PART 1 of 2

LAKE SUPERIOR BINATIONAL PROGRAM

ECOSYSTEM PRINCIPLES AND OBJECTIVES FOR LAKE SUPERIOR

(UPDATED AND REVISED)

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prepared by the

Lake Superior Work Group

in partnership with

The Lake Superior Binational Forum

with consideration of comments obtained through public consultation in the Lake Superior Basin

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PREFACE

A VISION FOR LAKE SUPERIOR

*Endorsed by the Lake Superior Binational Forum on January 31, 1992
as an expression of the hearts and minds of all of us.*

As citizens of Lake Superior, we believe...

that water is life and the quality of water determines the quality of life.

We seek a Lake Superior watershed...

that is a clean, safe environment where diverse life forms exist in harmony; where the environment can support and sustain economic development and where citizens are committed to regional cooperation and a personal philosophy of stewardship;

that is free of toxic substances at levels that threaten fish, wildlife and human health; where people can drink the water or eat the fish anywhere in the lake without restrictions;

where wild shorelines and islands are maintained and where development is well planned, visually pleasing, biologically sound and conducted in an environmentally benign manner;

which recognizes that environmental integrity provides the foundation for a healthy economy and that the ingenuity which results from clean, innovative and preventive management and technology can provide an economic transformation for the region;

where citizens accept the personal responsibility and challenge of pollution prevention in their own lives and lifestyles and are committed to moving from a consumer society to a conserver society; and

where there is greater cooperation, leadership and responsibility among citizens of the basin for defining long-term policies and procedures which will protect the quality and supply of water in Lake Superior for future generations.

We believe that by effectively addressing the issues of multiple resource management in Lake Superior, the world's largest lake can serve as a worldwide model for resource management.

INTRODUCTION

In its fifth Biennial report on Great Lakes Water Quality (IJC 1989), the International Joint Commission recommended to Canada and the United States, as parties to the Great Lakes Water Quality Agreement (GLWQA), that Lake Superior receive designation as "a demonstration area where no point source of any persistent, toxic substance will be permitted". The parties responded to this recommendation by establishing the Binational Program to Restore and Protect the Lake Superior Basin. The Binational Program is committed to the zero discharge objective, and integrates this with a broader program to restore beneficial uses which have been lost, and to protect and restore ecosystem integrity in Lake Superior and its watershed. The Lake Superior Work Group (comprised of representatives from government environmental and natural resource agencies) and the Lake Superior Binational Forum (comprised of representatives from public and industry groups) were established to guide and implement the Binational Program.

A Vision for Lake Superior, which prefaces this document, expresses the commitment and desire of the Lake Superior community to foster a healthy, clean, and safe Lake Superior ecosystem. It reflects the diverse pathways and mechanisms by which humans and nature interact within land and water ecosystems, and challenges the inhabitants of the Lake Superior watershed to accept personal responsibility for protecting the Lake and the landscape that sustains it. The Vision Statement specifies broad, powerful objectives for the Lake Superior ecosystem, in plain language.

PURPOSE

The Ecosystem Principles and Objectives for Lake Superior Discussion Draft is intended to:

1) **expand the broad objectives of A Vision For Lake Superior into more specific ecosystem principles and objectives** for key elements of the Lake Superior ecosystem, including aquatic communities, terrestrial wildlife, habitat, human health, and sustainability. This discussion document will undergo basin-wide public review to refine these ideas, and to help develop broad community consensus regarding ecosystem principles and objectives for Lake Superior. Ecosystem principles and objectives developed by consensus do not obviate or override regulations, laws and guidelines set by governments and resource regulatory agencies. Rather, the Lake Superior Ecosystem Principles and Objectives have been prepared to encourage informed discussion of the vision and practice essential for proactive, sustainable management of the Lake Superior ecosystem.

2) **facilitate progress towards a set of informative ecosystem indicators, with quantitative targets**, by which the health of the Lake Superior basin ecosystem, including its physical, biotic and cultural elements, can be measured. This next step is primarily a technical process based on expert consultation, where indicators and targets will be identified through consideration of relevant ecological, economic and cultural data. The ecosystem indicators and targets will address the Lake Superior ecosystem principles and objectives, and will reflect practical constraints faced by agencies responsible for environmental monitoring in the Lake Superior basin.

3) **provide guidance for land and water management in the Lake Superior ecosystem.** Ecosystem Principles and Objectives for Lake Superior are intended to assist regulators, managers and publics who are working to sustain and rehabilitate this greatest of the Great Lakes. These principles and objectives will establish Lake Superior as an ecological mirror not only for the region, but for the biosphere, by helping to answer the question: "What must we do now to ensure the existence of an intact and healthy Lake Superior ecosystem 500 years from now?"

SCOPE AND BACKGROUND

Ecosystem principles and objectives must be formulated with reference to a spatial context for the term "ecosystem". Here, we adopt an ecosystem context that emphasizes land-water linkages in the Lake Superior watershed (also basin, catchment, or drainage), as specified in the 1978 Great Lakes Water Quality Agreement. For the purposes of this document, the Lake Superior ecosystem refers to the interacting components of air, land, water and living organisms, including humans, within the watershed of Lake Superior.

The IJC selected Lake Superior as a demonstration area because the lake and its watershed were in a relatively pristine state. Lake Superior's small, granitic watershed and deep lake basin make its waters clear and remarkably attractive. It's shores are sparsely populated in comparison with the other Great Lakes, and the physical structure of the coastal zone is largely unaltered by humans. However, casual examination of the crystal waters and scenic shorelines does not reveal important changes that have occurred in the lake and its watershed over the last 150 years or so. The Lake Superior basin contains eight of the 43 Great Lakes sites that have been identified by the International Joint Commission as environmental Areas of Concern. Although pollution control efforts over the last twenty years have improved environmental quality in these developed areas, they still fail to meet the environmental standards specified in the Great Lakes Water Quality Agreement. Control structures at the outflow of Lake Superior have affected wetland habitat in some shallow bays and the St. Marys River, by reducing water level fluctuations. Many of the largest and most productive bays and river mouths on Lake Superior have been degraded since the late 1800's by waste inputs, primarily from sawmills, pulp and paper mill effluents, mine tailings, municipal sewage, and charcoal, coal gasification and chemical plants (Ryder 1968; Lawrie and Rahrer 1973; Waters 1987; Botts, Krushelnicki et al. 1988). These effects resulted for the most part from resource extraction and associated land uses within the Lake Superior watershed.

Unfortunately, airborne contaminants coming from outside the basin are causing impacts of their own. Through its physical characteristics, Lake Superior is tightly linked to regional and global air pollution. The large surface area of the lake makes it a good collector and mobilizer of airborne contaminants through the organic "surface film" at the air-water interface (Eisenreich 1982). This surface film may be the largest single vector for contamination of Lake Superior. Once contaminants enter the lake, they tend to stay there for a long time. Lake Superior has a large volume and relatively small discharge, making the average residence time for dissolved or suspended contaminants about 200 years (Quinn 1992).

Fish populations in Lake Superior have undergone profound changes, and continue to change today. Although some of these changes are believed to have been a result of overfishing and introductions of exotic species such as sea lamprey, rainbow smelt, rainbow trout, Pacific salmon, ruffe, zebra mussel and rusty crayfish, the mechanisms are poorly understood, even today (Lawrie and Rahrer 1973; MacCallum and Selgeby 1987; Pratt et al. 1992; Hansen 1994). Some changes may become moderated over time, as native species exhibit population recovery. This is currently happening to varying degrees with lake trout, lake herring, siscowet and walleye.

There is a strong correlation between the intensity of industrial, agricultural, and urban land use, and the severity of ecosystem degradation in the Great Lakes. The shoreline and watershed of Lake Superior currently support a much lower density of human development and industry than the other Great Lakes. This accident of geography, climate, and land use, rather than any proactive planning, is the primary reason that the Lake Superior ecosystem is as healthy as it is. Industrial development, urban development, and natural resource exploitation are all likely to increase within the Lake Superior watershed. If the health of the Lake Superior ecosystem is to be protected and improved, the causal linkages between human activity and ecosystem degradation must be modified or severed. This will occur in many ways, including the implementation of new and existing technologies for waste treatment, through abandonment of inappropriate or unnecessary industrial processes, through development of new land uses in some areas, through modification of existing land uses in other areas, and through active rehabilitation of degraded ecosystem features.

Present Ecosystem Objective for Lake Superior

The Great Lakes Water Quality Agreement of 1978, as amended in 1987, specifies an ecosystem objective for Lake Superior. This objective is based on an indicator species concept developed and documented in Ryder and Edwards (1985). The GLWQA ecosystem objective for Lake Superior reads as follows, in the Supplement to Annex 1, item 3a:

> "The Lake should be maintained as a balanced and stable oligotrophic ecosystem with lake trout as the top aquatic predator of a cold-water community and the Pontoporeia hoyi as a key organism in the food chain"

The ecosystem health indicators and targets for this objective are also specified in the GLWQA, Annex 11, item 4a:

> "Lake Trout
>
> Productivity greater than 0.38 kilograms/hectare;
>
> Stable, self-producing stocks;
>
> Free from contaminants at concentrations that adversely affect the trout themselves or the quality of the harvested products.
>
> Pontoporeia hoyi (NOTE: now Diporeia hoyi)
>
> The abundance of the crustacean Pontoporeia hoyi, maintained throughout the entire lake at present levels of 220 - 320/(metres)2 (depths less than 100 metres) and 30 - 160/(metres)2 (depths greater than 100 metres)"

The indicator species approach adopted in the GLWQA is explicitly based on a historical, pristine benchmark (Ryder and Edwards 1985), and identifies a clear target and trajectory for rehabilitation of degraded ecosystem elements. However, the current indicators are of limited value in assessing ecosystem health in habitats other than the oligotrophic, open water portions of the lake, i.e. in nearshore areas such as embayments, river mouths and wetlands. In addition, an indicator species approach that focuses on only two species may not be reliably diagnostic of the cause of degradation. Ryder and Edwards (1985) anticipated these concerns, and recommended development of indicators representative of these other habitats, and representative of specific degradative mechanisms, where that is possible.

The Great Lakes Fishery Commission has published fish community objectives for Lake Superior (Busiahn 1990), with the following goal:

> "To provide fish communities, based on foundations of stable, self-sustaining stocks, supplemented by judicious plantings of hatchery-reared fish, and provide from these communities an optimum contribution of fish, fishing opportunities and associated benefits to meet needs identified by society for: wholesome food, recreation, employment and income, and a healthy human environment"

Fish community objectives are specified for forage fish, predators, other species, sea lamprey, and habitat. They focus on the importance of native, naturally reproducing fish communities, on the need to maintain sea lamprey populations at low levels, and on protection and restoration of habitats supporting Lake Superior fisheries.

ECOSYSTEM PRINCIPLES AND OBJECTIVES FOR LAKE SUPERIOR

In drafting the following ecosystem principles and objectives for Lake Superior, we have followed the lead of the Ecosystem Objectives Work Group developing ecosystem objectives and their environmental indicators for Lake Ontario (Bertram and Reynoldson 1992). In most cases we have modified or expanded the Lake Ontario objectives to address the extremely high standards of protection and rehabilitation that have emerged from the Binational Program to Restore and Protect the Lake Superior Basin. The ecosystem principles and objectives presented in this document are intended to be compatible with, and complementary to the existing ecosystem objectives adopted by the Great Lakes Water Quality Agreement and the Great Lakes Fishery Commission.

1) General Objective

Human activity in the Lake Superior basin should be consistent with A Vision For Lake Superior, which prefaces this document. Future development of the basin should protect and restore the beneficial uses described in Annex 2 of the Great Lakes Water Quality Agreement.

2) Chemical Contaminants Objective

Summary

Levels of persistent, bioaccumulative toxic chemicals should not impair beneficial uses of the natural resources of the Lake Superior basin. Levels of chemical contaminants which are persistent, bioaccumulative and toxic should ultimately be virtually eliminated in the air, water and sediment in the Lake Superior basin.

Sub-Objectives: Sources

a) Per the Binational Program to Restore and Protect the Lake Superior Basin, the management goal for the nine designated persistent, bioaccumulative toxic chemicals is zero discharge and zero emission from sources within the Lake Superior basin.

b) Per the Great Lakes Water Quality Agreement, atmospheric deposition of persistent, bioaccumulative toxic chemicals that have an anthropogenic origin should be virtually eliminated.

Sub-Objectives: Environmental Impacts*

c) Open lake concentrations of the chemicals in the zero discharge and zero emission category or the lakewide remediation category should not exceed the most sensitive yardstick of environmental quality (Smith and Smith, 1993).

d) Concentrations of zero discharge and lakewide remediation chemicals in sediment in nearshore areas (<80m.), and in harbors and bays, should not cause or contribute to impaired uses in the Lake Superior ecosystem. Concentrations of local remediation chemicals in sediment should not impair uses in Areas of Concern in the Lake Superior basin.

e) Concentrations of the chemicals in the prevention/monitor category should not increase in air, water or sediment.

f) Initially, the presence of chemicals in the prevention/investigate category should be investigated in the ambient environment, in the appropriate media and location(s). In addition, sources of the chemicals in the prevention/investigate category should be identified and the presence or absence of these sources in the basin should be confirmed. Presence of a source should trigger continued monitoring of the media most likely to concentrate the chemical.

*note: see Sections 4.4.5 and 5.3 regarding concentrations of the nine designated zero discharge pollutants in fish and wildlife tissue

3) Aquatic Communities Objective

Summary

Lake Superior should sustain diverse, healthy, reproducing and self-regulating aquatic communities closely representative of historical conditions.

Sub-Objectives

a) Lake trout will continue to be recognized as a valuable integrators and indicators of the health of the Lake Superior ecosystem. Other aquatic species may also prove useful as ecosystem health indicators for the Lake Superior basin.

b) Native aquatic species associations will be recognized as key elements of a healthy Lake Superior ecosystem.

c) Aquatic biota living in the Lake Superior ecosystem should be free from contaminants of human origin.

d) Exotic fish species now present in Lake Superior (including rainbow trout, Pacific salmon and brown trout) should be managed in a way that is compatible with restoration and management goals established for native fish species by the Lake Superior Committee.

e) New exotic or nuisance species must not be intentionally or unintentionally introduced to waters of the Lake Superior ecosystem; accidental introductions of exotic species should be eliminated through effective use of regulatory and technological preventative measures. The use of live bait by anglers must not contribute to the dispersal of exotic species or genetic stocks.

4) Terrestrial Wildlife Objective

Summary

The Lake Superior ecosystem should support a diverse, healthy, reproducing and self-regulating wildlife community closely representative of historical conditions.

Sub-Objectives

a) Bald eagle populations that nest within the Lake Superior ecosystem should be recognized as valuable integrators and indicators of the health of the Lake Superior ecosystem. Other wildlife species may also prove useful as ecosystem health indicators for the Lake Superior basin; research addressing this possibility should be given high priority by agencies and institutions in the Lake Superior basin.

b) Native wildlife will be recognized as key elements of a healthy Lake Superior ecosystem.

c) Wildlife living in the Lake Superior ecosystem should be free from contaminants of human origin.

d) Management of game species and their habitat should not be detrimental to native and naturally occurring non-game wildlife species.

5) Habitat Objective

Summary

Extensive natural environments such as forests, wetlands, lakes and watercourses, are necessary to sustain healthy native animal and plant populations in the Lake Superior ecosystem, and have inherent spiritual, aesthetic and educational value. Land and water uses should be designed and located in harmony with the protective and productive ecosystem functions provided by these natural landscape features. Degraded features should be rehabilitated or restored where this is beneficial to the Lake Superior ecosystem.

Sub-Objectives

a) The ecological health of Lake Superior is determined in large part by the health of its tributary lakes and rivers. Land use planning and regulation in the Lake Superior ecosystem should eliminate or avoid destructive land-water linkages (e.g. erosion of agricultural land, urban stormwater, point and non-point sources of persistent contaminants), and foster healthy land-water linkages (e.g. continuous streamside vegetation buffers, on-site treatment of runoff).

b) The long-term consequences of incremental or cumulative landscape change, habitat destruction, and habitat fragmentation should be anticipated and avoided in the Lake Superior ecosystem, through research and planning at appropriate spatial and temporal scales.

c) The crucial importance of nearshore, shoreline and wetland aquatic habitats in Lake Superior should be addressed through continuing efforts to identify, protect and restore key sites for reproduction and rearing of fish, water birds, mammals, other wildlife and plants.

6) Human Health Objective

Summary

The health of humans in the Lake Superior ecosystem should not be at risk from contaminants of human origin. The appearance, taste and odour of water and food supplied by the Lake Superior ecosystem should not be degraded by human activity.

Sub-Objectives

a) Fish and wildlife in the Lake Superior ecosystem should be safe to eat; consumption should not be limited by contaminants of human origin.

b) Water quality in the Lake Superior ecosystem should be protected where it is currently high, and improved where it is degraded. Surface waters and groundwater should be safe to drink after treatment to remove natural impurities and microorganisms.

c) The waters of Lake Superior should be safe for total body contact activities, even adjacent to urban and industrial areas.

d) Air quality in the Lake Superior ecosystem should be protected where it is currently high, and improved where it is degraded. Communities, industries and regulators outside the Lake Superior ecosystem should be informed of the consequences of long-range atmospheric transport of contaminants into the Lake Superior basin.

e) Soils in the Lake Superior ecosystem should not present a hazard to human health through direct contact, dust inhalation or ingestion, groundwater contamination, or crop contamination.

7) Developing Sustainability

Summary

Human use of the Lake Superior ecosystem should be consistent with the highest ethical and scientific standards for sustainable use. Land, water and air use in the Lake Superior ecosystem should not degrade it, nor any adjacent ecosystems. Use of the basin's natural resources should not impair the natural capability of the basin ecosystem to sustain its natural identity and ecological functions, nor should it deny current and future generations the benefits of a healthy, natural Lake Superior ecosystem. Technologies and development plans that preserve natural ecosystems and their biodiversity should be encouraged.

Sub-Objectives

a) Public and private decisions will be right when they tend to preserve the integrity, stability, and beauty of the biotic community (Leopold 1966).

b) The Lake Superior ecosystem provides resources and services to humans. These include water, fibre, minerals, energy, waste transport and treatment, food, recreation, and spiritual sustenance. These resources and services should be valued as environmental capital, in the same way that other capital is assigned value.

c) Institutional capacity to integrate technology and sustainable design should be developed within the Lake Superior ecosystem.

d) The basis for guiding sustainable development at the scale of the Lake Superior ecosystem should be the pattern of land, water and air use, as these affect ecological, social and economic processes.

These principles and objectives for developing sustainability are based on scientific, ethical and environmental planning concepts from a number of sources, including: Lee et al. 1992; Architects for Social Responsibility 1991; Ecological Society of America 1991; UNCED 1992; and Government of Canada 1990).

REFERENCES

Architects for Social Responsibility. 1991. A sourcebook for environmentally responsible design. Boston Society of Architects. 33p.

Bertram, P.E. and T.B. Reynoldson. 1992. Developing ecosystem objectives for the Great Lakes: policy, progress and public participation. Journal of Aquatic Ecosystem Health. 1:89-95.

Botts, L., B. Krushelnicki et al. 1988. The Great Lakes: an environmental atlas and resource book. Environment Canada (Toronto, Ontario) and U.S. EPA (Chicago, Illinois). 44p.

Busiahn, T.R. (ed.). 1990. Fish community objectives for Lake Superior. Great Lakes Fishery Commission Special Publication 90-1. Great Lakes Fishery Commission, Ann Arbor, Michigan. 23p.

Ecological Society of America. 1991. A sustainable biosphere: the global imperative. International Association of Ecology, Ecology International. 1991:20.

Eisenreich, S.J. 1982. Overview of atmospheric inputs and losses from films. Journal of Great Lakes Research. 8(2):241-242.

Government of Canada. 1990. Canada's Green Plan. Minister of Supply and Services, Canada. 174p.

Hansen, M.J. (ed.). 1994. The state of Lake Superior in 1992. Great Lakes Fishery Commission Special Publication 94-1. Great Lakes Fishery Commission, Ann Arbor, Michigan. 110p.

IJC. 1989. Fifth biennial report on Great Lakes water quality. International Joint Commission, Windsor, Ontario. 20p.+ 59p.

Lawrie, A.H., and J.F. Rahrer. 1973. Lake Superior: a case history of the lake and its fisheries. Great Lakes Fishery Commission Technical Report No. 19. Great Lakes Fishery Commission, Ann Arbour, Michigan. 69p.

Lee, R.G., R. Flamm, M.G. Turner, C. Bledsoe, P. Chandler, C. DeFerrari, R. Gottfried, R.J. Naiman, N. Schumaker, and D. Wear. 1992. Integrating sustainable development and environmental vitality: a landscape ecology approach. p. 499-521. In Naiman, R.J. (ed.) Watershed management: balancing sustainability and environmental change. Springer Verlag, New York, New York. 542p.

Leopold, A. 1966. A sand county almanac. Ballentine Books, New York, New York. 295p.

MacCallum, W.R., and J.H. Selgeby. 1987. Lake Superior revisited 1984. Canadian Journal of Fisheries and Aquatic Sciences. 44(Suppl. 2):23-36.

Pratt, D.M., W.H. Blust, and J.H. Selgeby. 1992. Ruffe, Gymnocephalus cernuus, newly introduced in North America. Canadian Journal of Fisheries and Aquatic Sciences. 49:1616-1618.

Quinn, F.H. 1992. Hydraulic residence times for the Laurentian Great Lakes. Journal of Great Lakes Research. 18(1):22-28.

Ryder, R.A. 1968. Dynamics and exploitation of mature walleyes (Stizostedion vitreum vitreum) in the Nipigon Bay region of Lake Superior. Journal of the Fisheries Research Board of Canada. 25:1347-1376.

Ryder, R.A., and C.J. Edwards (ed.) 1985. A conceptual approach for the application of biological indicators of ecosystem quality in the Great Lakes basin. Report to the Great Lakes Science Advisory Board of the International Joint Commission, Windsor, Ontario. 169p.

UNCED. 1992. The global partnership for environment and development: a guide to Agenda 21. United Nations Development Programme. 116p.

Waters, T.F. 1987. The Superior north shore. University of Minnesota Press, Minneapolis, Minnesota. 361p.

PART 2 of 2

CANDIDATE ECOSYSTEM INDICATORS AND TARGETS

as measurements of progress towards

Ecosystem Principles and Objectives for Lake Superior

DRAFT: May 4, 1998

Drafted in accordance with guidelines provided by the Binational Program to Restore and Protect Lake Superior.

TABLE OF CONTENTS

1.0 Introduction

This document was prepared to address Purpose 2) from the Lake Superior Ecosystem Principles and Objectives:

> *"facilitate progress towards a set of informative ecosystem **indicators**, with quantitative **targets**, by which the health of the Lake Superior basin ecosystem, including its physical, biotic and cultural elements, can be measured. This step is primarily a technical process based on expert consultation, where indicators and targets will be identified through consideration of relevant ecological, economic and cultural information. The ecosystem indicators and targets will address the Lake Superior ecosystem principles and objectives, and will reflect practical constraints faced by agencies responsible for monitoring in Lake Superior basin. Concepts and products developed by the Ecosystem Objectives Work Group for Lake Ontario (Bertram and Reynoldson 1992), and other initiatives, will be used in this exercise"*

In mid-1994, interested subgroups and partners of the Lake Superior Work Group were invited to draft ecosystem indicators and targets relevant to their areas of expertise. The writing teams were invited to consult with other experts as required, and to focus on simple, easily communicated indicators of the complex ecological and cultural phenomena referred to in the Lake Superior Ecosystem Principles and Objectives. The ecosystem indicators and targets were intended to be:

- relevant to the ecosystem objectives established in the discussion paper Ecosystem Principles and Objectives for Lake Superior;

- scientifically credible, and prepared in the context of the recent scientific literature on ecosystem monitoring;

- simple, yet reliable for their stated purpose;

- thoroughly documented with regard to purpose, technical characteristics, limitations, and interpretation;

- suitable for serious consideration by U.S. and Canadian agencies with a mandate for environmental monitoring;

The writing teams adopted the format used by the U.S. EPA's Chesapeake Bay Program. This format was developed to communicate environmental monitoring information to environmental managers and to the public through periodic newsletters and press releases. Included is a display of the current data (or trend) in a graphical form, a clear display of the reference or target value (or range) to be achieved, some interpretive statements about the present status of the indicator and what it tells us about progress being made toward the ecosystem objectives, and a graphic to indicate at which level of the spectrum the indicator is located. See the Background sections for each Objective, and Appendix 1 for more information.

The reader should remember that the objective of this document was to make a good first attempt at specifying ecosystem indicators and targets for the Lake Superior basin. Further development of these indicators will require information and expertise of an increasingly technical nature. This document will have been successful if the compilation of potential indicators and targets provides a reliable starting point for discussion and iterative refinement by the agencies and individuals responsible for ecosystem monitoring in the Lake Superior basin. Through its subcommittees, the Superior Work Group will continue to provide a forum for the communication and integration of these activities.

2.0 Indicators and Targets for the General Objective

2.1 Incorporation of Lake Superior Ecosystem Principles and Objectives into regional planning at the scale of the Lake Superior basin.

A. Ecosystem objective addressed by this indicator:

General Objective *"Human activity in the Lake Superior basin should be consistent with A Vision For Lake Superior, which prefaces this document. Future development of the basin should protect and restore beneficial uses as identified in Annex 2 of the 1978 Great Lakes Water Quality Agreement."*

B. Purpose or Nature of the indicator:

The very broad scope of the General Objective (e.g. "human activity in the Lake Superior Basin", and "Future development of the basin") precludes direct measurement of its achievement. Targets and indicators for other Lake Superior ecosystem objectives will address important individual components of the General Objective. Therefore, an "activity measure" that measures formal or informal incorporation of the General Objective into planning activities in the basin is recommended as an indicator of progress under this objective.

C. Features of the indicator:

Through direct contact on behalf of the Lake Superior Binational Program, State, Provincial, First Nations and Municipal governments in the Lake Superior basin would be requested to formally adopt the Lake Superior Ecosystem Principles and Objectives, as an element of land use planning and regulation in the Lake Superior basin. "Adoption" would constitute a formal commitment by a government body to test plans and regulations relating to land use activities in the Lake Superior basin against the intent of the General Objective, including relevant elements of the Vision for Lake Superior, and Annex 2 of the 1978 Great Lakes Water Quality Agreement (appended below). The terms of the formal commitment would reflect a general intent to plan land use in the basin in a way that recognizes the objectives of the Binational Program. An example of this type of agreement, from the Grand Traverse Bay Watershed Initiative (an embayment and its watershed on the northeastern part of Lake Michigan) which has been signed by more than 130 partners, is also appended.

The **indicator** would be a count of the proportion of relevant agencies and bodies in the Lake Superior basin that have agreed to participate in the restoration and protection of the Lake Superior ecosystem, as outlined above. The **target** would be 100%. This approach could also be attempted with agencies outside of the basin, with regard to long-range transport of pollutants.

An alternative or supplementary indicator could be generated in the form of a "report card" evaluating progress towards the various elements of the Vision for Lake Superior. Input for the report card could be solicited from members of the Binational Forum or from independent observers of the Binational Program.

D. Illustration of the indicator:

Progress with acceptance of the General Objectives could be illustrated as a pie chart of "% acceptance"; as a simple graph of "% acceptance" vs. time, or as a basin map showing jurisdictions who have agreed to accept the challenge of the General Objective.

E. Limitations and uncertainties:

1) It will require a substantial, coordinated effort to solicit this kind of participation at the scale of the whole basin; 2) Municipalities and regulatory agencies may be unwilling to undertake any kind of formal agreement relating to the General Objective; 3) even if the General Objective is adopted in principle by a municipality or agency, it will be difficult to measure the practical results at the scale of the Lake Superior basin.

F. Interpretation of the indicator:

This indicator will index the willingness of basin leaders to express their acceptance of the concepts and attitudes advocated by the Binational Program.

2.2 Data trends and participation levels in Superior Lakewatch, a program to monitor water clarity in Lake Superior

A. Ecosystem objectives addressed by this indicator:

General Objective, plus elements of **Aquatic Communities Objective**, **Habitat Objective**, and **Developing Sustainability Objective.** The goals of Lakewatch, i.e., monitoring of Lake Superior waters by citizens, address several elements of "A Vision For Lake Superior", particularly those relating to the pursuit of environmental integrity through the commitment and involvement of citizens of the Lake Superior Basin.

B. Purpose or nature of the indicator:

In 1990, Superior Lakewatch was organized with these major goals in mind:

1. To obtain long-term water quality data that is currently lacking from Lake Superior, and in the process...

2. Create a basin wide network of citizen volunteers, professionals and scientists of this region who are linked via newsletters and,

3. Through use of educational programs enhance awareness of Lake Superior problems and challenges of the future.

C. Features of the indicator:

The secchi disk is an accurate, easily used, and widely accepted tool for measuring the transparency of lake water (See Megard & Berman, 1989, J. Limnol. Oceanogr, 3:1640-1655). Secchi disk data is robust in that it is very easy to collect, and errors in readings are rare. Secchi disk measurements integrate several aspects of a lake's water quality, and have been used to establish lake basin development policy (Example, Lake Tahoe: see Goldman, 1993, Verh. Internat. Verein. Limnol. 25:388-391.)

Water transparency, as indexed by secchi disk data collected through the Lakewatch Program, are collected on a basin wide scale. The data reflect nearshore (eg. land erosion, stream turbidity) and offshore processes (eg. primary productivity levels, or current patterns). Superior Lakewatch, as a binational volunteer organization designed to collect this information, fosters citizens' stewardship of Lake Superior, and provides a network system for stewardship activities.

Superior Lakewatch is organized around citizen volunteers, who collect secchi disk data from sites within Lake Superior. Such volunteer programs have been highly successful in Wisconsin (DNR) and Minnesota (MPCA); Superior Lakewatch is the only program on any of the Great Lakes. This network provides a communication link among the states and Canada, which (in addition to providing valuable water quality data) can be exploited for educational purposes. The program is unique for the Great Lakes in that it couples public education/participation to scientific goals.

The scope of Superior Lakewatch is broad; it has the support of 15 state and federal agencies including the Canadian Park Service, U. S. National Park Service, Environment Canada, Ontario Ministry of Natural Resources, Sea Grant Programs from Wisconsin, Michigan and Minnesota, and the DNR agencies from these states, and the Great Lakes Indian Fisheries Commission. The program is run and administered through the Lake Superior Center in Duluth by a project coordinator. The coordinator provides informational materials on the program, develops and prints the training manual, and provides a communication link among trainers and the citizens conducting the monitoring. Regional coordinators from Sea Grant Agencies in Minnesota, Michigan, Wisconsin and the Ontario Ministry of the Environment train, collect, and screen data from volunteers in their regions. A scientific advisory group consisting of Mel Whiteside (University of Minnesota--Duluth), Mary Balcer (University of Wisconsin--Superior), and Charles Kerfoot (Michigan Tech) oversee the project.

The **targets** for this indicator could include:

1) establish a secchi disk data set for Lake Superior of at least 10 years duration;
2) involve at least 75 volunteers in the Superior Lakewatch program each year;
3) produce at least three newsletters annually summarizing Lakewatch activities.

D. Illustration of the indicator:

Secchi disk data can be illustrated in a variety of ways, including graphs of secchi depth with time, or as histograms associated with maps of sample locations.

E. Limitations and uncertainties:

Secchi disk data is most useful in the form of long-term records. There are several "local" factors that can affect readings on any particular date, but this variation is averaged out when long-term data sets are gathered. A data set of less than 5 years has marginal usefulness; 10-15 years would constitute a valuable data set. Secchi disk data gives no information regarding pollutants, unless they are reflected in water transparency.

F. Interpretation of the indicator:

Changes (decreases in water transparency) can be detected, but the cause of changes have to be identified by other means. Loss in transparency can indicate increased eutrophication, or turbidity increases due to erosional processes. If we apply the stewardship objective to the program, then measures of volunteer activities could be an indicator of stewardship commitment in the basin.

2.3 Attachments

2.3.1 Excerpt from Annex 2, 1978 Great Lakes Water Quality Agreement

"Impairment of beneficial use(s)" means a change in the chemical, physical or biological integrity of the Great Lakes System sufficient to cause any of the following:

i) Restrictions on fish and wildlife consumption;

ii) Tainting of fish and wildlife flavour;

iii) Degradation of fish and wildlife populations;

iv) Fish tumours and other deformities;

v) Bird or animal deformities or reproductive problems;

vi) Degradation of benthos;

vii) Restrictions on dredging activities;

viii) Eutrophication or undesirable algae;

ix) Restrictions on drinking water consumption, or taste and odour problems;

x) Beach closings;

xi) Degradation of aesthetics;

xii) Added costs to industry of agriculture;

xiii) Degradation of phytoplankton and zooplankton populations; and

xiv) Loss of fish and wildlife habitat.

2.3.2 Grand Traverse Bay Watershed Initiative partnership agreement

GRAND TRAVERSE BAY WATERSHED INITIATIVE
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Protecting Our Quality Resources for Future Generations
PARTNERSHIP AGREEMENT

This document serves as a partnership agreement between various units of government, education, economic development groups, special interest groups and private sector organizations interested in the future of the Grand Traverse Bay Watershed region.

The parties committed to this partnership are united by a mutual concern for the protection of the integrity of the Grand Traverse Bay Watershed for quality use by future generations. The parties recognize that the region`s future quality of life and economic health are dependent on the maintenance and sustainability of the natural resources of the Grand Traverse Bay Watershed.

Background

Grand Traverse Bay is a unique resource to the Great Lakes and to the State of Michigan. The Bay is unique because it is one of the few remaining Great Lakes bays which exist in a relatively unpolluted condition. The Bay has 132 miles of shoreline, is over 600 feet deep in the East Arm, and contains 39 species of fish. The Grand Traverse Bay Watershed encompasses approximately 973 square miles and includes parts of five counties (Grand Traverse, Antrim, Leelanau, Kalkaska & Charlevoix). The Bay can also be viewed as a model of the whole of Lake Michigan (having a populated urban area at its southern end).

Vision

"The ecological integrity of the Grand Traverse Bay Watershed
will be sustained or restored to ensure regional economic
viability and quality use by future generations."

Action

We the undersigned, considering the best interest of the water, natural resources, and the future development of the region, mutually agree to fully cooperate and to provide technical and financial assistance, as available, to support the multi-year Grand Traverse Bay Watershed Initiative. Coordination of the initiative will be accomplished jointly through the Grand Traverse Bay Watershed Initiative Steering Committee, comprised of members signing this partnership agreement.

3.0 INDICATORS AND TARGETS FOR THE CHEMICAL CONTAMINANTS OBJECTIVE

3.1 BACKGROUND

In 1987, the Great Lakes Water Quality Agreement (GLWQA) committed the US and Canada to virtually eliminate persistent toxic substances in the Great Lakes system. In response to a challenge to the Parties from the IJC, the governments announced the Binational Program to Restore and Protect the Lake Superior Basin in 1991. The Lake Superior binational program includes a Zero Discharge Demonstration Project for nine designated chemicals[1] and provides for a Lakewide Management Plan (LaMP) for critical chemicals in Lake Superior.

In the Stage 1 LaMP, the Parties summarized information on the levels of contaminants in fish, water, sediment and wildlife. These levels were compared against the “yardsticks” that were compiled in Smith and Smith (1993). Beneficial use impairments at the Areas of Concern in Lake Superior were also summarized in the Stage 1 LaMP (SWG, 1995). The Parties also compiled lists of high priority toxic chemicals from the US and Canada.

After analyzing this information, the Parties developed several categories based on the concentration and toxicity of the persistent, bioaccumulative substances found in Lake Superior and the use impairments they caused. A description of the chemical categorization process is included in the Stage 1 LaMP (SWG, 1995) and summarized in the draft Stage 2 LaMP (SWG, 1996). The nine designated zero discharge and zero emission chemicals have the highest priority for reduction in Lake Superior.

One characteristic of persistent, bioaccumulative toxic chemicals in Lake Superior is that most of them have a large loading from atmospheric deposition. Since much of this deposition comes from sources outside the Lake Superior basin, programs that cover a broader area than the LaMP are needed to virtually eliminate inputs per the GLWQA. This is the purpose of the Great Lakes Binational Toxics Strategy, which was signed by the US and Canada in April 1997. In addition, U.S. states and Ontario are embarking on a variety of toxics reduction strategies throughout their jurisdictions.

The following indicators for the chemical contaminants ecosystem objective are designed to track inputs of persistent, bioaccumulative chemicals to the air, water and sediment of the Lake Superior basin. There are also indicators for sources of these chemicals in the basin. Indicators for levels of these chemicals in fish, wildlife and humans are included under the aquatic community, terrestrial wildlife and human health objectives.

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[1] The nine designated zero discharge chemicals include chlordane, DDT, dieldrin, dioxin, hexachlorobenzene, mercury, octachlorostyrene, PCBs, and toxaphene

3.2 PROGRESS TOWARDS ZERO DISCHARGE AND ZERO EMISSION

A. Ecosystem objective addressed by indicator:

Chemical Contaminants Objective Summary Objective and Sub-Objective a) *"Per the Binational Program to Restore and Protect the Lake Superior Basin, the management goal for the nine designated persistent, bioaccumulative toxic chemicals*[2] *is zero discharge and zero emission from sources within the Lake Superior basin."*

B. Purpose or nature of indicator:

The Lake Superior Binational Program includes a goal of "zero discharge and zero emission of certain designated persistent, bioaccumulative toxic chemicals which may degrade the ecosystem of the Lake Superior basin." Nine chemicals have been designated for zero discharge in the agreement. This zero discharge demonstration arises from the Great Lakes Water Quality Agreement, which notes that zero discharge is "the philosophy adopted for the control of inputs of persistent toxic substances." The indicator for progress towards zero discharge and zero emission is the trend in releases of the nine chemicals from sources within the basin.

C. Features of the indicator:

While the ultimate indicator of trends for the nine zero discharge chemicals will be the levels in water, fish, sediment and other compartments in the ecosystem, the indicators of progress towards zero discharge must be linked to sources. The effect of achieving zero discharge from sources in the basin will probably be masked by the atmospheric loading from sources outside the basin, the persistent nature of these chemicals and natural sources. Therefore, progress on the zero discharge demonstration cannot be tracked adequately by environmental indicators.

Instead, the zero discharge indicators will be a series of measurements and estimates of the release of chemicals from sources in the basin. Many of the zero discharge chemicals are used or produced in various ways that can lead to eventual release to the environment through several pathways. Ideally, measurements of releases from facilities that discharge to air or water could be used as indicators of progress towards the zero discharge/zero emission objective. However, these measurements are often lacking or inadequate. In addition, the focus of the Lake Superior zero discharge demonstration program is on human activities that use or generate these chemicals, not simply treatment at the end of a pipe or stack. If these chemicals and their precursors are not used in processes or products, they cannot be released to the environment. The baseline year established in the LaMP Stage 2 load reduction schedules for these indicators is 1990 for mercury, PCBs, dioxin, hexachlorobenzene, designated pesticides and octachlorostyrene (SWG, 1998).

D. Illustration of the indicator:

A variety of zero discharge indicators are under discussion. The background and references for most of these indicators are discussed in the load estimate documents that Canada and the US prepared for the Stage 2 LaMP (Thompson, 1994 and Tetra Tech, 1995). This document presents a menu of possible indicators with which to judge progress of the zero discharge demonstration program for Lake Superior. More work and consideration will be needed to further define the usefulness of these other potential indicators for sources of zero discharge chemicals. Because direct measurement is often not possible, some indicators may be surrogates. Possible indicators (in no particular order) include the following:

- Concentrations and loads in discharges to water from permitted facilities.
- Concentrations and loads in emissions to air from permitted facilities.
- Concentrations and loads in biosolids (sludge) from permitted facilities.

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[2] chlordane, DDT, dieldrin, dioxin, hexachlorobenzene, mercury, octachlorostyrene, PCBs and toxaphene

- Quantity of mercury-bearing products such as thermometers, switches, thermostats and mercury-added batteries purchased in the basin.
- Quantity of mercury recovered in sweeps, including household hazardous waste, commercial hazardous waste, and sweeps done within a facility.
- Quantity of mercury used and disposed by medical and dental facilities.
- Use of mercury or dioxin contaminated feedstock chemicals.
- Quantity of PCB-bearing equipment decommissioned in the basin.
- Mass of PCBs, hexachlorobenzene, mercury and dioxin included in sediment remediation projects.
- Quantity of chlordane, DDT, dieldrin, hexachlorobenzene, mercury, toxaphene and dioxin contaminated pesticides gathered in agricultural waste pesticide collections in the basin.
- Quantity of chlordane, DDT, dieldrin, hexachlorobenzene, mercury, toxaphene and dioxin contaminated pesticides gathered in household hazardous waste collections.
- Coal and oil fired electricity production and cogeneration of electricity within the basin to indicate trends in potential release of mercury and dioxin.
- Electricity consumption patterns of basin residents to track willingness to conserve electricity and reduce release of mercury and dioxin.
- Combustion of different fuels (e.g., wood, coal, gas, railroad ties or tires) for energy and the amounts of dioxin and mercury released.
- Mining production and the amount of mercury, dioxin and HCB released through refining processes.
- Amount of solid waste produced by residents or small business and burned in incinerators or backyard burn barrels
- The amounts of dioxin, HCB and mercury released by residential and small business incinerators and burn barrels.
- Amount of solid waste and medical waste incinerated in the basin and the amounts of dioxin, HCB, OCS and mercury released.

E. Limitations and uncertainties:

Some of the indicators listed above will be difficult to quantify or even to estimate. For example, burn barrels may generate a significant amount of dioxin, but direct measurements may not be possible. A surrogate indicator would be an estimate of the amount of household trash burned. Even if the amount of trash burned can be estimated, there is no emission factor for dioxin from burn barrels. So, even though we may not know exactly how much dioxin is being released, we can say whether the trend is increasing or decreasing.

Some indicators will suffer from a lack of monitoring data. For example, very few facilities have monitoring requirements for mercury, dioxin or the other zero discharge chemicals. In addition, discharges to water do not appear to be a major source of these chemicals. Stack testing for air emissions of these chemicals is expensive. Regulatory reporting is frequently done using emission factors, which are usually derived from other facilities and assumed to be broadly representative. Thresholds for reporting requirements are often too high for accurate load calculations. Estimates can be made, especially if we believe that a study population (e.g., a subset of US power plants in a nationwide study) is representative of facilities in the basin. However, if facilities in the basin are dissimilar to those used in nationwide studies, the estimates will not be applicable and basin specific information will be needed. Programs to collect this data may need to be developed if they do not presently exist.

Some of the indicators do not directly measure the quantity of a particular contaminant actually released to the environment. For example, tracking thermometer sales does not imply that the mercury in every thermometer will end up in Lake Superior. However, since the zero discharge chemicals are persistent, it is reasonable to assume that over time, there is potential for the mercury in the thermometers to be released to air, water or land in the basin.

F. Interpretation of the indicator:

Whenever possible, the indicators will be expressed as kg/yr of mercury, PCBs, designated pesticides, dioxin, hexachlorobenzene or octachlorostyrene (e.g., kg/yr of mercury released to the air from taconite processing in the basin). In some cases, the indicator will be reported as mass (e.g., kilograms of designated pesticides collected from the basin). For the indicators that are surrogates for actual measurements of the zero discharge chemicals, the reported units will vary (e.g., number of mercury bearing devices purchased in the basin). For all the indicators, the 1990 baseline will be compared to the milestones identified in the Lake Superior Lakewide Management Plan Stage 2 (SWG, 1998). The Stage 2 schedule of load reductions is summarized in the following table.

Summary of Stage 2 Load Reduction Schedules.

Pollutant	Reduction Schedule
Mercury	60% reduction by 2000 80% reduction by 2010 100% reduction (zero discharge/zero emission) by 2020 (1990 base line)
PCBs	Destroy accessible/in-control PCBs : 33% destruction by 2000 60% destruction by 2005 95% destruction by 2010 100% destruction by 2020 (1990 base line)
Chlordane DDT/DDE Dieldrin Toxaphene	Retrieve and destroy all canceled pesticides in the basin by the year 2000.
dioxin[1] HCB OCS	80% reduction by 2005 90% reduction by 2015 100% reduction by 2020 (1990 base line)

[1] The Lake Superior Binational Program designates 2,3,7,8-TCDD (dioxin) for the Zero Discharge Demonstration Program. By convention, however, dioxin is measured and reported as toxic equivalents (TEQ).

References:

SWG. 1998. DRAFT Load Reduction Targets for Critical Pollutants: LaMP Volume 2. Superior Work Group. (under revision).

Thompson, S. 1994. Zero Discharge Strategy for Lake Superior: Fishing for Sources of Contaminated Water. Draft report submitted to Environment Canada, Toronto, Ontario.

Tetra Tech. 1996. DRAFT Estimates of Mercury, PCBs, Dioxins, and HCB Releases in the U.S. Lake Superior Basin. Superior Work Group.

3.3 ATMOSPHERIC DEPOSITION TRENDS FOR ZERO DISCHARGE CHEMICALS[3]

A. Ecosystem objective addressed by indicator:

Chemical Contaminants Objective Summary Objective and Sub-Objective b) *"Per the Great Lakes Water Quality Agreement, atmospheric deposition of persistent, bioaccumulative toxic chemicals that have an anthropogenic origin should be virtually eliminated."*

B. Purpose or nature of indicator:

The goal of the GLWQA is to virtually eliminate zero discharge chemicals from the environment. This indicator demonstrates progress towards that goal.

C. Features of the indicator:

Atmospheric deposition of the zero discharge chemicals is still a predominant source of these chemicals to the Lake Superior system. This deposition consists of a small continuing source of these chemicals from within the basin plus a larger source of these chemicals arriving from out-of-basin sources. The primary routes of deposition to the lake consists of tributary inputs of the chemicals which have an atmospheric deposition source (rain, snow and subsequent runoff), direct precipitation input to the lakes, dry deposition of particles and gas-phase exchange between the lake surface and the atmosphere. This indicator tracks the change in these components to atmospheric deposition with time with a 1992 baseline.

D. Illustration of the indicator:

Estimates of atmospheric deposition have been made since 1988 (Strachan and Eisenreich, 1988; Eisenreich and Strachan, 1992). More recently atmospheric deposition fluxes and loads have been measured by the Integrated Atmospheric Deposition Network (IADN) (Hoff et al., 1996; IADN Steering Committee, 1997). The indicator follows procedures set out in the IADN Quality Assurance Program Plan (1994). Several primary indicators of progress towards virtual elimination are found in the estimation of loading to the lakes, L, where L = W + D + G, below.

Wet deposition (W) is calculated as:

$$W(ng\ m^{-2}y^{-1}) = 1000\, C_p\ R_p$$

where C_p (ng/l) is the volume-weighted mean precipitation concentration averaged over a year period, R_p is the precipitation rate in m y^{-1} (water equivalent for snow), and the factor of 1000 converts litres to cubic metres. The magnitude of W and its change with time is an indicator of progress towards virtual elimination. It should be noted, however, that yearly variations in the rain rate (dry years versus wet years) will complication the interpretation of the indicator. Therefore, the concentration of the chemical in precipitation should also be evaluated as an indicator.

Dry deposition of particles is calculated from:

$$D(ng\ m^{-2}y^{-1}) = v_d C_{a,part}$$

where v_d (m y^{-1}) is the dry deposition velocity of the species in question (a function of particle size and hygroscopic nature of the particles) and $C_{a,part}$ (ng m^{-3}) is the particulate phase concentration of the chemical in air. Since the dry deposition velocity of particles is not well known, it has been specified as 0.2 cm s^{-1} in previous work (Eisenreich and Strachan, 1988; Hoff et al. 1996). Since the deposition velocity is not expected

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[3] chlordane, DDT, dieldrin, dioxin, hexachlorobenzene, mercury, octachlorostyrene, PCBs and toxaphene

to be a determining factor in the long-term trend of dry deposition (particle sizes will not change much with time), the air concentration of chemicals on the particles will be a primary indicator which can be tracked for trends.

Gas exchange is computed from the knowledge of both the gas phase species concentration in air ($C_{a,gas}$, ng m^{-3}) and the concentration of the chemical in water (C_w , ng/l) through the formula:

$$G(ng\,m^{-2}y^{-1}) = k_{oL}\ (C_{a,gas}\frac{RT}{H} - 1000\,C_w)$$

where k_{oL} (m y^{-1}) is the air-water mass transfer coefficient, H is the temperature dependent Henry's Law constant, R is the gas constant and T is the surface water skin temperature (Schwarzenbach et al., 1993). As expressed above if G>0 then the lakes are being loaded from the atmosphere and if G<0 then the lakes are a source of the chemical to the atmosphere. There is uncertainty (see below) in some of the chemical and physical properties which are part of the gas phase flux. A more precise indicator of trends in this flux are the air and water concentrations of the chemical themselves.

The rate of change of the loading, L = W + D + G, is dL/dt. Since it is known that the loads have seasonality for some components, in order to properly determine the trend, the data should be statistically deseasonalized (i.e, using a Rank-Kendall statistic, standard temperature correction, or equivalent).

Even after deasonalizing the trend data, there may be considerable error in the magnitude of the gas phase exchange. In order not to overstate the loading indicator precision, a secondary measure of the indicator will be the sign of the change in L, in the above equation. If the indicator is positive, the trends in the loadings are increasing and the objective is not being approached. If the indicator is negative, the loadings are decreasing and the objective is being approached. It is likely that if the sign of W+D+G is negative, the change in the atmospheric contributions to the tributary loadings is likely to be of the same sign.

A third component of the indicator is the relative rate of change of the loading with time. The more negative this indicator becomes the faster the goal of virtual elimination will be reached.

E. Limitations and uncertainties:

There are limited monitoring data sets which have a long enough basis and consistency to evaluate these indicators. The time constants at which many virtual elimination chemicals are decreasing in the system (in water, air and fish) are on the order of a few to tens of years. This requires a systematic measurement of loadings to be made over time. IADN provides a nearly nine year record so far of a number of the zero discharge chemicals (chlordane, DDT, dieldrin, hexachlorobenzene, PCBs) and has recently added mercury and toxaphene to an evaluation agenda for inclusion in the program. Dioxin has been measured largely in urban areas and few data exist over the open waters of Lake Superior.

There are significant uncertainties in the calculation of loadings to the lakes. The wet deposition loading to the Lake is believed to be precise to about 50%, dry deposition is known to about 100-150%, and gas transfer depends on the relative difference of air and water concentrations. Typically, gas absorption is known to about a factor of 2-3 and gas volatilization to a factor of 2. Systematic trends in these terms, however, will be known more precisely because the trend is largely due to the change in the air and water concentrations with time. For this reason, the precision in the primary component of the indicator, the sign of the term, will have higher accuracy than the magnitude. There is a formal mechanism to determine the precision of the loading terms above (Hoff, 1994). Using this formalism, estimates of the errors of each of the loading terms can be determined. The error in the indicator can be calculated using the statistical tests of the trend equation versus the null hypothesis (i.e. is a negative slope statistically different at the 95% confidence level from zero slope, or no change?).

The atmospheric tributary loading has been estimated to be as small as 10% of the deposition of the chemical to the entire basin (Dolan et al., 1993). More recently, however, there has been a suggestion that tributary loadings due to atmospheric input can be higher than this. This load is poorly quantified at present and may change with more scientific knowledge. There is currently insufficient information to include atmospheric-tributary contributions into the indicator.

F. Interpretation of the indicator:

For the indicators which are components of the loading equation (water concentration, gas phase air concentration, particulate phase air concentration), the change in their magnitude with time (corrected for seasonal effects) determines the trend. The magnitude of the trend is an indication of whether virtual elimination from the Lake Superior environment (air and water) is being achieved.

If the sign of the indicator is negative, the goal of virtual elimination is being approached and progress is being achieved. If the sign of the indicator is positive, there are residual inputs of these chemicals to the basin and sources for these chemicals must be decreased before virtual elimination can occur.

References:

Dolan, D., …. 1993

Hoff, R.,…1996.

IADN Quality Assurance Program Plan. 1994.

IADN Steering Committee. 1997.

Eisenreich, S.J. and W.J.M. Strachan. 1992.

Strachan, W.J.M., and S.J. Eisenreich. 1988.

Schwarzenbach,…. 1993.

3.4 OPEN LAKE CONCENTRATIONS OF ZERO DISCHARGE AND LAKEWIDE REMEDIATION CHEMICALS

A. Ecosystem objective addressed by indicator:

Chemical Contaminants Objective Summary Objective and Sub-Objective c) *"Open lake concentrations of the chemicals in the zero discharge*[4] *and zero emission category or the lakewide remediation*[5] *category should not exceed the most sensitive yardstick of environmental quality (Smith and Smith, 1993)."*

B. Purpose or nature of indicator:

Guidelines/ criteria/ objectives/ standards [henceforth, referred to as "standards"] have been established by various agencies to define acceptable water and sediment quality for specific uses. These standards apply within the political jurisdiction of each agency, including the Areas of Concern. One of the tasks identified for the Superior Work Group was to identify standards that could be used on a lakewide basis, to measure and report on progress in reducing loadings of critical pollutants. To ensure that use impairments do not occur, it was agreed that the most sensitive available standard (exclusive of drinking water standards) would be used for these evaluations, and would be called the "yardstick" (see Smith and Smith, 1993). For this indicator, water concentrations in the offshore waters of Lake Superior (>80m, as per definition on p.27) would be compared to the most sensitive yardstick (see Table xx, below) to ensure protection of the most susceptible species/use.

Table xx. Water quality yardsticks for zero discharge and lakewide remediation chemicals as per Smith and Smith (1993).

Chemical	Water Quality Yardstick (ng/L)
chlordane	0.073
DDT	0.024
dieldrin	0.0065
dioxin, 2,3,7,8-TCDD	zero
hexachlorobenzene	0.056
mercury	0.18
octachlorostyrene	Not Available
PCBs	0.005
toxaphene	0.02
PAHs, total	2.8
alpha-BHC	9.2
cadmium	100
heptachlor + heptachlor epoxide	0.1

As new standards are adopted by the jurisdictions, it will be important to review the yardsticks. For example, recently Minnesota adopted new standards which are more sensitive than the yardsticks given in Table xx for chlordane (0.040 ng/L), DDT (0.011 ng/L), dieldrin (0.0012 ng/L), PCBs (0.0045 ng/L) and toxaphene (0.011 ng/L). During each reporting cycle, the yardsticks would be updated to reflect the most sensitive guideline.

C. Features of the indicator:

Every 2 years, water concentrations of zero discharge and lakewide remediation chemicals should be monitored throughout the offshore waters of Lake Superior, for comparison with appropriate yardsticks. Sampling should

[4] chlordane, DDT, dieldrin, dioxin, hexachlorobenzene, mercury, octachlorostyrene, PCBs and toxaphene

[5] PAHs, alpha-BHC, cadmium, heptachlor and heptachlor epoxide

be conducted during spring, isothermal conditions, as maximum concentrations have been reported during this time.

The offshore region of Lake Superior has an extremely low rate of sediment accumulation; for example, the sedimentation rate at NOAA Site 3, in the Chefswet sub-basin of Lake Superior, is estimated to be 0.3 mm/yr. This extremely low rate of sediment accumulation hampers our ability to sample recent sediment deposits for comparison to yardsticks. Comparison of sediment concentrations against standards will be limited to the nearshore region where sediment accumulation is greater (see Section 3.5).

D. Illustration of the indicator:

To comply with the methodology used by the Superior Work Group in defining critical pollutants, comparisons with the yardsticks will be assessed against the 95th percentile – this is, pollutant concentrations will be considered as acceptable only if 95-100% of the available data indicate levels below the yardstick. Water concentrations of the zero discharge and lakewide remediation chemicals should be presented in a table which provides both the 95th percentile and the yardstick, for comparison. Spatial distribution maps, showing raw concentration data, should also be provided to indicate spatial gradients and to discern any problem areas.

E. Limitations and uncertainties:

It is important to note that, for octachlorostyrene, it will not be possible to report against the yardstick, as there is not one available (due to the lack of jurisdictional standards). Also, while there is a yardstick for "total PAHs", there are also yardsticks for individual PAHs. Since "total PAHs" is not defined, the individual PAHs should be reported and compared against their respective yardsticks.

The yardstick for dioxin (2,3,7,7-TCDD) is "zero"; analytical chemists continually strive for lower detection limits (some currently operating in the part-per-quadrillion range), so the concept of "zero" does not exist. Thus, the target for dioxin should be "less than detection limit using the best available technology". For all other chemicals, it is important that organizations responsible for carrying out this monitoring effort use analytical detection limits that are sufficiently sensitive to allow for comparison with the yardsticks (*cf* Table xx).

With each reporting cycle, as the yardsticks are updated to reflect the adoption of new, lower standards by the jurisdictions, there is the potential for a greater number of chemicals to exceed yardsticks. To the casual reader, this may imply that water quality conditions are deteriorating. It is, therefore, important to maintain the reporting format that presents not only the 95% confidence limit, but also the yardstick that is being used.

As this document is being written, there is ongoing controversy concerning how standards for contaminants in the environment are determined. Some standards are driven by the ability of scientists to actually detect and measure the compounds (or family of compounds) in environmental media; these standards are commonly known as chemical standards. Toxicity based standards prove more acceptable than the chemical standards, since the biological effect of a contaminant is used to determine a value for allowable levels in the environment. The controversy emerges with the fact that most toxicity based standards are determined using single compound (or single compound families, i.e. PCBs, dioxins, toxaphene, etc.) assays, which may not adequately represent the actual environmental exposure for the species of concern. The actual environmental exposure would include the entire suite of toxic contaminants present in the environmental media, and the single compound toxicity standards may not prove protective of the most sensitive species of concern. The concept of synergistic toxicity (the toxicity of a mixture of chemicals being greater than the additive toxicity of the individual chemicals) is well established in the field of toxicity, but current methodologies for determining synergistic toxicity are not readily available. Until multiple chemical exposure toxicity assays are developed and verified, the yardsticks based on single contaminant toxicity assays will be used to evaluate the indicators discussed above.

F. Interpretation of the indicator:

The indicator will be used to monitor achievement of lakewide targets, based on yardsticks. This indicator will also provide useful information to assist in the interpretation of some of the biologically-based indicators, such as bioassays, aquatic community health, etc.

References

Smith, J. and I.R. Smith. 1993. Yardsticks for assessing the water quality of Lake Superior. For the Superior Work Group.

3.5 SEDIMENT CONCENTRATIONS OF ZERO DISCHARGE, LAKEWIDE REMEDIATION AND LOCAL REMEDIATION CHEMICALS

A. Ecosystem objective addressed by indicator:

Chemical Contaminants Objective Summary Objective and Sub-Objective d)
"Concentrations of zero discharge[1] and lakewide remediation[2] chemicals in sediment in nearshore areas (<80m.), and in harbors and bays, should not cause or contribute to impaired uses in the Lake Superior ecosystem. Concentrations of local remediation[3] chemicals in sediment should not impair uses in Areas of Concern in the Lake Superior basin."

B. Purpose or nature of indicator:

Sediments in biologically productive areas can serve as a sink for contaminants which can enter the food chain, contributing to impaired uses of the Lake Superior ecosystem. Index sampling of contaminant levels can track trends in sediment over time. For this indicator, concentrations of zero discharge and lakewide remediation chemicals in sediment of nearshore areas of Lake Superior, and in harbors and bays, including Areas of Concern, will be compared to yardsticks, guidelines, or standards. Concentrations of local remediation chemicals will be compared to local standards in Areas of Concern. The nearshore habitat areas are defined in the aquatic community objective and applied to the aquatic community indicators of this document.

The yardsticks of environmental quality, put forth in Smith and Smith (1993) provide a means to determine potential for impairment. The yardsticks also enable temporal and geographic comparison in the context of the entire Lake Superior basin. Use of the yardsticks for this indicator is not intended to set clean up standards for contaminated sediment sites.

Concentrations of critical chemicals in sediment should be assessed as follows:

Zero Discharge and Lakewide Remediation Chemicals: concentrations in sediments from the nearshore waters of Lake Superior would be compared to the most sensitive yardstick (see Table xx, below) to ensure protection of the most susceptible species/use. Concentrations in sediments from harbors and bays, including Areas of Concern, would also be compared to the most sensitive yardstick. Monitoring locations would be selected in the near shore zone and in harbors and bays based on several factors, including correspondence to areas where other contaminant work had been done. In Areas of Concern, monitoring conducted for Remedial Action Plan purposes would be used, if possible, for the lakewide comparisons.

Table xx. Sediment yardsticks for zero discharge and lakewide remediation chemicals as per Smith and Smith (1993).

Chemical	Sediment Yardstick (ug/g)
aldrin/dieldrin	0.0006
DDT (total)	0.007
hexachlorobenzene	0.01
PCBs (total)	0.01

Local Remediation Chemicals: concentrations in sediments from Lake Superior's Areas of Concern would be compared to the applicable local standards to ensure restoration of impaired uses.

C. Features of the indicator:

In the nearshore areas and harbors and bays, cores would be collected every 10 years from sites selected for index monitoring. Index sites should include areas where sediment sampling would provide added value to contaminant investigations, for example, sites previously monitored for contaminants in sculpin (DeVault et al., 1998). Sites would also be chosen based on sediment type, expected sedimentation rates, and proximity to potential sources. Cores would be sectioned, dated and analyzed for the zero discharge[1] and lakewide remediation[2] chemicals. Concentrations for recent years (i.e., last 10 years) would be compared against the Smith and Smith (1993) yardsticks.

Certain estuaries, bays, and harbors on Lake Superior, are designated as Areas of Concern because of past or on-going pollution problems. Sediment contamination in these areas, taken together, represent cumulative impacts to productive habitat areas. In addition, Areas of Concern can serve as contaminant source areas to the rest of the Lake. Application of the sediment indicator at Areas of Concern is intended to integrate the information gathered by RAP monitoring efforts to give a lakewide picture for these important habitat areas. In the Areas of Concern, sediment concentrations of zero discharge and lakewide remediation chemicals would be compared to Smith and Smith yardsticks and evaluated on a lakewide basis. Data for local remediation chemicals would be compared to appropriate standards or guidelines used by the jurisdiction (i.e. " local standards") Additional index sampling in these areas would be proposed if the RAP data are not adequate for the lakewide tracking purposes of this indicator. Sites would be chosen based on Remedial Action Plan information, including the nature of the use impairment, type of sediment and proximity to historical or ongoing sources of local remediation chemicals[3].

D. Illustration of the indicator:

The sediment concentrations would be depicted using the standard tables and figures showing the change in concentration at different depths. Only the upper segment of the core would be compared to the yardstick or local standard. In addition, a set of maps showing the location and concentrations in the nearshore areas and a set of maps showing concentrations in the Area of Concern would serve to illustrate the indicator.

E. Limitations and uncertainties:

When comparing sediment concentrations against standards, it is important to consider the natural, local background concentrations of trace metals; these can be obtained by looking at the *Ambrosia* pollen horizon levels in the cores, or by radionuclide dating of the sediments. Mudroch et al. (1988) conducted a literature survey to summarize background concentrations of selected elements (As, Cd, Cu, Cr, Fe, Ni, Pb, Zn and Hg) in sediments from different areas of the Great Lakes. For example, background concentrations of Cd in depositional basins of Lake Superior were found to be in the range of 0.4-0.7 ug/g, however, MOE's lowest effect level for Cd is 0.6 ug/g. Persaud et al. (1991), in discussing MOE's lowest effect level guidelines, states that "The Ministry recognizes that in areas where local background levels are above the lowest effect level, the local background level will form the practical lower limit for management action."

Furthermore, it is important that analytical methods used for both the nearshore and Area of Concern monitoring have detection limits low enough for comparison to the appropriate sediment yardsticks, guidelines, and standards.

The type of sampling proposed for this indicator is index sampling, where certain sampling sites would be selected and followed over time, as opposed to condition monitoring which would be designed to determine extent of sediment contamination in the Lake Superior ecosystem. Depending on how index sites are chosen, they may not give a representative picture of sediment contamination in the Lake. However, index sampling is more economically feasible for the Lake Superior ecosystem. In the case of Areas of Concern, data acquired for RAPs would be used wherever possible, rather than proposing an additional sampling program for those areas.

F. Interpretation of the indicator:

The indicator will be expressed as concentration (ug/g) at different depths in the sediment core. The trend over time will indicate the change in the zero discharge[1], lakewide remediation[2] and local remediation[3] chemicals. Concentrations that exceed the appropriate yardstick or cause use impairments will indicate a need for further reductions.

[1] chlordane, DDT, dieldrin, dioxin, hexachlorobenzene, mercury, octachlorostyrene, PCBs and toxaphene
[2] PAHs, alpha-BHC, cadmium, heptachlor and heptachlor epoxide
[3] aluminum, arsenic, chromium, copper, iron, lead, manganese, nickel and zinc

References:

DeVault, D.S, D.D. Helwig, G. Flom, D.L. Swackhammer and P. McCann. 1998 (in print). Contaminant Concentrations in Lake Trout and Sculpin from Lake Superior.

Mudroch, A., Sarazin, L., and T. Lomas. 1988. Summary of surface and background concentrations of selected elements in the Great Lakes sediments. J Great Lakes Res. 14(2): 241-251.

Persuad, D., Jaagumagi, R. and A. Hayton. 1991. The Provincial Sediment Quality Guidelines. Water Resources Branch, Ontario Ministry of Environment. Toronto, Ontario.

Smith, J. and I.R. Smith. 1993. Yardsticks for assessing the water quality of Lake Superior. For the Superior Work Group.

3.6 AMBIENT CONCENTRATION TRENDS OF PREVENTION/MONITOR POLLUTANTS IN WATER, SEDIMENT, AIR/PRECIPITATION

A. Ecosystem objective addressed by indicator:

Chemical Contaminants Objective Summary Objective and Sub-Objective e) *"Concentrations of the chemicals in the prevention / monitor*[6] *category should not increase in air, water or sediment."*

B. Purpose or nature of indicator:

Chemicals identified in the prevention/monitor category are those for which there is very little information available regarding their distribution in the Lake Superior environment, although there is no evidence to date to suggest that they are negatively impacting the ecosystem. Because these chemicals are bioaccumulative, persistent and toxic, continued monitoring of their status in the ecosystem is warranted to ensure maintenance of, if not a decrease in, current levels.

C. Features of the indicator:

Building on the monitoring proposed for air (section 3.3) and water (section 3.4), concentrations of the prevention/monitor chemicals should also be tracked annually in air/precipitation, and every 2 years in water.

Bottom sediments in 6 major depositional basins of the open lake provide a mechanism for focusing contaminant loadings in lake systems. Every 10 years, sediment cores should be taken in each of these depositional zones of the offshore, sectioned, dated, and analysed for prevention/monitor chemicals.

D. Illustration of the indicator:

Bar graphs showing changes in concentration of the prevention/monitor chemicals over time in air/precipitation (volume-weighted means for precipitation) and water, will be used to illustrate this indicator.

Dated sediment core profiles (adjusted for sediment focusing) will be used to depict trends in sediment concentrations and accumulation rates over time, to illustrate whether or not concentrations/accumulation rates are increasing or decreasing.

E. Limitations and uncertainties:

Air and water concentration data provide a snap shot of current conditions, however, their utility for reporting long-term trends is limited by a lack of comparable historical information. Sediment cores, on the other hand, are not as definitive in delineating conditions in the short-term (e.g., sediment concentrations for a given year), however, they can provide a historical record of contaminant concentrations/loadings.

Water, sediment and/or air/precipitation concentrations may be below the analytical detection limit for these chemicals, hence, it may be impossible to demonstrate changes over time. It is thus assumed that, as long as concentrations are maintained below this limit, the ecosystem objective is being met.

Uncertainties exist in dating the sediment profiles, particularly in the surface layer due to vertical mixing, and in the derivation of accumulation rates, given that sedimentation rates are not necessarily uniform across the lake or with time.

F. Interpretation of the indicator:

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[6] 1,4-dichlorobenzene, 1,2,3,4-tetrachlorobenzene, mirex/photo-mirex, pentachlorobenzene, pentachlorophenol, gamma-BHC

If concentrations of the prevention/monitor chemicals in air, water and sediment are not increasing with time, then it can be assumed that levels are not negatively impacting the Lake Superior ecosystem. Depending on the results, these chemicals may be added to the lakewide remediation or local remediation categories.

3.7 PREVENTION - INVESTIGATE CHEMICALS

A. Ecosystem objective addressed by indicator:

Chemical contaminants Objective Summary Objective and Sub-Objective f) *"Initially, the presence of chemicals in the prevention/investigate category*[7] *should be investigated in the ambient environment, in the appropriate media and location(s). In addition, sources of the chemicals in the prevention/investigate category should be identified and the presence or absence of these sources in the basin should be confirmed. Presence of a source should trigger continued monitoring of the media most likely to concentrate the chemical."*

B. Purpose or nature of indicator:

Chemicals identified in the LaMP as prevention/investigate are persistent, bioaccumulative and toxic but data on their presence in the Lake Superior basin is lacking. Their presence in Lake Superior may be due to historical deposits, long-range transport, or current in-basin sources. As a first step, ambient monitoring (air/water/sediment) should be conducted to determine the presence/absence of these chemicals. Furthermore, in order to be proactive, potential source categories for these chemicals should be identified. Where possible sources exist in the basin, source monitoring should be conducted. With this new information, the Parties can decide which category each of these chemicals should belong in.

C. Features of the indicator:

A literature search for each chemical must be carried out. Sources should be identified and their presence or absence in the basin confirmed. The literature should also be searched for information on physical properties (HLC, octanol-water coefficient, etc), availability of analytical techniques, and the media that the chemicals are likely to be detected in (e.g., is the chemical likely to be found in air, sediment, biota or water?). Based on this information, these chemicals should initially be included, as appropriate, among the targeted list of chemicals being measured in air, water, sediment and biota to investigate their presence in the Lake Superior ecosystem. For example, use of available monitoring facilities such as the IADN station at Eagle Harbor would allow investigation of the presence or absence of these chemicals in air (*cf* Section 3.3).

D. Illustration of the indicator:

Use trees should be completed for the chemicals. The sources identified in the use trees should be compared to the facilities listed in the LaMP Stage 1. The results of ambient monitoring should be reported in their entirety, as raw concentration data, so that the Parties can decide how to re-categorize these chemicals.

E. Limitations and uncertainties:

Possible sources of uncertainty include analytical methods and identification of potential sources in the basin using existing data bases (e.g., SIC codes and other business registries).

F. Interpretation of the indicator:

Data collected from ambient and source monitoring in the basin will be used to determine whether continued monitoring is warranted. Depending on the results, these chemicals may be added to the lakewide remediation, local remediation or prevention/monitor categories.

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[7] 1,2,4,5-tetrachlorobenzene, 3,3-dichlorobenzidine, 2-chloroaniline, tributyl tin, beta and delta BHC and hexachlorobutadiene

4.0 Aquatic Community Objectives and Indicators of Aquatic Community Health within the Lake `Superior Basin

4.1 Background

This section was drafted by the Lake Superior Technical Committee (Mark P. Ebener, editor) of the Great Lakes Fishery Commission. The Committee adopted a slightly different format than that suggested by the Binational Program. Instead of being "indicator" driven as suggested in the charge to the writing teams, this section is more "objective" driven. This approach was taken to improve conceptual "flow" and readability.

The actual indicators in this draft section do not yet contain quantitative values. However, within the "Features of the Indicators" sections, we have provided rationale for the indicators along with discussion of which species should be present. If exact quantification of these key species is desired - as opposed to "trends" - further conceptual development is required. It is typically quite difficult to both determine "how much" of each species is desirable and/or possible, and to evaluate the relative seriousness of the situation should abundance fall below (or above) a specified value. Thus, exact quantification of an indicator can be a difficult process - especially within a changing ecosystem - but one which can be attempted at some time in the future.

4.2 Goal

The overall goal for this section is:

> "*To secure fish communities, based on foundations of stable self-sustaining stocks, supplemented by judicious plantings of hatchery-reared fish, and provide from these communities an optimum contribution of fish, fishing opportunities and associated benefits to meet needs identified by society for: wholesome food, recreation, employment and income, and a healthy human environment.*"

The goal of the Aquatic Community Section of the Bi-national Program should relate to this goal, and to those already agreed to and developed under the auspices of the Great Lakes Fishery Commission. All Great Lakes fishery management agencies developed a common strategy to ensure that the agencies hold similar goals. From this strategy, the Joint Strategic Great Lakes Fishery Management Plan (GLFC 1980) was developed.

4.3 Aquatic Community Objectives

1. Diversity and self-sustainability

To restore and maintain diverse, healthy, reproducing, and self-regulating aquatic communities, comprised largely of indigenous species, which are sustainable, and ecologically efficient.

2. Exotic species

Prevent the introduction of any "new" non-indigenous species, and exotic species currently inhabiting Lake Superior should be managed in a manner that is not detrimental to native species.

3. Habitat

Achieve no net loss of habitats that presently support Lake Superior fisheries; restore and maintain the productive capacity of aquatic habitats that have suffered damage.

4. Contaminants

Levels of toxic contaminants in aquatic organisms should be below levels which are harmful to both human and aquatic community health

4.4 Aquatic Community Objectives Indicators

The aquatic community of Lake Superior contains species which are currently unique within the Great Lakes basin. Self-sustaining populations of indigenous fish species such as lean lake trout, siscowet lake trout, and lake herring are present throughout Lake Superior, although they are not yet at historical levels of abundance (Hansen 1994a; MacCallum and Selgeby 1987). Self-sustaining populations of these species are either not present at all, or, are present at very low levels of abundance in the other Great Lakes (Ebener et al. in press; Kerr and LeTendre 1991). On the other hand, Lake Superior also contains non-indigenous fishes such as ruffe, sea lamprey, Pacific salmon, rainbow smelt, brown trout, and the non-indigenous cladoceran *Bythotrephes cederstroemi* (Pratt et al. 1992; Peck et al. 1994). Some of the indigenous fishes (lake trout) are long-lived and occupy the open lake and near shore areas, and may respond slowly to changes in the ecosystem and perturbations. Invertebrates and non-indigenous fishes are short-lived, occupy tributaries and estuaries for at least part of their life, and either induce or respond to ecosystem changes faster than the indigenous species. Therefore, we propose short-term action-required and long-term milestone indicators for the aquatic community. For example, lean lake trout are a good long-term milestone indicator for judging the health of the open lake aquatic community (Marshall et al. 1987). However, because lake trout respond slowly to change, they are not a good indicator of short-term stresses which will occur in harbors and tributaries to the lake. Changes in the aquatic invertebrate community of harbors and tributaries will provide indicators of short-term action-required stresses that may potentially alter the offshore aquatic community.

We propose to monitor aquatic ecosystem health in four habitat zones of Lake Superior: 1) offshore open waters of the lake >80 m deep; 2) nearshore open waters of the main lake 0-80 m deep; 3) harbor, estuaries, and embayments which are separated from the open waters of the main lake, are subjected to seiche, and the fish community is dominated by percids and minnows; and 4) tributaries which are not affected by lake seiche.

We developed three basic types of indicators that can be used in each habitat type to monitor health of the aquatic community. These indicators are trends in abundance of both indigenous and non-indigenous species, the amount of natural reproduction, and levels of toxic contaminants in fish flesh. In developing indicators we attempted to insure that indicator species are specific as possible to a habitat type, especially for contaminant monitoring.

Little of the information describing the status of indicators in offshore areas is being collected by federal, state, provincial, or tribal fishery agencies as part of their routine long-term research and assessment activities. Although some sampling has been done in all zones, agencies are doing a comprehensive job only in the nearshore and harbors-estuaries-embayment habitats. Much of the offshore habitat has not been routinely sampled. The major harbors-estuaries-embayments have been sampled only in recent years in response to invasion of this habitat by non-indigenous species. Of the roughly 120 tributaries to Michigan waters of Lake Superior, only 3 to 5 have been routinely assessed to determine fish abundance (J. Peck Mich. Dept. Nat. Res, Marquette, MI, per. comm.). Some information currently being collected is based on short-term studies with definite time lines, so these studies will not provide long-term milestone indicators. It is very costly to gather the information necessary to evaluate health of the aquatic community. In most instances the information will be collected annually unless rising administrative costs restrict activities.

Most of the measures of abundance can vary tremendously from year to year. Therefore, short-term increases or decreases in abundance of indigenous fish species should not be worrisome since indices of abundance are notorious for abrupt changes. Long-term trends in abundance should be the milestone for measuring progress toward achieving the objectives since most the offshore fish community is made up of slow-growing, late maturing fish species. What becomes important is to distinguish between observational variability and natural variability. In addition, abundance may not be equal among geographic areas of Lake Superior because of differences in catchability of a species between areas. Weighting indices of abundance based on the amount of habitat will be used to make comparisons among areas be more appropriate.

4.4.1 Offshore Community (>80 m deep)

INDICATORS: Monitor trends in abundance of key aquatic species
Monitor for presence of non-indigenous species

A. Purpose or nature of the indicators:

The present offshore aquatic community of Lake Superior reflects historic conditions and is considered to be healthy, upon which deviations can be judged as unhealthy. The presence and relative abundance of lean lake trout, siscowet lake trout, and lake herring are measures of the degree of natural reproduction that is occurring in this habitat. Self-sustainability of indigenous species is a method of measuring progress toward achieving the aquatic community objectives. We recognize that the presence of exotic species in the offshore habitat of Lake Superior may prevent achievement of the aquatic community objective.

B. Features of the indicators:

1) The offshore fish community of Lake Superior should contain fishes such as pelagic, mature lean lake trout, siscowet lake trout, lake herring, burbot, deepwater ciscoes, and deepwater sculpins; particularly spoonhead sculpin. Historically, these fishes made up the structure of the offshore community. All these species are currently present in the offshore community, but probably not at historic levels of abundance, and probably not in the same structure as historically.

2) The zooplankton community should contain *Cyclops bicuspidatus thomasi, Diaptomus sisilus, Diaptomus ashlandi, Limnocalanus macrurus, Senecella calanoides, Mysis relicta, Diporeia hoyi, Kertella cochlearis, Killicottia longispina, Daphnia longispina, Bosmina longirostris, and Epishcura lacustris.* These species were all reported as common or abundant by various researchers during the 1940s through the 1970s in Lake Superior (Lawrie and Rahrer 1973).

3) Benthic invertebrates such as amphipods, dipterans, heterodonta, chironomids, and oligochaetes should be present (Lawrie and Rahrer 1973).

4) The phytoplankton community should include a simple assemblage of diatoms such as; *Cyclotella glomerata-stelligera, Cyclotella ocellata-kutzinginana, Fragilaria crotonensis, Rhizosolenia eriensis, Asterionella formosa, Synedra nana, Tabellaria fenestrata, Melosira granulata, and species of Stephanodiscus and Dinobryon* as reported by Lawrie and Rahrer (1973).

5) The presence of non-indigenous species such as Pacific salmon, sea lampreys, and *Bythotrephes cederstroemi* should be viewed as stressors to the system. The impact of *Bythotrephes* and Pacific salmon on the offshore community is unknown, but these species must be utilizing energy that otherwise would be used by indigenous species. Sea lampreys are known to be a stressor on lake trout stocks in Lake Superior (Pycha and King 1975).

Long-term trends in abundance of these species will be indexed as the catch of each species in a given unit of sampling effort. Graded-mesh gill nets, bottom or midwater trawls, and long-line hooks will be used to sample fish. Long-term trends in abundance of plankton and zooplankton will be monitored annually during routine assessments using vertical hauls of a half-meter plankton net. Benthic invertebrates will be collected using Ponar grabs. The number and trends in abundance of indigenous fishes caught during surveys will be developed separately for each component of the offshore habitat; pelagic fishes, pelagic zooplankton and plankton, and benthic invertebrates. Survival, growth, amount of reproduction, and food habit information will also be collected and reported as part of the sampling program in the offshore habitat.

Benthic (deepwater ciscoes) and pelagic (herring) coregonines should be the most abundant fish species present in the offshore community. This assemblage of ciscoes should serve as the primary forage for pelagic lean lake trout, siscowet lake trout, and burbot as they did historically (Dryer et al. 1965). Deepwater sculpins should be the tertiary prey species for all predatory fishes. Siscowet lake trout should be the top predator structuring prey fish abundance in the offshore habitat, and all forms of lake trout should constitute about 15% of the biomass of the principal forage species (Marshall et al. 1987). Burbot should be common in the offshore habitat and serve as both a predator on coregonines and sculpins, and as prey for siscowet lake trout. Standing stocks of burbot should be about 10% greater than those of lake trout since lake trout prey upon burbot, and because low standing stocks of burbot may reflect a benthic community under stress (Marshall et al. 1987).

Stable or increasing levels in abundance of indigenous species indicate that the offshore habitat is self-regulating, healthy, and not being impacted by the presence of non-indigenous species. However, indigenous species should be much more abundant than non-indigenous ones. Abundance of pelagic, mature lean lake trout is partly an inverse measure of the survival rate for this species, therefore, survival of lean lake trout in the offshore habitat should be >55% (Healey 1978; LSLTTC 1986; Marshall et al. 1987; LSTC 1995).

C. <u>Illustration of the index</u>:

Relative abundance of indigenous and non-indigenous species over time will be used to illustrate changes in the pelagic and benthic fish community, plankton and zooplankton community, and benthic invertebrates. A pie chart will be used to illustrate the percentage of the community made up of non-indigenous species. No historic data exist to compare with the indices that will be developed.

D. <u>Limitations and uncertainties</u>:

Labor and equipment costs will limit establishment and maintenance of any of these indices. No agency currently gathers much information concerning the offshore aquatic community. Agency commitments to increase data collection in the offshore habitat of Lake Superior will undoubtedly mean a re-direction of efforts away from other parts of the ecosystem. Information concerning abundance of plankton, zooplankton, and benthic invertebrates should be collected annually since these are generally short-lived species and will respond quickly to environmental changes. Information describing abundance of lean lake trout, siscowet lake trout, chub, and lake herring may be collected less often because they grow slowly and respond to ecosystem changes slower than invertebrates. Efforts should be made to sample the offshore habitat within each political jurisdiction; Michigan, Wisconsin, Minnesota, and Ontario.

E. <u>Interpretation of the indicators</u>:

Francis et al. (1979) list 18 human stresses on Great Lakes ecosystem, and of those, three impact the offshore community of Lake Superior. These stressors include fishing and other harvesting of biota, introductions and invasions of exotic species, and nutrients and eutrophication from sewage plants, agricultural and urban run-off. Long-term increases in abundance of planktonic plants and animals may suggest eutrophication is changing productivity of Lake Superior and both educational and regulatory changes will be necessary to affect productivity. Increases in abundance of non-indigenous species suggest that educational, administrative, and regulatory changes will be necessary to control their numbers and future introductions. Indicators of overfishing would be changes in composition of the fish community from high-valued to low-valued species, reductions in size structure, declines in mean age, disappearance of distinct stocks, and continual declines in abundance through time (Francis et al. 1979). Regulatory solutions will be necessary to reduce the impact of harvesting and overfishing.

4.4.2 Nearshore Community (<80 m deep)

INDICATORS: Monitor trends in abundance of key aquatic species
Monitor for presence of non-indigenous species
Monitor and document habitat loss or restoration

A. <u>Purpose or nature of the indicators</u>:

The nearshore aquatic community of Lake Superior is reverting to historic conditions since many indigenous species are self-sustaining, but is still subject to the stressors which modified it away from historic conditions (Hansen 1994a). Native species assemblages are well represented in the nearshore habitat by lean lake trout, siscowet lake trout, lake herring, lake whitefish, longnose and white suckers, walleye, slimy sculpin, *Diporeia* spp. and *Mysis relicta*. A non-indigenous species like sea lamprey is also abundant in the nearshore area and is known to exert detrimental and measurable influences on lean lake trout (Pycha and King 1975; Hansen et al. 1994). We are less certain of the effects of non-indigenous species on the nearshore aquatic community. These indicators will provide a measure with which to evaluate diversity and long-term sustainability of the aquatic community.

B. **<u>Features of the indicators</u>:**

1) Long-term trends in abundance of lean lake trout will be measured by annual monitoring and expressed as the number of fish caught with a given unit of effort during spring gill net surveys in specific management units (Hansen et al. 1994; Hansen 1994b).

2) Relative abundance estimates of non-indigenous fishes and zooplankton caught annually during routine agency assessments will be developed.

3) Long-term trends in abundance of lake herring and rainbow smelt will be monitored annually and expressed as the number or weight of fish caught with a given unit of effort during spring trawl surveys and summer gill net surveys.

4) Long-term trends in abundance of zooplankton will be monitored annually based on vertical plankton net tows made at specific sites along the entire shoreline of Lake Superior.

Besides abundance, other population parameters such as survival, growth, reproduction, and food habits, at least for fishes, will be collected and analyzed concurrently to assist with interpretation of the indicator.

Mysis and *Diporeia* should be the dominate zooplanktors which serve as food for small lake trout and the principal forage species (Marshall et al. 1987). Size, abundance, and composition of zooplankton should be sufficient to support growth and sustain recruitment levels of pelagic and larval fishes (Kitchell 1985; Crowder et al. 1987; Kitchell et al. 1994). A healthy nearshore aquatic fish community should be dominated by lake herring with an age and size structure suitable to serve as the primary food for nearshore predators. Self-sustaining populations of lean lake trout should be the dominant nearshore predator at levels of abundance approaching that found during 1929-43 (Baldwin et al. 1979; LSLTTC 1986; LSTC 1995). All historic spawning areas should contain self-sustaining populations of lean lake trout that reflect the many known historic phenotypic forms once found in Lake Superior (Marshall et al. 1987). Sea lamprey abundance should only be 10% of that currently found in nearshore areas (Busiahn 1990). Non-indigenous salmonines should be present in the nearshore community at levels which do not interfere with lean lake trout growth and reproduction (LSLTTC 1986; LSTC 1995).

C. **<u>Illustration of the index</u>:**

Graphs illustrating trends in abundance of lean lake trout in each political jurisdiction will serve as one way to measure health of the nearshore aquatic community (Hansen 1994b). Annual estimates of abundance can be compared with both historical levels as far back as 1929 and to the average during 1929-43; a reference period for describing lake trout abundance in Lake Superior.

Graphs illustrating trends in abundance of non-indigenous species will be developed for the pelagic and benthic zones as Klar and Weise (1994) provided for sea lamprey.

Trends in relative abundance of lake herring, other coregonines, and non-indigenous fishes will be described graphically for each jurisdiction as by Peck et al. (1994), Selgeby et al. (1994), and MacCallum et al. (1994).

A twenty year time series describing abundance of zooplankton already exists at the Ashland Station of the National Biological Service and this information will be updated annually in a table illustrating trends in relative abundance of the principal species.

D. Limitations and uncertainties:

Much of agency efforts to gather information regarding Lake Superior fishes has been concentrated in the nearshore habitat. Consequently, some of the information needed to evaluate this indicator already exists, or can be incorporated into existing surveys.

Estimates of relative abundance generated from gill net survey data are notorious for exhibiting wide annual variations over short time frames. In addition, coregonine populations in Lake Superior produce large and small year-classes that easily vary 10 fold at any given level of adult abundance (Selgeby et al. 1994). The effects of these large and small year-classes can influence relative abundance estimates for many years, so long-term stability should be the measure of community health.

Biological information necessary to evaluate this indicator should be collected annually throughout the nearshore habitat. Our understanding of aquatic community dynamics in the nearshore habitat of Lake Superior is developing only now; after 30-50 years of gathering information (Hansen 1994a; Hansen 1994b). Gaps in information produced from sampling programs which do not take place every year make interpretation of the data even more difficult. Indices of abundance for a species in an area will be weighted by the square kilometers of habitat to make comparisons across regions of Lake Superior more appropriate.

E. Interpretation of the indicators:

Of the 18 human stresses on the Great Lakes ecosystem listed by Francis et al. (1979), probably nine of them affect the nearshore aquatic community. Major stressors to the nearshore aquatic community include the following human perturbations: fishing and other harvesting of biota, introductions and invasions of exotic species, nutrients and eutrophication from sewage plants, industry and agriculture, and shoreline destruction due to filling and development. Overfishing has been implicated in the demise of many fish stocks in Lake Superior (Lawrie and Rahrer 1972; Selgeby 1982), but the collapse of many fish stocks has ultimately been due to a synergistic effect of overfishing coupled with introductions of exotic species and habitat destruction (Lawrie and Rahrer 1972).

As stated earlier, we do not fully understand the dynamics which allow non-indigenous species to thrive at the expense of indigenous species (Crowder 1980; Selgeby et al. 1994), but they sometimes do. The introduction of non-indigenous species ultimately produces declines in abundance of preferred indigenous species (Pycha and King 1975; Loftus and Hulsman 1986; Evans and Loftus 1987; Eck and Wells 1987). Proliferation of sea lamprey and *Bythotrephes* in the nearshore habitat of Lake Superior is a problem because we have allowed industrial interests like the Great Lakes shipping industry to control the flow of exotic species. Control of exotic species can be accomplished through regulatory changes over industry, by educating the public to the dangers of exotic species in Lake Superior, and finally by stocking of predators to control the exotic species.

Overfishing and shoreline destruction both cause declines in abundance by affecting the ability of the population to sustain itself, but these two stressors affect fish populations differently. Overfishing limits the number of adults available for reproduction and subsequently reduces the number of progeny. Regulatory changes can be instituted to control fishing and increase adult abundance. Shoreline development decreases the amount of habitat available for reproduction which then also reduces the number of progeny. A species can not sustain itself without the appropriate habitat. Most habitat is lost through activities which are controlled by local units of government such as townships and county boards. The basic solution to controlling shoreline development is education of local units of government, and building administrative linkages between local governments and resource management agencies.

4.4.3 Harbor-Embayments-Estuaries Community

INDICATORS: Monitor trends in abundance of key aquatic species
Monitor for presence of non-indigenous species
Monitor and document habitat loss or restoration

A. Purpose or nature of the indicators:

Nearly all the Areas of Concern (AOC) identified by the International Joint Commission (IJC) on Lake Superior are located in harbors, bays, or estuaries. Aquatic communities in these areas have born the brunt of environmental damage throughout the basin. This indicator provides a direct measure of the health of the Lake Superior ecosystem since the impact of remedial action plans to alleviate the environmental damage will be felt here first.

B. Features of the indicators:

1) Long-term trends in abundance of walleye, yellow perch, northern pike, and smallmouth bass will be monitored annually in selected sites and expressed as the number of fish caught in a given unit of effort using fyke nets, gill nets, trawls, or electrofishing gear.

2) Trends in abundance of non-indigenous species will be monitored annually at selected sites and expressed as the number of fish caught in a given unit of effort using fyke nets, gill nets, trawls, electrofishing, or hydro acoustics gear.

3) Trends in abundance of chironomid, oligochaete, and burrowing mayfly larvae in bottom sediments will be monitored annually in selected sites and expressed as the number of animals per unit area collected with Ponar grabs.

(1) The table will be subdivided into species indicative of a healthy benthic community and species which inhabit degraded benthic habitats.

Abundance of aquatic species will be monitored in relatively healthy areas and compared to catches in unhealthy areas as a way to evaluate progress at achieving the aquatic community objectives. Fish catches in relatively healthy areas like Waiska Bay, Chequamegon Bay, Black Bay, and Cloud Bay should be compared with catches made in AOC's like the St. Louis Estuary, Thunder Bay, Nipigon Bay, and Jackfish Bay.

Abundance and composition of benthic invertebrates in the sediments of harbors, bays, and estuaries are valuable indicators of ecosystem health because these animals are sensitive to pollution, and respond quickly to changes in the environment. These animals can provide the short-term action-required indicators necessary for measuring progress toward achieving aquatic community objectives.

C. Illustration of the index:

Graphs will be developed to illustrate trends in abundance of yellow perch, walleye, and non-indigenous species in AOC and non-AOC sites.

A table will be developed to illustrate density of benthic invertebrates in AOC and non-AOC sites.

D. Limitations and uncertainties:

The development of remedial action plans in AOC's should provide the impetus for creation of sampling programs to monitor health of harbors, bays, and estuaries. Current agency efforts in these areas of Lake Superior are often limited in scope and duration, so that no consistent long-term information on abundance is being collected. Fishery agencies from Minnesota, Wisconsin, and the U. S. federal government have begun an exhaustive program of monitoring fish abundance in the St. Louis estuary in response to invasion of the area by ruffe. The Ontario Ministry of Natural Resources also has an ongoing ruffe monitoring program in Thunder Bay. The monitoring programs in Thunder Bay and the St. Louis Estuary are providing valuable information on trends in fish abundance, but neither program is intended to gather long-term milestones for evaluating aquatic community health.

E. Interpretation of the indicators:

Fifteen of the eighteen human stresses on Great Lakes ecosystems listed by Francis et al. (1979) probably affect the aquatic communities in harbors, bays, and estuaries on Lake Superior. These stressors include those listed previously for other indicators, but they also include water diversions, draining of wetlands, dredging, disposal of dredge spoils, eutrophication from sewage plants, agricultural and urban runoff, thermal loading, and entrainment and impingement in water intake structures. Short-term changes in fish abundance and species composition due to improved water quality will be detected over a relatively short time period in this habitat type and provide a measure of community health. However, this indicator may or may not diagnose a specific problem. Improved water quality in harbors and estuaries may increase survival and growth of a fish species, but increases in angler exploitation because of improved water quality may reduce abundance. Because of the complexity of interactions among the stressors to harbors, bays and estuaries, solutions to the problems will involve educational, administrative, and regulatory actions.

4.4.4 Tributary Community

INDICATORS: Monitor trends in abundance of key aquatic species
Monitor for presence of non-indigenous species
Monitor and document habitat loss or restoration
Monitor self-sustaining indigenous species

A. Purpose or nature of indicators:

Reproducing and self-regulating aquatic communities are the basis for judging the health of the Lake Superior aquatic community. Many Lake Superior fishes depend upon tributaries for growth, survival, or reproduction sometime during their life cycle. Walleye, lake sturgeon, suckers, minnow species, lake trout, and non-indigenous salmonids move freely between tributaries and the lake. Unfortunately, construction of hydroelectric dams, logging, and saw mill operations during the early part of this century destroyed the usefulness of many tributaries for Lake Superior fishes. As a result, abundance of many fish populations declined. Tributaries provide the linkage between the terrestrial and aquatic habitats of Lake Superior and achievement of aquatic community objectives is contingent upon restoration of tributary habitat.

B. Features of the indicators:

1) The presence of self-sustaining populations of brook trout, white suckers, walleye, sturgeon, burbot and other indigenous fishes in selected coldwater and coolwater tributaries to Lake Superior will be monitored annually.

2) Trends in abundance of salmonines in selected tributaries will be monitored annually and expressed as the either the absolute number per unit area, or as the number caught in a given unit of electrofishing.

3) Information on growth and abundance of larval sea lamprey will be used as indicators of water quality and stream productivity.

Healthy tributaries to Lake Superior will contain abundant populations of indigenous and non-indigenous fish species. Although non-indigenous fish species are considered as stressors to the aquatic community, they also are excellent indicators of the health of the habitat in Lake Superior tributaries. In many instances, a non-indigenous species is the only index we have to measure the health of tributary systems. Non-indigenous fishes such as coho salmon, pink salmon, and sea lamprey require healthy tributary systems for survival of their species.

Relative abundance of walleye and lake sturgeon will be monitored periodically in the Bad River and Sturgeon Rivers within U. S. waters. Not all salmonine species will be present in each tributary sampled, but absolute and relative abundance of rainbow trout, brown trout, brook trout, coho salmon, chinook salmon, and pink salmon will be monitored annually in the following tributaries:

Minnesota	-	Knife River, Blackhoof River, Kimball Creek, and Devils Track River.
Wisconsin	-	Little Souix and Big Souix River, Fish Creek, Little Brule, Brule River, east fork of the Flag River, Pikes Creek, Cranberry River, Onion River.
Michigan	-	Chocolay River, Little Garlic River, and Chinks Creek.
Ontario	-	Nipigon River, Steel River, Michipicoten River, and Kaministikwia River.

The United States Fish and Wildlife Service and Canadian Department of Fisheries and Oceans maintain long-term data series describing growth and abundance of larval sea lamprey in many tributaries of Lake Superior. Larval sea lamprey require high quality habitat for growth and survival and the long-term data series will be useful for evaluating changes in health of the habitat in tributaries.

C. Illustration of the index:

Absolute abundance of juvenile salmonine fish species in selected tributaries will be described in tables based on mark-recapture estimates made from electrofishing surveys.

The number of coho salmon, brown trout, rainbow trout, chinook salmon, and brook trout migrating up tributaries that have monitoring or trapping facilities will be illustrated in a table.

A table will be developed which illustrates larval sea lamprey growth and survival in tributaries of varying productivity and health.

D. Limitations and uncertainties:

Most of the information concerning this indicator is currently being collected by the state and provincial agencies, but only in selected tributaries. Expansion of this indicator to tributaries throughout the Lake Superior would be ideal, but will require additional monies that the agencies currently do not possess.

F. Interpretation of the indicators:

Human stressors to the aquatic community of Lake Superior tributaries include logging activities, road and pipeline stream crossings, sedimentation caused by poor land-use practices, industrial pollution, non-indigenous species, hydroelectric dams, and water diversion. These activities can only be controlled through a combination of educational, administrative, and regulatory solutions. Logging and land-use practices reduce the amount of habitat available for reproduction and survival of fishes which use tributaries, while industrial pollution reduces the number of animals which survive the reproductive process. Dams prevent fish from reaching spawning grounds and kill fish which move downstream. Reductions in the influence of these stresses to aquatic communities should be reflected by increased abundance and survival.

4.4.5 Contaminants

INDICATOR: Monitor toxic contaminants in aquatic organisms

A. **Purpose or nature of the indicator:**

The amount of human contaminants in fish flesh is a direct measure of the progress that is being made at reducing inputs of toxic contaminants to the Lake Superior ecosystem, and also help evaluate the potential of having aquatic biota that are reasonably free of contaminants from human activities.

We chose to monitor contaminants in species which tend to spend all or most of their life within one of the four aquatic habitat types of Lake Superior. This way, the level of contaminants in a particular species should reflect loadings into that habitat type, thus making it easier to identify sources of the contamination, and ultimately easier to manage the issue.

B. **Features of the indicator:**

At a minimum, concentrations (mg/l) of PCB, DDT, chlordane, mercury, dioxin, DDE, dieldrin, and toxaphene should be determined for one prey and one predator species of fish from each habitat type.

1) Offshore habitat

Trends in levels of toxic contaminants in siscowet lake trouts, deepwater ciscoes, and deepwater sculpins will be monitored in each of the political jurisdictions of Lake Superior. Siscowet lake trout and deepwater ciscoes will be collected with bottom set gill nets during routine assessment surveys that are conducted by each of the fishery agencies.

2) Nearshore habitat

Long-term trends in concentrations of contaminants in lean lake trout, walleye, lake whitefish, rainbow smelt, slimy sculpins, burbot, lake herring, coho salmon and chinook salmon should be monitored in each of the political jurisdictions. Each of these fish species will be collected with either bottom set gill nets or bottom trawls during routine assessment surveys that are conducted annually by each of the fishery agencies.

3) Harbors-embayments-estuaries

Trends in concentrations of contaminants in walleye, brown bullhead, yellow perch, channel catfish, and spottail shiners should be monitored annually in AOC’s and compared to non-AOC areas. There are four AOC's in Canadian waters and three in U. S. waters of Lake Superior. Potential non-AOC sites could include Kakagon and Bad River Sloughs, Waiska Bay, Cloud Bay and Lac La Belle. Fish species will be collected with fyke nets, gill nets, trawls, and seines during routine fishery agency surveys. Trends in contaminants in this habitat should also be evaluated using a benthic invertebrate such as *Hexagenia*.

4) Tributaries

Monitor long-term trends in concentrations of contaminants in mottled sculpins, and non-anadromous species like white suckers, rainbow trout, brook trout and brown trout. These species will be collected from selected tributaries using electrofishing gear. The Wisconsin Dept. of Natural Resources currently monitors long-term trends in contaminants in fish collected from the Brule River.

C. **Illustration of the index:**

IJC already possesses information regarding concentrations of contaminants in lean lake trout and rainbow smelt collected from various areas of Lake Superior over the last 20 years. Concentrations of PCB's in lean lake trout and rainbow smelt collected from the nearshore habitat as part of the IJC monitoring program should be presented graphically over time at each of the major collection sites. Concentrations of contaminants in lake herring and siscowet lake trout should also be monitored since both species are abundant in Lake Superior.

Concentrations of contaminants in the flesh of other species collected as part of the monitoring program should be presented in a table which details levels of the major contaminants found annually in each fish species collected from each habitat type.

D. <u>Limitation and uncertainty</u>:

Man-made contaminants are known to inhibit reproduction of Great Lakes fish, but the linkage between specific levels of contaminants and reproduction have not been established on Lake Superior. Most indigenous and non-indigenous fishes living in Lake Superior are successfully reproducing. Where reproduction is limited, the belief is that contaminants are not the cause. High levels of contaminants in Lake Superior fish are more an indication that the fish are unhealthy for human consumption rather than an indication of the health of the fish populations.

E. <u>Interpretation of the indicator</u>:

Unlike other indicators, the level of man-made contaminants found in fish flesh provide a direct measure of the health of the Lake Superior ecosystem. Typically, concentrations of contaminants in fish flesh do not vary as much on an annual basis as do trends in abundance of a fish species. Because of this characteristic, trends in levels of contaminants in fish provide a direct feedback concerning our ability to reduce and control point and non-point sources of man-made contaminants into the lake. Changes in the levels of contaminants found in fish species from the offshore habitat of Lake Superior measure the rate of atmospheric deposition. In most instances, atmospheric deposition originates outside the Lake Superior basin. To reduce contaminants in offshore fish species will require a change in our collective behavior as a society, and solutions to the problem will have to be addressed through educational and regulatory actions. On the other hand, contaminants in fish from tributaries and harbors usually indicate a problem with a local industry that can be addressed through regulatory solutions.

5.0 Indicators and Targets for the Terrestrial Wildlife Objective

5.1 Background

The Habitat Committee of the Lake Superior Binational Program was asked to develop potential indicators for the **Habitat Objective** as well as the **Terrestrial Wildlife Objective**. This was accomplished through meetings held in Duluth, Minnesota (Dec.1-2,1994), and Sault Ste. Marie, Michigan (Jan. 11-13, 1995), and through the work of individual committee members. A review of other indicator development exercises and relevant literature preceded the meetings, the first of which took the form of a brainstorming session followed by review of the resulting ideas. Those ideas which the committee judged to have merit as potential indicators were assigned to individuals to complete.

The core group responsible for this work was:

Pat Collins, Minnesota DNR
Richard Hassinger, Minnesota DNR
Rich Klukas, US Parks Service
Karen Kroll, Minnesota PCA
Jeri Graham, Lake Superior Programs Office
Ed Iwachewski, Ontario MNR/Environment Canada

Others who attended meetings and provided valuable contributions were:

John Kelso, DFO Canada
Nancy Larson, Wisconsin DNR
Thomas Busiahn, US Fish and Wildlife Service
Stephen Schlobohm, USDA Forest Service
Barbara Leuelling, USDA Forest Service
Dave Morton, USDA Forest Service
Richard Greenwood, USFWS/USEPA
Sonny Myers, 1854 Treaty Authority
Ann McCammon-Soltis, GLIFWC

Within the area of the Basin, there are significant differences in climate, land use and cover, and aquatic and terrestrial communities. Some species or species assemblages which might have been excellent indicators in a portion of the Basin would have little or no value in assessing the remainder of the Basin. This narrowed the range of potential indicators to those which could be used basinwide.

The components of the Terrestrial Wildlife Objective have been addressed using: eagles; ungulate range; mink; and neotropical birds as potential indicators.

Several potential indicators were discussed and rejected by the our committee, for a variety of reasons:

Otter - the rationale for use of the otter in monitoring contaminant levels is similar to that for the mink, and it was decided that this represented an unnecessary duplication.

Wolves- they are only common in the northern portion of the basin and thus would not have basinwide application.

Bears- because of their omnivorous diet, movement within large home ranges and widespread distribution, it was thought that black bears might be an ideal indicator of habitat status in the Basin. It was determined however that it was difficult to establish the linkage between habitat changes and either bear populations, reproductive effort or condition because of compounding factors (e.g. hunting mortality) and the lack of ongoing monitoring.

Amphibians - several recent studies have suggested a worldwide decline in amphibian populations. Despite some existing efforts elsewhere (e.g. FrogWatch in some Canadian Areas of Concern) there was little or no experience or ongoing application at present in the Basin.

Loons- it was not clear to the Committee how programs such as LoonWatch (in Minnesota) would be applied basinwide, nor what the best use of the information would tell us in comparison to other proposed indicators.

Peregrines- collecting contaminant information from the ongoing effort to restore peregrine falcons in the Basin was thought to be a duplication of the eagle work, and that the low numbers of peregrines would represent an inadequate sample size.

5.2. Bald Eagle Abundance and Contamination

A. <u>Ecosystem Objective addressed by this indicator</u>:

Terrestrial Wildlife Summary Objective and Sub-Objective a) *"Bald eagle populations that nest within the Lake Superior Ecosystem should be recognized as valuable integrators and indicators of the health of the Lake Superior ecosystem"*

B. <u>Purpose or nature of the indicator</u>:

The Bald Eagle Biosentinel Protocol is being developed by an Interagency Working Group to coordinate monitoring of Bald Eagle populations and contaminant loads in the Great Lakes. The Bald Eagle has been identified as a suitable indicator of ecosystem health and water quality because it is a fish eating species at the top of the food chain, and is important to the general public.

C. <u>Features of the indicator</u>:

The protocol uses a multi-tier approach to accommodate the needs and resources within each state or province.

Tier 1 - Optimum Monitoring. This level of monitoring should be employed in regions where Bald Eagle populations experience elevated contaminant exposure and/or productivity rates below the long-term average for a 3 year period or when productivity of a subunit averages less than 1.0 young/occupied territory over a five year period.

Aerial Surveys: Conduct annual late winter/spring (dependent on regional laying date) aerial surveys to locate all occupied Bald Eagle territories in Lake Superior watershed and reference area subpopulations. Conduct a second productivity flight to document the number of young produced per occupied territory when chicks are 5-7 weeks old. Additional flights may be required if greater knowledge of the stage of nest failure is required (i.e., incubating vs. post-hatch).

Nestling Banding/Blood Sampling/Egg Collections: Color band and collect blood samples from nestlings (5-7 weeks of age) at successful nests in the survey region annually. Examine nestlings for deformities and search failed nests for unhatched eggs. Nestling plasma and unhatched eggs will be archived and analyzed for organochlorine content every 3-5 years.

Adult Turnover Rates: Participate in research to evaluate the use of nestling DNA fingerprints to measure rates of adult turnover at Lake Superior vs. reference area nest sites. Plasma should be collected at survey nest sites annually for this analysis.

Nestling Biomarkers/Immune Function: Participate in research program to develop biomarkers/bioassays which assess nestling health status and endocrine and immune function to quantify the physiological impact of contaminant exposure. Nestling Bald Eagles with a range of contaminant exposure should be sampled for this analysis.

Necropsy/Mortality Data: Determine cause of death and archive tissues from all Bald Eagles found dead during the breeding season in Lake Superior watershed, utilizing the National Wildlife Health Laboratory of the U. S. Fish and Wildlife Service.

Tier 2 - Minimum monitoring. This is the minimum level of monitoring that an agency should employ to detect changes in the population status or contaminant exposure of a Bald Eagle subpopulation exhibiting elevated contaminant exposure and/or reduced productivity:

Aerial Surveys: Conduct annual late winter/spring (dependent on regional laying date) aerial surveys to locate all (or a sample of) occupied Bald Eagle territories in Lake Superior watershed and reference area subpopulations. Conduct a second productivity flight to document the number of young produced per occupied territory when chicks are 5-7 weeks old.

Nestling Banding/Blood Sampling/Egg Collections: Color band and collect blood samples from nestlings (5-7 weeks of age) at successful nests in the survey region annually. Examine nestlings for deformities and search failed nests for unhatched eggs. Nestling plasma and unhatched eggs will be archived and analyzed for organochlorine content every 3-5 years.

Tier 3 - Healthy Population Monitoring. This level of monitoring will be recommended for Great Lakes Bald Eagle subpopulations which achieve a five year productivity average of ≥ 1 young/occupied territory. Specific monitoring requirements will be developed by the Interagency Bald Eagle Workgroup once this level of productivity is achieved in a Great Lakes Bald Eagle subpopulation. Monitoring will reflect a scaled-down version of Tier 1 and Tier 2.

For this indicator the target would be: <u>greater than 1.0 young/occupied territory and zero organochlorine contaminants in eggs and nestling serum.</u>

D. <u>Illustration of the indicator</u>:

Using this protocol, presentation of the index could include graphical comparisons between productivity and contaminant loads between subpopulations within the Lake Superior watershed, and with other Great Lakes subpopulations.

E. <u>Limitations and uncertainties</u>:

Bald Eagles do not spend their entire lives on one territory. While migration distances are not as great as those of neotropical migrant birds, eagles do spend a significant part of the year off their nesting territories. Isolating contaminant exposure on breeding territories from potential exposure from other areas is difficult. However, this monitoring protocol focuses on indices that are believed to be predominantly influenced by environmental conditions of the breeding territory.

F. <u>Interpretation of the indicator</u>:

Using this monitoring protocol, interpretation of the indicator is based on deviations from reference regions where Bald Eagle populations are believed to be relatively healthy. Reference regions include Wisconsin's North Central District, Minnesota's Superior and Chippewa National Forests, and those inland upper and lower Michigan nests where eagles are not likely to forage on anadromous Great Lakes fish. These regions retained the core of the Bald Eagle population during the "DDT-era", have been found to have the lowest levels of contaminants in eagle eggs and nestling serum, and have a stable, healthy rate of productivity (1.0-1.3 young/occupied territory).

5.3. Ungulate Range in the Lake Superior Basin

A. Ecosystem Objective addressed by this indicator:

Terrestrial Wildlife Summary Objective and Sub-Objective b) *"Native wildlife will be recognized as key elements of a healthy Lake Superior ecosystem"*

B. Purpose or nature of the indicator:

Within the Lake Superior basin and surrounding area, the ranges occupied by large herbivores (woodland caribou (Rangifer tarandus caribou), moose (Alces alces), white-tailed deer (Odocoileus virginianus) and elk (Cervus elaphus)) have been substantially altered from conditions existing presettlement. Changes in ungulate range have been associated with changes in land use and landscape patterns, resultant changes in wildlife community structure, and other anthropogenic stressors such as hunting and poaching. Declining populations of woodland caribou and a reintroduced population of elk must be carefully managed and monitored if these species are to remain as components of a healthy Lake Superior ecosystem.

For this indicator, the ranges of the four ungulate species currently present in the basin would be mapped on a Geographic Information System database and any changes in range size or location would be monitored. The index would allow quantitative analyses of gains or losses in species range over time, and a comparison to known historical range. This would indicate the health of native ungulate populations within the basin and, because of the requirements of each species for different forest types, also provide an impression of how forest management activities may be affecting wildlife communities in general. Since one or more of these ungulates is absent in various parts of the basin, and because one species may be affected by the presence of another, assessing trends in only one species of large herbivore, without considering relationships with other species, provides an incomplete picture for the Lake Superior watershed. In addition, the recreational (hunting) and aesthetic appeal of these animals to the general public increases the usefulness of this indicator as a communication tool about ecosystem health.

C. Features of the indicator:

I. Proportion of historical range occupied

Current and historical ranges of white-tailed deer, moose, woodland caribou and elk would be mapped as data layers for GIS analysis. The range would be recorded as presence or absence in grid blocks, about 10x10 km^{2}, compiling data for a 5 year survey period. An index of proportion of historical range currently occupied (size of current range/size of historic range) would be the primary measure.

Monitoring of ungulate populations varies widely among the different jurisdictions within the Lake Superior basin. Nonetheless, it should be possible to incorporate much of the monitoring required for this range index from ongoing inventory programs and recorded observations:

Woodland caribou: Continuous caribou range is found only in the northernmost region of the basin, along with isolated populations on islands on the north shore of Lake Superior. Many of the island populations are intensively monitored for research purposes. Aerial flights to determine range occupancy of the boreal forest dwelling caribou, particularly for winter range, have been carried out on a irregular basis since the mid-1970's as information for forest management plans and park expansion was required. Anecdotal information about declining range exists from 1880 onwards. Because of the ongoing decline of this species within the basin, it will be important to provide annual funding for aerial surveys to assess further changes in range.

Moose: Moose have been intensively monitored in Ontario and Minnesota, from about 1950-60 onwards, to estimate population and reproductive success for the purposes of establishing harvest quotas. Surveys are carried out based on a 20% stratified random sample of moose management units every one to three years. Such surveys give an indication of moose range although they do not sample it directly. Additional information may be obtained during flights to determine caribou range occupancy or through an expansion of regular census coverage along the edges of range every 5-6 years. The introduced and migrant populations in Michigan will be surveyed using aerial transects every few years (at least every 4 years). In Wisconsin, where only a remnant and unmonitored moose population exists, moose presence is anecdotal. Information about historical distribution is also primarily anecdotal although there is some written documentation in the form of old reports such as surveyor's records.

Deer: Deer are currently widespread throughout Minnesota,Wisconsin and Michigan. Population estimates and harvest quotas in the first two states are set using population models based primarily on hunter return data and have been ongoing since the 1950's. Information about kill location, and thus deer distribution, is included with hunter information provided to the responsible agency. A system of pellet counts along transects is ongoing in Michigan, also since the 1950's to determine population and distribution. Deer in Ontario, which have been established from animals moving north from the States, are no longer specifically inventoried as they were in the 1970's, when aerial surveys were conducted and hunter return data collected. However, extensive aerial surveys for moose are conducted throughout the Ontario portion of the basin, during which the presence or absence of deer in the survey blocks is noted. Historical information about deer distribution is anecdotal.

Elk: A reintroduction of elk is planned for 1995 in the Chequamegon National Forest in Wisconsin. There are currently no other elk populations within the basin. Historical information is mostly anecdotal and may be further discussed in agency feasibility assessments (in Michigan and Wisconsin) of reintroduction possibilities.

II. Range shifts

For the situation where a species is increasing its range in one part of the basin but decreasing its range in other areas of the basin, a numerical index summarizing historical range occupancy may not indicate these changes. GIS maps of current range, range limits 5, 10 and 20 years previous and the historical boundaries could be used to illustrate trends.

An index to measure how far the geographic centre of the current range is from the centre of the historic range has been proposed. This could be done using GIS technology to determine the central point of a polygon encompassing the outer limits of the current range for all populations of a species to compare to the central point of a similar polygon of historical range. Reintroductions and inclusion of widely dispersed, isolated populations would, however, greatly affect such an index.

For this indicator the target would be: the ranges occupied by native ungulate species (woodland caribou, moose, elk, and white-tailed deer) will remain at current levels or shift toward those ranges occupied during pre-settlement times.

D. Illustration of the indicator:

If historical range size is taken as 1, a bar graph can be used to illustrate changes in range size as compared to historical limits (Fig. 1), where values greater than 1 indicate an expanded range and values less than 1 reveal a shrinking range. A line graph may be used to show changes in this index over time and illustrate whether or not the index is moving in the desired direction (Fig. 2). Changes in range size for various populations around the basin can be illustrated on computer generated maps showing current vs. historical ranges of the three species, highlighting the changes over time. Data should be mapped for at least four historical periods from presettlement to current depending on existing information. Ongoing monitoring data should be assessed on five year intervals.

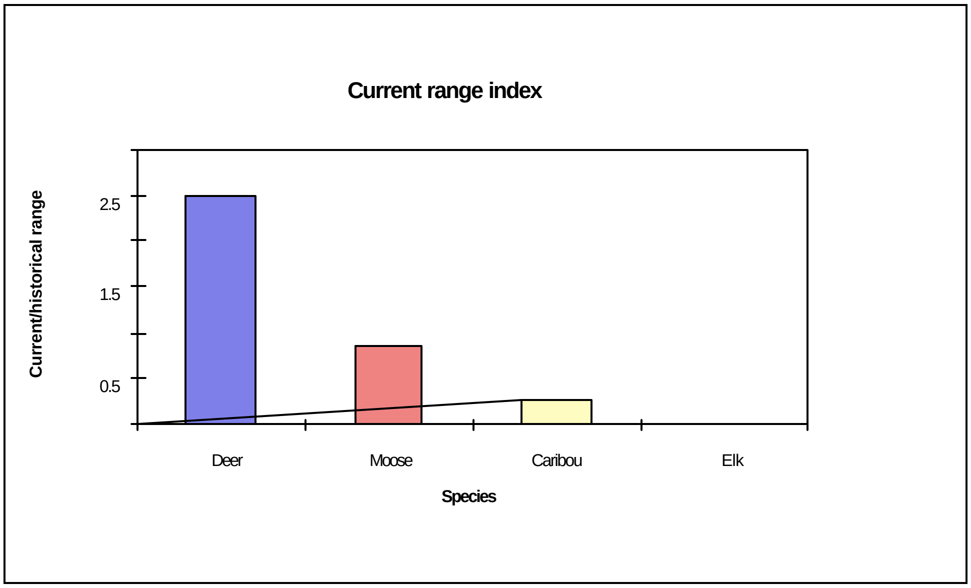

Figure 1. An example, using hypothetical data, of a bar graph to represent the proportion of historical ungulate range as compared to current limits.

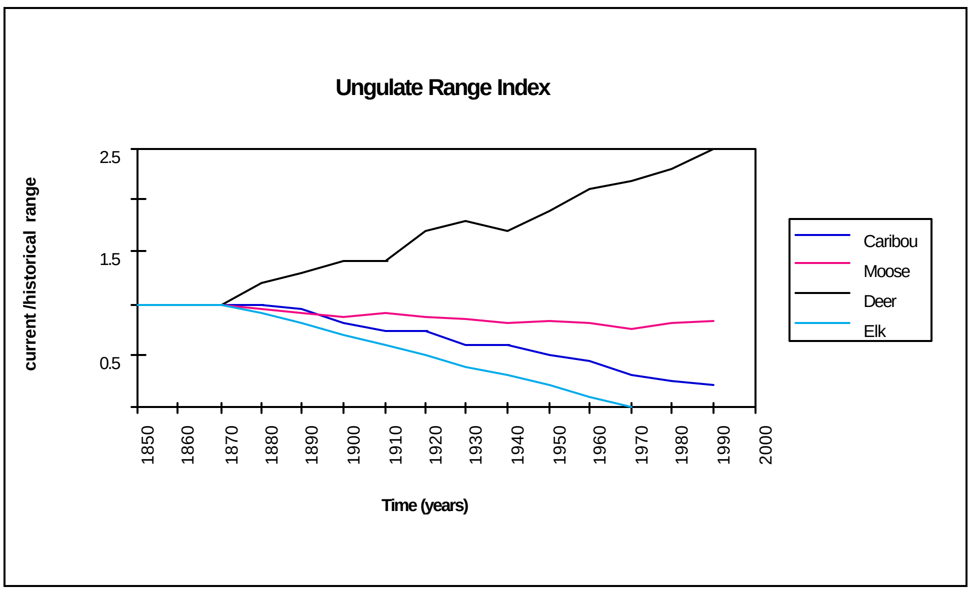

Figure 2. An example, using hypothetical data, of a line graph to illustrate changes in the ungulate range index over time.

E. **<u>Limitations and uncertainties</u>**:

Although many of the necessary data for monitoring current range size are already being collected by resource management agencies in the various jurisdictions, additional aerial monitoring to refine ungulate range descriptions will likely be required and will be expensive. Further costs would be associated with mapping the data, digitizing, compilation of historical range information, and analysis.

For much of the historical data, range size must be estimated based on anecdotal information. Little, if any, information has been published from before 1900. This makes it difficult to establish a baseline year and a standard for historical range. As well, there is no way to confirm species identification from early records, for example, whether the animals observed were moose or elk. Care must be taken when defining the range of a species, particulary for periods when little information is available. Reintroduced populations or small, isolated populations should be identified and excluded from estimates of historical, contiguous range for that species.

There is some difficulty applying this indicator to the basin as a whole since the species which are present and dominant varies across the basin. Caribou, which are arguably the population most sensitive to ongoing land use activities (ie. logging) and which fulfil many of the criteria for a good indicator species (Noss 1990), are present in a relatively limited portion of the watershed. Thus, this species is an indicator of ecosystem change in a very small area. Furthermore, the danger that this species will be extirpated from the Lake Superior basin is very real. Its ability to regain lost range is unknown and debatable which further decreases the usefulness of this species as an indicator. For white-tailed deer, which are fairly widespread throughout the basin, range size is a less sensitive indicator than for caribou. Commonly, the harshness of the winter is one of the most important factors influencing deer population and range.

Following from the last point, it is important to consider that future changes in the range size of ungulates in the basin may indicate substantial changes in habitat structure but may also be influenced by hunting intensity, access for poachers, disease, the severity of winter conditions, or changing levels of predation. Thus, it is not necessarily clear whether the stressors effecting changes in the index would be anthropogenic or part of a natural process.

Finally, given the changing landscape structure which has resulted from resource extraction, agriculture and urbanization, it is not clear that a return to “historical” conditions is possible or even desirable. The altered community structure should be considered particularly when proposing reintroductions of species to areas of former range.

F. Interpretation of the indicator:

The target for this indicator is to maintain the ranges occupied by native ungulate species (woodland caribou, moose, elk, and white-tailed deer) at current levels (1995) or move toward those ranges occupied during pre-settlement times. As the range size index approaches one, the closer the species gets to occupying an area similar to its historic distribution. GIS maps for each species of historic, current and range 5, 10 and 20 years previous will indicate whether or not the range is stable, expanding past historic limits, increasing towards historic ranges, or declining.

It is not realistic to state a desired future condition to be represented by a range size index of one and a full return to historic range for all species. Current land use patterns, long-term changes to forest composition and structure, and even interactions between ungulate species themselves make this unlikely. Specific management activities which address landscape issues will be necessary to maintain the current ranges for some species or to move them in the desired direction.

5.4 North American Amphibian Monitoring Program

A. Ecosystem objective addressed by this indicator:

Terrestrial Wildlife Summary Objective and Sub-Objective b) *"Native wildlife will be recognized as key elements of a healthy Lake Superior ecosystem"*

B. <u>Purpose of nature of the indicator:</u>

Amphibian abundance, species richness and species composition is likely influenced by toxic contaminants, increased acidification, atmospheric changes, and habitat destruction. Assessment of population and community trends of amphibians in the Lake Superior region can provide information about both aquatic and terrestrial wildlife habitats.

The broad goal of the North American Amphibian Survey is to "Provide a statistically defensible program to monitor the distributions and abundance of amphibians in North America, with applicability at the state, provincial, ecoregional, and continental scales" (September 11, 1994).

C. <u>Features of the indicator:</u>

Two monitoring techniques are likely to be most successful with current protocols and understanding in the Lake Superior region. Professional and volunteer partnership based programs to survey calling amphibians and sample larval amphibians are the most promising. Roadside call surveys using volunteers can provide good breeding-season data when observers are well trained and follow well defined protocols. A regional or continental scale indicator for larval amphibians will also require significant training and protocol development, but could provide index for salamanders and less vocal anurans.

D. <u>Illustration of the indicator:</u>

This index can provide information on the status and trends of conspicuous amphibian populations. It would also indicate status of some community-level measures (i.e., species composition, richness). As with most population indices, the results can be illustrated by using population vs. time graphs. Additional comparisons, based on geographic areas (e.g., Areas of Concern vs. Areas of Quality) could be made to illustrate regional or local effects.

E. <u>Limitations and uncertainties:</u>

Status and trend data for amphibian populations and communities are, at present, incomplete and inconsistent. Additionally, precision and bias estimates for calling surveys of amphibians are not well understood. Sampling methodologies and training materials required for sampling larval amphibians have not, as yet, been developed. Validation of larval survey methodologies also needs to occur before a monitoring protocol can be developed.

Factors that might be responsible for regional or global changes in amphibian populations are not yet understood. Several potential anthropogenic causes have been suggested as important factor in the observed decline in different amphibian species. Multiple interacting factors that may be difficult to isolate may be responsible for observed population trends.

F. <u>Interpretation of the indicator:</u>

A large body of evidence, largely anecdotal until recently, suggests that amphibian populations are declining globally. Monitoring population trends of species native to the Lake Superior area will provide an important link between wildlife health monitoring in the Lake Superior region and global wildlife health issues. Coordination on monitoring and analysis at this scale could help to provide perspective to regional issues of concern.

5.5 Mink Contamination

A. <u>Ecosystem Objective addressed by this indicator</u>:

Terrestrial Wildlife Summary Objective and Sub-Objective c) *"Wildlife living in the Lake Superior ecosystem should be free from contaminants of human origin"*

B. Purpose or nature of the indicator:

Mink are predatory mammals near the top of the food chain. They therefore have the potential to be concentrators of chemical contaminants through bioaccumulation. Monitoring contaminant loads provides an indication of the movement of these chemicals through the food web in the basin. Monitoring population trends provides an indication of the effects of that chemical contamination in wildlife species. Exposure to contaminants and cause and effect relationships between toxic contaminants and mink population responses have been examined to determine the appropriateness of mink as environmental indicators (Welch 1992, Ensor 1991, Addison, et al., 1991, Wren 1991). Results suggest that the species is sensitive to environmental contaminants and population responses may be measurable in the wild. (Giesy, et al., 1994, Welch 1992)

C. Features of the indicator:

Contaminant loads in mink will be monitored by collecting mink carcasses from known locations in cooperation with trappers and resource management agencies. Body burdens of selected chemicals can then be tracked over time and compared between geographic areas within the basin and outside the watershed.

Population trends in mink would be monitored basin wide through trapping data, and assessed on a watershed scale as well as a site specific basis. Comparing population trends between areas with demonstrated contaminant problems and other areas will provide an index of population response to contaminants. Comparing population trends in the Lake Superior region with other North American mink populations will provide a broad-scale picture of the status of mink in this region.

For this indicator the target would be: reduction of contaminant body burdens in mink to recommended levels.

D. Illustration of the indicator:

Contaminant loads can be compared between areas using bar graphs, changes in body burdens over time can be presented as line graphs, population trends can be presented as line graphs. Relationships between contaminant concentrations and population trends could be represented by regression lines.

E. Limitations and uncertainties:

Mink carcass availability depends on relationships with trappers and on trapping effort. There is likely a relationship between harvest data and fur prices, but this relationship has not been adequately examined (Welch 1992). Mink are neither prey nor habitat specialists. They inhabit a wide variety of wetland habitats, and feed on a range of aquatic and terrestrial animal species (Hazard 1982). Cause and effect relationships between population changes and habitat are, therefore, more difficult to establish than in specialist species. Likewise, because of the variety of prey species consumed, linkages between specific sources of environmental contamination and observed body burdens are less clear.

F. Interpretation of the indicator:

The feasibility of using mink as an indicator of ecosystem health needs to be investigated more fully. Contaminant loads in mink carcasses from the Lake Superior watershed suggest that mink in some areas are being exposed to elevated levels of bioaccumulative toxics. Specific chemicals of concern can be identified using this indicator. There is potential for identifying 'hot spots' of contamination with proper experimental design, but additional work must be done on food habits, dispersal, and reproductive success of mink to more fully establish cause and effect relationships between population trends and chemical contamination.

5.6 Neotropical Bird Abundance and Diversity

A. **<u>Ecosystem Objective addressed by this indicator</u>:**

Terrestrial Wildlife Summary Objective and Sub-Objective d) *"Management of game species and their habitat should not be detrimental to native and naturally occurring non-game wildlife species"*

B. **<u>Purpose or nature of the indicator</u>:**

The Lake Superior basin supports a rich diversity of forest bird species. Long-term, comprehensive monitoring of forest bird population trends will allow land managers to determine the health of bird communities and forest environments. Because health of forest bird communities is closely linked with habitat conditions, this indicator has the potential to have cross application to other terrestrial wildlife taxa, and the Habitat Objective.

Birds make up about 70% of the terrestrial vertebrate species of Great Lakes forests. Understanding population dynamics and habitat associations of forest birds will provide a good understanding of major elements of ecosystem health.

By following a consistent protocol of 10 minute point counts by highly trained professional bird censusers, stratifying points by habitat, and conducting surveys only on rain-free, calm days, compatible data can be collected by many researchers and agency staff.

C. **<u>Features of the indicator</u>:**

Forest bird communities throughout the Lake Superior watershed will be monitored during the nesting season in a variety of habitats. Monitoring efforts ongoing in several National Forests (Superior, Chippewa, Chequamegon) and National Parks (Apostle Islands) can be used as models for developing monitoring programs in other areas. A highly refined basin-wide monitoring protocol for gathering habitat-specific information on birds, coordinated with systematic landscape-scale vegetation data will allow basin-wide biodiversity mapping based on bird populations.

Forest bird monitoring is most efficient when survey data on all singing bird species are collected. Multiple indices of ecosystem health can then be calculated based on the data gathered. An "index of biotic integrity" has been used successfully for bird communities in other areas and should be examined as an easily communicated element of this monitoring program. For this approach to be successful in the Lake Superior watershed, reference areas with healthy bird communities would be identified and compared to other, potentially less healthy areas.

For this indicator the target would be: <u>no decrease in populations of bird species beyond normal variability and no net loss in biodiversity in the forest bird community within the Basin.</u>

D. **<u>Illustration of the indicator</u>:**

Data from this approach would be presented in a variety of ways. Population trends of bird species of interest would be presented in simple line graphs representing selected geographic areas or the whole basin. Commonly used indices of diversity (e.g., species richness, Shannon-Weiner, Simpson's) would be used as other descriptive attributes of the health of the bird community and would be tracked over time. Indices of biotic integrity for areas surveyed would be presented in bar graph form and compared to other areas for which the index has been calculated.

Broader scaled biodiversity patterns across the Lake Superior Basin could be presented in map form that identify key habitat areas and illustrate changes in bird population patterns over time.

E. **<u>Limitations and uncertainties</u>:**

Breeding bird survey data are applicable to the area for which data are collected. Extrapolation of site specific trends in populations to other geographic areas is problematic. Confidence in using these data to express the health of a large-scale, diverse ecosystem, would depend on having site specific data that adequately represented the range of habitat conditions in the region. For example, relying only on bird monitoring activity in National Parks, where disturbance and fragmentation of habitat is likely relatively low, could result in overly optimistic pictures of population trends or ecosystem health. Conversely, reliance on data from easily accessible areas such as road-side counts, could lead to indices that suggest conditions that are worse than they really are. Data gathering for this indicator is personnel intensive during the short, early-summer breeding season. To adequately survey the Lake Superior Watershed, very large numbers of trained staff, and substantial travel expenses are required. Expansion of ongoing monitoring and efforts to standardize data gathering and quality control would be one way to approach the development of this indicator with the funds that might realistically be expected.

F. Interpretation of the indicator:

This indicator allows interpretation at multiple scales. Population trends of an individual species within a limited geographic area provides useful information to a land manager, and may suggest specific management activities that should be undertaken. Comparisons of indices of biotic integrity between sites would provide a way to evaluate the variety of management strategies employed in similar environmental settings. Analysis of broad patterns, using biodiversity maps provide opportunities to identify landscape level activities that influence ecosystem health.

6.0 Indicators and Targets for the <u>Habitat Objective</u>

6.1 Background

The Habitat Committee of the Lake Superior Binational Program was asked to develop potential indicators for the **Habitat Objective** as well as the **Terrestrial Wildlife Objective**. This was accomplished through meetings held in Duluth, Minnesota (Dec.1-2,1994), and Sault Ste. Marie, Michigan (Jan. 11-13, 1995), and through the work of individual committee members. A review of other indicator development exercises and relevant literature preceded the meetings, the first of which took the form of a brainstorming session followed by review of the resulting ideas. Those ideas which the committee judged to have merit as potential indicators were assigned to individuals to complete.

The core group responsible for this work was:

Pat Collins, Minnesota DNR
Richard Hassinger, Minnesota DNR
Rich Klukas, US Parks Service
Karen Kroll, Minnesota PCA
Jeri Graham, Lake Superior Programs Office
Ed Iwachewski, Ontario MNR/Environment Canada

Others who attended meetings and provided valuable contributions were:

John Kelso, DFO Canada
Nancy Larson, Wisconsin DNR
Thomas Busiahn, US Fish and Wildlife Service
Stephen Schlobohm, USDA Forest Service
Barbara Leuelling, USDA Forest Service
Dave Morton, USDA Forest Service
Richard Greenwood, USFWS/USEPA
Sonny Myers, 1854 Treaty Authority
Ann McCammon-Soltis, GLIFWC

A difficulty in the development of Habitat indicators was that habitat is a major factor of ecosystem health for both aquatic and terrestrial communities. There was concern about overlap with the Terrestrial Wildlife indicators and the work of the Aquatic Communities Objective group. It was decided to proceed by attempting to develop indicators which addressed each of the components of the objectives, and that, while duplication was not desired, some overlap was not a bad thing. Final selection of indicators, after public and agency review, would focus on the best suite of indicators that will provide an integrated assessment for the status of ecosystem health in the Lake Superior Basin.

The components of the Habitat Objective have been addressed using: streamflow/sedimentation, benthic invertebrates, and inland lake transparencies; forest fragmentation; and wetland area/accessible stream length as potential indicators.

6.2 Streamflow/Sedimentation

A. <u>Ecosystem objective addressed by this indicator:</u>

Habitat Summary Objective and Sub-Objective a) *"The ecological health of Lake Superior is determined in large part by the health of its tributary lakes and rivers. Land use planning and regulation in the Lake Superior ecosystem should eliminate or avoid destructive land-water linkages (e.g., erosion of agricultural land, urban stormwater, point and non-point sources of persistent contaminants), and foster healthy land-water linkages (e.g., continuous streamside vegetation buffers, on-site treatment of runoff)"*

B. Purpose or nature of the indicator:

There is extensive evidence linking changes in land use or cover with changes in runoff and sediment regimes in streams and rivers (e.g. Borman and Likens, 1970; Scheuler, 1987; Hartman and Scrivener, 1990). Lawrie and Rahrer (1973; p. 14) suggest damaging alterations to habitat have already occurred in the Lake Superior Basin as a result of historic forest harvest practices. Changes in runoff and sediment regimes can result from watershed or landscape scale effects (e.g. clearcutting; agricultural conversion) or from local or instream effects (e.g. loss of bank stability; ditching). Impacts at the local or instream level have been greatly reduced because of the adoption of guidelines and Best Management Practices (BMP). However, changes on the watershed or landscape scale have not been fully assessed.

Fitzgibbon and Imhof (in press) identify geomorphology, climate, landuse and landscape features as four causal indicators which condition the inputs of water and sediment into fluvial systems. Changes in landuse for urban development, agriculture or forestry alter the runoff regime and sediment production from the watershed, which alters flows and patterns of erosion and deposition, causing changes in channel characteristics that ultimately affect the habitat available for macroinvertebrates, fish, aquatic mammals, waterfowl and other associated species.

It is proposed that monitoring stream flows and sediment transport will provide a suitable indicator of these watershed scale changes.

C. Features of the indicator:

Bennett (1978) provides a description of the water budget for Lake Superior and noted that time-series discharge data was available for 32 tributaries around Lake Superior. He divided the basin into eighteen drainage areas, and estimated the mean annual rate for and drainage to be 1709 $m^3 sec^{-1}$. Kemp et al. (1978) estimated that 2.41 million metric tons of suspended materials were carried into the lake by rivers and streams. In Ontario, Environment Canada maintains 14 hydrological (stream-gauge) stations while the Ontario Ministry of Environment and Energy has over thirty water quality sampling sites (OMOE, 1992). Similar stations to record discharge and water quality are located in Minnesota, Wisconsin and Michigan.

Many of these stations have been in operation for some time (30+ years) and provide a long-term basis for comparison. These existing monitoring programs around the Basin provide a relatively inexpensive method for obtaining information on stream flow and sediment discharge (expressed as total particulates or through turbidity, total dissolved solids or conductivity).

For this indicator the target would be: through habitat restoration and protection, to maintain the pattern of annual stream discharge and reduce the net loading of sediments into Lake Superior.

D. Illustration of the indicator:

The index would be presented through line graphs depicting mean discharge, stream base flow, peak-to-low ratio and sediment loading (or a surrogate) on an annual basis for the streams which maintain hydrological stations. Comparison with historical trends will allow a determination of change occurring within each monitored watershed. Johnston (1992) suggests GIS techniques could be combined with watershed models to simulate the effects of land-use change on water quality.

E. Limitations and uncertainties:

Environment Canada is presently reviewing its national program for the hydrological stations it maintains, and up to half of them may be closed, although the exact number on Lake Superior is not yet known. A review of water quality monitoring stations and stream-gage stations by provincial and state agencies may result in similar reductions in monitoring. Tributary sediment monitoring is a difficult task, and the extent of historical data and potential for future data collection is uncertain.

There is also some uncertainty in attributing changes in stream flow and sediment transport to watershed level changes in land use and cover. There is a high variability in climate (precipitation, temperature) from year to year which affects flow and runoff regimes. Similarly local or short-term events (e.g. streambank collapse, road construction) could cause impacts similar to those resulting from watershed changes.

F. Interpretation of the indicator:

Changes in stream flow such as increased annual streamflow, greater peak-to-low ratio, increased frequency of peaking and increased sediment transport could indicate significant degradation in the watershed had occurred.

6.3 Benthic Invertebrates

A. Ecosystem objective addressed by this indicator:

Habitat Summary Objective and Sub-Objective a) *"The ecological health of Lake Superior is determined in large part by the health of its tributary lakes and rivers. Land use planning and regulation in the Lake Superior ecosystem should eliminate or avoid destructive land-water linkages (e.g., erosion of agricultural land, urban stormwater, point and non-point sources of persistent contaminants), and foster healthy land-water linkages (e.g., continuous streamside vegetation buffers, on-site treatment of runoff)"*

B. Purpose or nature of the indicator:

Aquatic macroinvertebrates in streams, inland lakes or estuaries of the Lake Superior Basin are in general quite sensitive to changes in water quality conditions resulting from human activities in adjacent terrestrial areas. Use of agricultural chemicals, discharges from urban and industrial areas, forest fires, floods and erosion from heavy rains are all often registered both over long and short time scales on aquatic communities and species.

Trends in aquatic species populations (density and richness) and community structure can serve as indicators of improvement or deterioration in terrestrial conditions. Monitoring of aquatic macroinvertebrates in streams, estuaries, and inland lakes is useful for understanding the nature and effects of habitat modifying physical-chemical elements, and mechanisms and processes associated with human activities in terrestrial areas within the basin. Moreover, such monitoring is critical to understanding, and if necessary, mitigating physical, chemical, and biological changes occurring within waters of Lake Superior.

C. Features of the indicator:

The macroinvertebrate monitoring system will involve collection of two major categories of data: physical-chemical characteristics of the waters themselves; and selected species, groups, and communities of aquatic macroinvertebrates. Determination of water characteristics and macroinvertebrates to be monitored would best be achieved by convening a workshop-type assemblage of subject experts.

Monitoring sites will be established in stream, estuary and inland lake locations. Locations will include pristine as well as human influenced settings. Some sites may be within parks and refuges that have already begun monitoring programs. Sampling will occur two to three times annually for the first five years in order to establish baseline conditions. Thereafter, monitoring intensity may be reduced but should continue as long as there is a need to assess trends in the health of the ecosystem. Protocols to be followed are those now used by U.S. Fish and Wildlife Service, National Biological Service, and National Park Service units in the Great Lakes basin. There may be a need to rectify differences in approaches among these agencies in order to obtain comparative data.

For this indicator the target would be: <u>to maintain healthy aquatic macroinvertebrate communities and restore degraded communities back to an accepted baseline condition. The desired baseline community will be defined based on conditions in "pristine" control areas or by using a model to simulate the expected community for a given area.</u>

D. <u>Illustration of the indicator</u>:

The experts who determine physical and biological characteristics to be monitored, and specify sampling and monitoring protocols, would likely define appropriate strategies for data analysis and exposition of results. Their recommendation may include use of bar and line graphs and tables to detail conditions at each monitoring site. These could be used to compare conditions between sites as well as changes occurring over time.

Important water quality characteristics that would likely be displayed in these illustrations would include pH, turbidity, total nitrogen, total phosphorus, and organic carbon. Anticipated illustrations of biotic parameters that might be covered include density, taxonomic richness, and diversity. Simpson's <u>D</u> would provide an index to changes in density of rare species while site by site portrayal of Shannon-Wiener <u>H</u> results would illustrate changes in density of more dominant species.

E. <u>Limitations and uncertainties:</u>

Analysis of water and invertebrate samples can be costly and time consuming. All parties involved in the Lake Superior program would be required to devote considerable resources for development of this indicator.

There is a nationwide program in the United States to develop standardized approaches to gathering and interpreting water quality and macroinvertebrate data. This may in time lead to changes in sampling and analysis strategies. However, no universal strategy is foreseen. Instead it can be anticipated that various strategies will be recommended, reflecting inherent differences in habitats and biota over broad geographic areas. From the Canadian perspective, there is no regular monitoring program for aquatic macroinvertebrates and standard procedures for sampling and analysis are similarly lacking.

Many of the current sampling strategies employed in the Great Lakes are based on a state-of-the-art system developed by the US Environmental Protection Agency (EPA). If current EPA water quality-macroinvertebrate monitoring strategies are used in Lake Superior sites, it seems unlikely that the program would be considerably compromised by the release of new standards.

F. <u>Interpretation of the Indicator</u>:

Changes in human use patterns in the terrestrial environment, and their effects on aquatic ecosystems of the Lake Superior Basin, will be detected by this proposed indicator. Site by site comparisons of changers in land use, along with changes in aquatic systems, would allow managers to develop strategies to mitigate detrimental activities. Data on water quality characteristics and status of macroinvertebrate species and communities can be developed at site, landscape, and regional levels to detect and define problem sources and develop appropriate mitigation strategies. Correlation of changes in various characteristics of Lake Superior's aquatic ecosystem, with changes in inland systems monitored through this indicator, is also likely.

6.4 Inland Lake Transparencies

A. <u>Ecosystem objective addressed by this indicator:</u>

Habitat Summary Objective and Sub-Objective a) *"The ecological health of Lake Superior is determined in large part by the health of its tributary lakes and rivers. Land use planning and regulation in the Lake Superior ecosystem should eliminate or avoid destructive land-water linkages (e.g., erosion of agricultural land, urban stormwater, point and non-*

point sources of persistent contaminants), and foster healthy land-water linkages (e.g., continuous streamside vegetation buffers, on-site treatment of runoff)"

B. Purpose or nature of the indicator:

There are a large number of inland lakes within the Lake Superior Basin that are monitored by citizen programs. These data may be the only mechanism for determining changes over time in water quality. Some of these data goes back as far as the early 70's, providing the only baseline information for some lakes. Understanding Secchi transparency as one measure to characterize the trophic status of lakes, is important in determining the status of ecosystem health for aquatic environments and habitat areas for aquatic communities, terrestrial wildlife, and terrestrial biota.

Secchi transparency (clarity) is an indicator of suspended material in water and provides an indirect measure of algal concentrations. This is important to measuring water quality trends and trophic status over time.

By collecting these data and continually monitoring inland lakes within the Basin, trends can be determined. Changes in these trends (positive, negative, no change) would be significant in determining overall ecosystem health.

C. Features of the indicator:

Transparency readings for inland lakes will be taken through the citizen monitoring programs. These data will be collected and compared, along with data from natural resource agencies, over time, and on a geographic basis, while monitoring continues. Minnesota, Wisconsin, and Michigan each have a program that involves citizens who voluntarily monitor. Since historical data has dated back as far back as 1973, analysis can take place on the state of the ecosystem and its changes. This type of monitoring will continue, and is a significant factor in allowing detailed information on inland lakes.

Secchi transparency is an excellent tool for citizens to measure water quality. Detecting trends and trophic status is the goal of this type of monitoring. Comprehensive data sets which require many years of data already exist within the Basin. The summer-mean transparency for a lake may vary from year to year, based on biological and climatic fluctuations and must be taken into consideration when making assessments based on these data.

For this indicator the target would be: to maintain or increase water transparencies for lakes within the Lake Superior Basin, consistent with the management objectives for each lake.

D. Illustration of the indicator:

Data from monitoring will be presented in the form of map depicting the depth of Secchi readings for lakes that are monitored, negative changes, positive changes, and lakes that have seen no significant changes. This approach might lead to a better understanding of areas that might be seeing a decline in water quality.

E. Limitations and uncertainties:

The historical data will vary for the lakes involved in monitoring, so that comparisons will be skewed, to a certain extent. These data, however, can be compared by the amount of change, if any. Climatic and biological changes (e.g. the excessive precipitation in Minnesota for 1993) can greatly influence monitoring results. Excessive precipitation in a lake's watershed might result in high pollutant loading in the form of nutrients and sediments to a lake. Variation might result in the monitoring programs across agencies.

F. Interpretation of the indicator:

A Basin-wide understanding of variations in lake transparency, due to pollutants, trophic states, and changes in geographic areas will provide a clear understanding of ecosystem health for inland lakes. These data can be observed in a small-scale and a large-scale basis, with the potential to provide resource managers with a clear understanding of areas that are degraded. Evaluation of healthy areas may further aid resource managers as to opportunities to improve and protect on a basin level.

6.5 Forest Fragmentation

A. Ecosystem objective addressed by this indicator:

Habitat Summary Objective and Sub-Objective b) *"The long-term consequences of incremental or cumulative landscape change, habitat destruction, and habitat fragmentation should be anticipated and avoided in the Lake Superior ecosystem, through research and planning at appropriate spatial and temporal scales"*

B. Purpose or nature of the indicator:

Forest fragmentation is one of the most prevalent features of landscape change occurring within many forested regions of the world and is recognized as a major cause of declining biodiversity (Whitcomb et al. 1981). Within the Lake Superior basin, forest fragmentation is associated with the habitat fragmentation and resulting extirpation of several native species, including buffalo (Bison bison), elk (Cervus elaphus), cougar (Felis concolors), wolverine (Gulo gulo) and black bear (Ursus americanus), from some or all of their range (Matthiae and Stearns 1981). Measuring indices of forest fragmentation provides an indicator of terrestrial habitat condition in the Lake Superior basin.

Harris (1984) describes forest fragmentation as a landscape-level process in which forested areas are sub-divided into smaller, geometrically more complex, and more isolated forest fragments as a result of both natural processes and human land use activities. Natural disturbances which alter forest structure include fire, wind, insects and climate effects (Baker 1992). Human-related factors are part of the expansion and intensification of human land use (Burgess and Sharpe 1981), including urbanization, and deforestation during timber extraction and clearing for agriculture. Additionally, humans may alter the patterns caused by natural disturbances, for example, through fire suppression (Baker 1992).

Habitat fragmentation involves habitat loss, reduced patch size and a greater distance between patches in a landscape (Andren 1994). To measure forest fragmentation, several indices or metrics must be measured and assessed in relation to each other. Suggested metrics include: total forest area, mean patch size and variability, mean patch core area and variability, total forest edge and average distance between forest patches.

C. Features of the indicator:

I. Indices of fragmentation

A spatial pattern analysis program, FRAGSTATS, has been developed to measure a variety of indices for quantifying landscape structure (McGarigal and Marks 1993). This program could be used to analyze GIS images of the Lake Superior watershed at different periods of time. Landscape metrics would be calculated to determine the degree of forest fragmentation and provide an indication of how landscape structure is changing.

As a starting point, mature, closed-canopy forest may be designated as the class or feature of interest. It must be a class that is readily detectable using remote sensing techniques, but also be ecologically significant. Forests could be further broken down into conifer, hardwood forest (Bauer et al. 1994) and mixed-wood.

The most fundamental metric is probably 'class area', that is, how much of the watershed is comprised of the patch type of interest (ie. closed-canopy forest). This, in essence, is a measure of habitat loss or gain (McGarigal and Marks 1993).

To determine the size of habitat patch generally available to wildlife, 'mean patch size' could be used, whereby a decreasing value would indicate an increase in fragmentation. A similar metric, but one which takes into account patch shape, is mean core area. This metric is more ecologically relevant for forest-interior species, since it assumes an edge effect within a certain distance of the patch boundary. Studies show, for example, increased predation and parasitism of bird nests along forest edges (Wilcove 1985). This metric will also differentiate between forest patches with similar overall area but different shapes. For example, it is possible that a long, thin strip of forest may be comprised largely of edge habitat and will, therefore, not be as valuable to forest-interior species a round patch of forest of similar area. An appropriate measure of edge width must be determined which is measurable and meaningful. If the satellite pixel size is 30 or 80 m, edge width cannot be defined as smaller than this level of detection.

It is also important to consider the 'patch size variability' or 'core area variability' in order to appreciate whether only a few very large patches are available together with many small patches, or whether patch size is more evenly distributed across the landscape. This feature may be considered as a summary statistic or, perhaps preferably, as a distribution.

Forest edge effects, caused by the differences in wind and light intensity along the edge of a forest patch, affect vegetation in the edge zone and are considered of great importance to many wildlife species. The conditions along forest edges has been the subject of much research and the basis for many wildlife management strategies (ie. increasing available edge for moose and deer). Total forest edge within the basin may be one of the most critical measurements of forest fragmentation since many of the adverse effects of fragmentation are related to edge effects (McGarigal and Marks 1993).

The distance between forest patches, or nearest-neighbour distance, may greatly affect the population dynamics of spatially subdivided populations and plays an important role in the conservation of endangered species (McGarigal and Marks 1993). Mean nearest-neighbour distance may be calculated as one index depicting changing landscape patterns in the basin.

Besides the amount and spatial arrangement of “closed-canopy” forest, changing forest composition may be assessed as a second, more detailed aspect of this indicator. Forest species composition is steadily changing based on natural successional patterns after various types of disturbance or due to planned reforestation activities. A breakdown into various forest classes, and corresponding analysis of fragmentation of those forest types, could further clarify patterns of forest change. Another possible index could be the change in area of each forest type over time and relative to total forest area.

II. Data collection and analysis

To assess a landscape feature such as fragmentation on a basin-wide scale, satellite technology provides a cost-effective means of collecting landscape data on a frequent and regular basis, as compared to air photos (Bauer et al. 1994). A study has been carried out in Minnesota to relate Landsat TM data to the existing FIA (Forest Inventory and Analysis) plot information (Bauer et al. 1994). There, it is proposed to analyze satellite data of the four major inventory regions on a rotational basis (once every four years). Satellite images may be interpreted using various software programs to produce GIS data files which can then be analyzed using a landscape analysis program such as FRAGSTATS. Annual field measurements will be used to check the accuracy of image processing, which classifies different reflectance values from the satellite data into landcover classes.

In the U.S., the Environmental Monitoring and Assessment Program (EMAP) is developing a Geographic Reference Database and a land-cover classification system. This is intended to standardize collection of landscape data and make available a number of spatial data sets. Studies using Landsat TM data to classify landscape cover types by relating satellite images to aerial photographs and ground plots have also been carried out in several parts of the basin in Ontario.

For this indicator the target would be: <u>no further increase in forest fragmentation in the Lake Superior basin as measured by several complementary indices of landscape composition and pattern. A decrease from the current level of fragmentation is desirable.</u>

D. <u>Illustration of the indicator</u>:

Each metric will be calculated for the entire basin, and bar or line graphs could be used to indicate increases or decreases over time. Some related metrics, for example mean patch size and patch size variability, may be combined in a single chart to demonstrate their relationship more clearly. A summary statement will likely be required relating the different metrics to the changes occurring in the landscape. To illustrate which areas of the basin may be particular problem areas, or where improvements have been made, a GIS map of the basin may be used depicting colour-coded Landsat pixels as either showing an increase, decrease, or no change in forest canopy (see Bauer et al. 1994) as compared to the image taken 1-4 years previously. This information could be further summarized into a map illustrating, using colour codes, portions of the basin where fragmentation is considered a problem (ie. red), a concern (ie. yellow) or not an immediate issue (ie. green).

E. <u>Limitations and uncertainties</u>:

The values of the landscape metrics will be greatly affected by the amount of resolution inherent in the satellite images (McGarigal and Marks 1993). This will be determined by the type of imaging chosen, for example Landsat TM (Thematic Mapper) provides information for a pixel size of 30x30m while the Landsat MSS (Multispectral Scanner) interprets the landscape at a much broader scale, 80x80m. It is important that forest fragmentation in different parts of the basin be calculated based on the same degree of resolution. Given the large size of the Lake Superior basin, technical considerations rather than purely ecological aspects will likely determine the scale and resolution at which this data is to be analyzed. Since the "optimum" patch size varies for different species or guilds of species, this provides a standard for an otherwise difficult issue.

The large area means there are additional confounding factors in land-cover gradients and in atmospheric and phenologic differences in different parts of the basin (see Bauer et al. 1994). This may require stratifying the basin into different regions, perhaps using ecoregions (U.S.E.P.A. and Environment Canada 1988) or by using another method for analyzing remote sensing data (ie. guided clustering (Bauer et al. 1994)). There must be a basin-wide consistency when defining the forest classes to be measured.

There are always some classification errors, that is, assigning a landcover type to a spectral class. Part of this problem comes from the difficulty of assigning a unique class to a pixel which may, in fact, be composed of several landcover types. In particular, cutover/shrub-land/grassland classes may be easily confused with other classes (Bauer et al. 1994, Gluck and Rempel 1995).

Designating a boundary around the Lake Superior watershed, or setting a boundary around any analysis area, inherently creates problems when assessing patch distance. The distance to nearest neighbour may not be as great as indicated by the metric; patches just outside the boundary may act as a source from species can disperse to suitable habitat within the watershed.

Although a number of studies and programs are in place around the Lake Superior basin to relate satellite (Landsat) data to landscape cover types, coverage of the basin is not complete. Initial efforts could be focused on areas where fragmentation is already thought to be a problem. Initial investment in equipment is considerable and some staff time is required for ongoing data analysis and checking the classification using air photos and ground plots.

F. <u>Interpretation of the indicator</u>:

The metrics describing forest fragmentation should be considered in the context of each other and what they indicate about overall landscape structure. In general, the target is no net loss of forested area, no decrease in mean patch size/core area, no increase in distance between forest patches and no increase in patch edge. These targets apply to the basin as a whole. A balance must be found between the overall goal for the basin and local land management goals which may be, for example, to increase agricultural land use.

6.6 Accessible Stream Length

A. <u>Ecosystem objective addressed by this indicator</u>:

Habitat Summary Objective and Sub-Objective c) *"The crucial importance of nearshore, shoreline and wetland aquatic habitats in Lake Superior should be addressed through continuing efforts to identify, protect and restore key sites for reproduction and rearing of fish, water, birds, mammals and other wildlife"*

B. <u>Purpose or nature of the indicator</u>:

Steedman (1992) notes that of Lake Superior's 1127 km Canadian shoreline, only 17% is composed of embayments or estuaries that would provide the protected conditions suitable for establishment of wetlands and macrophytes. The U.S. side of the lake has approximately 17,400 hectares of coastal wetlands (Dodge and Kavetsky, 1994). Estimates of the loss of wetlands in sections of the other Great Lakes range from 11% to 100%, but this information appears to be lacking for Lake Superior (Bedford, 1990). It is fair however, to assume that wetland loss has occurred in Lake Superior, especially in developed sites such as the seven Areas of Concern, each of which has identified habitat loss as a beneficial use impairment (Hartig, 1993). The importance of coastal wetlands to the biological productivity and diversity of Lake Superior is evident, as are the stresses acting to degrade or destroy them (The Nature Conservancy, 1994).

There are 840 tributaries to Lake Superior, and of those on the Canadian side, there are 1091 km of accessible stream below the first barrier to migration (Steedman, 1992). Similar information is likely available on the U.S. side through stream surveys or lamprey control studies. A variety of natural and manmade barriers to migration exist, however many of the manmade dams are no longer required to maintain water levels (e.g. for log drives, mills). Many structures are decaying and need to be removed or rebuilt. Other structures to be kept and maintained (e.g. small hydropower) and natural barriers (e.g. rapids, waterfalls) are being examined for the addition of fish passage devices. The combination of new fishways and removal of old barriers creates a potential for significant expansion of stream length accessible to migrating fish.

C. <u>Features of the indicator</u>:

Remote sensing technologies and GIS would provide a rapid method of mapping and estimating changes in wetland area or accessible stream length (based on field data input). Johnston (1992) cites the use of this technique for wetlands and streams in Minnesota. This could be updated on an annual basis, or longer, depending upon management requirements.

For this indicator the target would be: <u>through habitat restoration and protection, to increase the net area of coastal wetland (in hectares) on the Lake Superior shoreline and the net length of accessible stream (in kilometres) in its tributaries, in each of the states and the province bordering the lake.</u>

D. <u>Illustration of the indicator</u>:

A GIS-based analysis system would be able to provide both graphical (i.e. map, graphs) and database (i.e. spreadsheets, charts) representation of changes in wetland area and accessible stream length.

E. <u>Limitations and uncertainties</u>:

Quantity is not necessarily a good indicator of quality. An increase in the area of wetland or in stream reach available to migrating fishes does not mean any increase in production will result. Ground truthing or alternative quality assessment techniques will still be required, as will assessment of any change in production.

F. <u>Interpretation of the indicator</u>:

An increase in the area of wetlands or in accessible stream length will provide simple indications of positive change in Lake Superior's ability to produce fish and other aquatic life.

7.0 Indicators and Targets for the Human Health Objective

7.1 Background

In 1989, the Ecosystem Objectives Working Group (EOWG) was formed by the US and Canadian governments (parties to the Great Lakes Water Quality Agreement) as the instrument for developing ecosystem objectives and their indicators of progress for each of the Great Lakes. The EOWG was asked to focus first on Lake Ontario in order to complement the Lake Ontario Toxics Management Plan. In 1992, the EOWG outlined the objectives for human health in Lake Ontario and derived indicators to measure progress in reaching the objectives:

Environmental Health Indicator: The following media were proposed to be monitored for contaminants and the levels compared to standards: food originating in the Great Lakes basin (e.g. fish and wildlife), drinking water, recreational water, air and soil.

Body Burden Indicator: The concentration of toxic contaminants in human tissues to serve as an indicator for exposure.

Health Effects Indicator: Traditional indicators such as cancer and birth defects.

Public Perception Indicator: Indicator to gauge if people are not using certain resources because of perceived health risks.

In 1994, human health objectives were developed by the binational Lake Superior Work Group for Lake Superior and a set of human health indicators, essentially those identified above, were proposed by Health Canada to measure progress.

The five objectives are outlined in the "Ecosystem Principles and Objectives" document for Lake Superior. Briefly they are:

a. fish and wildlife should be safe to eat;
b. water quality should be protected or improved;
c. water should be safe for total body contact activities;
d. air quality should be protected or improved; and
e. soils should not present a hazard to human health.

The indicators proposed by Health Canada for the above objectives (status in parentheses) are:

1) Fish Contaminant Indicator (ongoing sportfish contaminant monitoring program)
2) Drinking Water Quality Indicator (ongoing monitoring by DWSP)
3) Recreational Water Quality Indicator (ongoing monitoring by regional health units)
4) Air Quality Indicator (ongoing monitoring by AQUIS)
5) Radionuclides Indicator (ongoing monitoring of radiation)
6) Body Burden Indicator (ongoing monitoring by health agencies)
7) Health Effects Indicator (ongoing studies by several agencies)
8) Cohort Indicator of Exposure and Effects (ongoing studies by several agencies)

note: an indicator for soil was not presented since Health Canada is not currently doing work in this area.

This suite of indicators was sent out for comments to US federal and state agencies and other interested groups. Comments were received from the Michigan Department of Natural Resources and the US Environmental Protection Agency - Great Lakes National Programs Office, and incorporated into this document.

A Note of Caution: Description of these indicators presented in this document refers mainly to Ontario or Canadian standards. Often agencies, particularly those in the US, would have to use their own standards when developing these indicators for their use.

Development of these indicators on a Great Lakes basin-wide basis would benefit from multi-partite involvement in and coordination of monitoring programs throughout the basin.

The following individuals from Health Canada have been involved in working on this document: Moe Hussain, Jennifer Rae, Rick Jeffery and Libbie Driscoll.

7.2 Monitoring Contaminant Levels in Fish

A. Ecosystem objective addressed by indicator:

Human Health Summary Objective and Sub-Objective a) *"Fish and wildlife in the Lake Superior ecosystem should be safe to eat; consumption should not be limited by contaminants of human origin"*

B. Purpose or nature of indicator:

Through the Ontario Sportfish Contaminant Monitoring Program, The Ministry of Environment and Energy (MOEE) monitors the concentration of an assortment of contaminants in sportfish. Monitoring levels of contaminants in fish is an important part of a comprehensive monitoring strategy since it can give a direct measure of exposure to contaminants from the Great Lakes. Freshwater fish represent one of the main links between contaminants in the aquatic environment and humans. The exposure by other sources is relatively small. This indicator will provide information on the exposure of humans to toxic chemicals through consumption of sportfish.Subsistence fishing should also be monitored for contaminant levels.

C. Features of the indicator:

Concentration of contaminants in fish will be determined from a boneless, skinless fillet of dorsal muscle flesh removed from the fish. This provides not only the most consistent test results, but is also the most edible portion of the fish. This tissue is analyzed for the following contaminants at the Ministry of Environment and Energy's laboratories using a variety of analytical methods: mercury; PCBs (total); mirex (Lake Ontario only).

The state of Michigan monitors for many more contaminants. Fish consumption restrictions occur when trigger levels for a number of chemicals are exceeded. A trigger level is a contaminant concentration at which a fish consumption advisory is considered. A health protection value of 0.05 $\mu g\ kg^{-1}\ day^{-1}$ is established for PCB residue in sport fish (average meal = 227 g uncooked fish) for a 70 Kg adult consumer. Choosing an appropriate indicator species is crucial, and should be based on species popularity, species that tend to be the most contaminated, and availability of data. The following four top predator species of sportfish have been chosen to represent the indicator: coho salmon, walleye, rainbow trout and perch.

D. Illustration of the indicator:

Results of raw data will be used to construct simple bar graphs showing the fluctuation of contaminants over time and space in Lake Superior. The chosen contaminants will be summed to provide an overall indicator of fish contamination. This indicator will be similar to the index used for the air indicator.

E. Limitations and uncertainties:

Data for use in developing indicators exist, but there are problems including:

a. differences in surveillance techniques for fish consumption; and

b. lack of coordination of data with regard to bacterial monitoring for recreational purposes. The Ontario Ministry of Natural Resources is responsible for the collection of fish. Thus, MOEE has no direct control over where fish are caught. Due to expense involved in the collection and analysis of fish samples, retesting locations are divided into three groups:

i) areas where contaminant levels are elevated or fluctuate substantially are tested every one to three years;
ii) areas with no substantial change in contaminant levels, but are popular angling sites are tested every five years; and
iii) all other areas, usually remote locations with little contamination are tested every 10 years, or as resources permit.

This sporadic sampling protocol has resulted in a lack of direct cause and effect linkages and a lack of high quality baseline data.

Lack of knowledge concerning the migratory patterns of fish, combined with lack of knowledge of growth rates in and amongst lakes, confounds the ability to release fish advisories with high levels of confidence.

F. <u>Interpretation of the indicator</u>:

The indicator will be used to monitor fluctuations in the concentration of contaminants. The indicator will allow regulatory agencies to make suggestions regarding remedial plans as well as issuing advisories to the public on safe consumption limits.

7.3 Drinking Water Quality

A. <u>Objective addressed by indicator</u>:

Human Health Summary Objective and Sub-Objective b) *"Water quality in the Lake Superior ecosystem should be protected where it is currently high, and improved where it is degraded. Surface waters and groundwater should be safe to drink after treatment to remove natural impurities and microorganisms"*

B. <u>Purpose or nature of indicator</u>:

Through the Drinking Water Surveillance Program (DWSP), the Ontario Ministry of Environment and Energy (MOEE) monitors 15% of the water supplies in Ontario, representing 85% of the population. Since 1986, DWSP has monitored approximately 180 parameters in water including microbiologicals, organics, inorganics and metals. Raw, treated and distributed water are analyzed. Results are compared against Ontario Drinking Water Objectives, Canadian Drinking Water Guidelines (accepted guidelines for Ontario), and WHO objectives.

C. <u>Features of the indicator</u>:

The following proposed contaminants would be monitored pre- and post treatment: lead; trihalomethanes; nitrates; benzo[a]pyrene; and mercury. The state of Michigan monitors for several other contaminants such as arsenic, barium, cadmium, silver, selenium, fluoride, etc.

Exposure in Ontario is based on 1.5 L/day/70 Kg adult. However, for most contaminants, guidelines are adjusted for more sensitive populations such as children and pregnant women. In the case of the Canadian Drinking Water Quality Objectives, the following levels have been set for contaminants:

Maximum Acceptable Concentration (MAC) - established for certain substances known or suspected to cause adverse effects on health.

Interim Acceptable Concentration (IMAC) - recommended values where sufficient toxicological data was unavailable for developing a MAC.

The state of Michigan sets maximum contaminant levels (MCLs) which are close to those of the EPA's maximum contaminant level goals (MCLGs).

D. <u>Illustration of the indicator</u>:

Data from the DWSP program would be presented as simple bar graphs representing selected locations in Lake Superior. Graphs would show the geometric average of the concentration of contaminants in raw, treated and distributed water. There are two possible approaches:

i) A reference value is developed for selected contaminant parameters from which observed trends and variations can be plotted as a baseline. Since most contaminants rarely exceed guidelines, reference values could be developed which are a percentage or fraction of the MAC or IMAC. From this reference point, it would be possible to report variations over time and assign a weighted value to the variations. These values should correlate with the condition of the environment in Lake Superior and could be used in early detection of increasing or decreasing exposure to contaminants and human health risk.

ii) Mean annual concentrations may be used as a pivotal reference point and plot increases or decreases over time. Data would be averaged from a baseline date from locations around Lake Superior. Changes over time would be indexed; for example, a 10% increase in annual concentration of certain contaminants could be scored as -1, whereas a 10% decrease would be scored as +1.

E. <u>Limitations and uncertainties</u>:

Most contaminants in drinking water rarely exceed guidelines; many are in fact below the detection limit for that contaminant. Since the absolute concentration of some contaminants may not be determinable, it is difficult, if not impossible, to show fluctuations in concentration levels. In cases where the contaminant level is below the detection limit, the detection limit itself may be used as the reference value.

Contamination of the treated water as it passes through the distribution system is beyond the scope of this indicator; lead pipes, lead solder and some types of metallic hardened plastic pipe may leach lead into the domestic water supply.

Due to cutbacks in the DWSP program, drinking water data is not continuous. Monitoring is often conducted on a bimonthly, or less, basis. Enhancement of the DWSP program would be one way to approach the continued development of this indicator.

F. <u>Interpretation of the indicator</u>:

This indicator would reveal trends in contaminant levels in raw and treated drinking water in various locations throughout Lake Superior.

7.4 Recreational Water Quality

A. <u>Objective addressed by indicator</u>:

Human Health Summary Objective and Sub-Objective c) *"The waters of Lake Superior should be safe for total body contact activities, even adjacent to urban and industrial areas"*

B. Purpose or nature of indicator:

One of the most important factors in recreational water is the microbiological quality. After a rainstorm, recreational waters become contaminated with animal and human faeces from surface run-off and poorly treated sewage. This indicator will monitor beach postings and *E. coli* counts spatially and temporally throughout Lake Superior to aid in beach management and prediction of episodes of poor water quality. This indicator could also monitor beaches for the "nine contaminants" in discharge effluents to identify chemical pollution of the beaches.

C. Features of the indicator:

The Ontario Ministry of the Environment and Energy (MOEE) and the Ontario Ministry of Health are currently reevaluating recreational water quality objectives. Prior to 1992, the quality of beach water was considered impaired when total coliform geometric means exceeded 1000 per 100 mL and/or faecal coliform geometric mean exceeded 100 per 100 mL. This was not, however, the ideal indicator since bacterial counts may have been caused by factors other than faeces. Industrial and commercial effluent may cause increases that would not realistically reflect human and animal intestinal fauna.

Since 1992, the most widely used organism for determination of water quality has been *E. coli*. The guidelines for Canadian Recreational Water Quality recommend that levels of *E. coli* not surpass 2000 per L of water.

In the state of Michigan, Rule 62 states that:

(1) All waters of the state of Michigan shall contain not more than 200 faecal coliform per 100 mL. This concentration may be exceeded if such concentration is due to uncontrollable non-point sources.

(2) Compliance with the faecal coliform standards prescribed by subrule (1) of this rule shall be determined on the basis of the geometric average of any series of 5 or more consecutive samples taken over not more than a 30 day period. Three or more samples should be taken in this area.

It is proposed that total *E. coli* counts be made at each of 20 sites in Lake Superior based on recreational water standard sampling 5 times per year. It is also proposed that current data for "the nine contaminants" be assessed or that monitoring programs for these contaminants at selected beaches commence.

D. Illustration of the indicator:

Raw data for each selected site will be presented as a bar graph showing trends over several years for: (i) *E. coli*, (ii) beach closures, and (iii) contaminant levels. Graphs will show the geometric means of *E. coli* over a five month period. Total arithmetic means may be used to examine the temporal and spatial trends in water quality amongst beaches.

E. Limitations and uncertainties:

A survey of beach closures by Rang et al (1992) concluded that the information reviewed was so varied that a trend assessment was difficult. The type of data varied (e.g. annual geometric means, summary of postings and verbal statements), and guidelines used by different health units were not consistent. The following are factors contributing to the erratic patterns in data on beach closures:

1) in the majority of cases, local practice variations in monitoring recreational water account for the inconsistencies. (e.g. number of days water was monitored may vary);

(2) the relevant monitoring criteria may have been changed in certain municipalities due to fiscal economic circumstances (e.g. the MAC may have been raised);

(3) water sampling done during the summer months, usually done weekly, may be done less often in some areas due to budget cutbacks;

(4) some beaches have a history of not closing often;

(5) poor reporting practices also contribute to the inconsistencies;

(6) episodic accidents may account for some of the leaps in beach closures from one year to the next.

Overall, the drastic changes from year to year indicated by data are not due to natural phenomena, but have more to do with the process of monitoring and reporting. In addition, monitoring of beaches for chemical pollution may be sparse.

F. <u>Interpretation of indicator</u>:

Analysis of data may show seasonal and local trends in recreational water. If episodes of poor recreational water quality can be associated with events (e.g. storms, run-offs and seasons), then forecasting for episodes of poor water quality may become more accurate.

7.5 Air Quality

A. <u>Objective addressed by indicator</u>:

Human Health Summary Objective and Sub-Objective d) *"Air quality in the Lake Superior ecosystem should be protected where it is currently high, and improved where it is degraded. Communities, industries and regulators outside the Lake Superior ecosystem should be informed of the consequences of long-range atmospheric transport of contaminants into the Lake Superior basin"*

B. <u>Purpose or nature of indicator</u>:

This indicator will use information from the existing Ministry of Environment and Energy (MOEE) air monitoring databases. Data from state agencies could also be used if they are available. Through the Air Quality Information System (AQUIS), MOEE monitors ambient concentrations of the following contaminant gases: SO_2 (sulphur dioxide); CO (carbon monoxide); O_3 (ozone); NO_2 (nitrogen dioxide); NO (nitric oxide); NO_x (oxides of nitrogen); THC (total hydrocarbons); RHC (reactive hydrocarbons); TRS (total reduced sulphur); and SP (suspended particulates - measured as a coefficient of haze (COH) to generate an estimate of SP).

The AQUIS network consists of ca. 262 continuous monitoring devices distributed at 99 sites to monitor up to nine different gaseous contaminants. The AQUIS data are divided into three major categories: (i) continuous (1-hour) measurements, (ii) daily (24-hour) measurements, and (iii) monthly measurements (collected over a 30-day period producing 12-monthly measurements per year).

The Air Quality Index (AQI), initiated in 1988 by MOEE, is a composite of several pollutants, including SO_2, O_3, NO_2, TRS, CO, and SP and provides the public with an indication of air quality at 34 sites in 27 major cities across Ontario. Categories of air quality include:

very good:	0-15
good:	16-31
moderate:	32-49
poor:	50-99
very poor:	100 and over

Data are compiled as the number of hours of unacceptable air quality (including hours of moderate and poor air quality) at AQI sites in Ontario as well as the number of hours in ranges of very good, good, moderate, poor and very poor.

The Air Pollution Index, a sub-index of the AQI, provides the public with 24-hour running averages of SO_2 and SP. Data is reported on the number of occasions when adverse conditions are forecast for 6 hours or more and the API is greater than 32 (air pollution advisory issued), 50 (first alert level), 75 (second alert level) or 100 (air pollution episode threshold level). Reporting frequency is increased to hourly releases when the index reaches 32. If the index value reaches 50-99, the air quality may have adverse effects on the most sensitive of the human or animal population.

The state of Michigan has established standards for seven pollutants: SO_2, NO_2, CO, O_3 (photochemical oxidants), hydrocarbons and lead.

C. **<u>Features of the indicator</u>:**

The following contaminants are proposed to provide an overall air quality index: SO_2, CO, O_3, NO_x, TRS and SP. The indicator may be presented as:

- **(a)** the number of days in high quality to low quality categories; and
- **(b)** the number of exceedances per year of the air pollution advisory (APA); for example, when APA exceeds 32 and 50 (first alert level).

D. **<u>Illustration of the indicator</u>:**

Raw data will be presented as geometric means in simple bar graphs showing trends over several years for: (i) each pollutant in Lake Superior, and (ii) each pollutant expressed as a collective over the entire Great Lakes basin.

The data will also be presented in the form of an index which is a "summation" of all exceedances, expressed relative to an arbitrary reference point for each pollutant, and presented as a simple line graph. The summation value is expressed as a percentage of the number of times per year that air quality levels were exceeded. The index will provide an indication of fluctuations in air quality for Lake Superior as well as overall air quality in the Great Lakes basin.

E. **<u>Limitations and uncertainties</u>:**

MOEE monitors air quality in major urban centres throughout the Great Lakes basin. The location of the majority of the monitors is at or near the top of buildings where air currents eliminate sampling problems associated with stagnant air. However, since ground level air is more stationary, it may contain higher concentrations of pollutants and toxic chemicals than air sampled at elevation. MOEE is currently remedying this with portable "nose level" air monitoring stations. Outdoor air quality may not be the best indicator of human health since exposure to outdoor air is generally brief, usually in the morning and afternoon. Indoor air quality is often of lesser quality, and exposure times are longer. Resources to monitor indoor air quality across Ontario are needed.

F. **<u>Interpretation of the indicator</u>:**

The results of the indicator will be easy to interpret since a single line graph will show the overall air quality trend for several years. This will allow regulatory agencies to suggest changes for improvement of air quality and/or show that remedial plans are having a positive effect.

7.6 Radionuclides

A. Objective addressed by indicator:

Human Health Summary Objective *"The health of humans in the Lake Superior ecosystem should not be at risk from contaminants of human origin"*

B. Purpose or nature of indicator:

Natural background radiation provides an average dose of approximately 2.6 mSv a^{-1} to every resident in the basin. The total committed dose to the year 2000 to each individual in the basin from weapons tests conducted up to 1980 has been estimated to be approximately 2.1 mSv (Ahier and Tracy, 1993). The Bureau of Radiation Protection of Health Canada, has a number of monitoring stations across Canada, several of which are in the Great Lakes basin. Samples of whole milk are collected monthly and analyzed for cesium-137 and strontium-90 quarterly. Monthly samples are also taken in the vicinity of nuclear power stations.

The Michigan Department of Public Health in coordination with the Department of Agriculture will monitor milk, as required, for I-131, Cs-134, Cs-137, Sr-90 and Sr-89. The total intake level is 7 microcuries for Cs-137 and 2 microcuries for Sr-90. The occupational level for Sr-90 is 3×10^1 microcuries for oral ingestion. The value for Cs-137 intake in water is 1×10^{-6} microcuries mL^{-1}; for oral ingestion, the value is 1×10^2 microcuries.

C. Features of the indicator:

Radionuclides which are soluble and chemically analogous to essential nutrients follow similar pathways as their nutrient analogues. Thus, strontium will compete with calcium, and cesium will compete with potassium. Total mean annual levels of cesium-137 and strontium-90 in cow's milk from three sites in the Great Lakes basin (Thunder Bay, Toronto and London) are assessed.

The maximum acceptable concentrations (MAC) recommended by the ICRP are 50 Bq L^{-1} for cesium-137 and 10 Bq L^{-1} for strontium-90.

D. Illustration of the indicator:

Results of almost 30 years of data will be presented as bar graphs showing the decline of cesium and strontium since cessation of atmospheric weapons testing. Simple bar and line graphs will show the total radiation expressed as a percentage of the MAC.

E. Limitations and uncertainties:

The trends provided by this data illustrate the decline in radioactivity in Canada and the Great Lakes basin after the ban on above ground nuclear testing. A focus group organized for Environment Canada on indicators suggested that providing levels of radioactivity in air was misleading because human and ecological exposure to radiation comes from a variety of sources (e.g. food, air and water). That exposure is down due to decreased weapons testing is not especially useful to policy makers and regulatory agencies.

Due to the cessation of atmospheric weapons testing, strontium and cesium have fallen to background levels. These radionuclides may not be the best indicators. Tritium and carbon-14 may be of greater interest since tritium is produced during nuclear power generation in the fuel rods, moderator and coolant in heavy water reactors, and carbon-14 since it is essential to all life forms and has a long half-life of 5730 years.

F. Interpretation of the indicator:

This indicator will show the trend in decline in concentration of cesium-137 and strontium-90 in cow's milk over a 30 year period. This indicator provides a measure of the overall exposure of the population in the Great Lakes basin from weapons fallout.

7.7 Body Burden

A. Objective addressed by indicator:

Human Health Summary Objective: *"The health of humans in the Lake Superior ecosystem should not be at risk from contaminants of human origin"* This indicator could also apply to sub-objective a) regarding monitoring of contaminant levels in fish, if it is assumed that tissue levels of contaminants are a reflection of consumption of Lake Superior fish.

B. Purpose or nature of indicator:

The concentration of toxic contaminants in human tissue can serve as an integrated indicator of exposure to toxic chemicals. Although exposure to chemicals does not necessarily imply expression of toxic effects, body burden information is valuable to help delineate potential from actually delivered doses of chemicals. There is an assumption that if the body burden of toxics goes down, a decrease in health effects should also occur. A good example of a body burden indicator is monitoring of organochlorine levels in mothers' milk.

C. Features of the indicator:

Currently it is not possible to define the biologic media, the specific contaminants or the measure of those contaminants. Health effects experts, toxicologists, epidemiologists and other experts would have to determine target chemicals, target tissues and protocols for sampling and analysis. Until protocols are developed, indices and/or reference points cannot be established.

D. Illustration of the indicator:

The method for presenting indices are dependent on how they are defined. Historical data may not exist or may not be comparable because of advances in measurement technologies.

E. Limitations and uncertainties:

Typically, health effects or indicators of exposure are not specific to a particular contaminant. It may be necessary to identify populations with known high exposures to a particular contaminant to establish whether and which health effect is expressed. This effort can be expected to be very costly and would need to be supported by an entity with institutional stability to assure funding and quality control.

F. Interpretation of the indicator:

For some measures, for example lead in blood, a great deal is known about both health and environmental implications. But, for the majority of contaminants, the exposure pathways are ill defined. In order for this indicator to be useful, exposure pathways and pharmacokinetics of relevant xenobiotics will need to be specified.

7.8 Health Effects

A. Objective addressed by indicator:

Human Health Summary Objective: *"The health of humans in the Lake Superior ecosystem should not be at risk from contaminants of human origin"* The indicator could also apply to sub-objectives a) - e) regarding fish consumption, drinking and recreational water quality, air quality, and soils.

B. Purpose or nature of indicator:

The occurrence of or change in rate of an adverse health outcome directly linked to exposure to Great Lakes basin contaminants is an indicator of effect.

C. Features of the indicator:

This indicator is measured in a variety of ways depending on the specific endpoint of interest. The endpoint may be rates of diseases such as cancer or birth defects, body burdens of xenobiotics such as lead or DDE, changes in function such as pulmonary capacity or liver enzyme production or occurrence of biomarkers such as adducts. Calculation of indices are generally straightforward using established methods for rates and ratios. Interpretation may be difficult in some instances because normative data for many endpoints do not exist.

D. **Illustration of the indicator:**

A 20-year retrospective ecologic study has been conducted by the New York State Department of Health that examined birth weight, gestational age and malformations of infants within and outside the Lake Ontario basin. A difference was found between infants born in and out of the basin 20 years ago, but since then an increase in birth weight in both groups has occurred and the differences are no longer significant.

E. Limitations and uncertainties:

Defining effects that are revealing is a major question and most effects are not specific to a particular contaminant even with good exposure assessment which is most often not possible; attributing particular effect to particular exposure can be inappropriate.

F. Interpretation of the indicator:

In addition to the limitations described above, it is often difficult to draw conclusions because factors in human populations in addition to contaminants exist that may exacerbate or mitigate the effect of interest. For example, in the 20-year birth study, the quality and accountability of prenatal care including supplemental feeding programs have improved. These factors may greatly outweigh any effect, if there is one, on birth outcomes.

7.9 Cohort Indicator of Exposure and Effect

A. Objective addressed by indicator:

Human Health Summary Objective *"The health of humans in the Lake Superior ecosystem should not be at risk from contaminants of human origin"* The indicator could also apply to sub-objectives a) - e) regarding fish consumption, drinking and recreational water quality, air quality, and soils.

B. Purpose or nature of indicator:

This indicator combines the derived features of the exposure and the effects indicator by establishing a carefully defined cohort of people within the Great Lakes basin, taking into account socio-economic factors, sex, life styles, etc. and repeatedly monitoring that cohort for exposure indicators (body burden and/or other biomarkers of exposure) and for expression of health effects. Over time (years or decades) this cohort will act as representative of the Great Lakes population.

C. Features of the indicator:

This indicator measures both individuals' exposures and health outcomes as described in the Body Burden Indicator and the Health Effects Indicator.

D. Illustration of the indicator:

The indicator can be illustrated using the full complement of techniques used in epidemiology. These include tables, graphs and equations. The 20-year retrospective reproductive outcomes study described in the Health Effects Indicator section was illustrated using tables and graphs.

E. Limitations and uncertainties:

The completion of the project would require federal coordination and funding and extensive collaboration with the Great Lakes states and provinces. The use of existing data bases is very limited for this purpose. A new monitoring program designed for this purpose would best get the need to identify direct human health effects from Great Lakes exposures.

F. Interpretation of the indicator:

This indicator is most similar in design to a laboratory study that can be conducted using human subjects. Interpretation of this indicator is relatively straight forward if adequate exposure and outcome measures are identified and if the cohort is selected appropriately.

8.0 Indicators and Targets for the Developing Sustainability Objective

8.1 Background

Conceptual Overview

There is no more important ecosystem objective than that which insures a sustainable human presence in the Lake Superior basin for generations to come. The reason the Binational Program dedicates itself to each of the other five objectives outlined in this document is, ultimately, because women and men have decided that this region is important, that humans and nature can coexist for the benefit of one another, and that a concerted effort to create a sustainable society will eliminate the false choice between jobs and the environment. Yet the fact we are all part of nature, that we could respect the Earth for its intrinsic worth, or that we might profit immensely by considering the rest of the world our equal is not the point. At the end of the day, it will be human society that has chosen between a healthy, vibrant, and sustainable future adjacent to Lake Superior or one which is bereft of the qualities which make this place so special in the minds of citizens in Canada and the United States.

Despite differences of opinion, definitions of sustainability generally share a variety of attributes. Developing sustainability in the Lake Superior basin involves making decisions about where we want to be (e.g., the targets for the other five objectives in this document) in comparison with existing regional conditions. It is also something that can only be seen over time; the true measure of a sustainable society is on the scale of generations rather than years (Pearce, 1993). Sustainability mandates that, at the very least, we conserve the existing resources in the basin so that our descendants can enjoy the same quality of life of the present generation, if not a qualitatively better standard of living. We must cultivate and appreciate a diversity of social and natural resources as they are harnessed to truly improve the lives of most citizens in the watershed. Ecology, society, and culture must be given equal weight in the calculus for promoting sustainability. To this end, we have divided the indicators of this section into three themes referencing: **sustainability of ecosystems**, **social infrastructures**, and **cultural values**.

The ecosystems component of this objective focuses on the inter-relationship between the physiobiological characteristics of the Lake Superior basin and the ability of humans to sustain their use of those resources in an adaptive manner. This calculation assumes that natural systems are dynamic to the extent they reflect a diversity of inputs into the regional resource base, that the natural dynamism of the ecosystem should be sustained, and that an inherent consequence of human action in the system will be a greater or lesser need for the remediation of deleterious impacts which, in turn, make humans an integral part of the ecosystem. These assumptions are supported by a variety studies and commentary suggesting that we must focus on general biotic systems when assessing sustainability (e.g. Wilson, 1992).

Currently, the primary reason most people would even want to sustain biotic ecosystems is because the resources contained therein support the society in which they live. And, clearly, when we consider the broad sense of sustainability, we are compelled to consider the extent to which social infrastructures can continue to flourish, provide succor for those in need, and enable a quality of life that is valued by the general public. Too often, the debate over sustainability reduces to simply a matter of economics wherein "jobs" become a rallying cry in defense of one policy or another (Hannon, 1992). While it is certainly the case that a stratified society resting on few economic bases is not going to be sustainable in the long run, or that a natural resource base under stress is likely to neither attract an influx of capital for further development nor retain a skilled workforce, there is more to sustaining social infrastructures than can be captured in models of supply and demand. Other key components deal with the less tangible issues of ethnicity, tradition, local ownership of problems and their solutions, and the commitment to developing an enlightened citizenry.

In the drive toward a sustainable society, it is not enough to simply insure that the natural and social environment is preserved so that people may continue to reap benefit from a region. The indispensable fact is that humans have values for the places in which they live and the things that they do in those environs. Such beliefs are shared in communities and are historically transmitted from generation to generation; in the context of how people use language to interact among themselves, engage in spiritual or political activities, and embrace world views associating themselves with the natural environment, communities reflect their cultural values (Geertz, 1973). Unfortunately, on the North American continent, the dominant culture has historically been one of resource exploitation and the devaluation of cultural diversity which has led us to the point where we must reassess what it is we believe in so that we may sustain ourselves in a society that even remotely resembles the one we have come to cherish. And these considerations of culture also extend to the Lake Superior basin wherein people have come to carve-out valued lifestyles and environmental relationships, some of which contribute to the long-term viability of the region and some that implicitly undermine survivability. For example, consider the tension that may exist between what has been described as a "hinterland mentality" advocating free access to resources in the basin versus the general resistance residents have to the growth of urban areas or the purchase of land by outside interests. Here, what is valued by basin peoples may not be valuable for the maintenance of that basin and its riches. Therefore, when we consider the promotion of a sustainability society around the largest body of fresh water in the world, we must sort though the competing visions of culture that exist in the basin and nurture those which best fulfil the natural and social promise of the region.

Process

Fifteen experts drawn from the private and public sectors, and who generally live near the US and Canadian shores or Lake Superior, were invited to draft statements reflecting their understandings and philosophies regarding the concept of sustainability. These statements (representing knowledge in fields as diverse as sustainable development, environmental ethics, economics, forestry, cultural anthropology, and ecosystem management) were synthesized by a workshop facilitator familiar with stakeholder decision making procedures; the combined ideas formed the basis for a two day workshop held in January of 1995. At that meeting, participants generated a wide range of potential sustainability indicators and, by consensus, selected the twenty indicators outlined in this document. Widespread agreement was obtained concerning the fundamental nature of most of the indicators during the course of the workshop. In the six cases where time constraints prevented discussion of the key elements associated with chosen indicators (e.g., target values, limitations), the facilitator drafted preliminary estimates of the expert's thoughts concerning issues and modified the draft based upon stakeholder feedback received after the meeting. Afterward, the participants had the chance to review the entire narrative for this document (written by the facilitator in light of an example and guidelines provided by the Binational Program) before it was submitted.

General Limitations

The experts who developed the following indicators, targets, and key considerations regarding the development of sustainability in the Lake Superior basin expressed a number of significant concerns regarding the document and process, as well as the concept itself. There was a general sentiment that the other five objectives would overshadow the importance of sustainability and that more time was devoted to the work of other groups examining biological indicators steeped in technical data than to the issue of how those natural features interwove with social needs in the basin. Some participants voiced reservations at the over-reliance on quantitative indicators of sustainability which might obscure the true measurement of how well we are sustaining a viable and harmonious presence in the watershed; a couple were troubled by the elevation of human interest over that of nature. There also was the noticeable absence of representatives from some of the significant sectors of the basin's population (e.g., First Nations) whom declined an invitation to participate. Finally, the members of the workshop insisted that the final report consider the full range of issues they chose to include in this document; to do otherwise would be to give short shrift to the most important objective of the lot and the <u>only</u> one which considers the role of such important factors as the economic viability of policies and the maintenance of valued lifestyles.

To gain a fuller appreciation of what the drive for sustainability means, readers of this document are urged to bear in mind a number of caveats. Unlike some other measures of objectives, there is no single best indicator of sustainability; it is a multifaceted determination which necessitates the simultaneous consideration of multiple indicators, grounded in a variety of disciplines. Such requires a substantial investment in time, effort, and finances especially for the creation of new indexes to measure complex interactions; it also requires the development of periodic (e.g., every ten years) reports that are easily understood by citizens and policy makers alike. Additionally, one should focus on the basin as a whole, rather than become fixated on one or two components of the larger system. This sense of getting "the big picture" is complicated by the need to appreciate the dynamism of the Lake Superior basin which steps to a cadence far in excess of the time frames we are used to. Though it is a resilient system, humans can and have had a dramatic impact on how it functions. Yet, because of its size, we often cannot see the harm or good we do in the short-term.

Nonetheless, seven generations from now, the steps we do or do not take today to develop sustainability at the turn of the century will be apparent.

8.2 Theme: Sustaining Ecosystems

8.2.1 Status of basin Diversity

A. Ecosystem objective addressed by this indicator:

Developing Sustainability Summary Objective and Sub-Objective a) *"Public and private decisions will be right when they tend to preserve the integrity, stability, and beauty of the biotic community (Leopold, 1968)"*

B. Purpose or nature of the indicator:

This indicator gives us an overview of the quality and quality of individual components in the ecosystems comprising the Lake Superior drainage including surface, subsurface, and aquatic features of the living and physical environment. In order to conclude if regional resources are being sustained for human use (e.g., sustainable growth and yield of timber stands), we need to understand something of the independent contributions made by biotic, geologic, and hydrologic elements in the system.

C. Features of the indicator:

Beginning in the first year in which the Lakewide Management Plan is put into operation (i.e., LaMP year-one), a comprehensive baseline inventory of resources in the Lake Superior basin will be constructed by combining existing taxonomies of ecosystem components (e.g., McNab & Avers, 1994) with those drawn from Geographic Information System (GIS) data bases yet to be developed (Ripple, 1988). As time goes on, each previous iteration of the evolving inventory will be compared with both the previous overview as well as ongoing trends in the presence or renewal (via remediation and restoration activities) of resources.

For this indicator the target would be: no net loss of basin resources.

D. Illustration of the indicator:

The inventory will be presented as a taxonomic listing indicating the quantity and quality of separate components (similar to what is currently presented in Ontario by the Forest Resource Inventory), in graphic illustrations revealing changes in feature qualities from iteration to iteration, and as statistical summaries demonstrating the magnitude and significance of changes in the basin given its LaMP year-one resource base.

E. Limitations and uncertainties:

Current base budget allocations for inventorying US and Canadian resources must be maintained and subsequently increased as a function of state-of-the-art measurement techniques and the need to coordinate perhaps incompatible sources of information regarding components. Assuming a ten year cycle of data collection and synthesis, interim decisions must be made as to what to include or exclude from the overall inventory given time and money available for the project (e.g., the cost of the 1993-94 US Forest Service inventory for Michigan's Upper Penninsula within the basin exceeded $1,000,000). By itself, the inventory lacks a spatial context in which to make site-specific interpretations meaningful; as policy makers move away from the regional scope of the inventory, errors in accounting for why certain resource levels change are bound to occur.

F. Interpretation of the indicator:

In determining the ongoing status of basin diversity, we will be able to identify the net gains, loses, and cyclic trends in the separate resources of the Lake Superior basin as well as single out particular classes of resources that may be reflecting nonsustainable practices or natural events (e.g., disease). However, in of itself, the inventory cannot suggest specific remedial or administrative policy.

8.2.2 Landscape Patterns

A. Ecosystem objective addressed by this indicator:

Developing Sustainability Summary Objective and Sub-Objectives a) *"Public and private decisions will be right when they tend to preserve the integrity, stability, and beauty of the biotic community (Leopold, 1968)"*, and *d) "The basis for guiding sustainable development at the scale of the Lake Superior basin should be the pattern of land, water, and air use, as these affect ecological, social, and economic progress"*

B. **Purpose or nature of the indicator**:

An analysis of landscape patterns tells us the extent to which the separate resources in the basin are either naturally configured, protected in close proximity to one another, or explicitly manipulated for human use. Regional patterns reveal important information regarding the state of the basin in areas as different as the existence of wildlife migration corridors, the ratio of developed to undeveloped land, and the density of roads as a function of recreational values, access to raw materials, or the need to insure safe havens for natural systems. In short, landscape patterns help illuminate the ebb and flow of dynamic connections which contribute to structural diversity in the watershed (Crow, Haney, & Waller, 1994).

C Features of the indicator:

Through the development and use of a comprehensive, region-wide GIS map, which overlays basin resources upon one another, we can measure the general shape of how the basin is or is not being transformed by human and natural conditions (cf. Tomlin, 1990). Using LaMP year-one as a basis, the indicator associates clusters of biotic systems with trends in human use, establishing the relative proportion of pressure being placed upon particular subregions of the watershed. For example, if cyclical mapping shows the expansion of urban development into previously undisturbed quarters, the independent effects of concomitant habitat disruptions and resource allocations (e.g., groundwater depletions) can similarly be charted (Falkenmark & Chapman, 1989).

For this indicator the target would be: a regional pattern of landscapes reflecting diverse and connected ecosystems, and containing protected areas (e.g., parks, preserves) representative of those ecosystems.

D. Illustration of the indicator:

Graphic and statistical indices of basin-wide and local alterations in landscape patterns will provide easily understood representations of large scale changes in the basin. However, since most people have a difficult time appreciating how broad changes in the face of the basin influence their specific niche in the ecosystem, the capabilities of GIS to pictorially represent sustainable and unsustainable patterns of land use ought to be exploited at public forums, in on-line services, and the like.

E. Limitations and uncertainties:

Assuming a ten year cycle of mapping (sequenced with the emergence of the ecosystem inventory noted earlier), the cost of developing a regional GIS will be substantial; 1990 estimates by the Natural Resources Research Institute suggest the initial US and Canadian costs will exceed $200,000 dollars. Furthermore, at least another $30,000 will be needed to develop a GIS for lake ecosystems; currently, there is no accepted classification scheme for doing so. Even with economical advances in the state of remote sensing technologies, significant barriers must be overcome to produce a truly usable view of landscape patterns in the basin. Wide variabilities in land-use objectives pursued by different public and private interests compound the problem of drawing causal relationships between land pattern fluctuations and overall sustainability. And, although much of the drainage is currently administered by public agencies, various property rights on either side of the border may complicate the gathering of data on the ground.

F. Interpretation of the indicator:

If financial and political barriers can be overcome, our ability to employ this indicator will be a great asset to the attainment and management of sustainable practices in the basin. Demonstrable trends in constellations of resources will provide policy makers with more or less specific directions for planning, as well as give advocates a powerful tool for the sustainability of natural resources. A regional map of the landscape around Lake Superior will also help us to understand the web of diversity that unifies the watershed and which should be especially heeded in the creation and maintenance of protected areas.

8.2.3 Integrity of Biotic Communities

A. Ecosystem objective addressed by this indicator:

Developing Sustainability Summary Objective and Sub-Objective a) *"Public and private decisions will be right when they tend to preserve the integrity, stability, and beauty of the biotic community (Leopold, 1968)"*

B. Purpose or nature of the indicator:

The biotic ecosystems of the basin are best understood as more than mere collections of natural characteristics; in a very important sense, the interaction within and between these clusters of life, land, and water create communities of interdependence. A focus on the quality and quantity of biotic communities in the region can provide an indicator of how well the system as a whole is responding to human and naturally caused disruptions. Furthermore, predicting the extent to which human communities can be sustained within an ecosystem depends, in part, upon an understanding of how their biotic counterparts affect each other's internal relationships (Sargent, 1991; cf. Katz, 1985).

For this indicator the target would be: various healthy and extensive biotic communities spread across the Lake Superior basin.

C. Features of the indicator:

Well established analytic tools (e.g., Karr, 1991; Ludwig & Reynolds, 1988) will be used to measure interactions within biotic communities and to assess the extent to which changes in one community may predict changes in adjacent systems (e.g., Jeffers, 1978). Foundation characteristics for the indicator must be established on a community-by-community basis, some of which has already been accomplished for habitat groups by the United States Forest Service and the Ontario Ministry of Natural Resources. In general terms, the indicator examines the extent to which distinct communities of organisms remain integrated, stable, and capable of rejuvenation over time (i.e., sustainable) in the wake of directly introduced (e.g., wildfire) or nearby (e.g., timber sales) changes in existing conditions.

D. Illustration of the indicator:

Considering the complexity of understanding biotic communities through the lens of ecological modelling, and associated probabilities for human sustainability in the Lake Superior catchment, we must exercise caution in reporting the status of this indicator. Whereas statistical projections may be most appropriate for resource managers, most of the public should be provided with a narrative describing what the status within and between biotic communities in the region means in terms of risks to or enrichment of human lives.

E. Limitations and uncertainties:

Although ecological science has made great advances in recent years, we still lack a full understanding of how to appropriately interpret many trans-community patterns of interaction, inconsistency, and causal relations. Similarly, we may not have some analytic tools given the size and complexity of the watershed; for example, it may be very difficult to distinguish between healthy dynamism and dangerous instability. On the other hand, we can expect that puzzles such as determining the sustainability of biotic communities in the basin will attract a good measure of interest from the academic sector which, in conjunction with ongoing government initiatives, will reduce the cost of the research endeavor. Thus, the financial burden and cycle of data gathering will depend on the degree to which we want more specificity about interactions between and within a greater number of communities. Certainly, those areas which have received the least scrutiny thus far (e.g., off-shore aquatic communities) will be the most expensive areas for which to establish baseline data.

F. Interpretation of the indicator:

Richer understanding of the nature of biotic communities in the basin should provide essential information regarding a host of interpretable patterns regarding sustainability. In particular, extensive research may suggest the presence of community-specific "keystone" species of plants and animals, upon which the fate of the remainder of the community rests. Therefore, in addition to providing insight into the stability, diversity, and adaptability of basin ecosystems, a focus on communities may point to critical areas in need of restoration or remediation.

8.2.4 Human Impacts

A. Ecosystem objective addressed by this indicator:

Developing Sustainability Summary Objective and Sub-Objectives a) *"Public and private decisions will be right when they tend to preserve the integrity, stability, and beauty of the biotic community (Leopold, 1968)"*, c) *"Institutional capacity to integrate technology and sustainable design should be developed within the Lake Superior basin"*, and d) *"The basis for guiding sustainable development at the scale of the Lake Superior basin should be the pattern of land, water, and air use, as these affect ecological, social, and economic progress"*

B. Purpose or nature of the indicator:

The major link between individual components, landscape patterns, and various biotic communities in the Lake Superior region, and one that is at the core of sustainable use, involves the extent to which we change the natural system of the basin. Yet, since change is an inherent part of a dynamic system, we must distinguish between what is functional and what is dysfunctional vis a vis the basin's promise for diversity and renewal; some human activities (e.g., prescribed burns) encourage the natural order while others may destroy the ability of the ecosystem to sustain itself in a way that insures lasting benefits for humans. Hence, this indicator focuses on the extent of ecosystem degradation compared with the rate of our remediation of historic and likely to continue damage to various biotic and abiotic (e.g., soil erosion) systems.

C. Features of the indicator:

Given the variety of possible impacts we can have on our environment, we will measure our progress toward the indicator target in a number of ways. One measure of damage or remediation will be changes in the raw number of "Areas of Concern" as defined by the International Joint Commission, and as extended to terrestrial systems, following LaMP year-one; as near shore and land based pockets of ecological disaster are reduced, we can suggest that humans are having less of a negative and more of a positive effect on the long term sustainability of the basin. Alternatively, Natural Resources Inventory data, collected by the United States Department of Agriculture and conceivably applied in Canada, can be used to assess impacts such as topsoil loss, salinity, and chemical loadings on land that is privately owned (including that found in urban areas) by way of built-in parameters and tolerances. Finally, some of the baseline data growing out of initial long-term forest-soil productivity estimates (Alban, Tiarks, Powers, Page-Dumroese, Ponder, & Bufford, 1994) may be extrapolated to various public lands in the region.

For this indicator the target would be: no long-term, human induced destruction of ecosystems in the basin.

D. Illustration of the indicator:

The easiest way to illustrate the indices for this general indicator would be to use graphs displaying changes in positive and negative human impacts. More sophisticated multi-media presentations, similar to those used to predict larger trends such as for global warming, might be constructed for use in public forums.

E. Limitations and uncertainties:

Since much of the data needed for this indicator is already being amassed on a continual basis by governments and scholars, the measurement of human impacts on the biotic ecosystem does not involve much financial commitment; there may be some cost involved with provisions for ongoing literature searches and the promotion of summaries in the popular press and trade journals. However, when one begins to speak of negative environmental impact, political hackles are raised, economies of scale are evoked envisioning dire tradeoffs, and the dogmatism of growth at any cost is mobilized. Such socio-economic forces may not only limit the acceptance of scientific findings, thus mitigating movement toward the target; pressure may also be exerted to scale back the collection and analysis of data itself in light of the threat it may represent. In this case, human nature and the natural order result in some uncertainty as to the interpretation of findings.

F. Interpretation of the indicator:

Setting aside the barriers of blame and politics, a discerned effort to comprehensively measure human impacts in the basin would result in a reasonable understanding of how well we are working in concert with, instead of against, basin ecosystems. It is an indirect test of an emerging ethic of sustainability and, by definition, points to potential sources of ecosystemic destruction. If we are to insure a long-term, compatible presence in the Lake Superior basin, we must determine to what extent our activities mend or rend the ecological fabric of the region.

8.3 Theme: Sustaining Social Infrastructures

8.3.1 Educational Achievement

A. Ecosystem objective addressed by this indicator:

Developing Sustainability Summary Objective and Sub-Objectives a) *"Public and private decisions will be right when they tend to preserve the integrity, stability, and beauty of the biotic community (Leopold, 1968)"*, b) *"The Lake Superior ecosystem provides resources and services to humans. These include water, fiber, minerals, energy, waste transport and treatment, food, recreation, and spiritual sustenance. These resources should be viewed as environmental capital, in the same way that other capital is assigned value"*, and c) *"Institutional capacity to integrate technology and sustainable design should be developed within the Lake Superior basin"*

B. Purpose or nature of the indicator:

Arguably, the single most potent element in the forging of sustainability in the Lake Superior basin is the level of knowledge residents have about their ecosystem (cf. Orr, 1992). Numerous studies suggest a direct link between one's level of education and the extent to which they begin to comprehend the role and impact of humans in natural systems (e.g., Grieg, Pike, & Selby, 1987; cf. Cantrill, 1993). By focusing on the educational achievement of individuals across the lifespan, this indicator also provides direct measures of the number of ongoing students in the basin, truancy and dropout rates, and the relative diversity of educational institutions in the region. Additionally, it provides an indirect examination of citizens' access to information, generally collected in on-line services or held by colleges and universities, which is vital to their participation in developing a sustainable society.

C. Features of the indicator:

A number of tolls may be used to track the overall educational achievement of those living in the region. One broad measure employs census data, collected every five (Canada) or ten (US) years, revealing matriculation rates through various levels of schooling. For instance, the 1990 US data can form a baseline to determine not only general grade advancement but also the dynamic age-related profile of those who come and go in the region. Alternatively, insofar as schools at various levels are now mandating the assessment of academic outcomes, standardized tests of achievement may be aggregated to produce a general index of knowledge. And, since an important measure of how knowledge gets used and appreciated in society is reflected in popular opinion regarding the worth of students, we will want to poll community attitudes in and subsequent to LaMP year-one. In each of these three measures, results can be compared with national norms to determine if those in the basin are more or less capable of sustaining action in a complex environment.

For this indicator the target would be: educational achievement will reflect appropriate adaptations to changing economic and environmental needs.

D. Illustration of the indicator:

Findings regarding educational achievement may be reported in a relatively straight forward manner with general trends and intra-regional differences represented by simple graphics. Nonetheless, such reports will have to be accompanied by a narrative placing the data into a regional context and explaining what the pattern portends for long-term sustainability.

E. Limitations and uncertainties:

Unfortunately, the collection, synthesis, and interpretation of educational achievement data is fraught with costs and dangers. Assuming information is gathered in conjunction with ongoing census efforts, to extract and cross reference the right parcels of data will cost between $10,000 and $20,000 every five to ten years; whereas the polling of local communities may be relatively inexpensive if local agencies assist in the effort, at least $20,000 will have to be expended each time we try to entice school administrators in the basin to share achievement measures simply because of the need to purchase comparable instruments. And care must be exercised in approaching people with the intent of assessing knowledge. For some, it will be viewed as a judgmental threat from outside forces and, for others, the results may be confounded by various impression management needs (e.g., people reporting they know more about nature or act more in line with ecological principles than they really do). As well, some findings may be contaminated by the influence of informal educational opportunities found on television which only some basin residents may be inclined to take advantage of.

F. Interpretation of the indicator:

If we can account for various threats to validity, this indicator can provide a longitudinal measure of emerging consciousness and intellectual ability dealing with sustainability. It can demonstrate the over abundance of outdated skills in comparison to the growing needs for adapting to a changing natural and social environment. And, at least to some extent, measures of educational achievement can pinpoint information deficits in the general population base of the catchment and suggest further focus on creating more viable educational opportunities.

8.3.2 Net Migration by Age

A. Ecosystem objective addressed by this indicator:

Developing Sustainability Summary Objective and Sub-Objectives b) *"The Lake Superior ecosystem provides resources and services to humans. These include water, fiber, minerals, energy, waste transport and treatment, food, recreation, and spiritual sustenance. These resources should be viewed as environmental capital, in the same way that other capital is assigned value"*, and c) *"Institutional capacity to integrate technology and sustainable design should be developed within the Lake Superior basin"*

B. Purpose or nature of the indicator:

As with natural ecosystems, human populations tend to sustain themselves in regions that support their physical and social needs and generally migrate out of or into an area as a function of available resources (Smith & Reeves, 1988). In particular, we would expect that the age distribution of people within a region would approximate national demographic norms if, indeed, such things as fertility rates and population size or density were adapted to the resource base. Thus, one indicator of sustainability would be the extent to which people of different ages "vote with their feet" by migrating to or from the Lake Superior basin. If there were disparities in migration patterns, reflected in differential ages of those moving in or staying or leaving the basin, it would indicate something about the social infrastructure and its ability to resemble a diverse and stable system. More importantly, a net loss in the basin's overall population could result in a variety of unwanted effects including a shrinking tax base, loss of intellectual and creative potential, and fewer economic opportunities in service industries.

C. Features of the indicator:

By again turning to census data or information generated by the Population Reference Bureau (e.g., Goldberg, 1993), a metric can be constructed which compares age related migrations in and out of the basin with long-term trends to and from various regions in the United States and Canada. Using LaMP year-one, we can chart relative and absolute changes in population density and stratification.

For this indicator the target would be: <u>human populations in the Lake Superior basin will remain stable and reflect national norms for age stratification</u>.

D. Illustration of the indicator:

Standardized graphs and those indexed to particular subregions of the basin would reveal time-series trends and typical population pyramids could demonstrate differences between ages and sites (e.g., urban versus rural communities) of projected migratory impacts.

E. Limitations and uncertainties:

An assumption underlying this index is that national demographic norms reflect a sustainable society which, as of yet, has not stood the test of time. Furthermore, any interpretations would have to be qualified in terms of local economic conditions which may not be representative of the entire basin. For example, because of an abundance of natural resources in some areas, employment opportunities might promote less pressure on social systems than found in other areas where even small increases or decreases in population may disrupt sustainablity. It is also important to recognize the limits of census data; in Canada, for example, First Nations have refused to participate and intra-basin migration by native peoples can be seen as an indicator of environmental stresses. And, although ongoing work by the US Department of Commerce may result in a very cost effective method for obtaining information in Michigan, Minnesota, and Wisconsin, the extraction and compilation of StatsCan data for Ontario is estimated to cost roughly $50,000. In this case, it may be more difficult to maintain a ten year cycle of data gathering and information reporting.

F. Interpretation of the indicator:

Although such a net migration by age indicator can suggest such factors as economic conditions, ecological strains, and the gentrification of Lake Superior cities, the data alone does not suggest possible solutions to the problem of, say, young adults fleeing from the region to find a growing economic base.

8.3.3 Employment Trends by Locality

A. <u>Ecosystem objective addressed by this indicator</u>:

Developing Sustainability Summary Objective and Sub-Objectives b) *"The Lake Superior ecosystem provides resources and services to humans. These include water, fiber, minerals, energy, waste transport and treatment, food, recreation, and spiritual sustenance. These resources should be viewed as environmental capital, in the same way that other capital is assigned value"*, c) *"Institutional capacity to integrate technology and sustainable design should be developed within the Lake Superior basin"*, and d) *"The basis for guiding sustainable development at the scale of the Lake Superior basin should be the pattern of land, water, and air use, as these affect ecological, social, and economic progress"*

B. <u>Purpose or nature of the indicator</u>:

A region-wide comparison of employment trends within various communities provides another estimate of microeconomic health to the extent it indexes sustainable levels of unemployment for existing social services, reveals patterns of underemployment, and may suggest aggregate levels of personal debt when cross-referenced with other indicators such as home ownership and national norms. Indeed, satisfactory levels of employment are generally regarded as a sign that a system of sustainable environmental practices will be able to withstand social and political pressures to further degrade the environment (Renner, 1993).

C. <u>Features of the indicator</u>:

Beginning in LaMP year-one, data generated by the appropriate Canadian and United States agencies (e.g., US Department of Commerce figures for employment classifications and capacities in the basin) will be analyzed to inspect regional employment trends in comparison with national averages. In combination with census data and chamber of commerce information generated on the local level, ratios of employment to population bases can be constructed with greater magnitudes indicating a greater likelihood of a community being able to sustain itself. A special index of employment trends in environmentally benign industries and professions can also be compared with local needs for employment.

For this indicator the target would be: <u>a diversified base of employment opportunities that approximates national norms for employment sector and wage rates, especially regarding environmentally benign businesses</u>.

D. <u>Illustration of the indicator</u>:

Obviously, one could produce a series of charts or graphs showing employment trends in the basin but it is likely that those skilled in technical and professional writing will have to explain the relationship between various economic forces (e.g., how much energy is consumed travelling to work in various localities, the relative economic stability of different types jobs). And, though most people are comfortable with national wage and employment comparisons, additional narrative will have to explain the role that different kinds of jobs play in determining economic sustainability.

E. <u>Limitations and uncertainties</u>:

The added costs of gathering and compiling the data for this indicator will be minimal since much is already being accomplished on an annual basis. However, for the indicator to be of the greatest value, resources will periodically have to be devoted to carefully interpreting the pattern of data in light of some relatively intangible social characteristics such as the perceived quality of life in the basin. It will also be difficult to track some sectors of employment that do not show up on regular reports (e.g., the self-employed or those who migrate into and out of the Lake Superior region on a seasonal basis). And an analysis of such factors as spin-off employment opportunities in specific communities will have to await the refinement of broader econometric models, such as that currently being piloted by the Ontario Ministry of Natural Resources (i.e., Inter-Disciplinary Sustainability Indicators).

F. Interpretation of the indicator:

Employment across the watershed can be interpreted as a one measure of how well local lifestyles remain viable in a changing social environment. It can reveal which communities are more at risk and which are more likely to survive as the region moves toward sustainability. Importantly, an indication of employment opportunity shortfalls and surpluses will empower citizens to make more informed decisions about where and how to live in the basin.

8.3.4 Home Ownership

A. Ecosystem objective addressed by this indicator:

Developing Sustainability Summary Objective and Sub-Objectives b) *"The Lake Superior ecosystem provides resources and services to humans. These include water, fiber, minerals, energy, waste transport and treatment, food, recreation, and spiritual sustenance. These resources should be viewed as environmental capital, in the same way that other capital is assigned value"*, and d) *"The basis for guiding sustainable development at the scale of the Lake Superior basin should be the pattern of land, water, and air use, as these affect ecological, social, and economic progress"*

B. Purpose or nature of the indicator:

Another way to measure the economic viability of society in the basin is to examine the extent of home ownership. Insofar as there are generally powerful incentives for people to purchase homes, and doing so more or less indicates a desire and ability to remain in a community, this indicator of the sustainability of social infrastructures indexes a wide variety of economic trends and social conditions.

C. Features of the indicator:

It is a relatively simple task to take periodic census data (segmented by districts) to determine the ratio of home ownership to population in the Lake Superior basin. Furthermore, federal (quarterly) and local (variable depending on agency preference) agencies estimate the average cost of housing in a region, which can then be compared to national norms. By cross-referencing employment statistics, this indicator shows the general extent to which basin residents can afford a home now or in the future (adjusted for inflation, changes in median income, and demand driven increases in real estate), trends in the actual supply and purchase of homes, and patterns of expanded development throughout the watershed. A relatively stable housing market is partially indicative of both a sustainable economic base and social system; declining home prices, decreases in available housing, or increases in ownership can signal potential problems regarding sustainablity.

For this indicator the target would be: a range of affordable housing opportunities within reach of basin residents.

D. Illustration of the indicator:

A series graphs focusing on the cost of basin homes, home ownership rates, and the relative availability of homes can be used since most people intuitively understand the relationship between such factors.

E. Limitations and uncertainties:

Although this indicator may not capture all communities in the basin and, by definition, excludes those who choose to rent or lease housing, there should not be many problems with its use. Various agencies are already collecting the data and the only costs will involve packaging the information for public consumption and integrating it with other measures of sustainability (e.g., wage rates).

F. Interpretation of the indicator:

A stable rate of home purchases and sales indexed to the availability of housing suggests that people have positive perceptions of opportunities (e.g., economic, social, recreational) in the basin and its economic outlook. It also reveals, in a small way, the degree of private sector confidence. And, even though deviations from a stable housing base will not automatically tell citizens and policy makers how to change the system, we can take the indicator as evidence of a healthy or decaying social infrastructure.

8.3.5 Regional Trade Balance

A. Ecosystem objective addressed by this indicator:

Developing Sustainability Summary Objective and Sub-Objectives a) *"Public and private decisions will be right when they tend to preserve the integrity, stability, and beauty of the biotic community (Leopold, 1968)"*, b) *"The Lake Superior ecosystem provides resources and services to humans. These include water, fiber, minerals, energy, waste transport and treatment, food, recreation, and spiritual sustenance. These resources should be viewed as environmental capital, in the same way that other capital is assigned value"*, and d) *"The basis for guiding sustainable development at the scale of the Lake Superior basin should be the pattern of land, water, and air use, as these affect ecological, social, and economic progress"*

B. Purpose or nature of the indicator:

A positive balance of trade between the Lake Superior basin and the rest of Canada or the United States is an important consideration when estimating the region's ability to maintain both a sound resource base as well as provide for the needs of its residents. Even accounting for some degree of value-added development of raw materials prior to export, if we are taking in less quantities and qualities of resources than we are shipping out, the economic and social foundation of the basin will likely change in largely unsustainable ways. In turn, greater and greater pressures would be placed upon the human and natural wealth that remains. Thus, this indicator explicitly recognizes the need to manage the "ecological footprints" non-basin forces leave when drawing upon the resources in the watershed (Pearce, 1993).

C. Features of the indicator:

This indicators requires the development of a new model which attends to the gross inputs and outputs cycling through the Lake Superior basin. By and large, data regarding basin imports and exports is already being collected by private industry and is generally reported to state and federal agencies. However, the index we would want to begin using in LaMP year-one on an annual basis will have to segment out basin characteristics from such aggregate measures and combine the inputs with enough specificity to track both the regional and local effects of trade imbalances as well as the independent contributions of various sectors (e.g., industrial, educational, service).

For this indicator the target would be: <u>a net trade balance for the region with import capital and products at least equal to what is exported</u>.

D. Illustration of the indicator:

As the index is being constructed, care should be exercised to insure that the measurement can be reduced to a few simple graphs and ratios, or even a single number, representing local and regional effect-size metrics for trade imbalances. Complicated econometric analyses will be too complex for public consumption and it is the citizens of the region who must use the information in maintaining a sustainable system.

E. Limitations and uncertainties:

This indicator is limited in that all it provides is an estimate of trade equity, generally measured in the context of absolute value for capital exchanges. As such, the index can be misleading in terms of the context of regional economies and national economic policy (cf. Pearce, Markandya, & Barbier, 1989). For example, nuclear waste has value and can be traded (e.g., payment for repository) but the mere dollar value hardly compensates for the potential risks involved in transport and storage; it would not contribute to the sustainability of trade. By the same token, the indicator must not be interpreted through the lens of short-term political gain wherein imbalances in trade are maintained despite their effect on the potential for natural and social sustainability. Finally, substantial funds must be diverted for the development and testing of the measurement tool itself though, arguably, once the model is created it would be more cost effective to subsequently employ.

F. <u>Interpretation of the indicator</u>:

This is a good, general measure of the basin's economic strength and its potential liabilities to compete in a national or international arena. The collected data and trajectories may target some commodities for special attention. For example, as the demand for veneer-quality hardwood increases, the regional balance of trade may be better safeguarded by selective forestry techniques designed to protect and develop the resource thereby contributing to both diversity in the basin and the economic basis for various communities.

8.3.6 Diversity of Community Economies

A. <u>Ecosystem objective addressed by this indicator</u>:

Developing Sustainability Summary Objective and Sub-Objectives b) *"The Lake Superior ecosystem provides resources and services to humans. These include water, fiber, minerals, energy, waste transport and treatment, food, recreation, and spiritual sustenance. These resources should be viewed as environmental capital, in the same way that other capital is assigned value"*, c) *"Institutional capacity to integrate technology and sustainable design should be developed within the Lake Superior basin"*, and d) *"The basis for guiding sustainable development at the scale of the Lake Superior basin should be the pattern of land, water, and air use, as these affect ecological, social, and economic progress"*

B. <u>Purpose or nature of the indicator</u>:

In most cases, a key to the survival of any community (and, by extension, a region) is the ability of its residents to find suitable sources of employment in companies and industries that, as a whole, can withstand changes in market forces or the depletion of resources. Therefore, this indicator deals with the diversity of employment options available to citizens rather than focusing on whether or not someone merely has a job. Pointedly, a social infrastructure is not sustainable if the economic base that supports it is vulnerable and a diverse employment base is least at risk. As the basin's range of different employment opportunities increases, and does so in areas adjacent to existing communities, it is more likely that those communities will be able to sustain themselves in the future.

D. <u>Features of the indicator</u>:

US Census and StatsCan data, in conjunction with what may be gleaned from local and regional development boards, can be used to estimate the rate at which new employment venues are being added to the basin as well as plot where these opportunities are being created. Data generated in LaMP year-one will serve as a basis from which to plot differences between sampling years regarding the diversification of basin employment opportunities. If mapped onto other regional data bases (e.g., GIS), the indicator can also reveal gross patterns of economic development.

For this indicator the target would be: <u>a range of available employment opportunities within reasonable distance to most communities in the basin</u>.

D. <u>Illustration of the indicator</u>:

Periodic tables and graphics can be used to chart the relative numbers of jobs being created in communities over time and a GIS-like map would demonstrate clusters of economic opportunities in relation to resources in the basin.

E. <u>Limitations and uncertainties</u>:

In addition to the qualifications and limitations noted earlier when addressing employment trends, an indicator of growth in different employment opportunities is even more sensitive to variations between communities. For example, some towns in the Lake Superior basin, by virtue of location, have become totally dependent upon tourist revenues and the introduction of additional employment opportunities could seriously jeopardize the tourism-driven values of those areas to visitors. Additionally, beyond the cost of producing a report every five years based upon annual updates, the expansion of the existing GIS platform to include employment data is likely to involve a substantial financial investment.

F. <u>Interpretation of the indicator</u>:

This indicator reveals which economies in the basin are most vulnerable to calamities such as resource depletions, natural catastrophe, or economic cooption by those industries not concerned with social sustainability. It also demonstrates the dynamism of the region and its ability to offer innovative opportunities and possibilities for those who migrate into the watershed. Although policy makers and people will have to go beyond the crude index of how much the employment base is expanding in order to suggest solutions to emerging problems, the indicator provides a clear picture of economic diversity and adaptation abilities.

8.3.7 Reinvestment in Natural Capital

A. <u>Ecosystem objective addressed by this indicator</u>:

Developing Sustainability Summary Objective and Sub-Objectives a) *"Public and private decisions will be right when they tend to preserve the integrity, stability, and beauty of the biotic community (Leopold, 1968)"*, b) *"The Lake Superior ecosystem provides resources and services to humans. These include water, fiber, minerals, energy, waste transport and treatment, food, recreation, and spiritual sustenance. These resources should be viewed as environmental capital, in the same way that other capital is assigned value"*, and d) *"The basis for guiding sustainable development at the scale of the Lake Superior basin should be the pattern of land, water, and air use, as these affect ecological, social, and economic progress"*

B. <u>Purpose or nature of the indicator</u>:

Perhaps the most significant indicator of social sustainability in the Lake Superior basin, and one which comes full circle back to fact that we must maintain the biotic ecosystem in order to flourish as a society, is measured by the extent to which we use our social resources to maintain natural resources (Repetto, 1992). As we withdraw raw materials and consume resources of the air, land, and lake we must reinvest in those sources of shared wealth at a rate which matches or exceeds depletion. This means we must not only learn to value natural resources as capital, and compensate for the costs incurred by their use, but also to accept that the reinvestment itself should be considered a capital asset rather than a debilitating loss incurred by industry. A rough measure of how well we are learning this lesson can be found in the amount of resources (especially financial) government and industry are committing to replace in kind what has been taken away from the watershed. In an open market, if a resource is depleted or if agencies and companies have no incentive for reinvestment, sustainability of economies and ecosystems is seriously compromised.

C. <u>Features of the indicator</u>:

In the past two decades, a variety of tools (e.g., the "Green" Gross National Product, the Index of Sustainable Economic Welfare) and accounting methods (e.g., Daly & Cobb, 1989; Pearce, 1993; cf. Hannon, Costanza, & Herendeen, 1986; Lutz, 1993) have been developed which could be applied on a regional basis. In essence, we would adapt measures such as these to calculate the rate of natural capital depletion not compensated by reinvestment in remedial (e.g., rehabilitating Areas of Concern) or regeneration (e.g., tree farms, tertiary waste treatment facilities) projects. Subsequent to LaMP year-one, we can track investment changes, factoring in the loss of those resources (generally mineral-based) which cannot be regenerated or renewed and for which in kind returns, such as contributions the Remedial Action Plans (RAPs), would be expected.

For this indicator the target would be: <u>no net loss of natural capital due to the development or use of regional resources</u>.

D. <u>Illustration of the indicator</u>:

Although the calculations for natural capital reinvestment are complex, changes in the existing value of natural capital can be graphically displayed in terms of regional and local totals, the type of reinvestment occurring, and the relative loss or gain from year to year. More problematic will be the explanation of why this is such a vital index of sustainability.

E. <u>Limitations and uncertainties</u>:

As would be expected, something as important as assessing reinvestment in natural capital confronts a family of related problems which may mitigate the utility of the index. Beyond the fact that the theory and methods of calculation have not been extensively tested in the marketplace, it will often be difficult to assess equitable replacement values for some resources or to collect sufficient measures of depletion for others (especially those that are influenced by forces beyond the basin, such as the atmosphere). Also, insofar as the existing regulatory environment often does not consider compensation for natural resource loss as capital investment, we may have to wait for the generation of wide-spread political will to change what is arguably a self-defeating system. On the other hand, however, the significant costs of developing models and collecting data (at best, accomplished yearly though extended for longer periods to establish lengthier trends) could be offset by entering into a partnership with private industry to promote proprietary development and public assessment.

F. <u>Interpretation of the indicator</u>:

Understanding the rate at which natural capital in the Lake Superior basin is being depleted potentially tells us much of what we need to know regarding economic sustainability in a natural and social environment. It helps illuminate the tradeoffs people make in daily commerce, some of which we may be unaware of or even consider likely. As reinvestment increases, we can also assume that society is moving away from a coercive regulatory environment (which does little more than repel capital investment) and toward one in which industry and the environment are partners in sustaining human activity. And, though only succeeding generations may be able to determine just how much our current investments in the basin have appreciated, short-term trends can be interpreted in light of the principles of sustainability and the goals of the Binational Program to restore and protect Lake Superior for those future residents.

8.3.8 Citizen Involvement in Decision Making

A. **<u>Ecosystem objective addressed by this indicator</u>:**

Developing Sustainability Summary Objective and Sub-Objectives a) *"Public and private decisions will be right when they tend to preserve the integrity, stability, and beauty of the biotic community (Leopold, 1968)"*, c) *"Institutional capacity to integrate technology and sustainable design should be developed within the Lake Superior basin"*, and d) *"The basis for guiding sustainable development at the scale of the Lake Superior basin should be the pattern of land, water, and air use, as these affect ecological, social, and economic progress"*

B. <u>Purpose or nature of the indicator</u>:

This is a measure of the political empowerment enjoyed by basin residents which represents our ability to forge <u>for ourselves</u> a sustainable society. Almost every element that affects the social infrastructure of the region, from our access to information to municipal tax-bases to the involvement of sovereign aboriginal peoples, depends on the extent to which citizens are isolated from the decision making that rules our lives (Heskin, 1991). And the purpose here is not merely to measure civic participation; it is to indicate ownership in the process of maintaining Lake Superior as an example of sustainability.

C. Features of the indicator:

Subsequent to LaMP year-one, we can employ three simple benchmarks as indicative of progress toward the target. First, as more and more local governments discuss and endorse Objective Six of the LaMP we can assume that involvement is increasing. Second, we can gauge public commitment by tallying the numbers of residents who wish to participate in ongoing stakeholder discussions or speak out at public forums which deal with sustainability issues (e.g., those sponsored by the Binational Program). And finally, the traditional method of participatory decision making in a democracy, voting behavior, will be used as a barometer of public commitment; as more people vote, more people participate.

For this indicator the target would be: 100% of residents are involved in decisions which affect the sustainability of the Lake Superior basin.

D. Illustration of the indicator:

A narrative will be produced which examines trends in participation as well as offering examples of how citizens in the basin are empowering themselves while providing for future generations.

E. Limitations and uncertainties:

This indicator is qualified by the need for time to bring in previously disenfranchised populations (e.g., First Nations), to improve upon the quality of information citizens have at their disposal, and demonstrate to all residents that they are not so busy or alienated that they cannot participate at least to a minimum degree. This will cost each of us a good deal of time, effort, and money since the burden of citizenship cannot be shouldered by only government agents or grassroots activists. However, the more often we can demonstrate that more people are deciding for themselves how best to sustain the systems of Lake Superior, the more likely communities will be facilitated to maximize participation.

F. Interpretation of the indicator:

This indicator only shows the level of citizen involvement within the basin and does not suggest specific solutions to the general problem of securing commitments to developing sustainability in the region. That is for us to decide in the process of community.

8.3.9 Demand on Social Services

A. Ecosystem objective addressed by this indicator:

Developing Sustainability Summary Objective and Sub-Objectives b) *"The Lake Superior ecosystem provides resources and services to humans. These include water, fiber, minerals, energy, waste transport and treatment, food, recreation, and spiritual sustenance. These resources should be viewed as environmental capital, in the same way that other capital is assigned value"*, c) *"Institutional capacity to integrate technology and sustainable design should be developed within the Lake Superior basin"*, and d) *"The basis for guiding sustainable development at the scale of the Lake Superior basin should be the pattern of land, water, and air use, as these affect ecological, social, and economic progress"*

B. Purpose or nature of the indicator:

An implicit assumption regarding sustainable societies is that most of those living in them will experience low levels of stress in comparison with nonsustainable societies (Milbrath, 1989). Also, sustainable societies have integrated systems of support for those individuals who do exhibit the symptoms of stress such as crime, substance abuse, and suicide. Consequently, this indicator is meant to give a quick reading of personal wellness by examining the relative need for and availability of the social "safety nets" in the region.

D. <u>Features of the indicator</u>:

The measure of sustainability will be to compare the relative availability of social service resources (e.g., doctors per capita by age strata, mental health counsellors, police officers) to county/district wide population bases. Local and regional indexes will have to be constructed; a likely prototype (i.e., the Comprehensive Human Needs Assessment Index) is currently being developed for Alger and Marquette counties in Michigan's UP which differentially weights increases or decreases in provision and demand for a range of social services. By LaMP year-one, such an index should be available to determine the configuration of basin-wide demand/availability ratios for select social services.

For this indicator the target would be: <u>medical, protective (e.g., fire and police), and welfare services meet the needs of basin residents and there is a decreasing call for such assistance</u>.

D. <u>Illustration of the indicator</u>:

This indicator can be illustrated in ratio form with graphs charting yearly trends. Some report should also be made concerning the historical backdrop for uses of various services; in many rural areas, for example, medical attention often is not sought until health conditions become critical.

E. <u>Limitations and uncertainties</u>:

One limitation of quantitatively assessing demand on social services is that it may obscure the determination of how much general stress in being placed on communities; the data itself does not indicate for the quality of services. Also, rural areas may not be adequately represented in the index and different standards of inter-agency cooperation may skew regional variations in reported demand. And consideration must be given to the fact that demands may vary with the general age of a population or the ethnic structure of particular communities. In terms of financing the gathering of data, until such time as a basin-wide system of reporting services is in place, labor intensiveness of polling separate communities and agencies will result in relatively high costs. Even if accomplished every five years at a county/district level via mail survey with one follow-up mailing (estimated 280 agency contacts), costs will approximate $8000 per survey.

F. <u>Interpretation of the indicator</u>:

If demand exceeds social service availability we can expect a population to exhibit greater degrees of environmental and social stress (e.g., crime rates, substance abuse) indicating a lessening of "wellness" as well as placing a greater drain on resources decreasing the quality of life in the basin. Furthermore, since the index also measures the absolute number of persons requesting assistance, we can assess the overall level of social stress even if services meet demand levels. In either case, we can pinpoint which types of services are experiencing the greatest pressures, identify overall trends reflecting movement toward the target, and provide information to local communities so that they may consider various remedial options.

8.3.10 Per Capita Membership in Community Organizations

A. <u>Ecosystem objective addressed by this indicator</u>:

Developing Sustainability Summary Objective and Sub-Objectives a) *"Public and private decisions will be right when they tend to preserve the integrity, stability, and beauty of the biotic community (Leopold, 1968)"*, and d) *"The basis for guiding sustainable development at the scale of the Lake Superior basin should be the pattern of land, water, and air use, as these affect ecological, social, and economic progress"*

B. <u>Purpose or nature of the indicator</u>:

It is in the nature of communities for individuals to form smaller secondary-groups which mirror the diversity of interests and commitments of those who live in the area. Such local organizations range from civic groups and religious organizations vested with a sense of voluntarism to recreation and social affiliations which contribute to a quality of life; they do not include membership in national organizations unless there is a chapter or affiliate in the immediate vicinity. In this sense, one very significant measure of community involvement is the extent to which people join in the activities of such local organizations (cf. Rothenbuhler, 1991). Thus, this indicator serves the purpose of identifying levels of community involvement which may contribute to sustainable practices.

C. <u>Features of the indicator</u>:

A community-by-community census of organizations in the basin will have to be conducted since, currently, no single index is available. Using standard techniques for measuring and extrapolating patterns from organizational membership (e.g., Tsai & Sigelman, 1982), this information can be cross-referenced with population data to provide an estimate of voluntarism and commitment within the larger communities in the region. The percentage of the population participating in civic, social, and voluntary service organizations in LaMP year-one will serve as the baseline for determining the average number of organizations residents belong to, those that cut across demographic boundaries (e.g., consist of different age groups or religious denominations), and ones which are dedicated to the preservation of particular ethnic traditions.

For this indicator the target would be: <u>increasing numbers of residents joining local organizations until at least 80% of the population in the basin is participating in some form or the other</u>.

D. <u>Illustration of the indicator</u>:

A representation of the diversity of organizations in the basin could be mapped onto the counties and districts in the region and general trends over time can be profiled using local percentages. Pie charts representing relative membership in types of organizations (e.g., civic, social, governmental,etc.) can be indexed to both communities and the basin as a whole.

E. <u>Limitations and uncertainties</u>:

The greatest limitation of this indicator is that it may fail to include a significant percentage of the catchment's population; few such organizations, if any, are found in rural areas which contain a sizable percentage of those who live in the region. Additionally, careful attention must be paid to the extent of active (versus passive) membership and the possibility that membership in multiple organizations may artificially inflate participation rates.Notably, some types of organizations may be relatively informal and difficult to identify in the census while others (e.g., anarchistic militias) are clearly not conducive to the stability and sustainability of society as a whole. There is a price to pay for the data as well. Since most communities only retain records of which organizations are found in a locality and do not indicate membership parameters, each organization will have to be contacted (at least once every ten years) on an individual basis. The cost of locating organizations in communities over 500 citizens and compiling information is estimated at $15,000 per survey (i.e., 200 hours to call roughly 2000 organizational contacts, perhaps twice, and query for three minutes each).

F. <u>Interpretation of the indicator</u>:

Organization membership is a measure of community "wellness" in that vibrant localities have populations that participate in the possibility of civic pride and voluntarism. Further, since some of these groups reflect heritage and life-outlook, the indicator also reveals something about cultural diversity and the desire of citizens to sustain valued lifestyles. In general, the larger the number of organizations, the greater their range, and the more unique needs they serve for a population, the more we can conclude that the social infrastructure is being sustained.

Alternatively, declining trends in either number or membership-to-population ratios indirectly suggests a lessening of civic participation in basin communities.

8.3.11 Energy Consumption

A. Ecosystem objective addressed by this indicator:

Developing Sustainability Summary Objective and Sub-Objectives a) *"Public and private decisions will be right when they tend to preserve the integrity, stability, and beauty of the biotic community (Leopold, 1968)"*, b) *"The Lake Superior ecosystem provides resources and services to humans. These include water, fiber, minerals, energy, waste transport and treatment, food, recreation, and spiritual sustenance. These resources should be viewed as environmental capital, in the same way that other capital is assigned value"*, c) *"Institutional capacity to integrate technology and sustainable design should be developed within the Lake Superior basin"*, and d) *"The basis for guiding sustainable development at the scale of the Lake Superior basin should be the pattern of land, water, and air use, as these affect ecological, social, and economic progress"*

B. Purpose or nature of the indicator:

CO_2 levels are the best omnibus estimate we currently have for the consumption of fossil fuels, which comprise the bulk of energy demands in the Lake Superior basin (cf. Pearce, 1993). Furthermore, we know that there is a balance between the production of CO_2 (accounting for that which results from natural decomposition and wildfire) and the ability of a regional biomass to capture and retain this gas, which significantly contributes to global warming (Bucholz, 1993). This indicator measures or estimates those loadings of CO_2 which are the direct result of energy use by industry and municipalities and factors in other measures of consumption (e.g., electricity use in communities) to determine the overall trend in basin energy.

C. Features of the indicator:

This indicator of energy consumption requires fairly sophisticated measuring tools and analysis. Current and future enhanced monitoring of general and site-specific CO_2 discharges, conducted as part of existing federal initiatives, will be compared with the estimated capability of basin biomass to mitigate overall production. The analysis of loadings, measured at representative basin sites, will begin in LaMP year-one. Appropriate analytic tools have yet to be refined, but can be anticipated on the basis of what we currently know about atmospheric monitoring and analysis (e.g., Spreng, 1988). Alternatively, state and federal reports of energy production (e.g., kilowatts) and sales (e.g., gasoline) will also be used, especially in the case of an upsurge in the use of non-CO_2 producing energy sources such as nuclear power.

For this indicator the target would be: a downward trend in the net production of CO_2 from point sources in the basin until stable levels of organic absorption matching discharge levels are achieved as well as an overall pattern of energy savings.

D. Illustration of the indicator:

The indicator will be reported by way of a graph representing both average loadings of CO_2 in the basin as well as regional biomass accumulations. Tables may also be constructed to reflect per capita energy consumption insofar as state, provincial, and federal estimates of energy production and sales can be pinned down to the level of actual use in the basin.

E. Limitations and uncertainties:

Most sophisticated measurements involve some level of uncertainty and error. In this case, CO_2 emissions from outside the basin may influence local and regional estimates and adequate atmospheric measuring instruments have yet to be calibrated on a basin-wide scale accounting for the separate contributors to CO_2 loads (including the prevalent burning of wood as a means of heat). Importantly, since the science of estimating the balance between

CO_2 emissions and organic uptake is still emerging, for the interim we may want to place greater stock in the crude measures of energy consumption drawn from agency reports and rely on best-estimates of the balance between use and reabsorption. Eventually, since federal agencies are already including the cost of CO_2 monitoring in their budgets and since biomass will be calculated based on the inventories established above in the section dealing with biotic ecosystems, we will be able to attain more precise measurements at minimal additional cost. Finally, since monitoring of CO_2 will be ongoing, the analysis and updating of this indicator will be largely determined by the gathering of biomass data (i.e., a 10 year cycle).

F. <u>Interpretation of the indicator</u>:

End-of-pipe monitoring may reveal CO_2 increases from point sources in the Lake Superior basin which should alert us to a continuing trend toward a nonsustainable society. However, if local and general levels of CO_2 show a decrease, we may reasonably infer that either energy consumption is also going down, basin residents are relying on more benign sources of energy (e.g., solar or wind power), the natural capacity of the ecosystem to absorb CO_2 is increasing, or end-of-pipe measures are being taken to prevent emissions. In any case, humans are acting in more sustainable ways (Uusitalo, 1983). In addition, an analysis of the different types of energy being used in the basin can be modeled in terms of factors which influence consumption within communities (Stern & Aronsen, 1984). Thus, although the indicator cannot specify general solutions to the problem of managing energy consumption, it is a tool policy makers, regulators, and individuals can use in the production of wise decisions.

8.3.12 Waste Stream Loadings

A. <u>Ecosystem objective addressed by this indicator</u>:

Developing Sustainability Summary Objective and Sub-Objectives a) *"Public and private decisions will be right when they tend to preserve the integrity, stability, and beauty of the biotic community (Leopold, 1968)"*, b) *"The Lake Superior ecosystem provides resources and services to humans. These include water, fiber, minerals, energy, waste transport and treatment, food, recreation, and spiritual sustenance. These resources should be viewed as environmental capital, in the same way that other capital is assigned value"*, c) *"Institutional capacity to integrate technology and sustainable design should be developed within the Lake Superior basin"*, and d) *"The basis for guiding sustainable development at the scale of the Lake Superior basin should be the pattern of land, water, and air use, as these affect ecological, social, and economic progress"*

B. <u>Purpose or nature of the indicator</u>:

Although the production of waste is an attribute of life in general, only human activity results in unwanted by-products which threaten the ability of the Lake Superior basin to further sustain a human presence and the continued use of its resources. This indicator is designed to evaluate residents' movement toward established governmental targets for two key types of waste. First, at the level of local communities, the major indicator of sustainability is "the trash crisis" (Connett, 1991), wherein the availability of usable landfill space is outstripping the conservation and recycling levels of consumers, despite the fact that reasonably high levels in reduction of MSW and household refuse are technically feasible (Platt, Doherty, Broughton, & Morris, 1990). Both the Environmental Protection Agency and Environment Canada have recommended these reduction levels be achieved within ten years (Pearce, 1993). Second, the International Joint Commission has designated Lake Superior as a "zero toxic discharge" demonstration project for at least nine bioaccumulative substances shown to pose direct threats to the ecosystems of the lake and those who draw upon Lake Superior for sustenance and which are sometimes found in the waste streams of basin communities or industries.

C. <u>Features of the indicator</u>:

Impacts on the waste stream in the basin will be measured by way of reviewing state and provincial records of landfill and incinerator capacity, trends in the amount of materials being recycled through public and private mechanisms, and EPA/EC or private industry monitoring of effluent for toxins. Existing methods for assessing and forecasting regional and local load configurations (based on LaMP year-one data), such as those developed by the Seattle Solid Waste Facility in the late 1980s, will be used to measure progress toward the target (cf. Brisson, 1993).

For this indicator the target would be: reduce municipal solid waste (MSW) by at least 25% (US) to 50% (Canada); increasing trends in the recycling of organic and inorganic household waste; zero measurable discharge of designated toxins from all point sources located in the basin.

D. Illustration of the indicator:

Graphic trend lines and pie chart conversions reflecting changes in loadings and percentage accumulations over time may be used to report to the public and government agencies the status of this indicator.

E. Limitations and uncertainties:

Experience has shown that the political backdrop of the basin may be slow in responding to the need to reduce waste and emissions and some interest groups may actively oppose either an incremental or absolutist regulatory climate regarding reductions in waste, mandatory recycling, or the release of human-produced toxins into the air, water, or terrestrial systems of the region. Furthermore, though access to and analysis of public record is relatively inexpensive to accomplish, obtaining data from the private sector may require extensive and costly personal contacts to annually obtain proprietary data so as to produce five-year reports. Also, our current inability to track large portions of raw material inputs into the basin resource cycle my skew comparative results until substantial time has passed.

F. Interpretation of the indicator:

The reduction in private citizens' contributions to the waste stream reveals significant commitments to sustaining social and physical resources and measures of toxic discharge reductions indicates the effectiveness of regulated sustainability efforts and/or the willingness of corporations to engage in sustainable economic practices. Yet, aside from being able to isolate particular industries, the indicator only gives clues to the general emergence of sustainable activity in the watershed. Its ability to reveal which elements of the waste stream require particular attention for either educational or regulatory action depends on the specificity of measurement and the political will of basin residents.

8.4 Theme: Sustaining Cultural Values

8.4.1 Political Pressure to Protect and Remediate the Environment

A. Ecosystem objective addressed by this indicator:

Developing Sustainability Summary Objective and Sub-Objectives a) *"Public and private decisions will be right when they tend to preserve the integrity, stability, and beauty of the biotic community (Leopold, 1968)"*, and b) *"The Lake Superior ecosystem provides resources and services to humans. These include water, fiber, minerals, energy, waste transport and treatment, food, recreation, and spiritual sustenance. These resources should be viewed as environmental capital, in the same way that other capital is assigned value"*

B. Purpose or nature of the indicator:

Without question, the primary way in which citizens actively promote the sustainability of their values in democratic society is through the political process and actions of local governments can be seen as the clearest measure of what the cultures in the basin wish to perpetuate (cf. Ehrlich & Ehrlich, 1991). If a culture of truly sustainable values is to emerge in the basin, it will be reflected in endorsement by elected officials which, in turn, should result in widespread commitments to restore and protect the biotic foundation for life in the region and to promote sensible environmentalism. Demonstrable political pressure measures such cultural allegiances.

C. Features of the indicator:

Actual endorsement of the Objective Six mandate to develop sustainability in the Lake Superior basin will be seen in the proportion of communities which pass resolutions to that effect, as well as in their ongoing requests for technical or logistical advice and their willingness to commit their generally limited resources to the initiative. This will be predicated upon large numbers of people having read the LaMP document, understanding what it means for themselves and future generations in terms of commitment, sacrifice, and perseverance.

For this indicator the target would be: all community governments in the basin endorse the objective, indicators, and targets for developing sustainability as outlined in this document.

D. Illustration of the indicator:

The political will of basin residents, as partially indicative of their cultural commitments, can be seen in year-to-year changes in the ratio of communities which have endorsed the spirit and substance of Objective Six. It will be useful to augment this quantitative measure with examples drawn from actual resolutions in order to provide guidance for communities yet to declare their support for a sustainable society.

E. Limitations and uncertainties:

This indicator is limited insofar as verbal commitments may be vague or not result in actual behavioral changes on the part of municipalities and individuals. Some communities may currently lack the resources to demonstrate lifestyle changes in the short-term or may not be aware of who to turn to in order to allay fears, counteract those self-serving interests opposed to the initiative, or gain needed information. And, as noted elsewhere, some communities are only loosely organized and many individuals live in a "hinterland" without formal ties to political structures. But these are not intractable problems. With a minimal initial financial investment to promote the value of the LaMP, and continuing efforts on the part of grassroots organizations, yearly tallies of endorsements should grow till the target is met.

F. Interpretation of the indicator:

Granting that political endorsements must be backed by public resolve and action in order to be meaningful, the explicit acceptance of what sustainability is and entails tells us much about the will of people in the Lake Superior basin as well as the extent to which they are even aware of the Binational Program. By charting the regional distribution of endorsements, we can identify and adapt campaigns to those areas resisting change or those communities that have yet to act upon their words.

8.4.2 Diversity of Cultures

A. Ecosystem objective addressed by this indicator:

Developing Sustainability Summary Objective and Sub-Objectives b) *"The Lake Superior ecosystem provides resources and services to humans. These include water, fiber, minerals, energy, waste transport and treatment, food, recreation, and spiritual sustenance. These resources should be viewed as environmental capital, in the same way that other capital is assigned value"*, and d) *"The basis for guiding sustainable development at the scale of the Lake Superior basin should be the pattern of land, water, and air use, as these affect ecological, social, and economic progress"*

B. Purpose or nature of the indicator:

It is generally accepted in pluralistic societies such as the United States and Canada that the presence of multiple cultures, each of which has the potential to provide positive contributions to solving problems, is something to be valued (Herskovits, 1973). In terms of sustainability in the Lake Superior basin, different cultures bring with them different traditions based upon ethnicity or world view, the combinations of which will more likely allow the range of people in the basin to meet emerging challenges. Conversely, as cultures become assimilated or die off for lack of interest, the basin becomes that much the less. And the impoverishment of cultural diversity is very difficult to reverse; all subsequent generations will not find ready access to traditions and folkways that may be best suited to those future times and places (cf. Barry, 1983). Thus, this indicator is a bellwether for future adaptability and sustainability.

C Features of the indicator:

Several measures of cultural diversity and sustainability are available. For example, the United States Forest Service has been able to use census data to construct a distribution of ethnic enclaves south of the Canadian border and the same could be applied for the entire basin after the LaMP is released. So too have sociologists constructed an array of surveys identifying distinct language communities and accompanying trends in attitudes (e.g., Bourhis & Sachdev, 1984). We also would want to develop new protocols to specifically be used in the watershed measuring such factors as mutual respect among various cultures in the region or the extent to which the environmental world views of groups were compatible with one another.

For this indicator the target would be: no lessening of basin-wide cultural diversity.

D. Illustration of the indicator:

The best way to relay the findings of this indicator to interested parties would be through a narrative describing changes in the cultural composition of the basin, perhaps augmented by multi-media presentations to be exhibited in schools and public forums.

E. Limitations and uncertainties:

Although the cost of extracting data from US and Canadian census materials is only tied to the hours one must devote to the project every five to ten years, the construction and distribution of survey instruments can be quite costly (i.e., upwards of $20,000 for each wave of data gathering). Even assuming the financing is available, cultural data are so inclusive that interpreting the data may be a daunting task, especially since the analyst would have to avoid value judgments and ethnocentric biases. And, similar to a problem encountered in another indicator, we cannot assume that all cultures contribute positively to sustainability and will have to go beyond mere numbers to assess the true worth of cultural diversity.

F. Interpretation of the indicator:

The interpretation of this indicator is directly parallel to that which accompanies the role diversity plays in non-human ecosystems: as the range and variety of cultures increase to the social carrying capacity of a region, so to does the ability of that society to discover innovative solutions and adapt to emerging needs. However, though we may conclude that a lessening of distinct cultures in the basin is indicative of a problem, this information does not suggest specific solutions per se.

8.4.3 Basin-Wide Sense of Identity

A. Ecosystem objective addressed by this indicator:

Developing Sustainability Summary Objective and Sub-Objective d) *"The basis for guiding sustainable development at the scale of the Lake Superior basin should be the pattern of land, water, and air use, as these affect ecological, social, and economic progress"*

B. <u>Purpose or nature of the indicator</u>:

An inherent part of developing sustainability in the Lake Superior basin will be the emergence of a unified sense of community which spans the border between the US and Canada and stretches from east to west. Applying the influential Brundtland report (World Commission on Environment and Development, 1987) to the region suggests that "our common future" will be largely dependent upon the agreement basin residents have regarding what this place means and how they should act toward it. Again, this world view is the product of culture and residents' attitudes may either be positive, neutral, or negative in regard to sustaining the lake and its environs. It is the nature of this indicator to provide snapshots of how unified people are in their identity as basin shareholders instead of individual dwellers on the land.

C. <u>Features of the indicator</u>:

A representative sample of residents in the Lake Superior catchment will complete yet to be designed surveys measuring their attitudes toward the basin as a bioregion and revealing the extent to which they exhibit a unified, implicit adoption of the "Vision Statement" for the lake environment. These surveys, distributed in LaMP year-one and periodically thereafter, will consist of updated protocols measuring the integration of environmental values (e.g., Van Liere & Dunlap, 1983), the valuation people attach to spiritual or aesthetic characteristics of the region (e.g., Brookshire, Ives, & Schultze, 1976), and other measures of shared outlook (e.g., content analysis of local media stories) regarding the vision for the basin adopted by the Binational Forum (e.g., Poyatos, 1976).

For this indicator the target would be: <u>basin residents recognize the cultural and economic connectedness of the bioregion and their shared destiny in its future</u>.

D. <u>Illustration of the indicator</u>:

Descriptive statistics generated from survey responses will be indexed to changes in attitudes over time and reflective of components in the "Vision Statement" with special attention paid to the distribution of different values across the basin. These findings will be combined with representative extracts from open ended responses by basin residents and interpreted in narrative form for the benefit of readers of periodic reports.

E. <u>Limitations and uncertainties</u>:

It obviously will be difficult to gain a true measure of a basin-wide identity. Expressed attitudes must be carefully considered in context of actual conduct; surveys must be general enough to capture the range of values embraced by basin residents yet specific enough to isolate commitments to a basin-wide identity; existing differences in the values of individualism between nations and urban versus rural communities must be taken into account. Also, expecting no more than a 60% return rate on mailed surveys, we will need two samples (one panel and one random) of roughly 1800 each to attain sufficient power to adequately interpret the data (assuming a relatively weak survey-to-survey difference in changes in group identity). The survey should be administered every five years (to reduce panel respondent attrition due to natural migration) and will entail the normal cost for collecting and analyzing such data.

F. <u>Interpretation of the indicator</u>:

People can only work in concert for a sustainable society to the extent they share an understanding for who they are as stakeholders in region and the coalescing of a group identity in the basin will indicate greater chances for sustainability. A lack of movement toward a shared identity over time will suggest the need for greater efforts at educating people and encouraging joint projects which enfranchise various publics in the Lake Superior watershed.

8.4.4 General Participation in Environmental Programs

A. Ecosystem objective addressed by this indicator:

Developing Sustainability Summary Objective and Sub-Objectives a) *"Public and private decisions will be right when they tend to preserve the integrity, stability, and beauty of the biotic community (Leopold, 1968)"*, and d) *"The basis for guiding sustainable development at the scale of the Lake Superior basin should be the pattern of land, water, and air use, as these affect ecological, social, and economic progress"*

B. Purpose or nature of the indicator:

For one reason or another, most people choose not to join formal environmental organizations yet commit themselves to a sustainable lifestyle just the same. In this vein, we would expect such individuals to gravitate toward programs reflecting their interests and one extremely useful index of the extent of environmental consciousness in society is to be found in a publics' participation in such events (Braden & Kolstad, 1991). This sort of passive endorsement of sustainable directions reflects deep seated allegiances and further serves to transform individuals into environmental activists (Cable & Degutis, 1991; Van der Ryn & Calthorpe, 1986). Thus, participation in environmental programs by the general public is a good indicator of how well the "right" kinds of cultural values are being sustained.

C. Features of the indicator:

Counts of people attending a representative sample of forums (e.g., those sponsored by the Binational Program) or participating in recurring activities (e.g., shoreline clean-up days, Earth Day) will be established in LaMP year-one and will serve as a baseline for subsequent tallies. An appropriate number of short interviews with residents attending those events will be used to distinguish those in specific environmental organizations from the general public. By returning time and again to the same sites, we can chart participation rates over a period of years.

For this indicator the target would be: <u>increasing numbers of citizens take part in formal gatherings, programs, and projects related to environmentalism</u>.

D. Illustration of the indicator:

Graphics and charts will provide the public with a view of how citizen participation is changing over time, especially in relative proportion to membership in environmental organizations.

E. Limitations and uncertainties:

Forums, programs, and activities may not be readily available to those living in rural portions of the basin. Another qualification of this indicator is that opportunities often depend upon the resources and inclination of community organizers; even if someone wanted to participate, they might not have the chance to act on their desires. Also, not all types of environmental program participation reveal emerging cultural values and some alternative venues, more indicative of sustainability, may be ignored. Thus, as always, analysts must be cautious in reading too much into a pattern of findings. If community or grassroots personnel can be mobilized to count and interview participants, costs will be minimal. Otherwise, we can expect to pay upwards of $10,000 for obtaining this sort of data for any given set of observations (even if we limit the sample of activities to 20 programs or events, that occur on a yearly basis, scattered around the basin).

F. Interpretation of the indicator:

Part of a people's culture is reflected in the community activities they choose to join as willing participants. If we assume that environmental programs largely reflect a commitment to a sustainable environment, we can conclude that voluntary attendance at such events indicates at least a partial allegiance to an environmental world view. Yet, as straightforward as this interpretation may be, the indicator cannot diagnose specific problems or suggest specific solutions.

REFERENCES

Aquatic Communities

Bailey, R. M., and G. R. Smith. 1981. Origin and geography of the fish fauna of the Laurentian Great Lakes basin. Can. J. Fish. Aquat. Sci. 38:1539-1561.

Baldwin, N. S., R. W. Saalfield, M. A. Ross, and H. J. Buettner. 1979. Commercial fish production in the Great Lakes, 1867-1977. Great Lakes Fish. Comm. Tech. Rep. No. 3. 187 p.

Busiahn, T. R. 1990. Fish community objectives for Lake Superior. Great Lakes Fish. Comm. Spec. Pub. 90-1. 23 p.

Crowder, L. B. 1980. Alewife, rainbow smelt and native fishers in Lake Michigan: competition or predation. Env. Biol. Fish. 5:225-233.

Dyer, W. R, L. F. Erkkila, and C. L. Tetzloff. 1965. Food of lake trout in Lake Superior. Trans. Amer. Fish. Soc. 94:169-176.

Ebener, M. P., J. E. Johnson, D. M. Reid, N. P. Payne, R. L. Argyle, G. M. Wright, K. Krueger, J. P. Baker, T. Morse, and J. Weise. In press. Status and future of Lake Huron fish communities. In M. Munawar, T. Edsall, and J. Leach [ed.] The Lake Huron ecosystem: ecology, fisheries and management. Ecovision World Monograph Series, S. P. B. Academic Publishing, The Netherlands.

Eck, G. W., and L. Wells. 1987. Recent changes in Lake Michigan's fish community and their probable causes, with emphasis on the role of alewife (*Alosa pseudoharengus*). Can. J. Fish. Aquat. Sci. 44:(Suppl. 2):53-60.

Evans, D. O., and D. H. Loftus. 1987. Colonization of inland lakes in the Great Lakes region by rainbow smelt, *Osmerus mordax*: their freshwater niche and effects on indigenous fishes. Can. J. Fish. Aquat. Sci. 44:(Suppl. 2):249-266.

Francis, G. R., J. J. Magnuson, H. A. Regier, and D. R. Talhelm. 1979. Rehabilitating Great Lakes ecosystems. Great Lakes Fish. Comm. Tech. Rep. No. 37. 99 p.

GLFC (Great Lakes Fishery Commission).. 1980. A Joint strategic Plan for Management of Great Lakes Fisheries. Great Lakes Fish. Comm., Ann Arbor, MI. 20 p.

Hansen, M. J. [ED.]. 1994a. The state of Lake Superior in 1992. Great Lakes Fish. Comm. Spec. Pub. 94-1. 110 p.

Hansen, M. J. 1994b. Dynamics of the recovery of lake trout (*Salvelinus namaycush*) in U. S. waters of Lake Superior. Doctoral dissertation, University of Michigan, Lansing. 114p.

Hansen, M. J., M. P. Ebener, J. Dale Shively, and B. L. Swanson. 1994. Lake trout, p. 13-34. In M. J. Hansen [ed.] The state of Lake Superior in 1992. Great Lakes Fish. Comm. Spec. Pub. 94-1.

Healey, M. C. 1978. The dynamics of exploited lake trout populations and implications for management. J. Wild. Manag. 42:307-328.

Klar, G. T., and J. G. Weise. 1994. Sea lamprey, p. 77-86. In M. J. Hansen [ed.] The state of Lake Superior in 1992. Great Lakes Fish. Comm. Spec. Pub. 94-1.

Lawrie, A. H., and J. F. Rahrer. 1972. Lake Superior: effects of exploitation and introductions on the salmonid community. J. Fish. Res. Bd. Canada 29:765-776.

Lawrie, A. H., and J. F. Rahrer. 1973. Lake Superior: A case history of the lake and its fisheries. Great Lakes Fish. Comm. Tech. Rep. No. 19. 69 p.

Loftus, D. H., and P. F. Hulsman. 1986. Predation on larval lake whitefish (*Coregonus clupeaformis*) and lake herring (*C. artedii*) by adult rainbow smelt (*Osmerus mordax*). Can. J. Fish. Aquat. Sci. 43:812-818.

Kerr, S. J., and G. C. LeTendre. 1991. The state of the Lake Ontario fish community in 1989. Great Lakes Fish. Comm. Spec. Pub. 91-3. 38 p.

Kitchell, J. F. 1985. An ecological rationale for managing predator-prey systems in the Great Lakes, p. 85-98. In R. L. Eshenroder [ed.] Presented papers from the Council of Lake Committees plenary session on Great Lakes predator-prey issues, March 20, 1985. Great Lakes Fish. Comm. Tech. Rep. 85-3. 134 p.

Kitchell, J. F., L. A. Eby, X. He, D. E. Schindler, and R. A. Wright. 1994. Predator-prey dynamics in an ecosystem context. J. Fish. Biol. 45(Supple. A):209-226.

LSLTTC (Lake Superior Lake Trout Technical Committee). 1986. A lake trout rehabilitation plan for Lake Superior. Lake Superior Committee, Great Lakes Fish. Comm. 18 p.

LSTC (Lake Superior Technical Committee). 1995. A lake trout restoration plan for Lake Superior. Lake Superior Committee, Great Lakes Fish. Comm.

MacCallum, W. R., and J. H. Selgeby. 1987. Lake Superior revisited. Can. J. Fish. Aquat. Sci. 44(Suppl. 2):53-60.

MacCallum, W. R., S. T. Schram, and R. G. Schorfhaar. 1994. Other species, p. 63-76. In M. J. Hansen [ed.] The state of Lake Superior in 1992. Great Lakes Fish. Comm. Spec. Pub. 94-1.

Marshall, T. R., R. A. Ryder, C. J. Edwards, and G. R. Spangler. 1987. Using the lake trout as an indicator of ecosystem health- application of the dichotomous key. Great Lakes Fish. Comm. Tech. Rep. No. 49. 35 p.

Peck, J. W., W. R. MacCallum, S. T. Schram, D. R. Schreiner, and J. Dale Shively. 1994. Other salmonids, p. 35-51. In M. J. Hansen [ed.] The state of Lake Superior in 1992. Great Lakes Fish. Comm. Spec. Pub. 94-1.

Pratt, D. M., W. H. Blust, and J. H. Selgeby. 1992. Ruffe, Gymnocephalus cernuus: newly introduced in North America. Can. J. Fish. Aquat. Sci. 49:1616-1618.

Pycha, R. L., and G. R. King. 1975. Changes in the lake trout population of southern Lake Superior in relation to the fishery, the sea lamprey, and stocking, 1950-70. Great Lakes Fish. Comm. Tech. Rep. No. 28. 34 p.

Selgeby, J. H. 1982. Decline of lake herring (*Coregonus artedii*) in Lake Superior: analysis of the Wisconsin herring fishery, 1936-78. Can. J. Fish. Aquat. Sci. 39:554-563.

Selgeby, J. H., C. R. Bronte, and J. W. Slade. 1994. Forage species, p. 53-62. In M. J. Hansen [ed.] The state of Lake Superior in 1992. Great Lakes Fish. Comm. Spec. Pub. 94-1.

Selgeby, J. H., W. R. MacCallum, and M. H. Hoff. 1994. Rainbow smelt - larval lake herring interactions: competitors or casual acquaintances? Nat. Biol. Surv., Tech. Rep. Ser., Biol. Rep. 25. 9 p.

Terrestrial Wildlife

Addison, E. M., G. Fox, and M. Gilbertson, eds. 1991. Proceedings of the expert consultation meeting on mink and otter, Windsor, Ontario, March 5-6, 1991.

Armstrong, Ted. Ontario MNR. Personal communication.

Carmean, William. Professor of Forestry, Lakehead University. Personal communication.

Cumming, H.G. and D.B. Beange. 1993. Survival of woodland caribou in commercial forests of northern Ontario. Forestry Chronicle 69(5): 579-588.

Darby, W.R., H.R. Timmermann, J.B. Snider, K.F. Abraham, R.A. Stephanski, and C.A. Johnson. 1989. Woodland caribou in Ontario: Background to a policy. Ont. Min. Nat. Resour. , Wildl. Br., Toronto. 38 pp.

Ensor, K. L. W. C. Pitt, and D. D. Helwig. 1993. Contaminants in Minnesota Wildlife: 1989-1991. Minnesota Pollution Control Agency. St. Paul, Minnesota.

Giesy, J. P. et al., 1994. Contaminants in fishes from Great Lakes-influenced sections and above dams of three Michigan rivers II: Implications for health of mink.

Gollat, Rick. Ontario MNR. Personal communication.

Hazard, E. B. 1982. The Mammals of Minnesota. University of Minnesota Press, Minneapolis, Minnesota.

Hyer, Bruce. Personal communication.

Langenau, Ed.Michigan DNR. Personal communication.

Noss, R.F. 1990. Indicators for monitoring biodiversity: a hierarchical approach. Conserv. Biol. 4(4): 355-364.

Racey, G. D., K. Abraham, W.R. Darby, H.R. Timmerman and Q. Day. 1991. Can woodland caribou and the forest industry coexist: The Ontario scene. Proc. 5th N. Am. Caribou Workshop.

Shad, Dave. Minnesota DNR. Personal communication.

Strand, Fred. Wisconsin DNR. Personal communication.

Welch, D. A. 1992. Mink along the shoreline of the lower Great Lakes. A report submitted to the Ontario Ministry of Natural Resources.

Wren, C. D. 1991. Cause-effect linkages between chemicals and populations of mink (Mustela vison) and otter (Lutra canadensis) in the Great Lakes Basin. J. Toxicol. Environ. Health 33:549-585.

Habitat

Andren, H. 1994. Effects of habitat fragmentation on birds and mammals in landscapes with different proportions of suitable habitat: a review.

Baker, W.L. 1992. Effects of settlement and fire suppression on landscape structure. Ecology. 73(5): 1879-1887.

Bauer, M.E., T.E. Burk, A.E. Ek, P.R. Coppin, S.D. Lime, T.A. Walsh, D.K. Walters, W. Befort, and D.F. Heinzen. 1994. Satellite inventory of Minnesota forest resources. Photogramm. Eng. Remote Sensing. 60(3): 287-298.

Bedford, B.L. 1990. Increasing the Scale of Analysis: The Challenge of Cumulative Impact Assessment for Great Lakes Wetlands. Wetlands of the Great Lakes. The Association of State Wetland Managers Inc. (pp. 186-195)

Bennett, E.B. 1978. Water Budgets for Lake Superior and Whitefish Bay. Journal of Great Lakes Research 4:331-342

Borman, F.H. and G.E. Likens. 1970. The nutrient cycles of an ecosystem. Sci. Amer. 223: 92-101.

Burgess, R.L. and D.M. Sharpe. 1981. Summary and conclusions. In: Forest island dynamics in man-dominated landscapes. R.L. Burgess and D.M. Sharpe (Eds.) Springer-Verlag. New York. pp. 267-272.

Dodge, D. and R. Kavetsky. 1994. Aquatic Habitat and Wetlands of the Great Lakes. SOLEC Working Paper. State of the Lakes Ecosystem Conference; Dearborn, Michigan.

Fitzgibbon, J. and J. Imhof. (In press). Managing for Natural Channel/Valley Systems Within an Ecosystem Context: A Hierarchical Indicator Model for Stream Ecosystems. Can. J. Fish. Aquatic. Sci.

Gluck, M. and Rempel R. In press. Structural characteristics of post-wildfire and clearcut landscapes.

Harris, L.D. 1984. The fragmented forest: island biogeographic theory and the preservation of biotic diversity. University of Chicago Press, Chicago. 211 pp.

Hartig, J. 1993. A Survey of Fish Community and Habitat Goals/ Objectives/Targets and Status in Great Lakes Areas of Concern.

Hartman, G.F. and J.C. Scrivener. 1990. Impacts of Forestry Practices on a Coastal Stream Ecosystem, Carnation Creek, British Columbia. Can. Bull. Fish. Aquat. Sci. 223: 148 p.

Johnston, C.A. 1992. Land Use Activities and Western Lake Superior Water Quality. Making a Great Lake Superior. Lakehead University. (pp. 145-162)

Kemp, A.L.W., C.I. Dell, and N.S. Harper. 1978. Sedimentation Rates and a Sediment Budget for Lake Superior. Journal of Great Lakes Research 4:276-287.

Lawrie, A.H. and J.F. Rahrer. 1973. Lake Superior: A Case History of the Lake and its Fishes. Great Lakes Fish. Comm. Tech Report No. 19.

Matthiae, P.E. and F. Stearns. 1981. Mammals in forest islands in southeastern Wisconsin. In: Forest island dynamics in man-dominated landscapes. R.L. Burgess and D.M. Sharpe (Eds.) Springer-Verlag. New York. pp. 59-66.

McGarigal, K. and B. Marks. 1994. Fragstats: Spatial pattern analysis program for quantifying landscape structure. Forest Science Department, Oregon State University, Corvallis, Oregon. 67 pp.

Ontario Ministry of Environment. 1992. The Provincial Water Quality Monitoring Network in Northwestern Ontario: Data Summary 1968 to 1990. Queen's Printer for Ontario. 272 p. + App.

Schueler, T.R. 1987. Controlling Urban Runoff. Metropolitan Washington Council of Governments.

Steedman, R.J. 1992. Centres of Ecosystem Function in the Lake Superior Coastal Zone. Making a Great Lake Superior. Lakehead University. (pp. 66-89)

The Nature Conservancy. 1994. The Conservation of Biological Diversity in the Great Lakes Ecosystem: Issues and Opportunities. The Nature Conservancy Great Lakes Program. 117p.

United States Environmental Protection Agency (USEPA) and Environment Canada. 1988. The Great Lakes: an environmental atlas and resource book. Toronto. 44 pp.

Whitcomb, R.F., C.S. Robbins, J.F. Lynch, B.L. Whitcomb, M.D. Dlimkiewicz, and D. Bystrak. 1981. Effects of forest fragmentation on avifauna of the eastern deciduous forest. In: Forest island dynamics in man-dominated landscapes. R.L. Burgess and D.M. Sharpe (Eds.) Springer-Verlag, New York. pp. 125-205.

Wilcove, D.S. 1985. Nest predation in forest tracts and the decline of migratory songbirds. Ecology 66: 1211-1214.

Human Health

Ahier, B.A. & Tracy B.L. (1993). SOLEC Paper on: Radionuclides in the Great Lakes. Environmental Radiation Hazards Division, Bureau of Radiation and Medical Devices, Health Protection Branch, Health Canada.

Great Lakes Science Advisory Board. 1993. Report to the International Joint Commission (general reference)

Rang, S., Holmes, J., Slota, S., Bryant, D., Nieboer E., & Reiger, H. (1992). The impairment of beneficial uses in Lake Ontario. In: Final report submitted to the Great Lakes. Environment Office, Environment Canada.

United States Environmental Protection Agency. 1992. Interim Report of the Ecosystems Objectives Work Group on Ecosystem Objectives and the Environmental Indicators for Lake Ontario (general reference)

Developing Sustainability

Alban, D.H., Tiarks, A.E., Powers, R.F., Page-Dumroese, B.S., Ponder, F, & Bufford, M.A. (1994). Forest management impacts on long-term productivity: early results from a US research program. Abstracted in: Proceedings: International Energy Association/Bio-energy T9/A4 workshop. May 16-23, Fredericton, New Brunswick.

Barry, B. (1983). Intergenerational justice in energy policy. In D. MacLean & P.G. Brown (Eds.), Energy and the future (pp. 15-30). Lanham, MD: Rowman & Littlefield.

Bourhis, R., & Sachdev, I. (1984). Subjective vitality perceptions and language attitudes: some Canadian data. Journal of Language and Social Psychology, 3, 97-126.

Braden, J.B., & Kolstad, C.D. (1991). Measuring the demand for environmental quality. Amsterdam: North-Holland.

Brisson, I. (1993). Packaging waste and the environment, economics, and policy. Resource, Conservation and Recycling, 17, 197-214.

Brookshire, D.S., Ives, B.C., & Schulze, W.D. (1976). The valuation of aesthetic preferences. Journal of Environmental Economics and Management, 3, 325-346.

Cable, S., & Degutis, B. (1991). The transformation of community consciousness: the effects of citizens' organizations on host communities. International Journal of Mass Emergencies and Disasters, 9, 383-399.

Cantrill, J. G. (1993). Communication and our environment: categorizing research in environmental advocacy. Journal of Applied Communication Research, 21, 66-95.

Connett, P.H. (1991). The disposable society. In F.H. Bormann & S.R. Kellert (Eds.), Ecology, economics, ethics: the broken circle (pp. 99-122). New Haven: Yale University Press.

Crow, T.R., Haney, A., & Waller, D.M. (1994). Report on the scientific roundtable on biological diversity convened by the Chequamogon and Nicolet National Forests. General Technical Report (NC-166). St. Paul, MN: USDA Forest Service.

Daly, H.E., & Cobb, J.B. (1989). For the common good: redirecting the economy toward community, the environment, and a sustainable future. Boston: Beacon Press.

Ehrlich, P.R., & Ehrlich, A.H. (1991). Healing the planet. Reading, MA: Addison-Wesley.

Geertz, C. (1973). The interpretation of cultures: collected essays. New York: Basic Books.

Goldberg, P. (1993). Americans on the move. Population Bulletin, 48 (3), 1 - 30.

Grieg, S., Pike, G., & Selby, D. (1987). Earthrights: education as if the planet really mattered. San Francisco: Kogan Page.

Hannon, B. (1992). Measures of economic and ecological health. In R. Costanza, B.G. Norton, & B.D. Haskell (Eds.), Ecosystem health: new goals for environmental management (pp. 207-222). Washington, DC: Island Press.

Hannon, B., Costanza, R., & Herendeen, R. (1986). Measures of cost and value in ecosystems. Journal of Environmental Economics and Management, 13, 391-401.

Heskin, A.D. (1991). The struggle for community. Boulder, CO: Westview Press.

Herskovitz, M.J. (1973). Cultural relativism. New York: Random House.

Kalkenmark, M., & Chapman, T. (1989). Comparative hydrology. New York: UNESCO.

Jeffers, J.N. (1978). An introduction to systems analysis with ecological applications. University Park, PA: University Park Press.

Karr, J. (1991). Biological integrity: a long-neglected aspect of water resource management. Ecological Applications, 1 (1), 66-84.

Katz, E. (1985). Organism, community, and the "substitution problem." Environmental Ethics, 7, 241-256.

Leopold, A. (1968). A Sand County almanac. Cary, NC: Oxford University Press.

Ludwig, J.A., & Reynolds, J.F. (1988). Statistical ecology: a primer on methods and computing. New York: Wiley.

Lutz, E. (1993). Toward improved accounting for the environment. Washington, DC: World Bank Publications.

McNab, W.H., & Avers, P.E. (1994). Ecological subregions of the United States. Washington, DC: United States Department of Agriculture.

Milbrath, L.W. (1982). Envisioning a sustainable society:learning our way out. Boulder, CO: Westview Press.

Mitchell, P.C., & Carson, R.T. (1989). Using surveys to value public goods: the contingent valuation method. Washington, DC: Resources for the Future.

Orr, D.W. (1992). Ecological literacy. Albany: State University of New York Press.

Pearce, D. (1993). Blueprint 3: measuring sustainable development. London: Earthscan.

Pearce, D. Markandya, A., & Barbier, E.B. (1989). Blueprint for a green economy. London: Earthscan.

Platt, B., Doherty, C., Broughton, A., & Morris, D. (1990). Beyond 40%: record setting recycling and composting programs. Washington, DC: Institute of Local Self Reliance.

Poyatos, F. (1976). Analysis of culture through its culturemes: theory and method. In A. Rapoport (Ed.), The mutual interaction of people and their built environment (pp. 265-274). The Hague: Mouton.

Renner, M. (1993). Jobs in a sustainable economy. Worldwatch Institute paper no. 104. Washington, DC.

Repetto, R. (1992). Earth in the balance sheet. Environment, 34 (7), 13-18, 43-45.

Ripple, W.J. (1987). Geographic information systems for resource management: a compendium. New York: American Society of Photogrammetry and Remote Sensing.

Rothenbuhler, E.W. (1991). The process of community involvement. Communication Monographs, 58, 63-78.

Sargent, F.O. (1991). Rural environmental planning for sustainable communities. Covelo, CA: Island Press.

Smith, S., & Reeves, J. (1988). Human systems ecology: studies in the integration of political economy, adaptation, and socionatural regions. Boulder, CO: Westview Press.

Spreng, D.T. (1988). Net energy analysis and the energy requirements of energy systems. New York: Praeger.

Stern, P.C., & Aronson, E. (1984). Energy use: the human dimension. Salt Lake City, UT: Freeman.

Tomlin, D.C. Geographic information systems and cartographic modelling. Englewood Cliffs, NJ: Prentice-Hall.

Tsai, Y., & Sigelman, L. (1982). The community question: a perspective from national survey data--the case of the USA. British Journal of Sociology, 33, 579-588.

Uusitalo, L. (1983). Consumer behavior and environmental quality: trends and prospects in the ways of life. New York: St. Martin's Press.

Van der Ryn, S., & Calthorpe, P. (1986). Sustainable communities: a new design synthesis for cities, suburbs and towns. San Francisco: Sierra Club Books.

Van Liere, K.D., & Dunlap, R.E. (1983). Cognitive integration of social and environmental beliefs. Sociological Inquiry, 53, 333-341.

Wilson, E.O. (1992). The diversity of life. Cambridge, MA: Harvard University Press.

World Commission on Environment and Development (1987). Our common future. Cary, NC: Oxford University Press.

Appendix 1. Charge to the writing teams

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July 5, 1994

TO: Writing Team Leaders, Ecosystem Indicators and Targets for the Lake Superior Basin

Per your recent discussion with Amy Owen, please find enclosed the "information package for writing teams", and various reference materials. Please review the information package carefully for details about the context and format for the ecosystem targets and indicators relating to your subject area. The reference materials provide examples and background that you may find useful.

Your expertise and networking abilities are essential to the drafting of practical ecosystem indicators and targets for the Lake Superior Basin. The challenge for us all is to draft technically feasible indicators that are demonstrably relevant to the Lake Superior Ecosystem Principles and Objectives. On behalf of the Lake Superior Ecosystem Principles and Objectives workgroup, we would like to thank you in advance for your efforts. Please contact us if you would like to discuss any aspect of this project.

Sincerely,

Rob Steedman
Research Coordinator
OMNR/CNFER

Bob Kavetsky
Fish and Wildlife Biologist
U.S. Fish and Wildlife Service
302 Manly Miles Building
1405 South Harrison
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Ph. 517-337-6650

Co-chairs, Lake Superior Ecosystem Principles and Objectives workgroup

cc. Jake Vander Wal
Chuck Ledin

DRAFT ECOSYSTEM INDICATORS AND TARGETS FOR THE LAKE SUPERIOR BASIN

INFORMATION PACKAGE FOR WRITING TEAMS

July 6, 1994

1. TERMS OF REFERENCE FOR THIS EXERCISE

PURPOSE:

To address Purpose 2) from the Lake Superior Ecosystem Principles and Objectives, November 17, 1993 version:

facilitate progress towards a set of informative ecosystem indicators, with quantitative targets, by which the health of the Lake Superior basin ecosystem, including its physical, biotic and cultural elements, can be measured. This step is primarily a technical process based on expert consultation, where indicators and targets will be identified through consideration of relevant ecological, economic and cultural information. The ecosystem indicators and targets will address the Lake Superior ecosystem principles and objectives, and will reflect practical constraints faced by agencies responsible for monitoring in Lake Superior basin. Concepts and products developed by the Ecosystem Objectives Work Group for Lake Ontario (Bertram and Reynoldson 1992), and other initiatives, will be used in this exercise.

PROCESS:

Interested subgroups and partners of the Lake Superior Work Group will be provided with this information package, and invited to draft ecosystem indicators and targets relevant to their areas of expertise. This process will rely on the good judgement of each writing team in obtaining additional expert advice where necessary. The process also relies on the commitment of the writing teams to deliver their products by the dates outlined below.

CONSTRAINTS:

The writing teams must be willing and able to focus on simple, easily communicated indicators of complex ecological and cultural phenomena; this simplification may be accomplished through various means, including conceptual constructs (i.e. identification of hierarchies, key processes or structures), methodology (i.e. use of highly integrative measures), or statistical interpretation (i.e. integrative indices based on large sample sizes or multiple data sources). The information package provides a number of examples from the Lake Ontario process.

The ecosystem indicators and targets must be:

- prepared in the format specified in the information package
- relevant to the ecosystem objectives established in the discussion paper Ecosystem Principles and Objectives for Lake Superior;
- scientifically credible, and prepared in the context of the recent scientific literature on ecosystem monitoring;
- simple, yet reliable for their stated purpose;

- thoroughly documented with regard to purpose, technical characteristics, limitations, and interpretation;

- suitable for serious consideration by U.S. and Canadian agencies with a mandate for environmental monitoring;

PRODUCT:

By December 1, 1994, each writing team will forward their targets and indicators as WordPerfect 5.1 DOS document files to:

Amy Owen,
Inter-Tribal Fisheries
186 East Three-Mile Road
Sault Ste. Marie, Michigan
USA 49783

Phone: 906-632-0072 FAX: -1141

Amy will compile the various indicators and targets, and prepare a brief description of the process used to draft them.

2. BACKGROUND MATERIALS

Included in this package are:

1. draft reports from one or more of the April, 1993 Lake Ontario pelagic, benthic, habitat, wildlife, human health, or stewardship working groups;

2. a copy of GLFC Technical Report No. 49, "Using the lake trout as an indicator of ecosystem health - application of the dichotomous key", by Terry Marshall, et al., 1987;

3. a copy of Lake Superior Ecosystem Principles and Objectives, November 17, 1993 version;

4. a few pages describing the format of the Chesapeake Bay environmental indicators cited in #3, above.

These provide many good examples of the type of product that we are trying to produce.

3. TEMPLATE

The U.S. EPA's Chesapeake Bay Program developed a format to communicate monitoring information to environmental managers and to the public through periodic newsletters and press releases. Included is a display of the current data (or trend) in a graphical form, a clear display of the reference or target value (or range) to be achieved, some interpretive statements about the present status of the indicator and what it tells us about progress being made toward the ecosystem objectives, and a graphic to indicate at which level of the spectrum the indicator is located.

Persons drafting indicators and targets for the Lake Superior basin should address the following types of information:

A. Ecosystem objective addressed by this indicator. Refer to the Lake Superior Ecosystem Principles and Objectives, November 17, 1993 version, for descriptions of the objectives, and examples of potential indicators.

B. Purpose or nature of the indicator. What component of the ecosystem objective is being monitored? Why?

C. Features of the indicator. What, precisely, is to be measured? If an index is used, how is it calculated? What is the calibration for the index? Why are high or low levels of the index related to high or low levels of ecosystem health in the Lake Superior basin? What "logic trail" exists from the indicator itself to the interpretation?

D. Illustration of the index. How is the indicator to be presented (as graphs, tables, pie charts, etc.)? What do historic data show when presented in the format of the proposed indicator?

E. Limitation and uncertainties. What issues may limit the usefulness of the index? How costly is it to gather required data? How often should data be gathered? What qualifiers should be applied? What about geographic and temporal scales of relevance?

F. Interpretation of the indicator. How do the magnitude, variability and trend of the indicator inform us about environmental conditions and ecosystem health? Does the indicator diagnose specific problems related to individual, collective or industrial behaviour? Does it suggest educational, administrative or regulatory solutions?

REMEMBER THAT OUR MAIN OBJECTIVE IS TO MAKE A GOOD FIRST ATTEMPT AT SPECIFYING THESE INDICATORS AND TARGETS, GIVEN THE INFORMATION AVAILABLE TO US FROM THE LAKE ONTARIO INITIATIVE AND OTHER SOURCES. THE COMPILATION OF OUR INDICATORS AND TARGETS WILL PROVIDE A SIGNIFICANT STARTING POINT FOR DISCUSSION AND ITERATIVE REFINEMENT OF THESE CONCEPTS FOR THE LAKE SUPERIOR BASIN.

4. DEADLINES

December 1, 1994 for completion of subgroup assignments

February 1, 1995 for compilation of indicators into a stand-alone document

Appendix 2. Partial List of Persons affiliated with the Ecosystem Principles and Objectives, Indicators and Targets activities of the Lake Superior Work Group, 1992-1997.

The following list includes persons who attended one or more of the subcommittee's working sessions, or who otherwise expressed active interest in the activities of the subcommittee. On behalf of the Lake Superior Work Group, the subcommittee co-chairs would like to thank these persons, and any others who have been inadvertently omitted from this list, for their expertise and commitment to this project. Note that many other individuals who contributed to Ecosystem Indicators and Targets as Measurements of Progress Towards Ecosystem Principles and Objectives for Lake Superior as workshop members, writers, or advisors, are acknowledged in the introductions to various sections of that document.

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Amy Owen, Inter-Tribal Fisheries, Sault Ste. Marie, Michigan
Darrell Piekarz, Environment Canada
Jennifer Rae, Health Canada, Ottawa, Ontario
Rob Steedman, Ontario Ministry of Natural Resources, Thunder Bay (Canadian co-chair, 1992-1995)
Bob Thomson, Ontario Ministry of Natural Resources, Thunder Bay
Danielle Valvassori, Wisconsin Department of Natural Resources, Madison
Mel Whiteside, University of Minnesota, Duluth
Robert Young, Canada Department of Fisheries and Oceans, Sault Ste. Marie, Ontario (Chair, 1991-1992)