mar.dfo-mpo.gc.ca
Gus van Helvoort	DFO / Area Director, Eastern Nova Scotia		VanHelvoortG@mar.dfo-mpo.gc.ca
Maxine Westhead	DFO / Ocean and Coastal Management Division	426-4215	WestheadM@mar.dfo-mpo.gc.ca
Tana Worcester	DFO / Regional Advisory Process Office	426-9920	WorcesterT@mar.dfo-mpo.gc.ca
Phil Yeats	DFO / Ecosystem Research Division	426-7689	YeatsP@mar.dfo-mpo.gc.ca
Kees Zwanenburg	DFO / Ecosystem Research Division	426-3310	ZwanenburgK@mar.dfo-mpo.gc.ca

Appendix 2. Meeting Remit

Background:

The Bras d'Or Lakes and surrounding watershed has been identified as a Coastal Management Area under the Oceans Act and, in conjunction with the Scotian Shelf, is now one of the five priority areas for Integrated Oceans Management as described in Canada's Oceans Action Plan (2005). Development of an integrated management plan for the Bras d'Or Lakes will be a multi-step process that will serve as a model for other coastal management areas. The Bras d'Or Lakes IM Planning process will build on existing activities and initiatives, including research conducted as part of the Science for the Integrated Management of the Bras d'Or Lakes (SIMBOL) program and work conducted by the Eskasoni Fish and Wildlife Commission and others. One of the first steps in the Integrated Oceans Management process is the development of an Ecosystem Overview and Assessment Report, which summarizes existing environmental and socio-economic information, evaluates key interactions and issues, and identifies Ecologically and Biologically Significant Areas. A draft Ecosystem Overview and Assessment Report has been prepared for the Bras d'Or Lakes, and review of this report will be the primary objective of the proposed Regional Advisory Process (RAP). It is expected that this report will help to facilitate the preparation of a State of the Bras d'Or Report and other management considerations currently being sought through the Collaborative Environmental Planning Initiative (CEPI).

The geographic focus of this Regional Advisory Process will be on the Bras d'Or Lakes and surrounding watershed. Connections to the Eastern Scotian Shelf Integrated Management area and other areas of Cape Breton will also be considered.

Objectives:

Objective 1: To review material contained in the Ecosystem Overview and Assessment Report for the Bras d'Or Lakes prepared by the Oceans and Coastal Management Division for accuracy and completeness. Any gaps in information are to be identified.

Objective 2: To review and reach agreement on the methodology for selection of Ecologically and Biologically Significant Areas (EBSA) in the Bras d'Or Lakes.

Preparation:

An Ecosystem Overview and Assessment Report that summarizes the available information on the various components of the Bras d'Or Lakes ecosystem has been prepared by the Oceans and Coastal Management Division and will be made available to RAP participants prior to the meeting. This report will include a preliminary assessment and identification of Ecologically and Biologically Significant Areas.

Products:

Products of this RAP will include:

- Ecosystem Overview and Assessment Report
- Proceedings of Meeting
- Science Advisory Report

Appendix 3. Agenda

Day 1: Wednesday, November 2nd

10:00-10:15	Introduction to the day (Worcester)
10:15-10:30	Presentation on Management Overview and Context (Naug)
10:30-10:45	Presentation on Physical Systems (Parts A and B) (Parker)
10:45-11:30	Discussion on Physical Systems
11:30-12:00	Presentation on Biological Systems (Part C) and start of discussion (Parker)
12:00-1:00	Lunch
1:00-1:30	Discussion on Biological Systems continued
1:30-2:00	Discussion on how to incorporate Local and Traditional Ecological Knowledge
2:00-2:15	Presentation on Ecosystem Relationships (Part D) (Parker)
2:15-3:00	Discussion on Ecosystem Relationships
3:00-3:15	Break
3:15-3:30	Presentation on Human Activities (Part F) and Human Activity Matrix (Appendix D) (Westhead)
3:30-4:15	Discussion on Human Activities and Matrix
4:15-5:00	Open discussion

Day 2: Thursday, November 3rd

9:00-9:15	Summary of previous day
9:15-9:45	Presentation on methodology and results for identification of Ecologically and Biologically Significant Areas (EBSA) (Part E, Appendix A) (Parker)
9:45-11:45	Discussion on EBSA
11:45-12:45	Lunch
12:45-3:00	Working session to complete the Scientific Status Report
3:00	Adjourn

Appendix 4. Written Submissions on the draft EOAR

Submissions are provided in no particular order. Names and other identifying information have been removed.

Submission 1

I think the document would benefit from having a brief explanation of the EOAR process, a bit more information on the purpose of the document (i.e., to provide ecological overview, not the status) and how it fits into the process. This could be added to the project definition section and would help put the whole document into perspective.

Page 56: Cod: This section on cod should be under the Groundfish Commercial species section since cod are groundfish.

Page 106: first paragraph,
"Moose on mainland Nova Scotia have been officially listed "endangered" under the Nova Scotia Endangered Species Act, so hunting for them occurs only on Cape Breton Island." The sentence implies that moose on mainland Nova Scotia and in Cape Breton are from the same population, however, the Cape Breton moose population is a different population from that on the mainland.

Part G - Conclusions
It would be beneficial to have the conclusion broadened to include key findings/highlights of the various sections of the document since people will often refer to the conclusions section rather than reading the whole document.

As this was the first attempt to take the EBSA criteria and develop a scoring/ranking scheme, I think it is important and appropriate to make it explicit what the results of the ranking process mean for the EBSAs identified in the Bras d'Or. We don't want people who read the report to think that these EBSAs are going to become MPAs. We need to be explicit that this was a preliminary exercise to try to identify EBSAs and that the methodology will have to be developed further, etc.

Page numbers are off by 1 in the Table of Contents beginning with Part F which is actually on page 79, not 80.

Overall, a great job was done on this report. Congratulations.

Submission 2

I had a chance to review the draft version of the Ecosystem Overview and Assessment Report for the Bras d'Or Lakes. At first glance, there are a couple of things I picked up on:

Page 79 - NS EL only administers the Environment Act. This Act amalgamated a number of Acts in 1995, including the water resource Act.

Page 98 - The sewage treatment plants in Whycocomagh and Evanston are not mentioned - only Baddeck and St. Peter's

Submission 3

Page 79 - Provincial Departments - DNR Acts should include the Crown lands Act as all land below the ordinary mean high water mark in Crown land except where water lots have been granted.

Page 83 - Middle River Watershed Society - Nova Scotia Agriculture and Fisheries (not Forestry)

Page 90 - 93 - Forestry - The write-up is good but it must be clearly understood that Stora Enso is only the contractor/manager of the Crown land within the Licensed area. All Stora plans must be submitted to DNR for review and are checked against the categorization which has been done for all Crown lands, that being the C1, C2 and C3 designation. Each of these denotes different levels of management options, from the multiple use lands of the C1 designation, to the lands where conflicts between uses may be more pronounced and as such the most critical values must be protected in any management regime, to the C3 designation where single use is the norm. This may range from a designated Park or sensitive habitat to a mine site where only that activity is permitted. DNR also carries out a minimum 10 % inspection of Stora Crown land operations and cooperates with Stora in another random sampling of their Crown and private operations known as the Stora Green Audit. Also DNR has conducted 28 public IRM sessions where input was gathered from all disciplines ranging from government departments to the general public. All issues were noted verbatim as submitted in these sessions and in the order of 2500 separate issues were recorded in total. These issues are in the process of being incorporated into a series of LRMF's (Long Range Management Frameworks) which are to be drafted for each of the Ecodistricts to be found within the province of Nova Scotia. In the case of the Bras d'Or, this will be in the order of 5 LRMF's. The process of the development of these will involve the striking of at least 2 Public Advisory Committees, one for the northern portion of Cape Breton Island and one for the southern portion. The final LRMF's will serve as an umbrella set of guiding principles and rules under which the Crown land will be managed by Stora. Their Long Term Plan will be required to be revised to match the LRMF. The LRMF process will follow established Ecosystem planning principles and will be a fully open and transparent process. In addition, all requests for use of Crown land by any proponent undergoes Integrated Resource Management scrutiny from all disciplines within the Department and requires a joint consensus from the IRM Team for approval. Suggest you replace with IRM information at end of this document

It is true that Private lands are much more difficult to gather harvesting information on, but through the use of satellite imagery, GIS and the Registered Buyers system administered by DNR, figures that can be used to predict wood supply are collected. Also, under the Wildlife and Watercourse Protection Regulations, regular inspections of both private and Crown land forestry operations are conducted to ensure compliance.

Page 94 - 15-4 - Development and Land Use Planning - There is an implied lack of responsibility or control in the write up in paragraph one of the Overview. In fact the 63 groynes, 44 seawalls etc. referenced in the document are in fact predominantly as a result of activities conducted prior to 1988. Since that year, DNR has administered all activities below the ordinary mean high water mark in the Bras d'Or, with the exception of some cases on First Nations Reserves. A Policy document called 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, with numerous successful convictions having been concluded. In each of these cases the court has ordered the removal of the structure. Bank protection is allowed if it does not extend below the OMHM. Full cooperation has been received by DNR from NSDOEL and DFO Habitat Division. In addition almost all of the man made structures along the coastal area of the Bras d'Or Lakes have been inventoried by DNR staff, GPS'd, measured, photographed and entered in to our GIS database.

Page 97 - 15.4.3 - Road Density - It is unknown what road density model was used in the Overview, but for consistency, it would seem that the DNR model might be the appropriate one to use as a lot of the other databases used are from the DNR GIS. This would ensure consistency if nothing else.

Page 106 - 15.5.4 - Hunting - CB moose population is a different sub-species than the Mainland population. Stems from a re-introduction of moose from Alberta to CB Highlands NP in the 40's.

Page 113 - 15.7.3.1 - Boat ramps - In addition to the public ramps referred to, there are many private ramps in existence. Boat ramps that are truly "public" are the ones operated and maintained by DNR. All others that are on private land are administered by the group operating them and may offer restricted use by the public for a fee or under certain rules. As well, all boat ramps, whether on Crown or private land, require DNR approval and if the proponent wishes to exceed the normal standards, a full IRM review of the proposal is required and DFO Habitat must review the proposal and provide their comments/approval. NSDOEL is consulted as required.

Page 115 - Humes River Wilderness Area (Proposed) - It is important to note that this is <u>not</u> a proposed wilderness area. It is simply an area that Ecology Action Centre has expressed interest in, and it is being evaluated from their prospective as to it's potential for this designation. It is currently classed as C2 in DNR's classification system for the predominant value found on the site, which is "Old Growth Forest".

Page 116 - Table 25 - Please include Battery Park in St. Peters as a portion of it fronts on the Bras d'Or Lakes.

<u>Overview of Integrated Resource Management</u>

A principal responsibility of the Department of Natural Resources is the management of Crown lands in the province. (Crown land is defined under the *Crown Lands Act* to be "land under the administration and control of the Minister of the Department of Natural Resources".) The natural resources provide significant social, cultural, environmental, and economic benefits to Nova Scotians There are strong public expectations, and numerous competing demands, for the use of this limited public land and resource base. Pressures on the land base are increasing for both consumptive and protection-oriented uses such as resource extraction, hunting and other outdoor recreation, wildlife and habitat, ecotourism, and conservation of natural areas. The Department's aim is to maintain an appropriate balance so that resource use continues to provide a substantial contribution to the province, while being carried out in a socially responsible and sustainable manner.

The Department of Natural Resources is a strong science and information based department. Land and resource data and scientific knowledge are the basis for much of the Department's planning and decision making. The combination of data and knowledge is critical for making informed, rational decisions on the sound management of Crown lands and for the Department's resources sectors, on both Crown lands and on private lands.

Long Range Management Frameworks (LRMF) are ecologically based land use planning documents that act as a structure to support the various management plans to be implemented on Crown lands within the defined ecodistricts of the province. They provide an overview of the management options, directions and strategies for Crown lands that will be implemented through the departments operational plans for resource management. The development of these frameworks is a continuation in the Department's Integrated Resource Management (IRM) process for managing Crown land.

1.2 Background

Integrated Resource Management (IRM) was introduced by the Department of Natural Resources to support the Department's decisions on the management and use of Crown land. IRM is intended to ensure that the Department's decisions reflect consideration of the different resources and special values linked to Crown land. The Integrated Resource Management process identifies land features, uses, and resource values on Crown land. It works to balance known and potential resource uses and values so that long term sustainable values are optimized and conflicts minimized. This process brings together resource groups and interests in Crown land to balance the economic, environmental, and social requirements of society, rather than each working in isolation.

Integrated Resource Management (IRM) planning for provincial Crown lands takes place within an existing framework of legislation, policy and contractual agreements. (Examples of these include the Endangered Species Act, the Mineral Policy and Sawmill License Agreements.) This structure, along with the Department of Natural Resources (DNR) Strategic Plan(December 1994), provided the background for the development of provincial wide resource goals and objectives.

Geology, ecology, forest productivity, social features and population patterns are just a few of the variables which vary across the Department's three administrative regions. Thus, in addition to the provincial resource goals and objectives, each of the three regions developed a set of regional goals and objectives (Appendix 1). These are based on a combination of staff knowledge of regional characteristics and input received during a consultation component of Phase 1 of the IRM process. These Regional Goals and Objectives must be considered by regional staff when developing the Long Range Management Frameworks

Phase 1 of the IRM project identified land features, uses, and resource values which have been incorporated into the Department's planning and decision making process for Crown land management; as new land features, uses, and resource values are identified they also will be included. In addition to the inventory of land features, uses and resource values, Phase 1 also included analysis of existing and potential resource utilization; and consultation with the public, stakeholders and other provincial departments and agencies. This information was used by teams of Natural Resources biologists, foresters, geologists, ecologists and parks planners to allocate Crown land into one of three categories:

-Category 1 (C1) General Resource Use

-Category 2 (C2) Multiple and Adaptive Resource Use

-Category 3 (C3) Protected and Limited Use

The three categories are fully described in Appendix 2.

Phase 1 of the Integrated Resource Management (IRM) process has been completed and approved by the Minister.

Submission 4

Overall very good compilation of all information and a very good starting point for defining EBSAs

Tunicates - Invasive species - Clarification on the 2 species names under tunicates and common names. Reference Benedicte Vercaemer.

SSO - Do no say what it means. Sea Side Organism. No indicator of host. Containment - harvest restrictions

P. 114. Barra Straight should be Barra Strait.

Competition between blue mussel and oyster based on temperature or on habitat type/ availability. Clarification required.

Cod - not a pelagic species.

Sunfish presence within Bras d'Or. Dolphin presence in St. Peters area.

9.3.2.2. Smelt - more recreational fishing activity in Malagawatch now.

Tidal Influences - intertidal species submerged most of life. More favourable? Potential benefits of limited exposure to sun.

Bay Scale approach - can this be further defined to include the 5 general habitats within each Bay.

Herring as indicator species. Consideration to effect on ecosystem of the loss of this major producer and consumer.

Oyster as indicator species.

Mussel as indicator species.

EBSA Matrix - categories should be tweaked to better define the Bras d'Or. Example, may be double counting with regards to species use and type of habitat if not clearly defined.

Eel grass - more description required under Macrophytes. Not only for herring. Further clarification. Predation on eel grass by green crab?

Oyster - Aquaculture - clarify harvest methods with type of fishery (ex. Lease and harvest methods allowed) Harvesters cannot use SCUBA, snorkling, or hand-picking during commercial fisheries - these harvest methods only permitted on an Aquaculture Lease by the Lease holder. Recreational Oyster fishery closed in Cape Breton.

Section 15.5.3 should be titled Oyster, not Aquaculture.

The Oyster Relay fishery – occurs during the spring months prior to spat fall. Oysters are harvested from contaminated areas for natural relay into areas approved by EC for the growing of shellfish.

The Commercial and Recreational 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.

PG. 105 – Regulations - In the commercial, relay, and recreational fisheries the minimum size of Oyster that may be harvested is 76mm shell height and the maximum size of Oyster that may be harvested is 125mm.

Industry conducts annual science surveys and enhancement projects in various locations of the Bras d'Or Lakes. Oyster enhancement projects have been initiated and Oyster Sanctuaries have been established to assist in the rebuilding and scientific study of the Oyster population in the Bras d'Or Lakes.

Impacting Activities and Stressors, Human Activities… Habitat Management Division reviews activities/projects based on impacts to fish and fish habitat (both freshwater and marine). Would be able to get more detail on types of impacts and mitigation measures. Also database (PATH) on activities, could have report run on types of works around Bras d'Or.

Submission 5

p. 21 – 5.1. Hopefully bottom type maps resulting from multibeam can be accessed. The resolution of these maps is much higher than anything available prior.

p.47 - fall peak in phytoplankton not seen? On p. 44 there is mention of elevated chl a in fall.

p. 50 - "However these various observations can not be quantified…." Sentence misleading. Fishermen in Bras d'Or Lake (LFA 28) cannot fish in LFA 27 (everything above Barra Strait). Thus we do have separate landings for LFA 28, but not for the Lakes above Barra Strait as landings are included with all of LFA 27. Description in 15.5.1 (p. 99) is correct.

p. 51 - Rock Crab - "Great Bras d'Or Channel is also one of the few places where preferred hard or rocky substrate exists within the Lakes." I wouldn't say hard bottom is preferred by rock crab since they are found on sand as well, and often in higher densities. We found the no m-2 of rock crab on sand/small gravel inside Carey Point (0.466/m2) was about twice that of hard bottom off Cape Dauphin. The commercial fishing takes place mainly on sand.

p. 56 - 9.3.2.1 Cod are considered groundfish and should be under previous section

p. 75-76 - Focus on keystone species - Need to define keystone species. Probably premature to do so given our minimal understanding of the roles of different species. Echinoderm biomass is high in the Lakes – what is their role as predators and nutrient recyclers? What about seals as a top predator? What about crabs and lobsters as consumers of benthic fauna such as bivalves?

p. 100 "The lack of reliable indicators… (Tremblay pers. com.)" This is in the SSR and it should be referenced rather than pers. com.

Part E – Ecological Assessment

As might be expected the approach used for defining EBSAs sparked the most discussion. I understand that this was the first cut and that more analysis with additional input will take place before the EBSAs are identified.

I think the identification of the 3 areas based on productivity, diversity and various physical mixing indicators was logical for the most part given the criteria used and the areas examined. I agree that mixing indicators should be scored but I think the physical and chemical characters carry more weight than they should. I don't understand why the temperature/salinity regime of the Great Bras d'Or scores higher than other areas. Temperatures and salinities in themselves should be neutral unless they are very unique (and the higher temperatures and lower salinities seen in the bays are more unique than those in the Channel).

It may be that more weight should be given to the Species Use characters. Actually I would change the name of this suite of characters to Populations and Biodiversity and include the 1st 6 columns (right now Biodiversity seems to be included with Physical & Chemical Characteristics). I suggest that more weight be ascribed to these because they integrate the physical and chemical characteristics. The fact that West Bay ranks highest in the Periodic/Historic column (herring, plaice; lobster should also factor in here), and that West Bay Bras d'Or Lake and St. Patricks Channel score the highest in the breeding area column says there is something inherently important about these areas. Yet these areas come out rather low in the EBSA scoring.

Lastly I think some serious thought needs to be given to the idea of a nearshore area or areas. The nearshore of the upper bays is where the Virginian fauna is most developed. Oysters are the most representative species of this group and are uncommon in coastal Nova Scotia. It is known that oyster reproduction is amazingly consistent is some areas (parts of Denys Basin) and historically at least oysters likely had a key role in ecosystem function (consumers of phytoplankton, modifiers of bottom). Lastly these nearshore areas are particularly vulnerable and sensitive (low resilience?) to nearshore development.

Submission 6

Firstly I want to commend you and Mike's efforts to produce the report. It was a huge task accumulating the information with an attempt at putting the EBSA model to practical use. This will be a living document that that will grow as the data input increases. It is unfortunate that the publishable data sources are quite old. With regards to the larger basins such as St Andrew's Channel and the Great Bras d' Or they have changed much less than the near shore as their volume alone acts as a buffer to ecological change. The near shore or coastal areas of the Bras d' Or have exhibited significant changes due to human influences such as sewage, siltation, and enrichment from land development. As I have been an active aquaculturist since the early 1970's we soon discovered that there was a huge shortfall in environmental data for the shallow areas of the Bras d' Or especially in the winter months. The many barrachois ponds were highly productive but very little information on productivity and hydrographic information were done in these areas. The aquaculture industry out of need was the main source of collection of ecological data as they were most impacted by changes. Year round monitoring of many parameters were collected such as temperature, salinity, dissolved oxygen, chlorophyll A, chlorophyll B, water clarity, suspended organics took place by several companies including Cape Breton Primary Production, Crane Cove Oyster Farm, Bluenose Oyster Farm, Nova Aqua Ltd., Scotia Rainbow Inc., Bras d'Or Fisheries Ltd., Loch Bras d'Or Salmon Farm, Golden Eagle Fisheries Ltd, Whycocomagh Oyster Farm, Bras d' Or Marine Farming, Devco Marine farming, Marine Colloids Ltd are just for a few examples. In the 1970's an extensive hydrographic survey was conducted to seek overwintering sites for salmonids which require > .7 Celsius to survive. Only a handful of areas were identified as suitable to meet the risk free criteria (Dena's Pond, Whycocomagh, Nyanza Bay). Today there are very few areas in the Bras d' Or which are temperature limiting as most areas stay above 0 degrees in the winter.

Ice conditions were safe enough to carry vehicles up until the early 1980's as a common form of transportation. Oyster winter hydrographic surveys were conducted from vehicles traveling on over 16 inches of ice cover. In the past 12 years there was only one winter (2002) in which the Great Bras d' Or froze over completely. The CNR station in Shenacadie was regularly reached from Baddeck in the 1920's, 1930's, 1940'sand 1950's via a marked (spruce trees) ice route across the St Andrew's Channel. This is no longer safe to do. These are factors indicating significant changes in the hydrography in the winter months. This is most noticeable in the shallower waters of the near shore.

In the short time frame that I started working on the Bras d' Or in 1973 many changes have taken place in the Bras d' Or related to changing ecosystems as was outlined in the report. The declining population of herring, eels, menhaden, oysters and lobsters was dramatic in just over 30 years in the near shore environment. The increase in the seal population overwinter was evident as the number of coves with ice edges increased as ice cover diminished.

Siltation as a result of human activity dramatically increased the siltation on valuable oyster beds such as Crowdis Bridge, South Basin, Nyanza Bay and the Whycocomagh Bay. Deforestation of the watershed and siltation from overflowing settling ponds were all contributors to this change. Shore front development of an increasing cottage industry also contributed to a deteriorating environment. A classic example is MacKinnon's Harbour, which had a good sustainable oyster population prior to the opening of a larger dredged channel to improve navigation for the cottage industry. The alteration severely affected the reliability of recruitment.

Some of the data collected is available but would require some in depth effort to obtain from the many private sources.

I like the idea of the GIS model suggested for describing an EBSA as a better means of understanding the multi facetted components making up the ecosystem in lieu of the more linear spreadsheet approach. The overlapping of data would help clarify the picture. We plan on using this method in our mapping of environmental changes that impact the MSX parasite.

The conclusion drawn about the low oxygen affecting the cod worm presence in Whycocomagh Bay due to the absence of mysids in the benthic community leaves one with a false impression. If you talk to many fishermen, of which I could provide names for reference sources, you would discover that cod worm is alive and well in the cod population fished thru the ice in the middle of Whycocomagh Bay. Bill Black who authored a fish report referred in the document was a friend and associate of mine in the 70's. He told me that there were two distinctly different cod populations in Whycocomagh Bay. The indigenous stocks that spent year round were less wormy than the migratory cod that came in the fall and stayed over the winter months.

Although finfish aquaculture is not active in the Bras d' Or I would not like to close the door on any future activity of species better adapted than those used. After all it was the data collected by the aquaculture industry such as algal blooms, bio-foulers, etc. that made people aware of the presence of these phenomena. This industry collected more relevant inshore data than any other party including the government for about 20 years.

EBSA
I am still trying to get my head around the application of an EBSA to describe an ecologically sensitive area in the Bras d' Or. The process that was attempted was a great deal of work but the ranking system did not identify the real problem areas of the Bras d' Or that have been most impacted and of concern by the First nations and the communities around the watershed. I still favour the use of a GIS overlap system to better understand specific environments as they relate to changes. The EBSA method seems to lend itself to too much interpretation thus giving varied results if done by different people.

I realize that ecologically significance is the criteria for EBSA rather than economic significance. The reality, however, is that the most impacted areas are the near shore in the Bras d' Or occupied by the declining species such as oysters, herring spawning grounds, eels, and lobster. The decline of these species and others in the near shore is the reason the First nations and community at large are interested in preventing any further deterioration.

There are many gaps in the data input that could make this document more useful to understand why these changes are taking place. More emphasis in the future should be placed on the collection of near shore parameters to detect change than has been done in the past. The picture is not complete without obtaining at least some of the data from the aquaculture activity the past 35 years.

One characteristic that I have discovered over the years while monitoring the Bras d' Or is not identified clearly enough in the document. It is a difficult and perhaps impossible chore to lump all the inshore barrachois ponds, coves, etc. as having identical ecological features. I realize it is easier to manage if this were possible. My data sets are clear that each cove and inlet is quite unique often to the point that they developed their own sub-species (e.g., Dena's Pond cod). Dr. Black brought this point up in numerous discussions. The characteristic of thermal groundwater contributing to these areas is very true as was mentioned by Lynn Baechler. I found coves in the Lakes' system such as Barrachois, which had almost, a 1.5-meter ice cover over which was found water with temperatures in February of 6 degrees Celsius. This is only one example of many unique coves. The near shore is a collection of many very unique mini ecosystems that have links to the outside and to each other but do not posses very similar traits as someone mentioned at the meeting. It is also important to establish the linkage or connectivity as stated by Keith.

More records should have been studied depicting the significance of oyster species as far back as the 1880's when production was at an all time peak. This was also a time when more people lived and worked on the Bras d' Or than presently. Factors that were probably important in negatively effecting the Bras d' Or in recent times was the construction practices of roads, deforestation, international boat traffic, sewage and other chemical waste products from industry and community.

Note should be given in the mention of oysters of mass mortalities over the past 100 years in many locations in the Bras d' Or. This information can be obtained verbally from elders but also in logged records of DFO such as Ellerslie Research Station yearly reports. It could provide an interesting overlap to hydrographic data and new mortalities.

I am fully in favour of protecting the Bras d' Or and taking preventative action to stop the further degradation of stocks and the ecosystems. I am not yet convinced that the EBSA model is the way to achieve this. I do believe that more data collection is vital to better understand the Bras d'Or and this could be done collectively by both government and the stakeholders. I would like to see a GIS that could be accessed by the Public to seek information on the Bras d' Or. It seems logical to me that UINR could be the vehicle thru which this GIS is maintained and updated in cooperation with all parties that can contribute valuable input. The Public in general would be totally baffled by this EBSA ranking process as I suspect would be the elders and non science personnel.

If identification of the Bras d' Or as an environmentally sensitive area is brought to light by some process then we all would welcome some protection including increased policing and more controls of issuing uncontrolled commercial fishing licenses that has contributed so significantly to the decline of some key species such as oysters, herring, lobsters, etc. and to the introduction of exotics or invasive species that has been permitted to take place despite the early warnings of their imminent approach. Any process will only work if all stakeholders will buy into the practice. This will only happen if all have input to the methodology to achieve this involves contribution from all sectors of stakeholders and regulators. I am not yet convinced that the EBSA process will achieve this objective although it is a start in the right direction.

Submission 7

Focus of report

Too much of the report is focused on previous 'deep water' work on main basins, giving the impression that the system is low productivity overall. Nearshore barachois ponds and other shallow basins may be important pockets of elevated productivity, need to describe them in more detail. These basins tend to be murky and warm, with elevated nutrient concentrations & chlorophyll a and periodic or chronic low oxygen levels (as described in scattered places in the present text). Perhaps information could be organized according to basin size:

1) Main basins – the present emphasis of the report
2) larger nearshore basins – could be considered large barachois ponds, like those with low oxygen issues as mentioned on page 40:
    a) Denys Basin
    b) Herring Cove
    c) Denas Pond
    d) Indian Cove
3) barachois ponds – gather more info from reports like Smith & Rushton 1964

The Ocean Science Associates five habitat system mentioned on page 71 is something like the above classification. Should not drop this just because of a lack of data (as suggested on top of page 72).

Discussion in middle of page 42, local eutrophication/pollution of barachois ponds is an important issue – should not be brushed off because "they have little impact on the Lakes as a whole"

Page 50 discussion of oysters emphasizes why the nearshore basins are important. Should add info about recently discovered oyster bioherms in Denys Basin (shallow and deeper). Bottom of page 64, could mention bioherms as potential spat settlement sites.

Macrophytes

Some of the comments made on macrophytes are questionable:

- page 41- "Organic carbon levels peak in autumn, showing maximum concentrations at the bottom, suggesting a relationship to macrophyte breakup and degradation." – where are these macrophytes coming from? I have seen large accumulations of semi-decomposed filamentous green algae (presumably *Cladophora*) on the bottom in Denys Basin and barachois ponds in the area, but the macrophyte (i.e. seaweed) density along the shores of the main lake areas is quite low overall.
- page 49 – MacLachlan and Edelstein (1971) note that eelgrass dominated in Denys Basin – but my recent survey along the south shore does not indicate much. Eelgrass should be resurveyed in some of these past hotspots (St. Patricks Channel, North Basin, East Bay & St. Peters Inlet)

Page 75, section 11.2.2 on keystone species – could add eelgrass to this list

EBSA discussion
On page 78, the scale for EBSA selection is forced to be bay level, based upon lack of info at present (same reason for the large scale approach used for most of this paper). It should be noted that this is just a practical way to handle the first cut in approaching the EBSA issue. I still think that a multiscaled approach (main basins, nearshore basins and then barachois) is more useful overall; and definitely for a discussion of EBSAs.

Page 130 does mention barachois ponds, but only for scoring purposes of larger units as sensitive habitat. These ponds should be their own unit and scored.

Appendix A & B on the EBSA scoring process – The process seems logical (I trust it does follow the 2004 DFO EBSA document). However, the feature headings and actual scores should be produced by a team of individuals who have expert knowledge of the Bras d'Or Lakes ecosystem. The actual scores in this document should be treated as a 'test run', and final scoring (a separate report) should be done by the team.

Industrial shipping
Page 112, section 15.7 – should mention ballast water issues.

Intertidal habitats
Page 127, Table 33. eelgrass coverage - Data in this table comes from Nova Scotia Department of Natural Resources (2000) Nova Scotia Wetlands and Coastal Habitats Inventory. The manager in charge of the inventory is Randy Milton (902-679-6091).

The coverage estimates come from air photo interpretation (approximately 1988 to 1995 air photos) done mainly by contractors. Not much ground truthing was done.

Air photo interpretation of submerged macrophytes (eelgrass and seaweed) is notoriously poor at estimating true vegetation cover. The eelgrass cover estimates in Table 33 are suspect and should be noted that way (considering the value of eelgrass as fish habitat).

A September 2005 survey in the southern portion of Denys Basin revealed very little eelgrass. The plants may have died back in the last 10 years, or the original air photo based estimate of over 600 ha coverage is wrong. Either way, eelgrass coverage should be revisited at the sites listed in Table 33 (and the Lakes as a whole). The scattered and patchy distribution of seaweeds in the Lakes means that eelgrass is the only marine macrophyte in the system capable of forming extensive beds, adding a carbon source and structure for fish / invertebrate habitat.

Data and information gaps (page 132)
"Also, there is little to no information about the nearshore shallow marine environment" – multibeam is mentioned for waters >20m, and although "the data gap from there to the water's edge still remains today"; the report should state that methods do exist to fill that gap (specialized shallow water sidescan and single beam echosounders, video transects).

Appendix 5. Draft Ecosystem Overview and Assessment Report.

Not to be cited without the Permission of the Author

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

DRAFT

October 2005

By:

M. Westhead[1] and M. Parker[2]

Oceans and Coastal Management Division
Fisheries and Oceans Canada
P.O. Box 1006, B500
Dartmouth, NS
B3L 2Y9

Canada

[1] Fisheries and Oceans Canada, Bedford Institute of Oceanography
[2] East Coast Aquatics Inc. P.O. Box 129 Bridgetown, Nova Scotia, B0S 1C0

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Executive Summary

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. Researchers have documented many of the physical and chemical properties of the Lakes, and explored the biological character of an array of species that colonize and utilize the Lakes. Many other people have documented the existing habitats of the marine environment as well as the terrestrial and freshwater aquatic character of the surrounding land base that comprises the greater Bras d'Or Lakes watershed.

To generally describe the Bras d'Or one would be ignoring so much of the heterogeneity of this ecosystem. However, one of its few rather general characteristics is the very small amplitude tides that exist. As might be expected, this property significantly reduces the intertidal zone habitats relative to much of coastal Nova Scotia. Much of the Bras d'Or can also be characterized as a two layer aquatic system where warmer less saline water lies atop a cooler more saline layer. However, spatially and temporally there is much heterogeneity to these waters, and a few areas such as the Great Bras d'Or Channel are relatively well mixed by strong tidal flows.

To evaluate the ecology of the Bras d'Or we examined the Lakes at a large "bay-scale" resolution. Ten "bays" have been defined with a terrestrial freshwater watershed component to each that together constitutes the whole of the Bras d'Or watershed. Each bay has been evaluated and subsequently compared to all others in order to describe the ecologically and biologically significant areas of the Bras d'Or Lakes ecosystem. Through this process of scoring and ranking (DFO 2004) the bay-scale areas of St. Andrews Channel, Great Bras d'Or Channel, and the North Basin were identified as the most ecologically and biologically significant areas of the Bras d'Or Lakes. As such they support the most critical functions, habitats, and / or species within the Lakes' ecosystem. Future management considerations for the Bras d'Or must give special consideration to these areas in order to ensure the ecological integrity of the system as a whole is maintained. Not surprisingly, all bay-scale areas north of the Barra Strait, with the exception of Whycocomagh Bay, ranked higher for ecological and biological significance than areas south of the Strait. However, within the southern portion of the Lakes Denys Basin and East Bay support the more significant biological process through ecological function and habitat. Whycocomagh Bay is one of the more unique areas of the Lakes. However, it does not have the habitat diversity or qualities to support a diverse and productive biota. The enclosed nature of Whycocomagh Bay further limits the impact that it has on the Bras d'Or Lakes ecosystem as a whole.

Through the identification of EBSAs this document lays the foundation upon which an ecosystem framework can be developed for the future management of the Bras d'Or Lakes. That framework must move beyond the ecologically and biologically significant areas presented here to consider the anthropogenic uses and threats to all areas of the Lakes. It further must identify keystone species from a variety of habitats and trophic levels that will serve as the focus for monitoring ecosystems changes that may occur over time and with resource use. In this way, the Bras d'Or Lakes ecosystem can be managed for acceptable risk and impact to the varied ecologically and biologically significant features that help maintain functional integrity.

Table of Contents

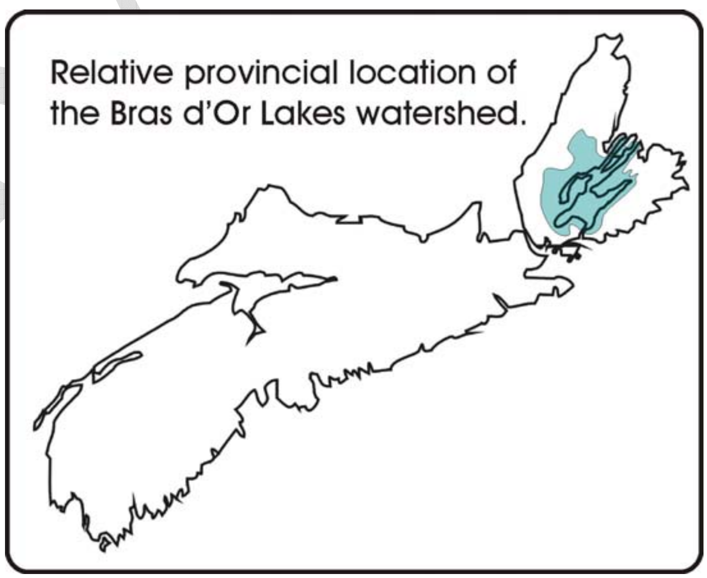
General Information

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 marine waters and the land 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.

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. "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.



Spatially the Bras d'Or Lakes are described in this document at two different scales. The first is the "bay-scale" delineation. This refers to the larger bay and channel areas such as St. Patricks Channel, West Bay, and Denys Basin and is graphically illustrated in Table 4. The less used term "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.

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 national scale. The identification of these ecologically and biologically significant areas (EBSAs) 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.

The focus of this particular document has remained on ecosystem interactions related to the aquatic resources, with particular attention to the marine environment. Terrestrial biota and land use have only been considered as they relate to the aquatic environment.

1.2 Boundaries of Study Area

This report covers the entire Bras d'Or watershed, which includes land, freshwater, and marine features. The total area of the Lakes and land within the watershed is approximately 2474 km^2, with the Lakes amounting to 1082 km^2 (44%) and the area of the land within the watershed being 1392 km^2 (56%). The length of the coastline is quite long, at approximately 1000 km. There are 12 sub-watersheds, 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 Lake 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 (see Figure 1). This watershed has an area of 3 700 km^2, of which 2 500 km^2 are terrestrial and freshwater, and 1100 km^2 are marine aquatic. It 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 about 1500 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 River, Benacadie, Baddeck, Middle, Skye, and the Washabuck River, 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.

[3] Figures calculated by the Cape Breton Regional Municipality

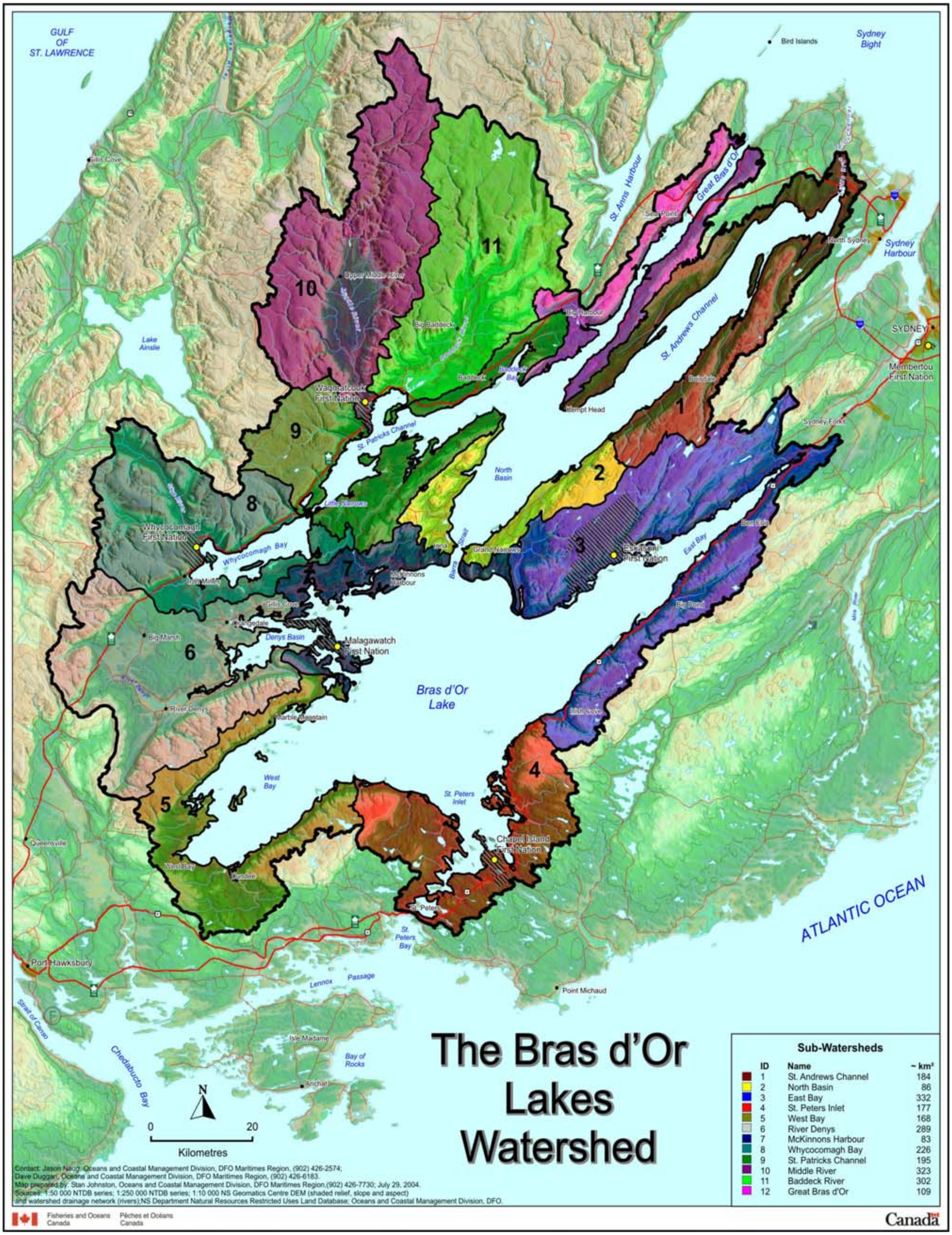


Figure 1. Watershed boundary for the Bras d'Or Lake Ecosystem Overview.

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. The second component is the identification of Ecologically and Biologically Sensitive Areas (EBSAS). This process of identification (DFO 2004b) highlights the more significant areas within the Bras d'Or (refer to this document for the general approach to EBSA identification). Appendix A documents the specific approach taken in scoring and ranking EBSA features within the Bras d'Or and Appendix B is the final scoring and ranking matrix. Following the EBSA identification is an overview of human activities and pressures in the area, both on land and in the water.

2.1 Information Use and Reliability

As much as possible, this document relies on scientific literature, and peer reviewed information. However, where gaps exist, marine 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.

Part A – Geological System

3. Geological History

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, show 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 becomes considerably more varied than the actual 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 extends 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 metres. The southern boundary of the Lakes is not quite as abrupt, but elevations of 150 metres 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 more gentle, rarely exceeding 75 metres elevation as much as 10 kilometres 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 hectares (30-40 acres) 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 Bay's (Taylor and Shaw 2002).

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	Sub-watershed	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 6ooo-9500 years ago (Shaw *et al.* 2002). At the end of the Wisconsinan Glaciation the sea 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 fiordal 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). Through definition it is most clearly defined as an estuarine system, in which the partially enclosed body has tidal exchange that 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. 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 metres 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.

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 till lines 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 across the shallow sills. 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, and 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 with 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 are 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 metre 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 (see Figure 2). 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 influence and exchange (Petrie and Bugden 2002); Copepod dispersion (Shih *et al.* 1988)
St. Andrews Channel	60 m	160 m	Point Clear	Not discussed in the literature.
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); 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 upwelling 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	Suggested but not researched that fish movement is influenced.
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.

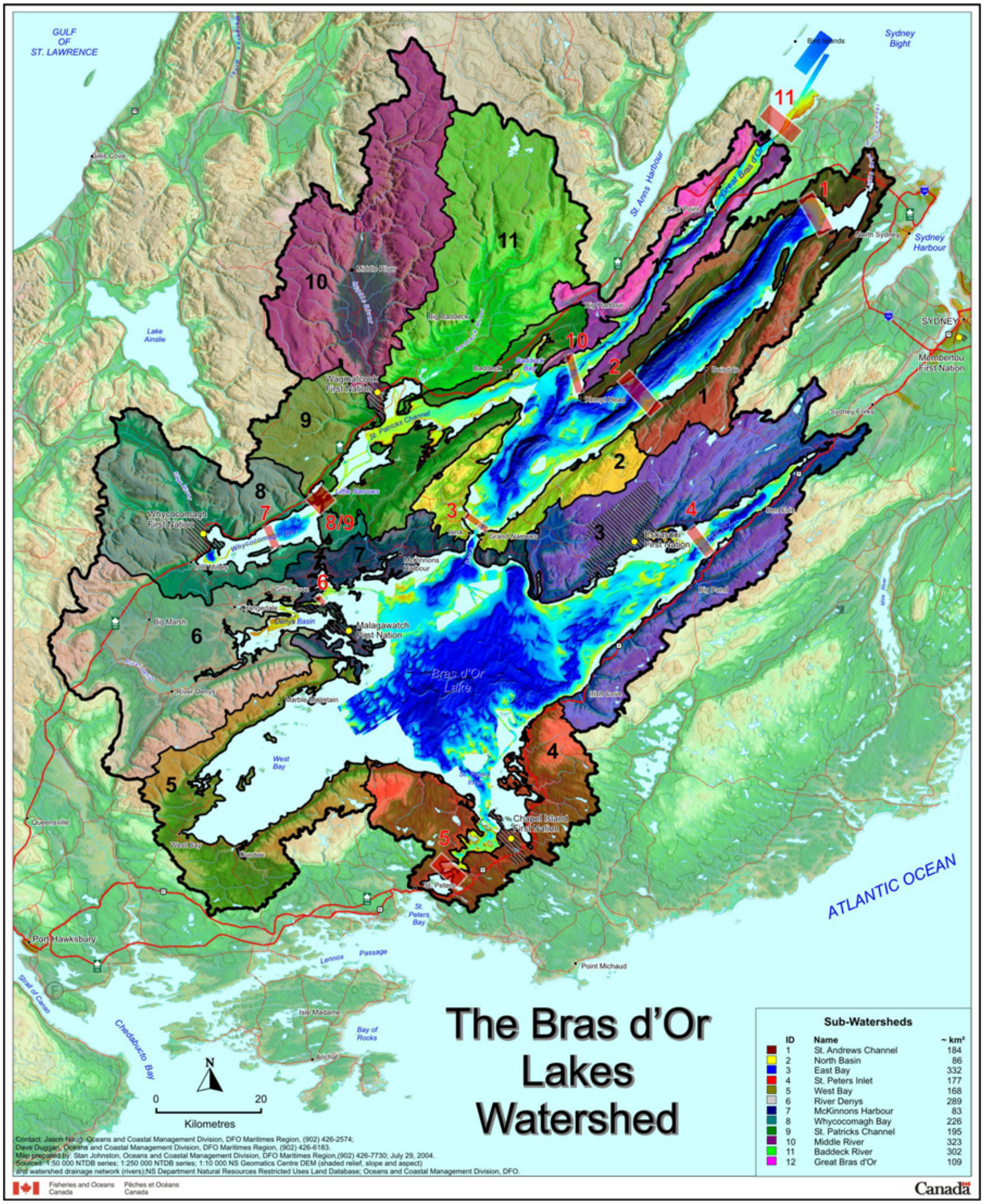


Figure 2. Partial multibeam coverage of the Bras d'Or Lakes and approximate location of the larger sills within the Lakes.

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.

5. Sedimentology

5.1 Characterization of Surfice 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 process. 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 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 have 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 1966).

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.

Part B – Oceanographic System

6. Atmospheric Components

6.1 Seasonal Climatic Patterns

6.1.1 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, do 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 parametres. Daily average temperatures for the Baddeck location are highest in July and August at just over 18°C for the 1971-2000 data. However, 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 2005).

6.1.2 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, which lie in the rain shadow of the Cape Breton Highlands, 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 (2005) 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 2005).

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 2005
* 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. com. 2005).

6.1.3 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 move large water bodies through wind induced flows, these phenomenon (tilting or setting up, and seiching) are typically not seen in the Bras d'Or because of the relatively short fetch, or open water distance over which winds can blow. When these phenomena do occur, they are very small in magnitude (Kenchington and Carruthers 2001). 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 from the hill slopes to the north (Kenchington and Carruthers 2001). These two wind directions can set up crossed waves in the area.

6.2 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-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 that a 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. 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.

7.1 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. 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 as well (Taylor and Shaw 2002).

The larger drainages on Cape Breton Island, such as the Margaree Rivers, Mira River, and River Inhabitants, do not flow into the Bras d'Or but instead flow directly to the Atlantic Ocean. The six larger rivers flowing into the lake account for 42% of all flowage (Table 1), 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 1/3[rd] 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 ppt 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. Along with influencing salinity, the freshwater bodies likely have local impact on the temperature regime of the bays into which they flow.

MacMillan *et al.* (2005), recently documented June15 - 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. Although such a statement is likely true, 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.

The last notable characteristic of the freshwater systems is the lack of significant lake headed river systems draining to the Bras d’Or. 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. Without the storage and moderation capacity that large lakes provide, streams tend to be more “flashy”, responding quickly to precipitation events with a rise and fall in water level. Lower summer low flows and higher high flows during the wet season relative to lake headed systems can also be expected.

7.2 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 narrowness 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 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 less than two kilometres from Sydney Bight along the Great Bras d'Or Channel, the tidal amplitude is already reduced by 50% (Petrie 1999). This attenuation increases further into the Lakes with the result being a small tidal range of 0.08 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).

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 2 years, and the deepest part of the lake in St. Andrews channel follows at about 260 days (Petrie and Bugden 2002). Slow flushing also means that the waters are generally moving slowly. 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 elevations of less than 0.03m (Dupont *et al.* 2003).

Although overall tidal flows are minimal 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). It has also been noted that tidal currents at the entrance to the Great Bras d'Or on the Atlantic side, reach 6 knots or more when the Lakes are elevated by spring runoff or northeast gales (Davis and Brown, 1996b).

The Bras d'Or has the smallest tidal ranges of shorelines around Nova Scotia. Interestingly, barometric pressure can therefore 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 their 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 time line over which the relevant fluctuations occur (Petrie and Bugden 2002). Barometric changes occur over days to weeks while lunar tides are occurring over a matter of hours. Friction and resulting turbulence in the Great Bras d'Or inhibit water level changes occurring in short time frames, but have less effect on the longer time frames associated with the barometric tidal changes. As this barometric influence does not have known periods of amplitudes on the tides, water levels within the Lakes cannot be predicted with much accuracy (Krauel 1976).

One of the ecological results of Bras d'Or tides being so minimal 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 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).

7.3 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 (Petrie and Bugden 2002). This allows the freshwater inputs from the land base to leave the Lakes though the surface flow, and the salt waters to enter along the bottom of the system 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 itself (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. For some areas of the Lakes, Gurbutt and Petrie (1995) modeled a third layer of deepwater. This layer is only directly connected to the layer of water above through a vertical plane. Because of bathymetric isolation there is no direct horizontal connection to other deepwater areas. Such deep layers are located in Whycocomagh Basin, St. Andrews Channel, and North Basin.

The complex bathymetry of the Bras d'Or does, however, provide an opportunity for some vertical exchange. Gravity 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 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 will then pour down a slope into the first deep basin of Great Bras d'Or Channel in an underwater cascade, displacing water that has received a higher proportion of Lake water (and so is less dense), which will then cascade into the second basin, and so on. Similar gravity-driven flows are probably involved in the filling 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. Tidal currents at the Barra Strait range are consistent in velocity of 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).

The overall pattern of outward surface layer flow is from the southwestern region of the Lakes toward the Barra Strait, with currents 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 carry higher salinity water into the system (Petrie and Bugden 2002). Sand waves and rippled sands have been observed on side scan sonar throughout much of the Great Bras d'Or Channel, indicating significant levels of bottom current activity and sediment transport (Meyers 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, thus driving the basic circulation of the Lakes, 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. There are no hard data available but the flow through this Strait may prove to be the primary engine driving the Bras d'Or ecosystem (Kenchington and Carruthers 2001).

7.4 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 and deepest 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 exhibit a bottom layer of dense saline water having a net inflow and a surface layer of less saline water with a net outflow. 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 more saline middle layer that can mix vertically with each other or have horizontal exchange of within layer characteristics. A third deep layer 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 separate and prevent exchange horizontally of this deep layer in these deep basin areas. 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 the surface layers, and is associated with weak currents at these depths (Petrie and Bugden 2002). Petrie and Bugden (2002) 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 5. The most significant mixing force appears to be the strong tidal currents in the Great Bras d'Or Channel and the Barra Strait (Davis and Brown, 1996a). 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 5. Some select mixing characteristics within the Bras d'Or Lakes.

	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	5-10
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.

Upwelling, the simple transport of water vertically in the water column, mixes differences of salinity, dissolved oxygen, nutrients, and temperature between the deep bottom and surface layers 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 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 re-circulated 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 of surface waters cool in the fall and become closer to temperatures 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 further reduce circulation within the Lakes by cutting off direct contact with atmospheric forcing (Petrie and Bugden 2002).

Once the surface begins to freeze, more complex processes may commence, 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).

Although overall the mechanism for deepwater mixing is not well understood, and likely occurs between early winter and ice off in the spring when little study of the Lakes has occurred, dissolved oxygen (DO) measurements in some of the deepest basins further 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).

7.5 Waves and Turbulence

During 1992-93, wave rider buoy data were collected in North Basin and Bras d'Or Lake by Environment Canada. The period between waves was documented as 2-4 seconds being the typical range. 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 the formation of waves. 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 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 and atmospheric sea level changes. However, given that substrates of the Bras d'Or Lakes are dominated in nearly every area by finer grain sizes of muds and sands, accompanied by minimal regular sea level changes little intertidal turbulence occurs 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.

7.6 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. 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).

The Bras d'Or Lakes' surface layer is of moderate salinity in early winter, freezing at a slightly higher temperature than the more saline water found in the open ocean. Ocean water typically freezes at -2.3°C. More importantly, the reduced salinity in the Lakes means the surface water expands as it cools towards freezing as does freshwater below 4°C. Fully-saline seawater does not exhibit this property. Therefore, in the Lakes, a thin, very cold layer can float above slightly warmer 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).

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.

A summary of most physical oceanographic features that have been discussed is provided in Table 6.

Table 6. A summary of the typical and range of measures for selected physical oceanographic parametres of the Bras d'Or Lakes.

Parametre	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%

7.7 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.). 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, a review of scientific information on seismic sound impacts indicates that there is no significant or long term impact to fish or invertebrates from this source, and the impacts to marine mammals are few (DFO 2004a). Given that seismic sounds are much stronger than anything that would be found within the Lakes, and given the infrequent presence of any marine mammals other than seals in the Lakes, ecological impacts associated with sound disturbances that may exist in the Bras d'Or Lakes are expected to be minimal. Most likely impacts would be associated with cumulative impacts from a number of noise sources, and not 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 2001 cited in TEC 2005). As shown in Figure 3, 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 parametres of temperature, salinity, and pressure (depth). The speed at which sound will travel through the water increases an average of 4m/s per°C rise in temperature, 1.5m/s per psu rise in salinity, and 0.0018 m/s per 1m 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.

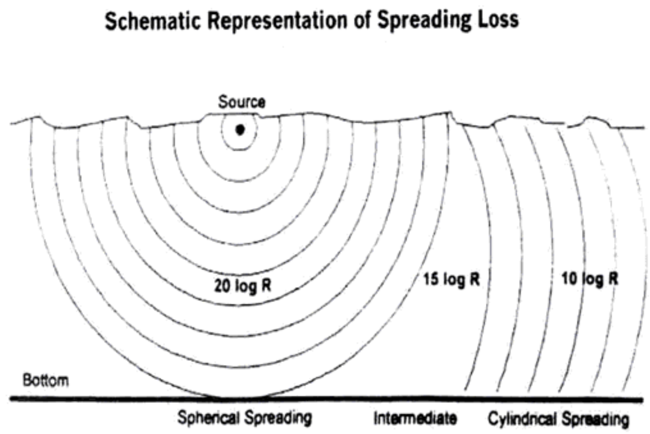


Figure 3. Sound attenuation in marine waters as presented by LGL Ltd. (2001 cited in TEC 2005).

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 of this noise is determined primarily by such propeller characteristics as number of blades, diametre, 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 (see Table 7) but will dissipate in approximately 70 m from the source to a level below which there is significant impacts.

Table 7: 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 adjust 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 8 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 lower the 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 8. 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

8. Physical-Chemical Properties of Seawater

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. Although such generalized comments may be made, 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.

8.1 Temperature and Salinity

The waters of the Bras d'Or are characterized primarily by a two-layer system of a low salinity, variable temperature out flowing 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 the Bras d'Or's 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 ppt, whereas the marine channel is 5.8 ^{o}C and 34.5 ppt (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.

8.2 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 do 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. And 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 a with nearly 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, Petrie and Jordan 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 extend 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 is 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 parametres over time.

8.3 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) given the large surface area of the Lakes. 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, not only on tides, but also on salinity. 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 low land 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 9) (Kenchington and Carruthers 2001).

Table 9. 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 through the Canal is the 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 down welling 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.

8.4 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 to be present 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 tend 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.

8.5 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).

8.6 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 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).

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 the and 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 times 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).

8.7 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 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. Eutrophication because of human inputs remains limited to a small total area consisting almost entirely of embayments. Typical seasonal nutrient levels for the Bras d'Or are presented in Table 10.

8.7.1 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 drop 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 '70s 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.

8.7.2 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).

8.7.3 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 10), 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.

Table 10. 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 ^oC	-	-
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

8.7.4 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-pigments 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 10).

8.8 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 in any real quantities (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 level (but less than probable effects levels) (Yeats pers. comm.). 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 1997over a wide range of metals examined. However, samples from this study were not corrected for grain size, likely resulting in an under reporting of results. 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.). 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.). 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 has not been verified. Furthermore, 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 (Young 1973a,b; Creamer *et al.* 1973; Chou *et al.* 1999), 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) compounds. 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, near bottom samples were collected and dissolved iron and manganese concentrations 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 (LRTAP) is usually seen 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).

Part C – Biological System

9. Flora and Fauna

9.1 Planktonic Communities

Planktonic communities are the base of the food web within the Bras d'Or, as they are in all aquatic environments. 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.

9.1.1 Phyto- and Zooplankton

In general, the Bras d'Or waters are quite clear for coastal waters, allowing adequate light levels 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 sampling was also almost exclusively composed of flagellates (Hargrave and Geen 1970). In 1973 and 74 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 mid summer 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 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. 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 the presence of a shallow sill at the Little Narrows and Barra Strait may act as effective barriers to dispersion of some deeper water species of copepod. Similarly, they believe the shallow sill of the Great and Little Bras d'Or Channels further limits dispersion of some Gulf of St. Lawrence species into the Lakes.

9.1 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).

9.2 Benthic Communities

9.2.1 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 even narrower 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 and, in McLachlan & Edelstein's (1971) words, "undoubtedly their contribution to the productivity of the lake is small".

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 3 or 4 metres in depth. Eelgrass (*Zostera marina*) was the most common species found at all sample sites. This seaweed can root in the muddy and loose substrates that dominate so much of the Bras d'Or seabed. 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). These eelgrass beds have been found to be a key spawning habitat for herring within the Lakes where it does occur.

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; the most abundant occurrence encountered by the surveyors in the Lakes (McLachlan and Edelstein 1971).

9.2.2 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).

9.2.2.1 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, although blue mussels have become more prevalent within the local aquaculture industry. 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

The Bras d'Or Lakes in general do not offer an ideal environment for the native oyster (*Crassostrea virginica*). Besides the doubts about the productivity of the waters, and hence the food supply for oysters, 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 them 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).

Oysters have been over fished in their native habitats in the Lakes, and today are only found in 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 reduces the competition from blue mussels that typically would compete with oysters for the limited habitat available (ECA 2001).

Lobsters

The Bras d'Or Lakes supports 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. Tremblay (2002) reports the industry's heaviest effort appears to be in the West Bay and St. Peters areas. However, these various observations can not be quantified by existing data as fishermen in these areas 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. Science shows that 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). The Great Bras d'Or Channel is also one of the few places where preferred hard or rocky bottom substrate exists within the Lakes. However, even with such limitations, Rock crab has been found widespread, including in tow surveys south of the Barra Strait (MacDonald 1968, and Lambert 2001 pers. comm. 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).

9.2.2.2 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 (Black 1956, 1958, 1976; Lambert 2002) and foraminifera (Vilks 1967).

Polychaetes

The "bristle worms", or polychaetes as they are known, in the sea take the place of the familiar earthworms on land. They 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.

As polychaetes are benthic creatures, 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 ^{o}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 sub littoral 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 ^{o}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 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 around a 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 tolerancesfor 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 back 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 were collected 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 couple 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 found in 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.).

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, with narrow to excellent 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*.

The sea urchin (*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).

9.2.3 Groundfish

Groundfish, or benthic fish species, have been sampled in several surveys of the Bras d'Or Lakes. Over a number of trawl surveys from 1952-2000 (Black 1976, MacDonald 1968, Lambert 2002), a total of 46 species of fish have been caught and identified in the Bras d'Or Lakes. Most are demersal or bottom living, 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).

9.2.3.1 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 by nearly double the number of the next most abundant species (plaice) in the ’50s (Black 1976), fell to second by weight in the late 60s (MacDonald 1968), before rebounding after the closure of the trawl fishery to be the most abundant by weight in the late 90s (Lambert 2002).

9.2.3.2 Non-Commercial Key Species

Comparison of trawl survey data over time indicate that the biggest change was the abundance of American plaice, which became rare in the recent trawl surveys. Although historically widespread and found in significant numbers, 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).

9.3 Pelagic Communities

9.3.1 Turtles

There are over 200 species of turtles living in the world. Only 7 are represented in Nova Scotia. 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 an effective barrier 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. Its distribution is likely limited to the southwestern extents of the watershed.

Table 11. List of terrestrial and marine turtles of Nova Scotia, and their status as listed with the Nova Scotia *Endangered Species Act*. This table 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	No 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)

9.3.2 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, that were present in trawl surveys of the 50s and 60s (Black 1976 and MacDonald 1968), were not found in more recent 99-00 surveys (Lambert 2002).

9.3.2.1 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. Secondly, 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 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).

Cod

One might expect cod (*Gadus morhua*) to top the list of 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 pelagic 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).

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. This was further compounded by the fact that cod from within Whycocomagh Bay, within the Bras d'Or Lakes, had virtually no seal worm. This lead the researcher to suggest 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 was that since cod over 50 cm length do not seem to eat the stationary mysids which carry the seal worm (Black 1956, 1958, and Scott and Black 1960), 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 were not moving freely between these areas. A reasonable explanation was 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, and / 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 (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 would still remain the same as have been measured elsewhere (Tremblay 2002).

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 et al.* 1982). A similar observation was made of the weight-to-length values. This is felt to primarily be the result of the gonad maturation stage of the fish. Data indicate 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 over fishing brought the herring population to the point of collapse. This was the result of an increased fishing effort on the declining herring stock as fishermen looked for a cheaper alternative to mackerel for lobster bait. In the third year of a closed fishery, the catch at age data for Bras d'Or show a higher % 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.

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.

Little published information exists on the eel and mackerel fisheries, which today are largely non-existent.

9.3.2.2 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).

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). A run of Rainbows occured in the Skye River in the late 1980s, as well as lesser numbers of them in other rivers (Hurley Fisheries Consulting 1989).

Atlantic salmon (*Salmon salar*) also enters the Lakes to spawn in some of the larger freshwater systems during September and October. Populations still exist in the Middle and Baddeck Rivers. 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).

Brown trout (*Salmo trutta*) is another introduced species, being 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 1930s. 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). Brown trout are currently stocked in some tributaries to the Bras d'Or Lakes to support the recreational fishery (Murrant pers. comm. 2005).

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 for study at Nyanza Bay, Gillis Cove, and Campbell's Cove in Whycocomagh Bay, but are found much more widespread through the Lakes. These fish exhibited both behavioural differences from the common Threespine stickleback (*Gasterosteus aculeatus*), and utilized different microhabitat for spawning in the nearshore areas.

9.3.3 Marine Mammals

Harbour seals (*Phoca vitulina*) and grey seals (*Halichoerus grypus*) are frequently sighted during the winter months, but scarcely seen during the summer. Although few written records of these seals exist, they are found around the Lakes, but most frequently 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 Fisher 1958; Scott and Black 1960). Both documented seal observations noted that they were actively feeding on cod, and that both immature and adult seal worm were found within this host (Scott and Fisher 1958; Scott and Black 1960). 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 made 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 report of a marine mammal in the Lakes is record of a single porpoise by Scott and Black (1960).

9.3.4 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, the 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 (Milton pers. comm. 2005) 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. 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 (see Table 12): Double-crested Cormorant (*Phalacrocorax auritus*), Great Black-backed Gull (*Larus marinus)*, Common Tern, Arctic Tern *(Sterna paradisaea)*, Herring Gull (*Larus argentatus*), Great Blue Heron (*Ardea herodias).* No trend analysis or reporting is available based on the completed field surveys.

Table 12. Colonial bird records for Bras d'Or Lakes watershed.

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

10. 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 to 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 out side 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 in 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 looks at 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.

10.1 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 extended into Sydney Bight and surrounding waters. Such 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, albeit not their typical spawning grounds. Together, the fish of Bras d'Or Lakes provide some spawning activity nearly all year round (see Table 13).

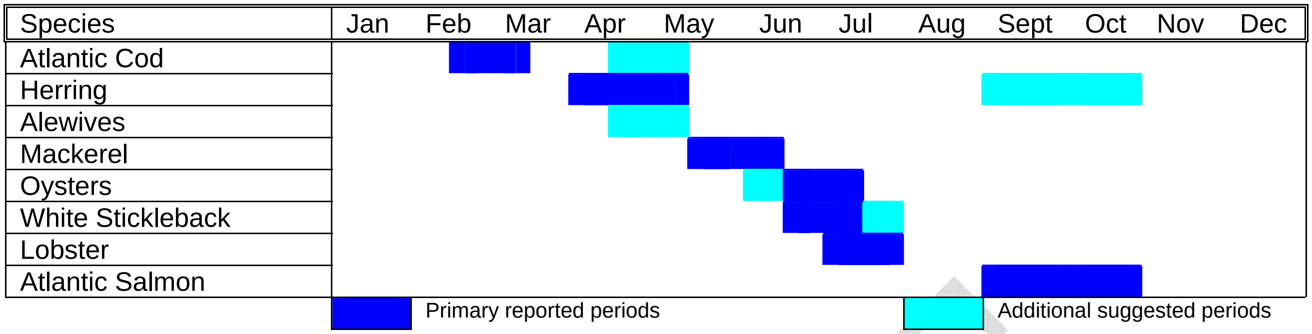
Although cod are regionally important, excessively worm infested fish in the Bras d'Or means limited commercial interest in this species within the Lakes. The literature has documented studies of seal worm, and genetic isolation of the cod in Bras d'Or, but little detail exists on the spawning behaviours 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, *Gadus morhua* (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).

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), and it can be seen how these areas correspond strongly with the historic spawning locations. However, an increased demand from the lobster fishery that 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, and 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. 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 both 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 appears 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 at 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).

Table 13. Approximate spawning times in the Bras d'Or Lakes for selected species as noted in the reviewed literature.



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, East Bay. Of these areas, Denys Basin has been the historic center for wild oyster production. It 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 productivity related 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' data also indicate that larval release by the "berried" female lobsters from West Bay and St. Peters occurs in the Bras d'Or during July (Stevens 1993). 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 then 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).

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.

10.2 Rearing Areas

Complete species' life cycle descriptions specifically within 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 deepwaters 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).

Based on plankton surveys and trawl surveys, White hake larvae or 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 the Lakes are not a primary spawning location the hake.

The best substrates for oyster spat to settle on are a combination of silt and sand. 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.

10.3 Foraging/Feeding Areas

The following are a series of observations and hypothesis made by various authors regarding the forage behaviours and locations for their species of study. None of the studies specifically aimed to define forage 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 of 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 impacted, 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 & Fisher 1958 cited in Kenchington and Carruthers 2001). The Bras d'Or serves as a winter feeding ground for these marine mammals.

10.4 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 parametres 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. Spawning migrations for most species found within the Lakes that have large numbers, such as herring, alewife, and mackerel, means 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 like 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).

Part D – Ecosystem Description

11. Ecosystem Relationships (Highlights)

11.1 Physical-Biological Linkages

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 2005). 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 (see Figure 4). Like ecodistricts, these bay-scale areas were established based primarily on physical and chemical properties (oceanographic), and bathymetric features. It is based on these ten "bays" and the twelve associated watershed areas that the process of identifying Ecologically and Biologically Significant Areas (EBSAs) has been applied.

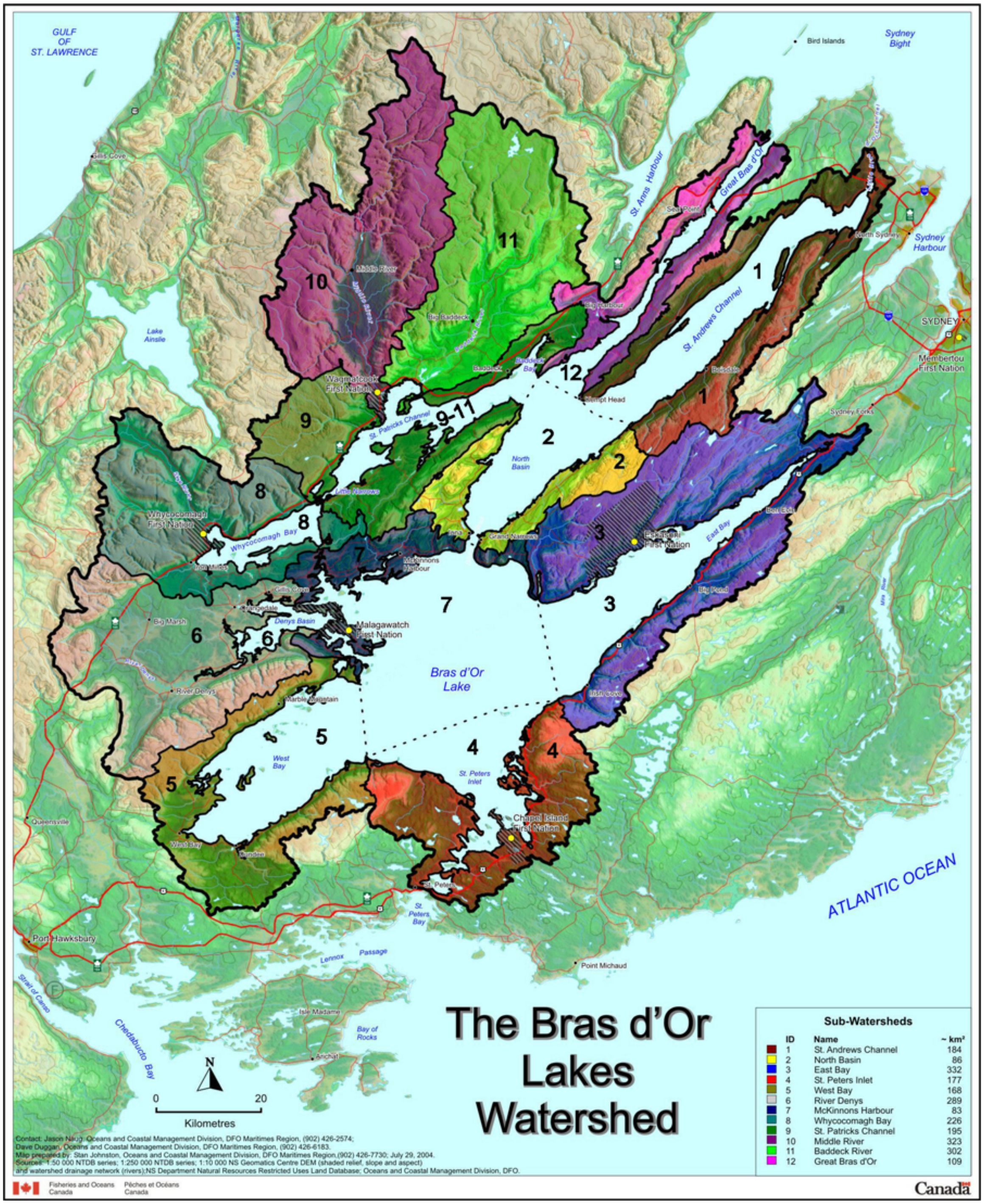


Figure 4. Overview of the Bras d'Or Lakes showing approximate boundaries of the twelve major watersheds and ten associated bay-scale delineations used in assessing ecologically and biologically sensitive areas (EBSAS).

11.1.1 Basic Cycles and Processes

The following discussion of ecosystem relationships should demonstrate how the biological and physical characteristics of the Bras d'Or Lakes watershed interact at the "bay" scale resolution use for identification of EBSAs.

11.1.1.1 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 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 were then able to rebuild after the bloom to nearly double the spring observed values (Strain and Yeats 2002). Silicate amounts do not determine size of the spring bloom, but do regulate how significant the diatom fraction is. 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 sources 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 comes from. 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 wastes that are 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 what sources of nutrient 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 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 salt to the fresher surface layer and the nutrients needed to promote plant production in the summer. There are no hard data available, but the flow through this Strait may prove to be the primary engine driving the Bras d'Or ecosystem (Kenchington and Carruthers 2001).

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.

11.1.1.2 Sealworm 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 as adults to a seal host where it will mature and reproduce.

Black and Scott (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 mophometry 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 then feed on other species, and grow 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 worm infested cod or seals from other areas of the Lakes across this sill, the cod population within Whycocomagh Bay remains uniquely worm free.

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).

11.1.1.3 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). The annual cycle of freshwater inflow to the Lakes features a strong spring pulse associated with ice and snow melt followed by rainfall. 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 more dense 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.

11.1.1.4 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.

11.1.2 High Biodiversity/Productivity Areas

Ocean Science Associates (1972) suggested that production in the Lakes could be categorized in 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 metres, 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 metres.
Shallow Bay Benthos	Areas less than 10 metres 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 used within this document for assessing ecologically and biologically significant areas (EBSAs) of the Bras d'Or Lakes. Although much research has been conducted on the Lakes, there does not exist adequate coverage across the complete system to evaluated EBSAs at the scale of productivity categorized by Ocean Science Associates.

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 1965; 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 used in assessing the EBSAs of the Lakes. At this scale, three areas appear as high biodiversity/ productivity areas. They are the Great Bras d'Or Channel, North Basin, and St. Andrews Channel.

High productivity areas have been mapped (Ocean Science Associates 1972) based on foraminifera (Vilks 1967) distributions. This was done with 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 productivity around the Lakes. Larger scale areas such as the Barra Strait in the North Basin and the southwestern portion of the Great Bras d'Or Channel were highlighted by this process, as were a number of smaller sub-bay-scale locations.

Based on 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 dependant on the Great Bras d'Or being a transition between the Lakes' and Atlantic Ocean populations, and St. Andrews 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 area within the range of Lake areas categorized would not change significantly given more complete surveys.

St. Andrews Channel

As noted earlier, at 280 m depth, St. Andrews is significantly deeper than any other area of the Lakes. This character offers cold, stable, and relatively saline waters, as well as significantly higher DO levels than much 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 (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 and it is the most saline at its outer limit, has significant hard bottom and coarse substrates; and 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. There were 19 species found only in this location, which were primarily warm water Virginian enclave species, surviving within a unique set of habitat parametres in the Lakes. Furthermore, the channel contained the greatest abundance of polychaetes found in the 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, both species that do not tolerate lower salinities and prefer harder substrate habitats.

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 drops 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, supply of incoming nutrients from the marine environment, storage of nutrients in the deepest body of the Basin, and supply of silicate could be expected to make the North Basin the mixing pot for Bras d'Or Lakes productivity. The components that would then spill into the other adjacent bodies, helping drive primary production in the Lakes, that is centred to some degree around the North Basin.

Other

At a finer resolution than the bay-scale evaluation conducted as part of the EBSA process, a few spatial observations on biodiversity and productivity 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, with 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, and 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 endeavors.

11.2 Biological Interactions

11.2.1 Food Webs and Energy Flows

A food web for the Bras d'Or Lakes has not been developed based on the biological inventories completed to date, however many researchers have noted predator prey relationships associated with the species they were assessing in passing. 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 are lost before hatching are 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) that 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 would feed around the seals' faeces, would pick up the larvae of the seal worm. Young Bras d' Or cod would 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 grab (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. It 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).

11.2.2 Focus on Keystone Species

Frameworks for the development of ecosystem monitoring exist (ECA 2003). To create such a system four primary steps need to be completed. The first is identification of ecotypes within the area of interest. This step has largely been completed for the Bras d'Or Lakes watershed through this document and the identification of EBSAs. The second step requires identification of keystone species from each trophic level in each ecotype. The final two steps of the ecosystem framework would involve defining habitat requirements for the keystone species using marine environmental quality (MEQ) guidelines, and then combining this information with the step one ecotypes information to create an ecozone description. The Ecozone description becomes the basis for ecosystem management.

In order to select an appropriate cross-section of keystone species, one must consider benthic and pelagic, sedentary and motile organisms. As well, it is wise 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 marine commercial and pleasure boat traffic, industrial and agricultural land based activities are likely to settle. As such, 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 in these tissues had good correspondence with local sediment concentrations (Chou *et al.* 1999). This example is 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 is spatially limited within the Bras d'Or Lakes ecosystem. Understanding what this limitation is would likely contribute to the establishment of a single parametre boundary for the St. Andrews and Bras d'Or Lake deepwater ecotypes.

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 when they are found in dense mats they provide substrate to which a small clam, *Hiatella artica*, attaches. This example demonstrates a preference of one species for 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 significant spawning sites that year (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, 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 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 even more than 120. This would make oysters one of the longer lived and more accessible organisms in the Lakes. Add to this that they are a filter feeder that would 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 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 keystone for an ecosystem. It also shows that once a critical ecosystem parametre is identified for monitoring, such as a metal level, the keystone species for monitoring that parametre may be different than the species that is to be protected. Tolerance levels and sensitivity as a monitoring organism do not necessarily exist within the same organism.

Part E – Ecological Assessment

12. Identification of Ecologically and Biologically Significant Areas (EBSAs)

The process of identifying ecologically and biologically significant areas (EBSAs) is described at length in two documents. Appendix A outlines the detailed methodologies applied specifically to the Bras d'Or Lakes ecosystem in deriving a score and relative rank for the various watershed bay-scale areas and Appendix B is the final scoring and ranking matrix. Although it is not imperative that one understands all details of the process undertaken, several points of the process do need to be presented.

Identification of ecologically and biologically significant areas 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, the ecological consequences would be greater 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, and will vary based on scale. For the purposes of the Bras d'Or Lakes EBSAs, evaluation has been carried out at the "bay" scale. This is a scale that appeared ecologically appropriate during the development of the overview report. It is a scale for which ecological functions appear to delineate the larger bays of the Lakes, and for which adequate scientific information is available. At the "within bay/basin" scale, smaller areas like Baddeck Bay or the western Whycocomagh Basin can be identified that have particularly unique ecological character. The information gaps that exist at this level, however, does not allow for adequate comparison and weighing of differences between all geographic locations within the Lakes. Therefore, the bay-scale is the finest resolution supported by scientific literature upon which to base the identification of EBSAs. As shown in Figure 5, ten separate bay-scale areas have been delineated. In terms of uniqueness and relative importance, evaluation was conducted on a "relative to the whole Bras d'Or ecosystem" spatial scale. For example, evaluating how important nutrient upwelling in North Basin is relative to the whole Bras d'Or system, unless there is additional regional or national significance.

The process of identifying EBSAs is based on information currently available. As such, it is only as good as the scientific knowledge we have 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 and Watershed Characteristics

13. Governance Structures
Section 13 contributed by Jason Naug, Fisheries and Oceans Canada

13.1. 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, Water Resources Protection Act*)
- NS Natural Resources: (*Beaches Act, Forests Act, Mineral Resources Act, Parks Act, Wildlife Act, Endangered Species 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*)

13.2. 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[4]:

- 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.

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

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 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.

Atlantic Policy Congress of First Nation Chiefs (APCFNC):

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.

Union of Nova Scotia Indians:

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

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

13.3 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
- 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

13.4 Non-Government Organizations

The main environmental NGO's operating in the Bras d'Or watershed include the following[5]:

The Bras d'Or Stewardship Society:

The Bras d'Or Stewardship Society is a membership organization of individuals committed to promoting accountable and responsible stewardship of the Bras d'Or Lake and its watershed. The Society promotes an appropriate strategy to conserve, restore and protect the Bras d'Or Lake 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.

[5] For a complete listing of all NGOs (environmental, social, cultural and economic) in the Bras d'Or watershed see Naug, J. *Summary of Groups within the Bras d'Or Lakes Watershed*. Oceans and Coastal Management Division, Department of Fisheries and Oceans. 2004.

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;
- 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 federal governments, the province of Nova Scotia, the Foundation itself, and other private sources. Current efforts are 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.

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.

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 Forestry, the Nova Scotia Department of Natural Resources, and community partners have formed a committee to explore how to maintain the Middle River Valley potential 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.

13.5 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:

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.

The Pitu'paq Committee:

The committee was formed in 2001 representing the five First Nation Chiefs and the five Mayors and Wardens in Cape Breton. 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 among their members 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 the Committee is provided by NS Environment and Labour and Environment Canada.

The Sustainable Communities Initiative (SCI):

The Sustainable Communities Initiative (SCI) arose from communities imploring governments to work together in ways that better support community's priorities. The SCI is an intergovernmental body with federal, provincial and municipal government departments and First Nation groups. 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.

14. Watershed Characteristics

14.1 Terrestrial Habitats

The NS Department of Natural Resources (DNR) maintains a database containing geographic areas that have significant species and/or habitats. Significant habitats include sites where species at risk or other species of conservation concern can be found and/or, sites where unusually large concentrations of wildlife occur and/or, habitats that are rare in the province.

The maps and database only include sites known to staff of the Department of Natural Resources or sites that have been supplied by knowledgeable naturalists, museums, universities, the Nova Scotia Museum of Natural History, the Atlantic Canada Conservation

Data Centre and other government departments. The data is not the result of a thorough survey and should not be considered a list of all the significant habitats in Nova Scotia, and it was last updated in August of 2004. Approximate areas for each classified habitat within the Significant Species and Habitats database have been calculated for each sub-watershed (Table 14).

Each of the Bras d'Or sub-watersheds 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%. Percentage of regeneration area for each sub-watershed is also similar and ranges between 5 and 10%. The percent coverage of areas defined as urban were highest in the Great Bras d'Or Channel, McKinnons Harbour, and St. Andrews Channel sub-watersheds. Areas covered by water, barrens, gravel pits and corridors were all minimal, at less than 5% of each sub-watershed area. It should be noted that gravel pits cover much more area in the River Denys and St. Patricks Channel sub-watersheds than all other areas (403 and 355 ha respectively).

Table 14. Habitat classification coverage for each sub-watershed in the Bras d'Or.[6]

Sub-watershed	NS DNR Habitat Classification in hectares (% of sub-watershed 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 dOr Channel	8960 (82)	615 (6)	592 (5)	18	10	64	250
East Bay	27 064 (81)	2 069 (6)	1262	174	31	69	186
McKinnons 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

14.2 Ecological Land Classification

The NS Department of Natural Resources has created the Ecological Land Classification (ELC) to aid with forest planning and management. It is a framework of mapped ecosystems which provides an understanding of terrestrial ecosystem form and function, and the dependent biodiversity 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, Ecozones (1:1 000 000), Ecoregions (1:500 000), and Ecodistricts (1:250 000) were available for use. Ecodistricts are subdivision of the ecoregions and reflect macroelements of the physical and biological attributes which will influence biodiversity. There are five Ecodistricts in the Bras d'Or watershed – their characteristics are summarized in Table 15 and arrangement displayed in Figure 5.

[6] Data from the NS DNR Forested land cover database. Approximate areas based on 1998-1999 photography and 1999-2000 satellite imagery.

Table 15. 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

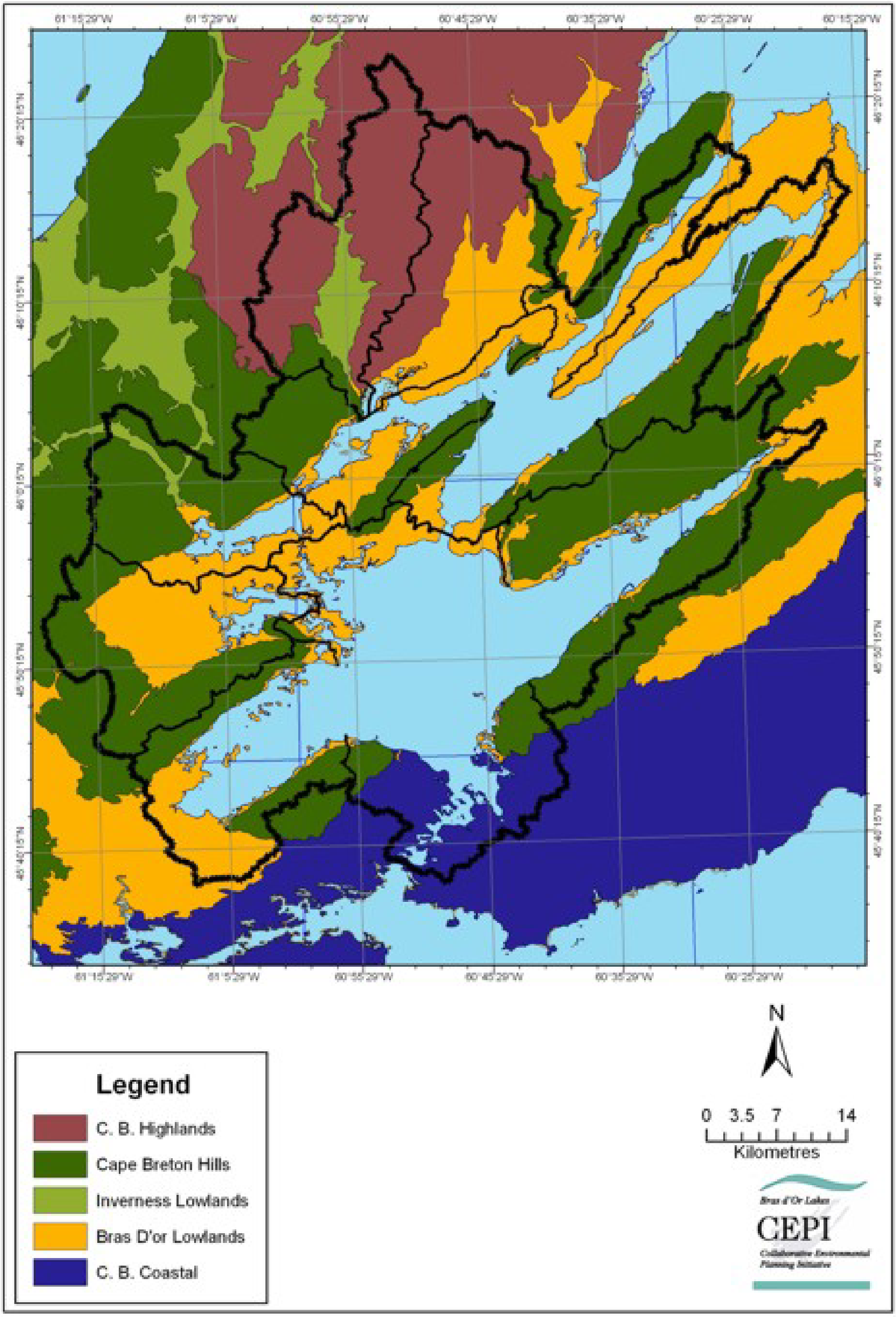


Figure 5. Ecodistricts of the Bras d'Or watershed[7].

[7] Data from NS DNR Ecological Land Classification database.

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

15.1 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. All four of the First Nation reserves are increasing in population, particularly Whycocomagh and Chapel Island which almost doubled in a decade (Table 16). 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, 2004) 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.

Table 16. Population, dwelling and education statistics for the larger settlements in the Bras d'Or Lakes watershed.[8]

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
Glendale	1756	-2	669	10	82,004	34	6	39	21
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

[8] Data from NS Community Counts website (http://www.gov.ns.ca/finance/communitycounts)

15.2 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 be more beef and dairy production while the northern side (Boularderie Island area) is more horticulture with some beef and dairy (McCabe pers. comm.). Most operations are located in Middle River, St. Andrews Channel, and Whycocomagh Bay sub-watersheds (Table 16). The eastern and southern side of the Lakes has very little agricultural activity.

Table 16. Agricultural activity in the Bras d'Or Lakes watershed, broken down by sub-watershed.[9]

Sub-watershed	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**

15.3 Forestry

The Nova Scotia Department of Natural Resources (NS DNR) 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. Specific watercourse protection measures include the mandatory provision for 20 metre 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 (2002b) which allows wildlife to move between stands of treed areas. On a provincial level, the Nova Scotia Wilderness Areas Act protects 19% of all provincial crown land.

Stora Enso Port Hawkesbury Limited (SEPH) holds a forest management licence agreement with the provincial government for some 607 000 hectares of crown land contained within the seven Eastern counties of Nova Scotia, and is one of the largest commercial forestry operation in the watershed. Under the terms of this agreement SE 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

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

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.

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 a voice of concern for the communities.

Stora Enso's Long Term Plan – 2002

Stora Enso's 180-page Long Term Plan is available to the public on their web site[10], and it 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 NS DNR's Integrated Resource Management (IRM) process and is based on their management categories as well as the Ecodistrict level of NS DNR's ecological land classification. As well, many of Stora Enso's Long Term Plan indicators are directly relevant to IRM objectives.

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 indicators that are closely monitored

[10] http://www.storaenso.com

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 sub-watershed is provided in Table 17. There are also specially managed areas in Stora Enso's management plans that includes 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 sub-watersheds (Figure 6). 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 17).

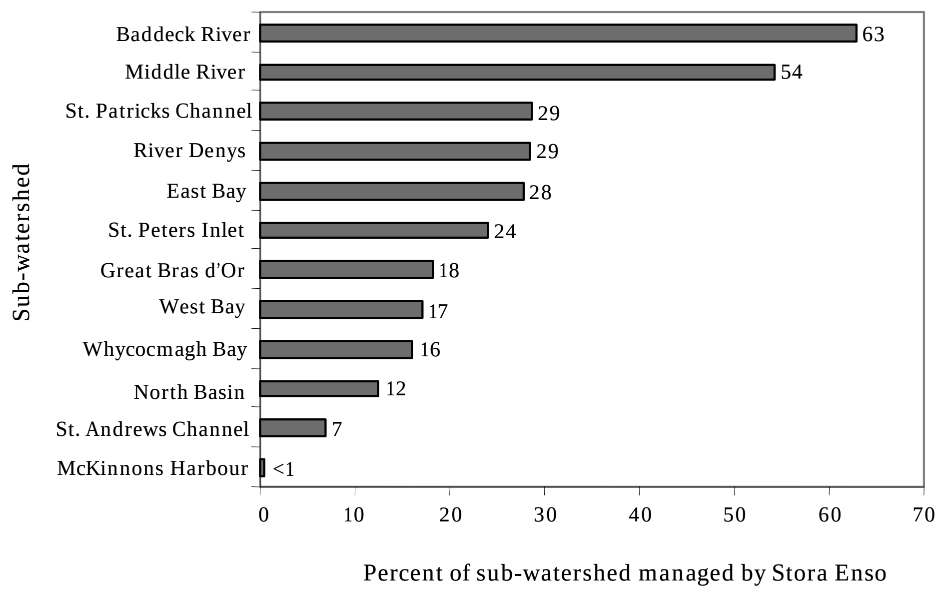


Figure 6. Amount of land in each Bras d'Or Lakes sub-watershed managed by Stora Enso Port Hawkesbury.

Table 17. Stora Enso Port Hawkesbury (SEPH) forestry areas and treatments broken down by sub-watershed from 2001-2004.[11]

Sub-watershed	Area in watershed managed by SEPH (ha,% of sub-watershed)	Sub-watershed managed by SEPH (%)	Steep slope reserve (ha)	Area of clearcut (ha)	Area of partial cut* (ha)	Area of recent cut** (ha,% of sub-watershed)	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)

[11] Data provided by Stora Enso Port Hawkesbury

15.4 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 has 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).

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 also 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. Peter's and Sporting Mountain; within Victoria County planned areas include Baddeck. 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.

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

Section 15.4.1 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 hectares, and the average waterfront lot size was somewhat smaller at 2.76 hectares. 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 hectares. Of the 100 lakefront lots for which permits were issued in CBRM over the nineteen-year period, only five were less than 0.28 hectares.

The trend in recent years has been toward less residential development in the watershed (Figure 7). For example, since 1996 there have been fewer than 20 permits issued in every year except one; prior to 1996 more than twenty permits were issued each year.

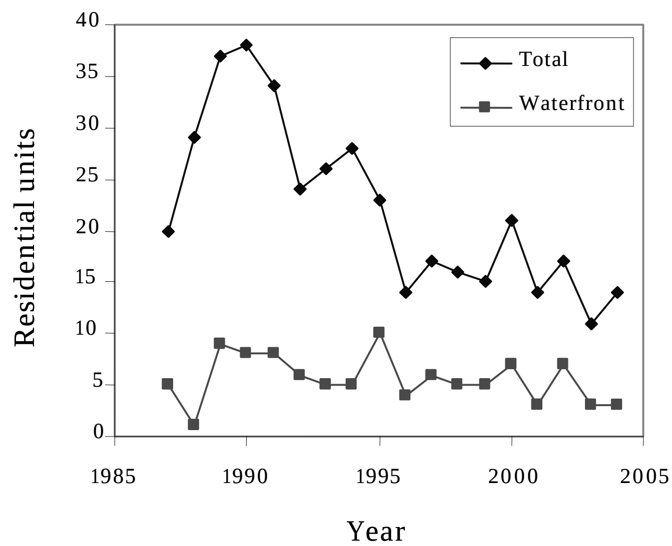


Figure 7. Summary of residential building permits issued in Cape Breton Regional Municipality within the Bras d'Or watershed from 1987-2004.

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[12]. As some lots have more than one development (ie. 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 18).

Table 18. Summary of developed lots in the Bras d'Or watershed as of 2003.

	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	2882	1619	1387	9863
	(40%)	(29%)	(16%)	(14%)	(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 are Little Bras d'Or, St. Peter's, Baddeck, Whycocomagh, Eskasoni, Wagmatcook, and Chapel Island, although a few developments in these areas may not be connected.

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%). Less than 3% of all watershed lands are owned by the federal, municipal and First Nations governments combined (Table 19).

Table 19. 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.

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

15.4.2 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 when it comes to 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 be Canadians as well as those from other countries. The analysis is summarized in Table 20, though it is important to note that these figures are by county and not the Lakes watershed. 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 20. 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

15.4.3 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, 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[13].

Road densities for each sub-watershed (Table 21) were calculated and include primary and secondary paved, tertiary, old roads, inactive trails and wood roads[14]. 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.

[13] http://www.epa.gov/maia/html/road.html
[14] Data provided by Stora Enso Port Hawkesbury

Table 21. Road density for each sub-watershed.

Sub-watershed	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

15.4.4 Sewage Treatment

The NS Department of Environment and Labour regulates all development which is intended to be serviced by on-site sewage disposal systems, and most of the development in this category excluding First Nations communities, Baddeck and St. Peter’s as they have a central sewer system.

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 inspect 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. Peter’s, 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:

The process of designating the Bras d'Or Lakes as a 'no-discharge' zone is currently underway, and will automatically apply the no-discharge regulations to both pleasure and non-pleasure crafts. 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. The cost of retrofitting a pleasure craft to comply with these regulations can range from $400 to $4,000, with an average cost of $1,500.

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, and St. Peter's. A new facility at the SS Marion Sailing Society Wharf in Whycocomagh is scheduled to open in August of 2005.

15.5 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 2001), and at that time, any individual in possession of a lobster license could fish for herring in the Lakes.

15.5.1 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. 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). The lobster fishery in LFA 28 – 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 2004).

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 8.

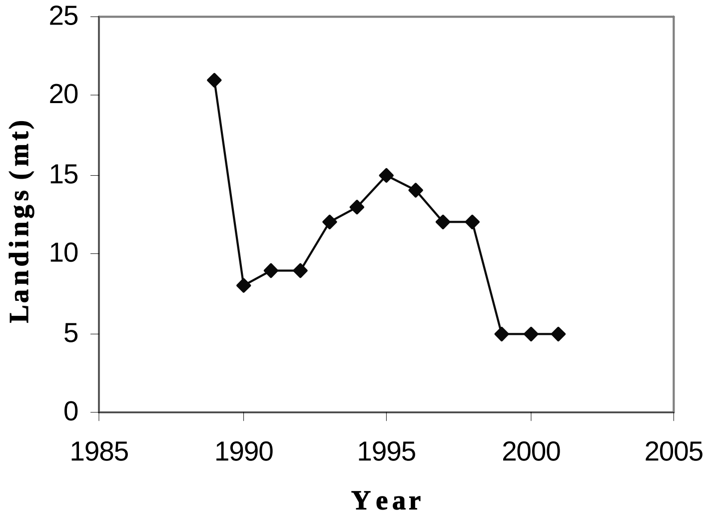


Figure 8. Lobster landings for LFA 28, the Bras d'Or Lakes area south of Barra Strait, from 1990 to 2002 (data from Tremblay and Reeves 2004).

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 of these only fish part of their gear in this area (Tremblay pers. com.).

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 (Tremblay pers. com.).

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)

15.5.2 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 after that, or if they stay (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 occurs outside of the spawning season (Kenchington 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, so intense localized fishing could deplete some sub-stocks while not impacting the rest of the population at that time (Kenchington 2001). For example, fishers targeting a small spawning group could essentially overexploit to depletion without affecting other nearby spawning groups. It can, however, have long-term consequences on the sustainability of the spawning group by decreasing recruitment and lowering spawning stock biomass to 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. We have seen spawning grounds having varying degrees of intensities in different years, largely dependent on the length to which ice remains on the lake and in the spawning coves. It has been observed that herring spawning in the Bras d'Or Lakes do so as many smaller spawning units.

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's 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 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 has 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.

Mackerel, mostly used for lobster bait, increased in price which raised demand for herring (also used for bait), which was much cheaper (Lambert 2002). With 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.

There is not much known about the Bras d'Or herring, such as 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 2003). However, 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.). This leads us to believe 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 2001). The winter flounder fishery ended in 1992 with the banning of commercial draggers from the Lakes, so possible damage from fishing gear is not longer a 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 individuals of this spawning unit 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 9). They suggest that low landings in the early 1970s might be from lack of reporting, with an average of 181t 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).

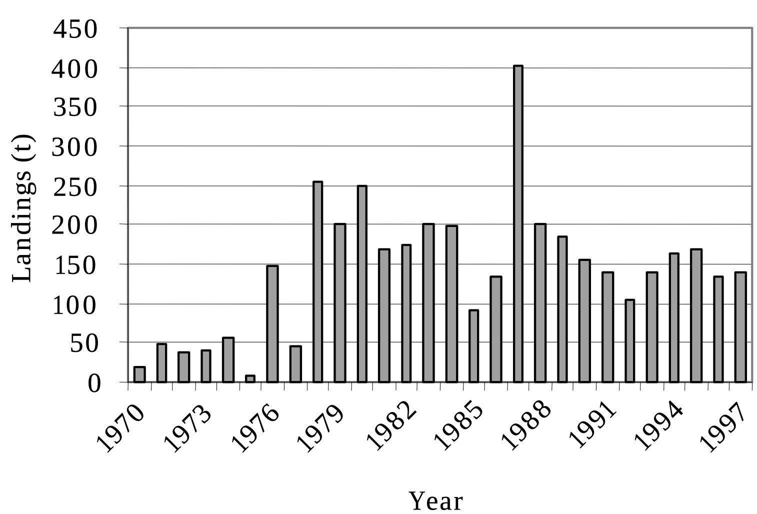


Figure 9. Recorded landings for the Bras d'Or spring herring fishery from 1970 to 1997 (from Denny *et al*., 1998). There has been no commercial fishery in the Lakes since.

15.5.3 Aquaculture

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 by members of the aboriginal communities with steady increased interest by aquaculturists and other commercial harvesters. Long handled tongs or rakes are the main gear used for harvesting, however SCUBA, snorkelling, and hand picking are also common (DFO Stock Status Report 96/124E, March 1997). First Nation fisheries tends to occur on public beds and leases with year round harvesting because of historical treaty rights (1997 stock status report).

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. 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 Shellfish Sanitation Program and the oysters are "re-layed" on leased areas. This fishery is administered by Fisheries and Oceans (DFO).
- The commercial and recreational fishery on public beds: Harvesting occurs on public grounds, and may only occur in areas that are deemed open or conditional by Environment Canada's Shellfish Sanitation Program. This fishery is administered by DFO.

The Lease/Aquaculture Fishery

The first private leases were issued in 1865, and some are considered family heirlooms. Although there is a grand total of 409 hectares of leased area allocated to 121 issued leases for aquaculture activity in the Bras d'Or Lakes, only 77 hectares (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 22. Not included in Table 22 are 37 inactive oyster leases in other areas of the Lakes.

Table 22. Summary of active and inactive aquaculture leases in the Bras d'Or Lakes at the bay-scale.[15]

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**

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

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.

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) through filter feeding in clean areas. 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). Only market sized oysters may be harvested (76 mm in length). 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.

Approximately 240 commercial and 53 recreational licenses (limit of 25 oysters per day) are held, although only 172 of the commercial licences were renewed in 2003 (Figure 10). All of these licenses were first issued for the 1998 fishery and were available to eligible historical users.

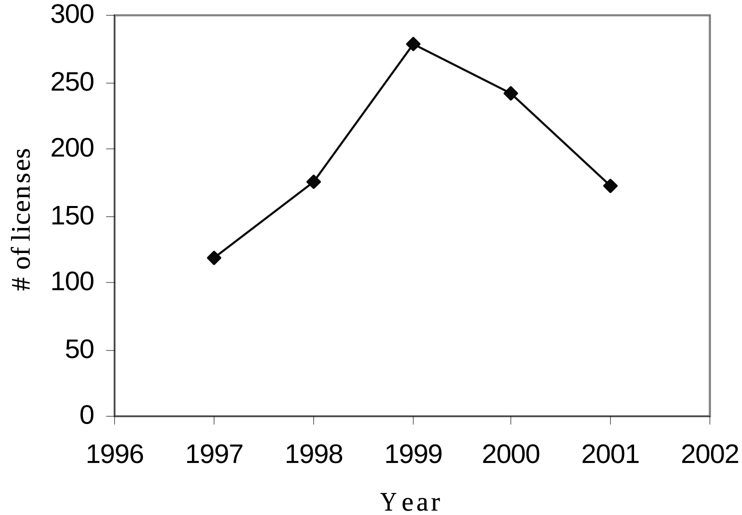


Figure 10. Number of commercial oyster licences issued for the Bras d'Or Lakes from 1997-2001. These licence holders are permitted to harvest oysters from any open public bed.

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 kgs 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)
- 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 1997).

In 2001, the Unima'ki Institute of Natural Resources did some research on the stocks in public beds as well as some enhancement projects. Also, industry funded yearly surveys are conducted in one or two areas within the Lakes. Unfortunately the data is not comprehensive in nature so cannot be compared to the 1990 data.

15.5.4 Hunting

No hunting statistics are 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 11), in Inverness and Victoria counties. Only 25 permits are issued for each of zones 3 and 4, out of 300-500+ applicants. Moose on mainland Nova Scotia have been officially listed "endangered" under the Nova Scotia *Endangered Species Act*, so hunting for them occurs only on Cape Breton Island. Since 1986, the annual harvest for all zones has ranged from 11 to 19 moose.

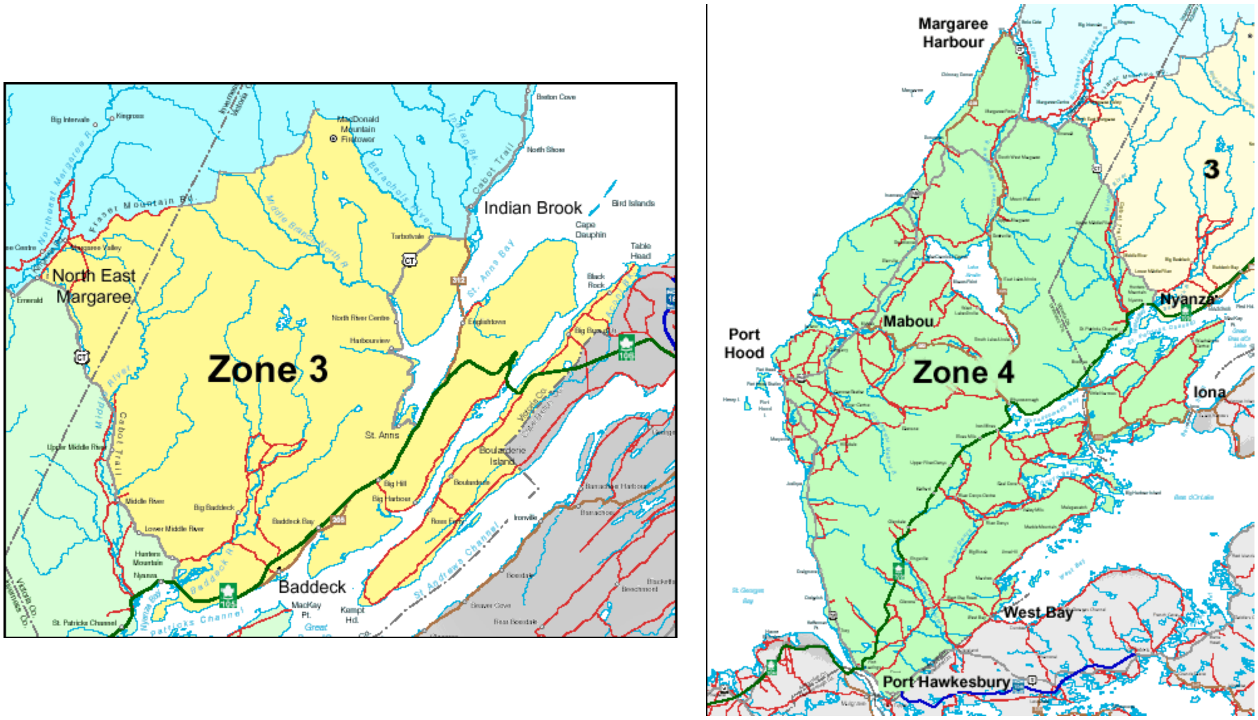


Figure 11. Location of moose management zones located in the Bras d'Or watershed.[16]

Deer management zones 6 and 7 cover the entire island (Figure 12). 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 50 were harvested in each of those counties in 2004; in 2004 a total of 142 deer were reported killed for zones 6 and 7 combined, compared to a total of over 7800 for the entire province of Nova Scotia.

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

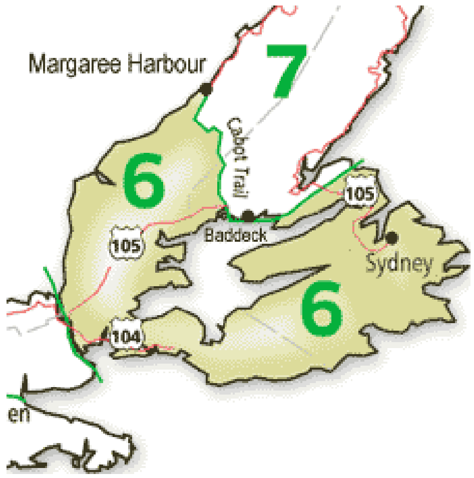


Figure 12. Deer management zones in the Bras d'Or watershed.[17]

There are also animals harvested for fur in each of the four Cape Breton counties; this includes 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.

15.6 Extraction of Non-Renewable Resources

15.6.1 Mining

Nova Scotia accounts for 81% of Canada's production of natural gypsum and for almost all of its exports. They are open-pit mines and the majority is shipped raw by ocean freighter to East Coast ports in the United States. Two companies operate in the watershed, Georgia-Pacific Canada Inc. in Melford and Little Narrows Gypsum Company in Little Narrows, and both operations have local workforces of over 100. There is also a small active red marble quarry owned and operated by MacLeod Resources near River Denys, and an inactive marble quarry owned by Shaw Resources.

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.

The Melford mine, 432 hectares in size, is located in the River Denys sub-watershed, and is approximately 20 km upstream from the Lake. The site is operational 24 hours a day, seven days a week. Mined gypsum is crushed on-site and transport 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 25 miles (40 km), and each can be loaded, weighed and dispatched in approximately six minutes. This results in approximately 42 100 truckloads annually via

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

Highway 105 and through Port Hastings and Port Hawkesbury to the Point Tupper marine terminal (KPMG LLP, 2003).

According to a consultants report (ADI, 1999), the life of the Melford mine is estimated to be approximately 20 years. Mining was expected to begin in 2000 or 2001 at an annual depletion rate of 180 ooo to 360 000 tonnes and gradually increase to 1 800 000 tonnes by 2004 to 2006. 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 combined cover an area of approximately 809 ha (2000 acres).

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 109 000 tonnes in 1994. Production for the 1997 calendar year was 112 402 tonnes of anhydrite and 903 097 tonnes of gypsum with 132 employed. Production for the 2000 calendar year was 1 169 101 tonnes of gypsum and 98 004 tonnes of anhydrite, with 102 employed in the area (NS DNR, 2005).

Kennedys Big Brook Red Marble Mine

In September of 2002, the Minister of Environment and Labour approved the development of a small red marble quarry. The pit boundary is 13 053 m^2 (1.3 ha), near the top of North Mountain, 6.4 km away from the settlement of River Denys. The mine operates on a nine-month season while the processing facility operates on an eleven-month season, and there are 11 full-time employees. 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). Marble is cut with a diamond wire sawing method, and no blasting occurs.

Marble Mountain

Inactive since 1991, Marble Mountain was mined 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 5 million tonnes of limestone have been removed from the site (Dickie pers. comm.).

15.6.2 Onshore Petroleum Activity

Section 15.6.2 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 for which we have the first record. Provincially, some 116 wells have been drilled specifically looking for oil and gas, and another 69 drilled as mineral exploration holes which encountered some indication of oil and natural gas. In Cape Breton there have been 64 wells drilled for petroleum between 1869 and today, and many of them were located in the vicinity of Lake Ainslie (Figure 13). The last well drilled on the Island was in 1988 and was in the vicinity of Mull River.

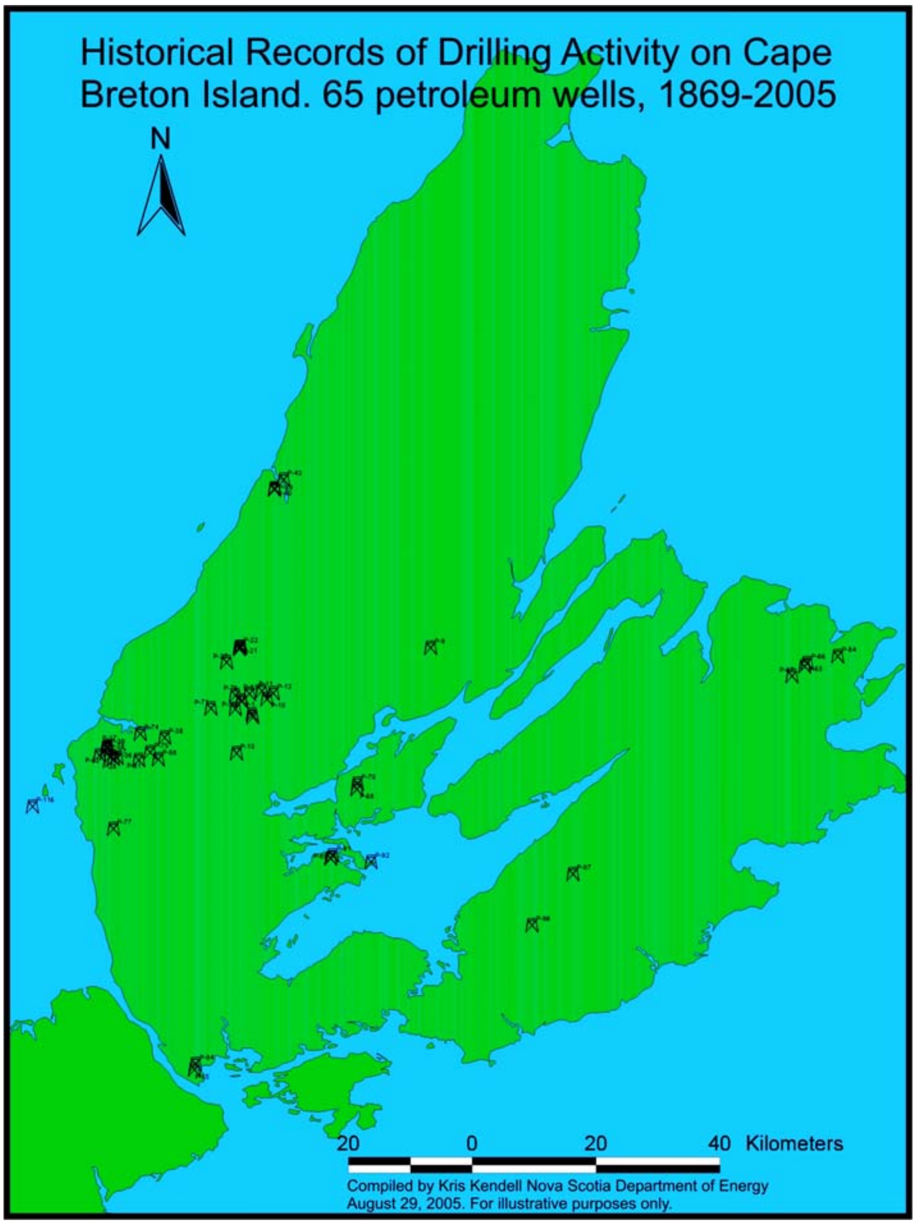


Figure 13. Map showing location and concentration of petroleum drilling on Cape Breton Island from 1869-2005.

Seismic activity which generally precedes drilling is more of a modern development when compared to drilling. There were two small programs acquired in the Sydney area in mid-1960. One survey of interest was actually conducted over the Bras d'Or Lakes using a ship-towed low energy air gun source (Figure 14). This program was acquired for Chevron Canada during the summer of 1980.

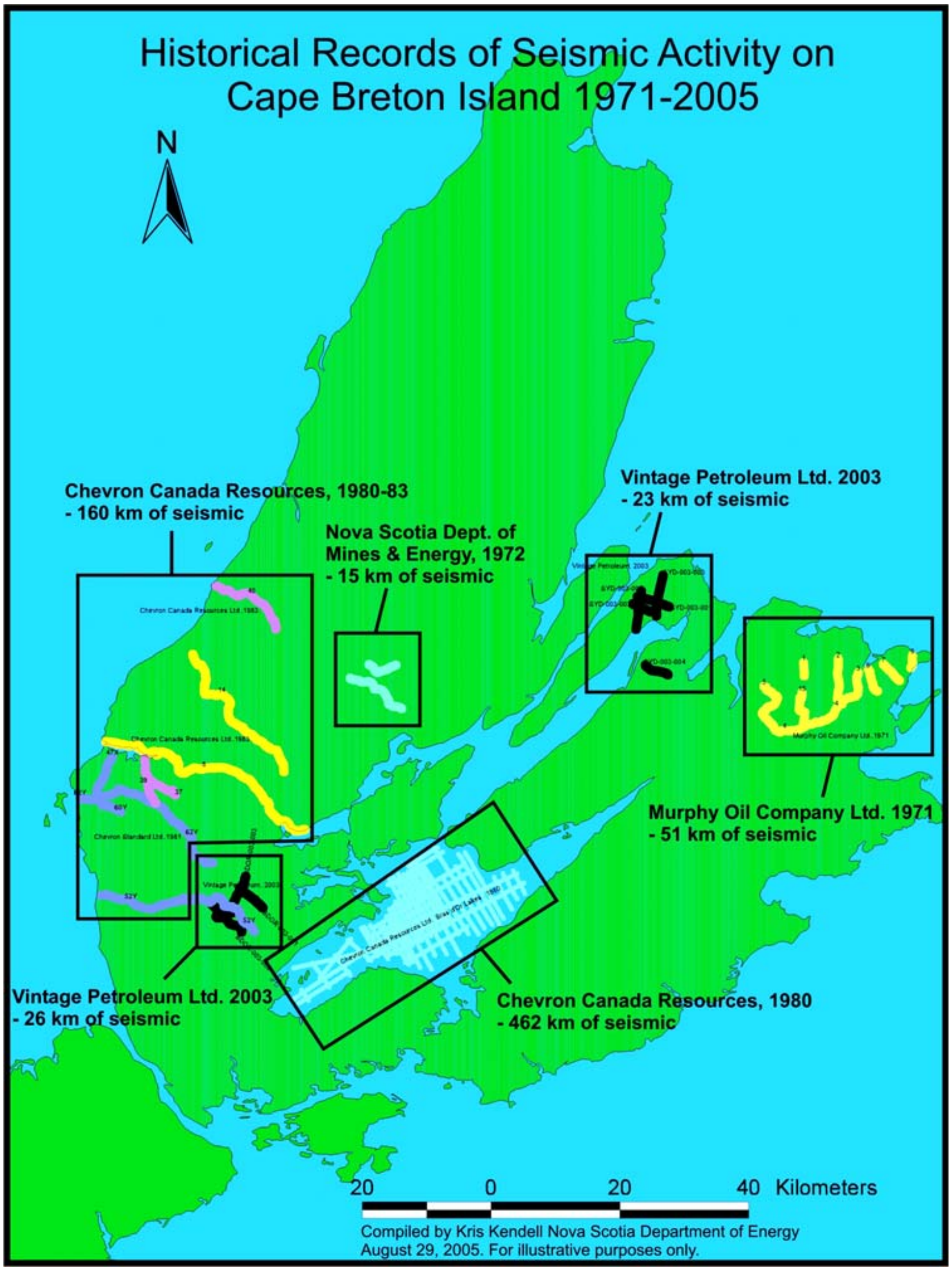


Figure 14. Map of all seismic activity on Cape Breton Island from 1971-2005.

Operational

On-land seismic utilizes one of two methods. The first is "Vibroseis" which use 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 diametre holes with a portable drill to depths of approximately 6 metres and then load them with 1 kilogram charges of dynamite. The hole is backfilled and the charge set off sends sound ways 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 so-called seismic profiles that industry uses to predict structures and traps where hydrocarbons might be found.

Drilling will often occur in the field season which follows the year that the seismic data was taken. 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 metres. The length of time it takes to drill the well depends upon its depth. Typically, wells can be as deep as 3000-4000 metres 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 may be involved who share jurisdiction,
- 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 Act, Regulations, and Approvals granted.

Current Activity

At this time no applications have been received for any on-the-ground work to be conducted this year (2005) on the petroleum licence blocks on Cape Breton Island as shown in Figure 15. As mentioned above, should an application be received to conduct work it would follow the above process.

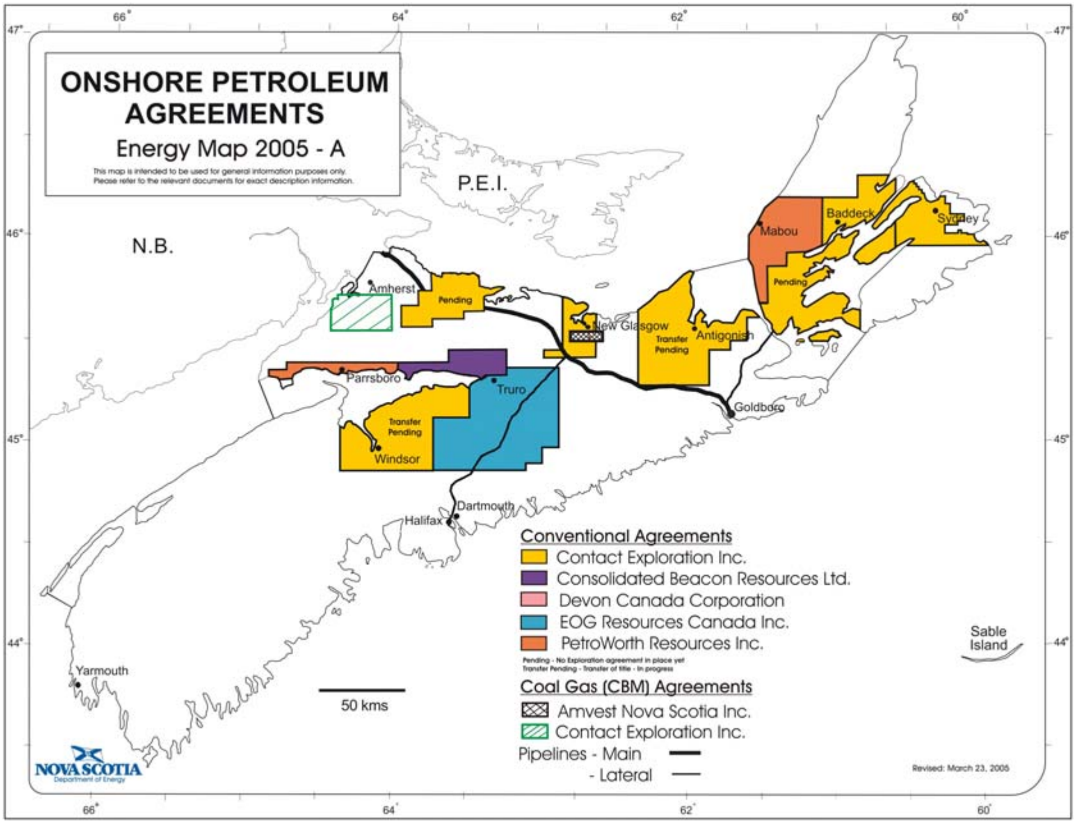


Figure 15. Map showing onshore petroleum agreements in Nova Scotia as of 2005.

15.7 Transportation and Communications

15.7.1 Industrial Shipping

The only 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 16), 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 and Jacksonville, Florida (Hemphill, pers. com.).

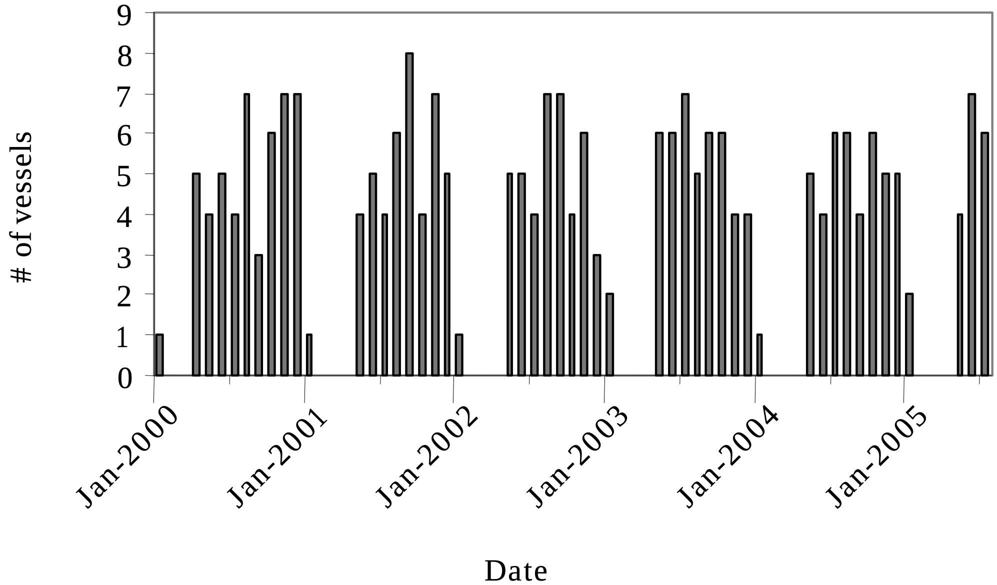


Figure 16. Total number of gypsum vessels per month which enter and leave the Bras d'Or Lakes via the Great Bras d'Or Channel. Each vessel enters empty, is loaded with gypsum at the Little Narrows Gypsum facility, and leaves the Lakes full.[18]

15.7.2 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's not a common occurrence.

A small vehicle and passenger cable ferry crosses the small channel of Little Narrows (less than ½ a kilometre). It is operated by the Department of Transportation and Public Works and runs year round. The ferry holds 12 average sized cars.

15.7.3 Harbours and Facilities

15.7.3.1 Boat Ramps

There are 13 boat ramps available around the Bras d'Or Lakes for launching and removing personal recreational boats (Table 23), and maintenance for these facilities varies from provincial departments to community groups. As no one department or group is responsible for the structures, no one is responsible for maintaining usage records of the facilities. 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.

[18] Data from Mark Hemphill, Plant Manager, Little Narrows Gypsum Company

Table 23. Boat ramp facilities on the Bras d'Or coastline.[19]

Location	Watershed	Width (feet)	Responsibility
Head of East Bay	East Bay	?	NS DNR
Ben Eoin	East Bay	12	NS DNR
Big Pond	East Bay	12	NS DNR
Dundee	West Bay	29	NS DNR
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/NS DNR
Grand Narrows	North Basin	12	Grand Narrows Preservation Society
St. Peters Canal	St. Peters Inlet	10	Parks Canada

15.8 Recreational Activities

15.8.1 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 24.

Table 24. 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 Straight	9	6
Outside of Lakes, but many boats travel into the Lakes via St. Peters inlet	St. Peters	57	10

15.8.2 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[20], 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.

[19] data from http://www.gov.ns.ca/nsaf/marine/ramps/
[20] http:www.geocities.com/cbdive1/scat.html

15.8.3 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 (Anon, year unknown). 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.

15.8.4 Parks and Wilderness Areas

Bornish Hills Nature Reserve: Originally identified in the 1970s, the 960 hectare Bornish Hills Nature Reserve 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 hectares, 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.

Washabuck Conservation Easement: Located on the peninsula in St. Patricks Channel, protects approximately 2.54 kilometres of shoreline. The shoreline provides an almost 360 degree vista that includes views of the south rise to the Cape Breton Highlands and Beinn Bhreagh. The property is covered by naturally regenerating forest, predominantly White and Black Spruce and Balsam Fir with a mixture of hardwoods. There are no roads on either side of this bay, so it's a favoured anchorage for boats and yachts.

Spectacle Island Game Sanctuary: A small game sanctuary intended to protect birds and their habitat, it encompasses 13 hectares (some of which is covered by water). Activities prohibited include hunting of wildlife or eggs, or destroy or disturb wildlife species or nesting sites. No person is allowed within the limits of the Sanctuary from April 15th to August 15th.

Humes River Wilderness Area (proposed): This area would protect an old hardwood forest and capture one of the few remaining tracts of Acadian hardwood forest. It is one of few publicly owned properties in the area and would connect with the existing Trout Brook Wilderness Area.

There are also four provincial parks in the Bras d'Or Watershed (Table 25), all of which are along the coast. There are 62 camping sites and lake access at Whycocomagh Provincial Park; the other three parks are only used for picnics and day use. There are also many hiking and multi-use trails in the watershed (Table 26).

Table 25. Summary of Provincial Parks in the Bras d'Or watershed.[21]

Provincial Park	Description	Watershed
Whycocomagh	A picnic park and campground on the shore on Highway 105	Whycocomagh
Uisge Ban Falls	Picnic park with hiking trails, day use only	Baddeck
Dalem Lake	Picnic park with hiking trails, day use only	Great Bras d'Or
Groves Point	Very small park just south of Groves Point available to the public for picnicking	St. Andrews Channel
Irish Cove	South of Irish Cove on Highway 4, this picnic park is a small roadside picnic park overlooking the Lake	St. Andrews Channel
Barachois	A small picnic park with a view of the water located on Highway 223 just north of MacSweens Beach	East Bay
Ben Eoin	A small picnic park on an old farm against hardwood covered hills, located on Highway 4, south of Ben Eoin	East Bay

Table 26. Summary of hiking and multi-use trails in the Bras d'Or watershed.[22]

Name	Sub-watershed	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

There are also other types of protected areas within the watershed (Table 27). The Nova Scotia Department of Natural Resources has protection designations ranging from wilderness areas to special places and historical sites, and the levels of activity permitted are different for each.

[21] data from http://parks.gov.ns.ca/ourparks.asp
[22] data from http://trails.gov.ns.ca., list may not be comprehensive

Table 27. Areas of provincial protection broken down by sub-watershed.[23] Levels of protection for each parcel could not be specified.

Sub-watershed	Area of protected areas (ha)	# of protected areas	Description
Middle River	5326	1	Wilderness area
River Denys	843	1	Special Places Act
Baddeck River	467	2	Wilderness areas
North Basin	459	5	Protected beaches
St. Patricks Channel	287	2	Wilderness areas
St. Andrews Channel	122	12	1 protected beach, 11 provincial parks and reserves
St. Peters Inlet	120	6	Provincial parks and reserves
Whycocomagh Bay	192	5	Provincial parks and reserves
East Bay	89	1	Provincial parks and reserves
West Bay	5	1	Protected beach
McKinnons Harbour	0	0	-
Great Bras dOr Channel	0	0	-

15.9 Other Activities

15.9.1 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 28).

Table 28. Navigation aids still standing in the Bras d'Or Lakes.[24]

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. Peter's 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

[23] data compiled by querying the NS Restricted Land Use database for 'designated provincial parks and reserves', 'protected beaches', 'special places act lands', and 'wilderness areas'.
[24] data from http://www.nslps.com

15.9.2 Ocean Dumping

It has been suggested that there is an old munitions dump off of Boularderie Island, near Kempt Head, however this could not be confirmed (Kehoe pers. comm. 2005). No dredging and/or dumping occurs regularly in the Lakes.

16. Threats and Stressors – Human Activities of Concern (regional scale)

Threats and stressors to the Bras d'Or ecosystem have not been directly considered in the evaluation of areas as being ecologically or biologically significant. As noted in the EBSA Guidance Document (DFO 2004b), these are management concerns, and risk factors do not directly relate to whether an area is ecologically or biologically significant.

16.1 Aquatic Invasive Species

16.1.1 Green Crab

Green Crab (*Carcinus maenas*), native to Europe, has recently been introduced to the Bras d'Or Lakes. Evaluation of their impact is not yet fully understood. Initial trapping surveys for Green crab began in August 1999 by DFO and Eskasoni Fish and Wildlife Commission. This survey 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 based on 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 (J. Roman, Stanford University pers comm. Cited in Cameron 2003), and the Bras d'Or population most likely derives from the Cape Breton population (Cameron 2003).

16.1.2 Tunicates

Tunicates have been found in various areas of the Bras d'Or Lakes. The Golden Star Tunicate (*Btryllus schlosseri*) and sea squirt (*Ciona intestinalis*) have both been identified in the Lakes (Paul, K. 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 diametre 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.

16.1.3 MSX and SSO

Two new oyster diseases have been found in the Bras d'Or since the fall of 2002. MSX (*Haplosporidium nelsoni*) and SSO 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, Whycocomagh Bay, St. Peters Inlet, the Barra Strait, and the eastern end of East Bay (Paul, K. pers comm. 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%.

16.1.4 Other

Brown trout is another introduced species, being native to Europe. It is believed they entered the Lakes in the 1930s from a hatchery in St. Peters and established a reproducing population in the Breac Brook and River Tom areas. They are known to be in some of the rivers draining to the Lakes but mostly seem to remain within the Lakes themselves. Over 56 000 were stocked in the Bras d'Or in 1986 (Hurley Fisheries Consulting 1989).

Rainbow trout have also been introduced to the Lakes both from significant aquaculture escapement and through stocking programs that may date back as far as the 1950s (Hurley Fisheries Consulting 1989). 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). Reproducing populations seem to have become established in some rivers entering St. Patricks Channel. A substantial run of rainbows were documented in the Skye River in the late 1980s, as well as lesser numbers of them in other rivers (Hurley Fisheries Consulting 1989). Currently, they are targeted by recreational sport fishermen within the Bras d'Or Lakes, particularly along the shores of Whycocomagh Bay and St. Patricks Channel.

17. Receptors and Key Issues – Impacts on Ecosystem Components and Properties

17.1 Biodiversity and Species at Risk

The limits to biodiversity in a semi-enclosed system like the Bras d'Or are complex. Active migration, drift and interspersion are all ways for biota to colonize new areas. There are also 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 parametres 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 does 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 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 is preferred by fewer species than the harder coarse grained substrates. Similarly, as with the physical habitat parametres, some of the more key chemical parametres 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 not be counted as part of the biodiversity of an area.

17.1.1 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 29). 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 document 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 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. One additional species listed by COSEWIC as endangered is the Piping Plover (*Charadrius melodus melodus*). It is found on the island of Cape Breton, but is only recorded outside of the Bras d'Or watershed on the Northwestern and Southwestern extents of the island.

Table 29: Summary of various species' listings 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	5	3 SC	2 En, 2 Vul	54
Great Bras d'Or Channel	3	2 SC	1 En, 1 Vul	18
West Bay	2	1 SC	1 En, 1 Vul	6
St. Andrews	2	1 SC	1 En	13
Whycocomagh Bay	2	1SC	1 Vul	29
Denys Basin	1	1 SC	1 Vul	26
North Basin	1	1 SC	1 Vul	16
St. Peters Inlet	1	1 SC	1 Vul	8
East Bay	1	-	1 En	7
Bras d'Or Lake	0	-	-	11

SC = Special Concern, En = Endangered, Vul = Vulnerable
Source: Atlantic Canada Conservation Data Centre

17.1.2 Other Species of Concern

Listed Species

Table 30 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.

Table 30: A summary of listed species found in the Bras d'Or watershed, and the general locations for which they have been recorded.

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
Reptiles				
Wood Turtle	*Glyptemys insculpta*	Special Concern	Vulnerable	GBC, SPC, NB, WHY, DB, WB, SPI
Amphibians				
None				
Insects				
None				

Source: Atlantic Canada Conservation Data Centre.

Unlisted species

Several other species, 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*), polychaete worms (*Euchone elegans, Polydora quadrilobata*, and *Myriochele heeri*) (Lambert 2002). Because these species are isolated by temperature requirements and 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 (1997) 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.

17.2 Limited Habitats

As with any ecosystem, some habitat types are abundant, and others are relatively limited. Having limited habitats does not inherently mean they are more important ecologically 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.

The Nova Scotia Department of Natural Resources owns and maintains a GIS database of significant species and habitats that include 12 habitat types and locations are identified. This includes 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 and confirm accuracy and completeness. The database is not a complete inventory of all significant habitats in the province, although it does provide us with a feel for what is known. A summary of classified habitats for each sub-watershed in the Bras d'Or is provided in Table 31 (excluding salt marshes and wetlands, covered later in Section 17.2.4).

Table 31. Classified habitat areas for each sub-watershed as defined in the NS DNR significant species and habitats database. These are approximate areas only.[25]

	NS DNR Habitat Classification in hectares (% of watershed if ≥5%)							
Sub-watershed	**Species at risk**	**Of concern**	**Deer wintering**	**Freshwater**	**Rare plant**	**Migratory bird**	**Old forest**	**Other habitat**
East Bay	7757 (23)	422	1759 (5)	143	19	27	116	1067
River Denys	1,015	132	3825 (13)	144	162	0	1064	497
West Bay	761	114	1155 (7)	160	0	0	0	639
North Basin	674 (8)	38	794 (9)	0	7	0	0	667 (8)
Whycocomagh Bay	600	983	267	93	52	3	0	529
St. Peters Inlet	322	227	243	69	0	10	0	472
Baddeck River	286	1416 (5)	23	77	19	19	0	308
St. Patricks Channel	72	160	1519	230	30	25	0	643
Great Bras dOr Channel	25	355	241	47	7	0	0	516 (5)
St. Andrews Channel	19	101	548	0	0	64	19	583
Middle River	0	1532 (5)	16	0	0	0	0	133
McKinnons Harbour	0	301	390 (5)	0	2	8	0	600 (7)

[25] Data from the NS DNR significant species and habitats database.

17.2.1 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 (1988) 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.

17.2.2 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.

17.2.3 Rocky substrates

Rocky substrates are limited to a few areas of the Lakes. The most significant amount of this habitat type would be 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. However, most of the Lakes are a very uniform substrate metres deep of fines and mud deposited from marine, glacial, and erosion sources.

Many marine species require rocky substrates as part of their physical habitat requirements, such as macrophytes which require gravels and rock to anchor to before they can grow into the water column. In areas where these macrophytes can not 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 limiting the production of such commercial species within the Lakes.

Side scan radar has highlighted isolated underwater bedrock outcrops and/or ridges both in Bras d'Or Lake and St. Andrews Channel (Myers and Gilbert 1993).

17.2.4 Wetlands

Freshwater wetlands are documented by the Nova Scotia Department of Natural Resources in the Wetlands Database Specifications (DNR 1999) and are differentiated by type. For the purposes of this overview, they have been grouped together to provide some indication of the total area covered by freshwater wetlands (Table 32). These freshwater wetlands are 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. Included in the saline wetlands category are any areas greater than 0.5 ha in size that were classified as a salt marsh, estuarine flat, or a marine flat (see Table 33). Saline wetlands are areas typically covered by low and high salt marsh communities, while eelgrasses are found on the estuarine and marine flats.

Table 32: Estimates of freshwater wetlands in the Bras d'Or Lake watershed (source NSDNR wetlands database).

Watershed	Total Freshwater Wetlands (km^2)	Total Saline Wetlands (km^2)	Total all wetlands (km^2)
St. Patricks Channel	43.8	20.9	64.7
East Bay	16.7	36.7	53.4
West Bay	3.6	32.5	36.1
Denys Basin	11.5	20.3	31.8
Bras d'Or Lake	1.4	28.5	29.9
St. Peters Inlet	6.8	14.0	20.8
St. Andrews	5.0	12.2	17.2
Whycocomagh Bay	6.9	8.5	15.4
North Basin	1.7	11.9	13.6
Great Bras d'Or Channel	1.5	6.8	8.3
Total	**98.9 km^2**	**192.3 km^2**	**291.2 km^2**

Source: Compiled from NSDNR 2000

The largest shoreline extent of wetland and marsh are within Denys Basin and the head of Whycocomagh Bay, 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 provide a number of important ecological functions, and support a diversity of species not typically found in other habitats. 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 significant in the EBSA process for Bras d'Or Lakes.

17.2.5 Deepwater Habitats

The average depth of the Bras d'Or Lakes is 30 m (Strain and Yeats 2002). However, several basins exist that are very deep by this standard. 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 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 parametres of the open ocean. The apparent long term stability of the habitat parametres in these areas is suspected to allow 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 makes these areas of the Bras d'Or ecosystem significant.

17.2.6 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 exposure lacks consistency between cycles. Furthermore, the lack of large shallow mudflat-type areas that might become exposed during a tidal cycle means that in most areas of the Lakes the intertidal zone is significantly limited to 5-10 cm vertical change over the slope of the shoreline.

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 33). The latter is considered here as it has been identified in the past as a key spawning area for herring. The herring population crashed because of overfishing in the late 1990s. Therefore, such habitats will likely be a key component of any recovery of the Bras d'Or herring population.

Table 33: 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: Compiled from NSDNR 2000

17.2.7 Dunes/ Saline Ponds

Dunes and saline ponds created behind barrier beaches are formed of fine grained materials, which makes them inherently more unstable than areas of coarse coastal substrates (Table 34). 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 also both sensitive to anthropogenic uses. Human traffic can destabilize dunes, and enclosed saline ponds can become highly eutrophic given accelerated nutrient loads from land based activities.

Table 34. Sensitive dune and saline pond habitat areas found in the Bras d'Or watershed.

Watershed	Total Dunes (m^2 x 1000)	Total Saline Ponds (m^2 x 1000)
East Bay	147	201
West Bay	60	5
Bras d'Or Lake	52	95
St. Andrews	35	62
North Basin	31	60
St. Peters Inlet	19	30
Great Bras d'Or Channel	5	160
St. Patricks Channel	5	38
Denys Basin	1	0
Whycocomagh Bay	0.3	0
Total	**1355.3**	**1651**

Source: Compiled from NSDNR 2000

17.3 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 born pollutants and contaminants that could not be quickly dispersed by water movement.

17.3.1 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 irrespective of the results of bacteriological analyses.

In 1995 there was 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

[26] From http://www.atl.ec.gc.ca/epb/sfish/maps/ns/area7.html

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.

17.4 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. In particular was concern of 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 this survey 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.

Part G – Conclusions

18. Bras d'Or Lake EBSAs

The process of identifying Ecologically and Biologically Sensitive Areas (EBSA) is generally outlined in a document produced by the Department of Fisheries and Oceans (DFO 2004b). The process recommends completing a science-led evaluation of the area of interest that produces an output such as a quantitative or qualitative ranking of different areas relative to their biological or ecological significance. Such a ranking does not give an area any special legal status, but helps to provide guidance on the standard of management that is appropriate for a given area.

For the Bras d'Or Lakes, an ecosystem overview was completed by compiling and reviewing scientific knowledge of the Bras d'Or watershed. This process also served to complete the first step in identifying EBSAs for the Bras d'Or Lakes. Then, a series of categories were established that reflected Species Use, Physical and Chemical Character, Sensitive/Limited Habitats, and Resource Use/Risk Factors. A total of some 25 feature headings were developed under these four categories. However, only the three categories and 18 feature headings shown in Table 35 were used for scoring and ranking of EBSAs. This is because the identification of EBSAs does not consider threats and risks to the site as a result of human activity. These things do not make an area ecologically or biologically significant. Instead these concerns are a component of the management decision process for areas that have been identified as ecologically and biologically significant (DFO 2004).

Table 35: The three categories and 18 feature headings under which narration was compiled during the scientific review for the Bras d'Or Lakes Ecosystem overview.

Category	*Species Use*						
Feature	Periodic / Historic	Forage Area	Rearing Area	Key Breeding	At Risk Status		
Category	**Physical and Chemical Character**						
Feature	Biodiversity	Ecosystem Function	Nutrients	*Anoxia*	Mixing/ Stratification	Temperature/ Salinity	Minerals and Metals
Category	**Sensitive Habitats**						
Feature	Hard Substrates	Barachois Ponds	Wetlands	Shoreline	Other Limited Habitat Type	Mature forest	

Each of these 18 feature headings was then scored on the five EBSA scoring dimensions of uniqueness, aggregation, fitness consequences, resilience, and naturalness (Table 36). A range of defined values was applied to these dimensions based on the current knowledge of each heading for each of the ten "bay" scale areas. The details of how scoring was applied is explained in Appendix A (results in Appendix B). Most of the knowledge upon which scoring was completed has been presented in the Bras d'Or Lakes ecosystem overview component of this document. Through this scoring and ranking process St. Andrews Channel was clearly identified as the most ecologically and biologically significant area of the Bras d'Or Lakes watershed (see Table 18). It is important to note that the numeric score achieved by each bay-scale area is insignificant, and it is the relative ranking of the watershed areas that is of importance in moving forward with a management strategy for the area. Understanding what makes the areas of the Lakes ecologically and biologically significant should help managers understand the relative importance of managing a species, habitat, or function within each area of the Lakes to achieve ecosystem objectives.

Table 36: Ecological and biological significance ranking of the bay-scale areas of the Bras d'Or Lakes watershed based on existing information.

EBSA Rank	Bay-scale Area	Total EBSA Score
1	St. Andrews	171
2	Great Bras d'Or Channel	148
3	North Basin	143
4	St. Patricks Channel	143
5	Denys Basin	140
6	East Bay	135
7	Bras d'Or Lake	129
8	West Bay	127
9	Whycocomagh Bay	112
10	St. Peters Inlet	98

The St. Andrews Channel was identified as the most ecologically and biologically significant area of the Lakes for a number of reasons, not all of which can be summarized here. Some of the characteristics include the unique deepwater habitat, the moderate level of dissolved oxygen at depth, the importance of nitrate and ammonia from the Channel to the productivity of the Lakes, the presence of arctic relic species, the high overall species diversity in the Channel, the potential importance as a cod overwintering area, the withdrawal of American plaice within the Lakes to the depths of the Channel, the unique low flushing period, and the diversity of such habitats as cliffs, barachois ponds, rocky shorelines, underwater outcrops, and the Little Bras d'Or Channel.

Although, the St. Andrews Channel ranked first in this EBSA process, it should be noted that both the North Basin and Great Bras d'Or Channel also were ranked relatively high. It is no surprise that of the ten bay-scale areas assessed, the three highest ranking areas are directly connected. Together they offer nearly all the diversity of habitats, species and functions that the Bras d'Or Lakes has to offer, and as such they support the most critical of species, habitats, and/or functions within the Lakes' ecosystem. Future management planning for the Bras d'Or must give special consideration to these areas in order to ensure the ecological integrity of the system as a whole is maintained.

In reflecting the character of the Bras d'Or Lakes through the EBSA process, all bay-scale areas north of the Barra Strait, with the exception of Whycocomagh Bay, ranked higher for ecological and biological significance than areas south of the Strait. This is largely a function of those habitat parametres that support basic production. Within the southern portion of the Lakes, however, Denys Basin and East Bay stand out as areas that support the more significant biological processes and unique or diverse habitats. Whycocomagh Bay is one of the more unique areas of the Lakes, yet it does not have the habitat diversity or qualities to support a diverse and productive biota as do the other areas north of Barra Strait. The enclosed nature of Whycocomagh Bay further limits the impact that it has on the Bras d'Or Lakes ecosystem as a whole.

19. 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 sub-watersheds). The Middle River sub-watershed has the largest amount of area in clearcut condition (518 ha), however this only amounts to 3% of the sub-watershed area managed by Stora Enso Port Hawkesbury, or 1.6% of the entire Middle River sub-watershed.

The greatest percentage of areas classified as urban are found in the Great Bras d'Or Channel, McKinnons Harbour and St. Andrews Channel sub-watersheds. The largest human settlements in the area are found in the East Bay, St. Andrews Channel and Baddeck sub-watersheds. The disparity between the sub-watersheds listed for high urban area and population centres (except the Bras d'Or Channel) is likely a result of small size of both McKinnons Harbour and St. Andrews Channel sub-watersheds.

Most of the mining activity (gravel pits, gypsum, marble) occurs in the Denys Basin sub-watershed, with a large gypsum operation also active in the St. Patricks Channel sub-watershed. Agricultural activity occurs mostly in the Middle River, St. Andrews Channel, and Whycocomagh sub-watersheds.

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 1990. 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.

A human activity matrix that attempts to quantify the level of human activities and resulting pressures occurring in each sub-watershed is presented in Appendix D.

Data and Information Gaps

It is difficult to come by data that can be queried by sub-watershed. Most statistics, particularly fisheries statistics, are kept either by county or management area. This renders the data ineffective for trying to understand the level of activity in only the Bras d'Or watershed or Lakes. Also, there is little to no information about the nearshore shallow marine environment. Multibeam mapping is only able to function in waters greater than 20 m deep, and the data gap from there to the water's edge still remains today.

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Appendix A: The EBSA Scoring Process

A Guide to the EBSA Scoring Process

Bras d'Or Lakes, Nova Scotia

Ecologically and Biologically Significant Areas

July 31st, 2005

Prepared by:

M. Parker[1]

Oceans and Coastal Management Division
Fisheries and Oceans Canada
P.O. Box 1006, B500
Dartmouth, NS
B3L 2Y9

Canada

[1] East Coast Aquatics Inc. P.O. Box 129 Bridgetown, Nova Scotia, B0S 1C0

1.0 Introduction

The process of identifying Ecologically and Biologically Sensitive Areas (EBSA) is generally outlined in a document produced by the Department of Fisheries and Oceans[28], referred to as the EBSA Identification Document or Identification Document herein. The process recommends completing a science-led evaluation of the area of interest that produces an output such as a quantitative or qualitative ranking of different areas relative to their biological or ecological significance. This document outlines how a manner of numeric scoring was applied to the Bras d'Or Lakes Ecosystem, augmented by a narrative that supports the scores applied. It is felt that this approach allows for discussion on individual points regarding relative scoring, and will allow for future re-evaluation as new research broadens our knowledge of the ecology of the Bras d'Or.

The Identification 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

Each of these is important to the application of the Identification Document, and is discussed here in the context of the Bras d'Or Ecosystem.

Identification of ecologically and biologically significant areas requires clear understanding of how term "significant" is being used. Species, habitat features, areas etc. that are significant are those that if they were perturbed severely, the ecological consequences would be greater 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 should not 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 2004).

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. However, the spatial scale for evaluation of EBSAs is critical, for interpretation of uniqueness, fitness consequences, and aggregation will vary based on the scale. For the purposes of the Bras d'Or Lakes EBSAs, evaluation has been carried out at the "bay- scale". This is a scale that appeared ecologically appropriate during the development of the overview report. It is a scale for which ecological boundaries appear to delineate the larger bays of the lakes, and for which reasonable amounts of scientific information with limited gaps can be assessed. At the "within bay-scale", smaller areas can be identified that have particularly unique ecological character, however, the information gaps at this level does not allow for adequate comparison and weighing of differences between geographic locations within the Lakes. Therefore, the bay-scale is the finest resolution

[28] Department of Fisheries and Oceans (DFO). 2004. *Identification of Ecologically and Biologically Significant Areas*. DFO Can. Sci. Advis. Sec. Ecosystem Status Rep. 2004/006.

supported by scientific literature upon which to base the identification of EBSAs. In terms of uniqueness and relative importance, evaluation was conducted on a "relative to the whole Bras d'Or ecosystem" spatial scale. For example, evaluating how important nutrient upwelling in North Basin is relative to the whole Bras d'Or system.

The process of identifying EBSAs is based on information currently available. As such it is only as good as the scientific knowledge we have at hand. Research in the Bras d'Or is ongoing on many fronts. Furthermore, other temporal changes such as climate change, shoreline development, and fishing efforts are likely to change existing qualities of the ecosystem. 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.

2.0 Application Steps of the EBSA Identification Document

Application of the Identification Document relative to the Bras d'Or was undertaken in a series of steps.

Step 1: *Review and Narrative* – Scientific knowledge of the Bras d'Or was compiled and reviewed. A Series of categories were established that reflected Species Use, Physical and Chemical Character, Sensitive/Limited Habitats, and Resource Use/Risk Factors. A total of some 25 feature headings were developed under these four categories. As documents were reviewed, relevant narration was added to each feature heading with a reference number to the source information.

Table 1. The four categories and 25 feature headings under which narration was compiled during the scientific review for the Bras d'Or Lakes Ecosystem overview.

Category	**Species Use**						
Feature	Periodic / Historic	Forage Area	Rearing Area	Key Breeding	At Risk Status		
Category	**Physical and Chemical Character**						
Feature	Biodiversity	Ecosystem Function	Nutrients	Anoxia	Mixing/ Stratification	Temperature / Salinity	Minerals and Metals
Category	**Sensitive Habitats**						
Feature	Hard Substrates	Barachois Ponds	Wetlands	Shoreline	Other Limited Habitat Type	Mature forest	
Category	**Resource Use / Risk Factors**						
Feature	Other Industrial	Land Clearing / Development	Shellfish Closures	Invasive Species	Rec. Use	Aquaculture	Commercial Harvest

The file containing the narrative is a MS Excel spreadsheet titled *EBSAs in Bras d'Or.xls*. The narratives in this file have reference numbers that correspond to those listed in the MSWord document *EBSA Ref list.doc*.

Step 2: *Spatial Definition* – In the case of the Bras d'Or, the Lakes were delineated at what has been referred to as the bay-scale. This scale was applied based on information reviewed during the first step that began to show what appeared to be reasonable ecological boundaries for which somewhat consistent levels of data existed for individual areas of the Bras d'Or Lakes. A finer resolution was not possible, for detailed information was missing for too many areas to adequately proceed with a weighting and evaluation process.

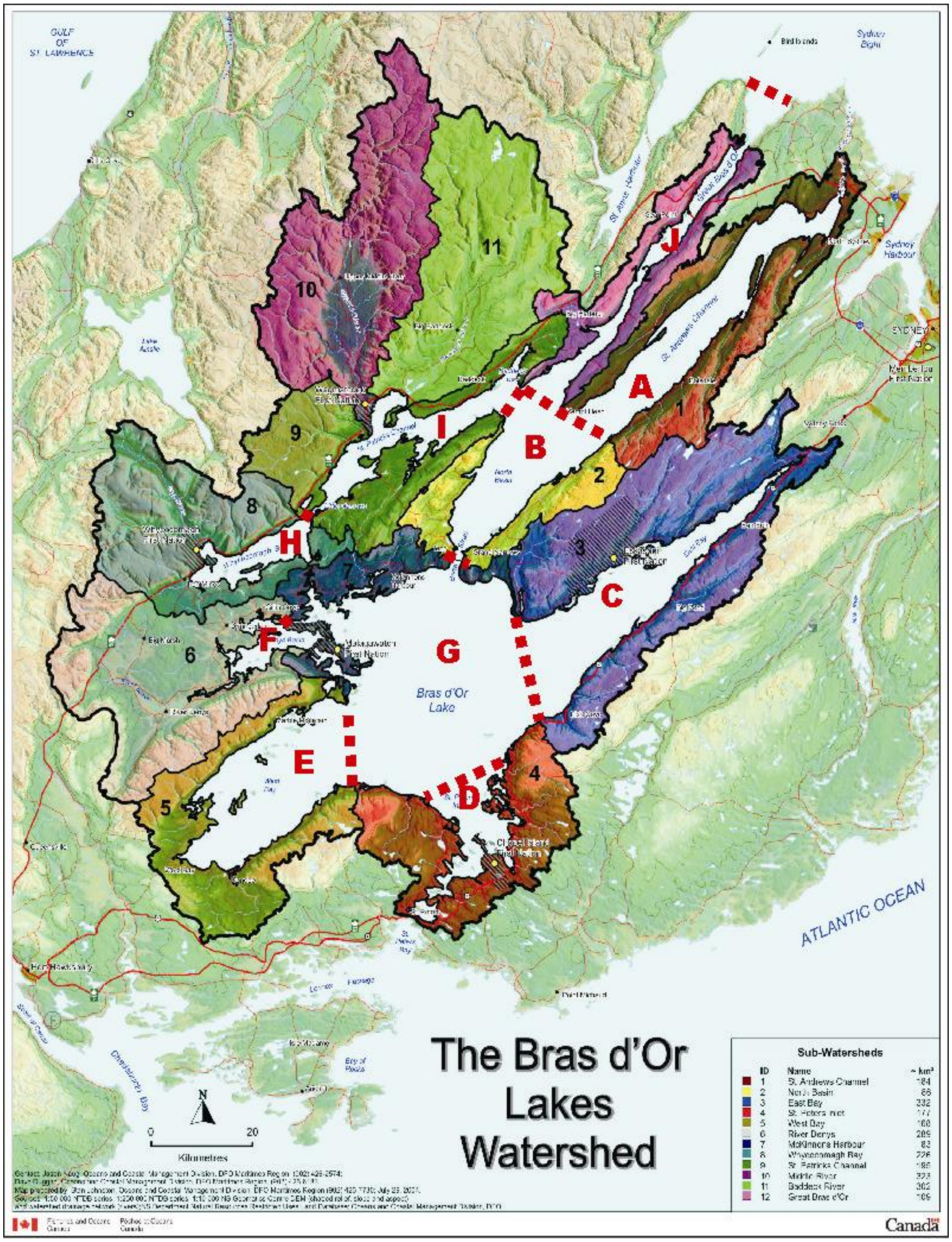


Figure 1: Bay-scale areas of the Bras d'Or Lakes and associated watershed sub basins.

Table 2. Bay-scale areas and associated sub-basin watersheds as identified in Figure 1.

Bay-scale Area	Letter ID	Associated Sub-Basins	Sub-Basin ID's
St. Andrews Channel	A	Numerous small watersheds	1
North Basin	B	Numerous small watersheds	2
East Bay	C	Benacadie River and numerous small watersheds	3
St. Peters Inlet	D	Numerous small watersheds	4
West Bay	E	Black River and numerous small watersheds	5
Denys' Basin	F	Denys River	6
Bras d'Or Lake	G	Numerous small watersheds	7
Whycocomagh Bay	H	Skye River	8
St. Patricks Channel	I	Humes, Middle, Baddeck, and Washabuck Rivers	9, 10, 11
Great Bras d'Or Channel	J	Numerous small watersheds	12

Step 3: *Quantitative Scoring* – This step involves providing a numeric score for the various narration found in each of the 25 feature headings for each spatially defined bay-scale area within the Bras d'Or. This step of the process, not specified in the EBSA Identification Document, is described in detail within this Guide.

Step 4: *Identification of EBSAs* – Once quantitative scoring is applied to the bay-scale areas and tallied, areas can then be ranked based on their relative biological and ecological significance. The ranking is not presented in numerical terms, although ranking is based on the scoring applied. Final scores, however, are not relevant as they are relative scores. Those areas with the highest ranking are the most ecologically and biologically significant to the Bras d'Or system.

Step 5: *Management Options* – Although human uses and related risks and threats do not determine EBSAs, they do affect how managers may make decisions regarding significant areas. Therefore, the same Steps 1-3 are carried out for the seven headings identified in the Resource Use/Risk Factors category. Numerical scores are applied and a total risk factor score tabulated. Managers can then consider the relative risks affecting each ranked EBSA within the Bras d'Or within their decision making process. A bay-scale area with a high EBSA rank and moderate risk factor score is more likely to be an area of management concern than an area with low ecological and biological significance and a moderate risk factor score.

3.0 Quantitative Scoring process

Step 3 of the EBSA Identification Document process is not fully defined in that document. Therefore, the process used in Bras d'Or needs documentation for future re-evaluation to occur in a consistent manner. This documentation is also meant to allow for better peer review of the process and discussion regarding specific points of scoring, by clarifying the approach used.

Each of the 25 feature headings for which narration was collected during the Step 1: Review and Narration for Bras d'Or now needed quantification. The Identification Document suggests that, " In real applications those conducting the evaluation would agree on a manner of scoring which would be augmented by the type of narrative presented…" The Identification Document provides five dimensions upon which such quantitative evaluation should occur. They are all defined in that document. The three main dimensions are:

- Uniqueness
- Aggregation
- Fitness Consequences

and the two additional dimensions for consideration are:

- Resilience
- Naturalness

As the main dimensions were recommended to be more heavily weighted than the additional dimensions they were given a scoring spread of 0-5 each where 0 is a low score and 5 is a high or important score. As weight was also to be given to spatial scope, scores for Uniqueness and Aggregation were 0-3 for local importance, and 4-5 for having regional or national scale importance. Fitness was a continuous 0-5 scale, and was spatially applied to what was known about a species population within the Bras d'Or. If it was a resident population, then fitness scores reflected that the whole population was more likely to be affected, whereas if it was a regionally migrating species that entered the Bras d'Or periodically or seasonally, fitness of the population would be less likely be impacted by local Bras d'Or changes.

Table 3. Scoring ranges and general score application guide for EBSA dimensions as applied to each feature heading.

Uniqueness 0-5	Aggregation 0-5	Fitness Consequences 0-5	Resilience 0-3	Naturalness 0-3	Total Score Per Feature Heading
0-3 Local 4 Regional 5 National	0-3 Local 4 Regional 5 National	0 does not affect pop. using Bras d'Or 5 dramatically affects pop. using Bras d'Or	0 Resilient 3 Sensitive	0 impacted 3 natural	0-21

The lesser two dimensions of Resilience and Naturalness, as defined in the Identification Document, were applied on a 0-3 point scale to each feature heading. For Resilience, 0 was equated with resilience and 3 with sensitivity or lack of resilience. Those areas that were most natural were scored a 3, whereas heavily human impacted areas or species might be scored a 0.

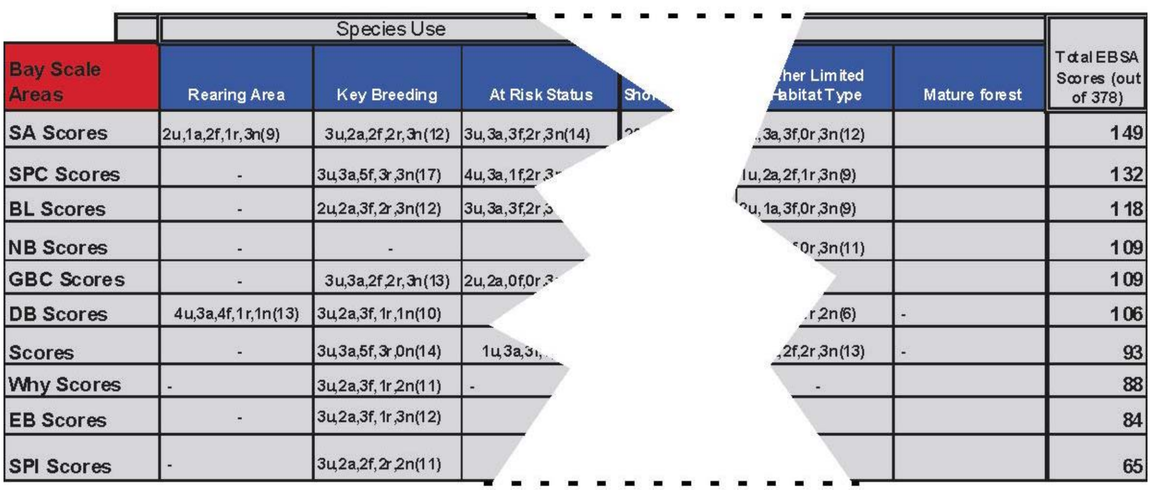
The score given for each dimension was recorded separately and then tallied by feature heading so that discussion could occur based on why a specific score was allocated to a particular dimension for a given feature in any of the bay-scale areas. They were recorded in the matrix as the score assigned followed by the letter denoting the relevant dimension. For, example "3u" for uniqueness. In this way, through peer review or periodic re-evaluation changes can accurately occur as necessary.

Table 4. Sample of the scoring matrix used for the five feature headings under the Species Use Category for Denys' Basin.

	Species Use				
Bay-scale Areas	**Periodic / Historic**	**Forage Area**	**Rearing Area**	**Key Breeding**	**At Risk Status**
Denys' Basin	Bobolink 88 &'90 breeding 3 birds, 90-99 cTern breeding on islands and mainland 1-36 pr.		highest oyster spatfall North Basin(34)	historic herring spawning(9); wild oyster spawn (7);	Wood turtle obs '65-'01 Vuln,
DB Scores	**-**	**-**	**4u,3a,4f,1r,1n(13)**	**3u,2a,3f,1r,1n(10)**	

Once the whole scoring matrix was completed, individual feature scores were tallied for each bay-scale area to provide a Total EBSA Score. This score consisted only of the quantitative scores applied to the Species Use, Physical and Chemical Character, and Sensitive Habitats categories. This approach again reflects the fact that risks and threats were not to be part of the process of identifying EBSAs. Theoretically, the score for each bay-scale area could range from 0 (if no narration or information existed) to 378 (if the highest score was assigned for every dimension) for each of the 17 feature headings under the three categories considered.

It is important to note that the scores assigned are much less important than the relative scores given between bay-scale areas. As long as the approach used is consistent, then the relative outcomes (EBSA rank by bay-scale area) will remain the same. Therefore, it is recommended that one person, or a consistent team of individuals assign all scores, so that relatively they are accurate. The result of the scoring matrix process is a final ranking of all ten bay-scale areas of the Bras d'Or Lakes from the most to least ecologically and biologically significant to the Bras d'Or Ecosystem.



	Species Use						
Bay Scale Areas	Rearing Area	Key Breeding	At Risk Status	Sho	her Limited Habitat Type	Mature forest	Total EBSA Scores (out of 378)
SA Scores	2u,1a,2f,1r,3n(9)	3u,2a,2f,2r,3n(12)	3u,3a,3f,2r,3n(14)		,3a,3f,0r,3n(12)		149
SPC Scores	-	3u,3a,5f,3r,3n(17)	4u,3a,1f,2r,3		1u,2a,2f,1r,3n(9)		132
BL Scores	-	2u,2a,3f,2r,3n(12)	3u,3a,3f,2r,3		u,1a,3f,0r,3n(9)		118
NB Scores	-	-			0r,3n(11)		109
GBC Scores	-	3u,3a,2f,2r,3n(13)	2u,2a,0f,0r,3				109
DB Scores	4u,3a,4f,1r,1n(13)	3u,2a,3f,1r,1n(10)			r,2n(6)	-	106
Scores	-	3u,3a,5f,3r,0n(14)	1u,3a,3		,2f,2r,3n(13)	-	93
Why Scores	-	3u,2a,3f,1r,2n(11)	-		-		88
EB Scores	-	3u,2a,3f,1r,3n(12)					84
SPI Scores	-	3u,2a,2f,2r,2n(11)					65

Figure 2. All dimensions for all features in each category for which there were bay-scale area narration get tallied to produce an overall EBSA score. The value of the score is irrelevant, it is the final ranking of bay-scale areas of the Bras d'Or that has significance.

Once the whole scoring matrix was completed, individual feature scores could also be tallied for each bay-scale area to provide a Total Risk Score. This score consisted only of the quantitative scores applied to the Resource Use/Risk Factors category. These scores did not add weight to assignment of EBSAs within the Bras d'Or, but do provide some measure to managers when considering options for each of the bay-scale areas identified. Theoretically, the Risk Factor score for each bay-scale area could range from 0 (if no narration or information existed) to 147 (if the highest score was assigned for every dimension) for each of the 7 feature headings under the Resource Use/Risk Factor category.

Appendix B: Final EBSA notation and scoring matrix

	Species Use					Physical and Chemical Character							Sensitive Habitats					
Bay-scale Areas	Periodic / Historic	Forage Area	Rearing Area	Key Breeding	At Risk Status	Biodiversity	Ecosystem Function	Nutrients	Mixing/ Stratification	Temperature/ Salinity	Minerals and Metals	Anoxia /Hypoxia	Hard Substrates	Barachois Ponds	Wetlands	Shoreline		Total EBSA Scores (out of 378)
St. Andrews Channel	1u1a1f1r 3n (7)	-	2u2a2f0r 3n (9)	2u2a3f0r 3n (10)	3u3a5f3r 3n (17)	3u2a4f2r 3n (14)	3u3a4f2r 3n (15)	3u3a5f0o 3n (14)	3u2a2f2r3 n (12)	1u2a2f0r3 n (8)	2u2a1f1r 3n (9)	3u2a3f0r 3n (11)	2u1a1f0r 2n (6)	1u2a1f0r 3n (7)	1u2a2f1r 3n (9)	2u2a2f0r 3n (9)		171
Grat Bras d'Or	1u1a1f1r 3n (7)	-	-	3u3a2f1r 3n (12)	3u3a4f3r 3n (16)	3u3a4f1r 3n (14)	3u3a3f1r 3n (13)	1u1a4f0r 3n (9)	3u3a4f0r3 n (13)	3u2a4f0r3 n (12)	2u1a1f1r 1n (6)	-	3u3a4f0r 3n (13)	2u2a2f1r 3n (10)	-	3u2a2f0r 3n (10)		148
North Basin	1u1a2f2r 3n (9)	-	-	-	2u1a1f2r 3n (9)	2u3a3f2r 3n (13)	3u2a4f2r 3n (14)	3u2a4f0r 3n (12)	3u3a5f0r3 n (14)	2u3a3f0r3 n (11)	-	3u2a4f0r 3n (12)	3u2a2f0r 3n (10)	1u2a1f0r 3n (7)	1u2a2f1r 3n (9)	3u2a2f0r 3n (10)		143
St. Patricks Channel	1u2a2f2r 3n (10)	-	-	3u3a4f3r 2n (15)	4u3a5f3r 2n (17)	2u2a2f2r 2n (10)	3u2a2f2r 3n (12)	3u2a4f1r 3n (13)	2u1a1f0r3 n (7)	3a3a2f0r3 n (11)	2u1a1f1r 2n (7)	-	-	1u1a1f1r 3n (7)	3u3a4f2r 3n (15)	2u1a2f1r 3n (9)		140
Denys Basin	2u2a2f2r 3n (11)	-	4u3a3f2r 2n (14)	3u4a3f2r 2n (14)	2u1a2f2r 2n (9)	2u2a2f2r 2n (10)	2u2a1f0r 2n (7)	2u1a4f2r 1n (10)	2u1a1f0r3 n (7)	3u2a2f0r3 n (10)	2u2a2f2r 2n (10)	-	2u1a2f1r 2n (8)	-	3u2a4f2r 3n (14)	1u0a1f1r 3n (6)		140
East Bay	1u1a2f2r 3n (9)	-	-	2u2a3f2r 3n (12)	2u1a1f1r 3n (8)	2u3a2f2r 3n (12)	2u2a2f1r 3n (10)	1u1a2f0r 3n (7)	2u1a1f0r3 n (7)	3u2a2f0r3 n (10)	2u2a3f2r 2n (11)	-	1u1a2f0r 3n (7)	2u2a2f2r 3n (11)	3u2a3f2r 3n (13)	2u1a1f0r 3n (7)		135
Bras d'Or Lake	1u1a2f2r 3n (9)	-	-	3u3a4f2r 3n (15)	1u2a1f2r 2n (8)	1u2a2f1r 3n (9)	2u2a2f2r 3n (11)	-	3u2a3f0r3 n (11)	3u1a2f0r3 n (9)	-	-	1u1a2f0r 3n (7)	1u2a1f2r 3n (9)	2u2a2f2r 3n (11)	3u2a2f0r 3n (10)		129
West Bay	3u2a4f2r 3n (14)	-	-	3u3a4f2r 3n (15)	3u3a3f2r 3n (14)	2u2a3f1r 3n (11)	2u2a1f0r 2n (7)	1u1a2f0r 3n (7)	1u1a1f0r3 n (6)	2u1a0f0r3 n (6)	-	-	2u3a2f0r 3n (10)	1u1a1f2r 3n (8)	2u2a2f2r 3n (11)	1u0a1f1r 3n (6)		127
Whycocomagh	-	-	-	3u3a3f2r 1n (12)	2u2a2f2r 3n (11)	2u1a1f1r 3n (8)	2u2a1f3r 3n (11)	3u2a3f1r 2n (11)	3u2a1f3r3 n (12)	2u1a2f0r3 n (8)	2u2a1f1r 3n (9)	3u3a3f0r 3n (12)	-	-	2u3a2f2r 3n (12)	1u0a1f1r 3n (6)		112
St. Peters Inlet	1u1a2f2r 3n (9)	-	-	2u1a2f2r 3n (10)	2u1a2f2r 2n (9)	2u2a2f2r 3n (11)	2u2a1f0r 2n (7)	2u1a3f2r 1n (9)	1u1a1f0r3 n (6)	2u1a3f0r1 n (7)	-	-	1u2a2f1r 3n (9)	1u1a1f1r 3n (7)	1u1a2f1r 3n (8)	1u0a1f1r 3n (6)		98

Appendix C: Stora Enso Special Management Areas

Stora Enso special management areas listed by sub-watershed, presented in hectares and (percentage of Stora Enso managed lands in each sub-watershed). Note that overlap occurs (e.g., significant habitat areas may also be deer wintering areas) so areas within sub-watershed cannot be totaled. Descriptions for each special management treatment described below, data provided by Stora Enso Port Hawkesbury.

Sub-watershed	Viewshed management	Significant habitat	Riparian zones	Recreation	Old forest	Connectivity mgmt zone	Marten mgmt 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 NS DNR. 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 metres 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 metres.
- **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 NS DNR 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 metres 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 NS DNR.

Appendix D: Matrix of Human Activity and Pressures

Sub-watershed	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 sub-watershed 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, read 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 sub-watershed has not been considered in this ranking scheme.