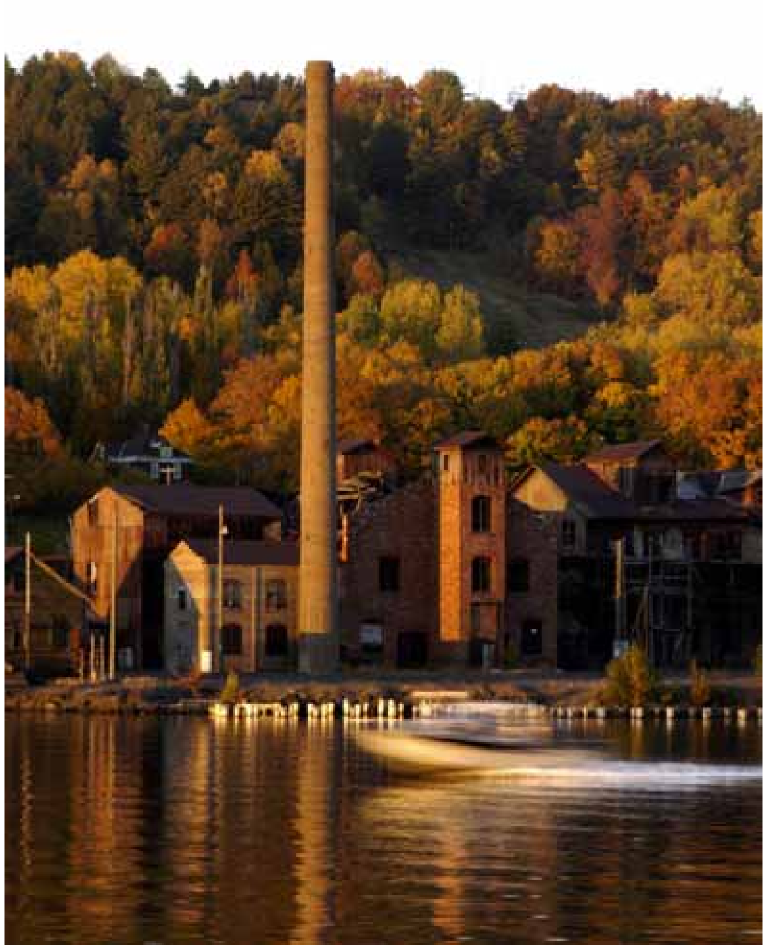
Chapter 3

Ecosystem Goals, Objectives, Indicators, Monitoring, and Beneficial Use Impairments



Quincy Smelter in the Keweenaw Peninsula.
Photo Credit: Brenda Jones, US EPA.

Lake Superior Lakewide Management Plan
2006

Chapter 3 Contents

Please Note: updated information in this chapter has been taken from published material with the exception of the binational cooperative monitoring update, and the draft habitat and wildlife ecosystem goals (section 3.3). These have not received final approval from the Task Force but are presented here as draft.

Chapter 3
Ecosystem Goals, Objectives, Indicators, Monitoring, and Beneficial Use Impairments

3.0 ABOUT THIS CHAPTER

The Binational Program is committed to the objective of zero discharge and to a broader program to restore beneficial uses and to protect and restore ecosystem integrity in Lake Superior and its watershed. A Vision for Lake Superior (see Chapter 1) expresses this commitment to the Lake Superior ecosystem and its landscapes. 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 Binational Program continues to expand the vision into more specific and technically-precise language.

As introduced in Chapter 1 (section 1.1.2), *Ecosystem Principles and Objectives, Indicators and Targets for Lake Superior* (EPO; LSBP 1998), first published in 1995, is the foundation to guide ecosystem management and monitoring in the Lake Superior Basin (see section 3.1). In 1999, so as to best monitor the current status of the ecosystem, the Superior Work Group narrowed the wide range of indicators in the EPO to a suite of "best bet" measures (see section 3.2) to guide its work (LSBP 1999) (http://www.epa.gov/glnpo/lakesuperior/binatmonwkshp.pdf). Ecosystem goals were further defined in 2003 for habitat and terrestrial wildlife (through the Superior Work Group; see section 3.3) and for aquatic communities (through the Great Lakes Fisheries Commission; see section 3.4).

This chapter provides an overview of these efforts to define ecosystem principles, goals, objectives, and indicators for ecosystem management in the Lake Superior Basin. Work Group committees continue to refine existing goals, objectives, principles, and indicators, and to address gaps where they exist (see Chapters 4, 6, and 7 for the most current information).

U.S. and Canada Binational Cooperative Monitoring, as described in section 3.5, was initiated in Lake Superior in 2005-2006. The Cooperative Monitoring approach is above and beyond the routine monitoring programs that agencies normally conduct. Its goal is to address key information gaps as identified through the lakewide management programs. It complements and builds on other monitoring and research projects being conducted on the lake in the same year.

Annex 2 of the Great Lakes Water Quality Agreement requires that each LaMP assess impairments to beneficial water resource uses (see section 3.6) as the first step in identifying restoration and protection actions for each of the Great Lakes. The Lake Superior LaMP identified six beneficial uses as impaired due to critical pollutants, but also recognizes that more than just these beneficial use impairments will need to be addressed before Lake Superior can be fully restored.

3.1 ECOSYSTEM PRINCIPLES AND OBJECTIVES FOR LAKE SUPERIOR

The *Ecosystem Principles and Objectives, Indicators and Targets for Lake Superior (EPO):*

1) Expanded the broad objectives of A Vision for Lake Superior into more specific ecosystem principles, objectives, and categories for key elements of the Lake Superior ecosystem, including aquatic communities, terrestrial wildlife, habitat, human health, and sustainability. This discussion document underwent review among Great Lakes practitioners. Ecosystem objectives developed by consensus do not obviate or override regulations, laws, and guidelines set by governments and resource regulatory agencies. Rather, the *Ecosystem Principles and Objectives* document was prepared to encourage informed discussion of the vision and practice essential for proactive, sustainable, and coordinated management of the Lake Superior ecosystem.

2) Facilitated progress toward 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.

3) Provided guidance for land and water management in the Lake Superior ecosystem.

Lake Superior ecosystem objectives and sub-objectives were developed by each of the Lake Superior Work Groups committees: chemical, aquatic community, terrestrial wildlife community, habitat, human health and developing sustainability. Table 3.1, Summary of Objectives and Sub-Objectives, presents each committee objectives and elaborates and clarifies them in the sub-objectives column.

A typical indicator identifies a practical measurement such as the abundance or distribution of a plant or animal species or an economic measure that tells us something significant about the health of the Lake Superior ecosystem. Each indicator is accompanied by a target that specifies the desired level of the indicator.

Table 3-1. Summary of Objectives and Sub-Objectives (EPO 1998)

1. General Objective	Human activity in the Lake Superior Basin should be consistent with <u>A Vision For Lake Superior</u>, 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	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.	• 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. • Per the Great Lakes Water Quality Agreement, atmospheric deposition of persistent, bioaccumulative toxic chemicals that have an anthropogenic origin should be virtually eliminated. • 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). • Concentrations of zero discharge and lakewide remediation chemicals in sediment in nearshore areas (<80 m), 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. • Concentrations of the chemicals in the prevention/monitor category should not increase in air, water, or sediment. • 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.
3. Aquatic Communities Objective	Lake Superior should sustain diverse, healthy, reproducing, and self-regulating aquatic communities closely representative of historical conditions.	• Lake trout will continue to be recognized as 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. • Native aquatic species associations will be recognized as key elements of a healthy Lake Superior ecosystem. • Aquatic biota living in the Lake Superior ecosystem should be free from contaminants of human origin. • 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.

Table 3-1. Summary of Objectives and Sub-Objectives (EPO 1998)

		• 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 prevented through effective use of regulatory and technological measures. The use of live bait by anglers must not contribute to the dispersal of exotic species or genetic stocks.
4. Terrestrial Wildlife	The Lake Superior ecosystem should support a diverse, healthy, and sustainable wildlife community in the Lake Superior Basin.	• There is a wildlife community-based program to monitor the health of Lake Superior Basin ecosystems. • Species at risk/concern (federally threatened and endangered) are recovered. • Encourage disturbances that are within natural variation. • Manage land and wildlife populations using practices that mimic natural disturbances. • Understand the relationship between wildlife and disturbance. • Keep wildlife species free of contamination. • Encourage the use of native species in all remedial projects. • Prevent and control the spread of undesirable exotic species. • Educate the public to integrate the values of wildlife in economic development. • Meet the restoration needs of wildlife communities.
5. Habitat	To protect and maintain existing high-quality habitat sites in the Lake Superior Basin and the ecosystem processes that sustain them. 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.	• Ecological health of the Lake determined largely by the health of tributary lakes and rivers; land use planning/regulation should eliminate/avoid destructive water linkages and foster healthy land-water linkages. • Long-term consequences of incremental landscape change, habitat destruction, and fragmentation should be avoided through research and planning. • Importance of nearshore, shoreline, and wetland habitats should be addressed through identification, protection, and restoration of sites for reproduction and rearing of fish, water birds, mammals, other wildlife, and plants.
6. Human Health	The health of humans in the Lake Superior ecosystem should not be at risk from contaminants of human origin. The appearance, taste, and	• Fish and wildlife should be safe to eat and consumption should not be limited by contaminants of human origin. • Water quality should be protected where currently high, and improved where degraded.

Table 3-1. Summary of Objectives and Sub-Objectives (EPO 1998)		
	odour of water and food supplied by the Lake Superior ecosystem should not be degraded by human activity.	• Lake Superior should be safe for total body contact activities, including areas adjacent to urban and industrial areas. • Air quality should be protected where currently high, and improved where degraded. • Communities, industries, and regulators outside basin should be informed of consequences of long-range atmospheric transport of contaminants into the basin.
7. Developing Sustainability	Human use of the Lake Superior ecosystem by all people in the watershed should be consistent with the highest social and scientific standards for sustainable use. Land, water, and air use in the Lake Superior ecosystem should not degrade it, or 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 such use place at significant risk the socioeconomic and cultural foundations for any group of citizens in the watershed, nor should we deny current and future generations the benefits of a healthy, natural Lake Superior ecosystem. Policies directed at the wise management of natural and social resources in the basin should not usurp the right of local communities to determine their future within the guidelines established by existing statutes and regulations. Technologies and development plans that preserve natural ecosystems and their biodiversity should be encouraged.	• Public and private decisions should be based on understandings, rooted in formal and informal educational settings, which contribute to the integrity and stability of social and biotic communities. • The Lake Superior ecosystem provides resources and services to humans. These include air, water, fiber, minerals, energy, waste transport and treatment, food, recreation, and spiritual sustenance. These resources should be valued as environmental capital, in the same way that other capital is assigned value. • Institutional capacity to integrate technology and sustainable design should be developed within the Lake Superior ecosystem that is compatible with existing and emergent social conditions. • The basis for guiding sustainable development at the scale of the Lake Superior ecosystem (especially in reference to community land use or comprehensive planning) 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); Christensen et al. (1996); and Government of Canada (1990).

The EPO has provided a reference point for discussion and refinement of binational ecosystem management and monitoring in the Lake Superior Basin, and will continue to do so in the future.

3.2 "BEST BET" INDICATORS (1999)

A Lake Superior Binational Monitoring Workshop was held on October 25-27, 1999, to further refine the EPO ideas; a summary of the workshop results can be found below in Table 3-2.

In 1999, sixty people from government, industry, and local environmental groups met to examine existing monitoring activities within the Lake Superior Basin, with a view to developing a coordinated, long-term monitoring program. This coordinated program would incorporate Lake Superior Binational Program's indicators. The workshop represented the first time that monitoring data and indicators were considered at this scale of ecosystem organization for Lake Superior.

The tasks of the workshop were five-fold:

1. To review the list of current "best bet" indicators,
2. To review and update a metadata summary of current monitoring programs,
3. To match monitoring efforts with indicators and identify gaps and overlaps,
4. To identify potential funding sources for future monitoring and coordination,
5. To solicit agency interest and support for future monitoring and coordination efforts.

Participants reached consensus on nine key recommendations for future coordination of monitoring and reporting structure for Lake Superior:

1. Develop a coordinated monitoring strategy for the Lake Superior Basin. All of the Lake Superior Binational Program agencies will participate and seek resources for implementation. The monitoring strategy will be peer reviewed and presented in the LaMP 2002.
2. Prepare a revised list of "better bet" indicators for each theme committee.
3. Build a more complete metadata summary. This involved three steps:
    a. Include additional metadata identified at the workshop in the existing summary table (see Appendix VI of the report);
    b. Approach the International Joint Commission regarding input of a complete Lake Superior metadata list to their website.
    c. Search for additional metadata.
4. Form ad hoc groups to address sampling protocols, sample analysis and data reporting standardization and comparability identified by theme committees.
5. Identify monitoring gaps and make recommendations on those that are most critical
6. Facilitate greater coordination among agencies and theme groups to address common issues (for examples, see section 4.0 of the report). Establish a coordination committee to address these issues.
7. Identify funding necessary to address monitoring gaps and coordination of monitoring activities.
8. Report monitoring results in the LaMP 2002.
9. Adjust the existing Lake Superior Binational Work Group functions to achieve recommendations 1 through 8.

Table 3-2. "Best Bet" Indicators (1999)

A. Chemical Contaminants

Indicator	Purpose of Indicator	Illustration of Indicator	Interpretation of Indicator
1. Progress Towards Zero Discharge & Zero Emission	To measure progress towards zero discharge & zero emission of 9 designated persistent, bioaccumulative toxic chemicals[1];	Trends of chemical concentrations in water, fish, sediment & other ecosystem compartments; Measurements & estimates of release of chemicals from basin sources;	Discharge/emissions (measured as kg/yr, mass or other units for surrogate measures) will be compared to 1990 baseline data to indicate whether progress is being achieved;
2. Atmospheric Deposition Trends for Zero Discharge Chemicals[1]	To indicate progress towards virtual elimination of zero discharge chemicals from the environment;	Rates of change in atmospheric loadings of zero discharge chemicals in the wet, dry & gaseous phases;	Magnitude of trend indicates whether virtual elimination is being achieved;
3. Open Lake Concentrations of Zero Discharge & Lakewide Remediation Chemicals[2]	To indicate whether open lake concentrations of chemicals meet water quality yardsticks (most sensitive standard available);	Measurement of zero discharge & lakewide remediation chemicals every 2 yrs. in open lake (>80 m.);	Concentrations will be considered acceptable only if 95-100 percent of data indicate levels below yardstick;
4. Sediment Concentrations of Zero Discharge, Lake Remediation & Local Remediation[3] Chemicals	Zero discharge & lakewide remediation chemicals: To indicate whether sediment concentrations meet sediment yardsticks; Local remediation chemicals: To indicate restoration of impaired uses at Areas of Concern (AOC);	Changes in concentrations of chemicals in sediments at different depths; Upper segments of sediment cores compared to local (AOC) yardstick; Maps of extent of chemical contamination at AOCs;	Sediment Concentrations at depths within sediment core expressed in ug/g; Trends over time indicates change in 3 classes of chemicals; Sediment Concentrations in exceedance of yardsticks, or causing use impairments indicate need for further reductions;
5. Ambient Concentration Trends of Prevention/Monitor Pollutants[4] in Water, Sediment, Air/Precipitation	To indicate whether concentrations of Prevention/Monitor pollutants increase in air, water, or sediment;	Bar graphs showing changes in concentrations over time in air/precipitation & water; Trends in sediment concentrations from dated sediment core profiles;	Concentrations in air, water & sediment not increasing over time will indicate levels are not negatively impacting lake; Chemicals may be added to lakewide or local remediation categories;

Indicator	Purpose of Indicator	Illustration of Indicator	Interpretation of Indicator
6. Prevention/ Investigate Chemicals[5]	To determine presence/absence of chemicals in ambient air, water, sediment; To identify potential sources of chemicals;	Decisions to re-categorize these chemicals to be based on information literature search, presence/absence in lake, & sources;	Data from ambient & source monitoring used to determine whether continued monitoring is needed; Chemicals may be added to lakewide remediation, local remediation, or prevention/monitor chemicals;

[1] Zero Discharge Chemicals: chlordane, DDT, dieldrin, dioxin, hexachlorobenzene, mercury, octachlorostyrene, PCBs, toxaphene;
[2] Lakewide Remediation Chemicals: PAHs, alpha-BHC, cadmium, heptachlor, heptachlor epoxide;
[3] Local Remedation Chemicals: aluminum, arsenic, chromium, copper, iron, lead, manganese, nickel, zinc;
[4] Prevention/Monitor Pollutants: 1,4-dichlorobenzene, 1,2,3,4-tetrachlorobenzene, mirex/photo-mirex, pentachlorobenzene, pentachlorophenol, gamma-BHC;
[5] 1,2,3,5-tetrachlorbenzene, 3,3-dichlorobenzidine, 2-chloroaniline, tributyl tin, beta & delta BHC, hexachlorobutadiene;

B. Aquatic Communities

Indicator	Purpose of Indicator	Illustration of Indicator	Interpretation of Indicator
1. Off shore Community - Abundance of Key Species - Presence of Exotic Species	To monitor presence & relative abundance of key species (lean & siscowet lake trout, herring) & exotics to evaluate progress toward achieving populations of self-sustaining indigenous species;	Trends in relative abundance of native & non-native fish (benthic, pelagic), plankton & benthic invertebrate species over time; Pie chart to illustrate percent of community made up of exotic species;	Data will allow measure of how stressors (harvesting, exotics, nutrient loadings) affect the offshore community & indicate what regulatory solutions are needed;
2. Nearshore Community: - Abundance of Key Species - Presence of Exotic Species - Habitat Loss or Restoration	To monitor presence & abundance of key species (lean & siscowet lake trout, herring, whitefish, longnose & white suckers, walleye, slimy sculpin, *Diporeia* spp. *Mysis relica*), exotics & habitat changes to evaluate diversity & long-term sustainability of nearshore aquatic community;	Trends in abundance of native & exotic fish, plankton & benthic invertebrate species over time for each jurisdiction; Graphs illustrating trends in abundance of exotic species;	Data will allow measure of how stressors (harvesting, exotics, nutrient loadings, changes to habitat) affect the nearshore community & indicate what regulatory solutions are needed;
3. Harbour-Embayments-Estuaries Community: - Abundance of Key Species	To monitor presence & abundance of key species (walleye, yellow perch, pike, small mouth bass) exotic & benthic	Comparison of trends in abundance of native & exotic fish, species over time at for AOC & non-AOC	Data will allow measure of how stressors (as above & including water diversions, dredging, thermal loading) affect harbours, bays &

Indicator	Purpose of Indicator	Illustration of Indicator	Interpretation of Indicator
- Presence of Exotic Species - Habitat Loss or Restoration	invertebrates (chironomids, oligochaetes, burrowing mayfly) to measure the impact of remedial action plans in Areas of Concern;	sites; Comparison of density of benthic invertebrates at AOC & non-AOC sites;	estuaries; Solutions will involve educational, administrative & regulatory actions;
4. Tributary Community: - Abundance of Key Species - Presence of Exotic Species - Habitat Loss or Restoration - Self-sustaining Indigenous Species	To monitor presence & abundance of key species (brook trout, white suckers, walleye, sturgeon, burbot, other salmonines, in selected tributaries to the lake; To monitor growth & abundance or larval sea lamprey in tributaries;	Absolute abundance of juvenile salmonine fish species over time; Number of coho salmon, brown trout, rainbow trout, chinook salmon & brook trout migrating up tributaries over time; Larval lamprey growth & survival in different tributaries;	Data will allow measure of how reductions in stressors (logging, road & pipeline crossings, sedimentation, pollution, exotics, dams, water diversion) tributary communities; Solutions will involve educational, administrative & regulatory actions;
5. Toxic Contaminants in Aquatic Biota	To monitor contaminants (PCB, DDT, chlordane, mercury, dioxin, DDE, dieldrin, toxaphene) in 1 prey & 1 predator species of fish from each of 4 habitat types;	Table documenting levels of the major contaminants found in each species collected from each habitat type on an annual basis;	Changes in levels of contaminants in offshore fish species provides measure of changes in atmospheric loadings to lakes; Changes in levels of contaminants in nearshore fish species provides measure of changes in point-source loadings to lake;

C. Terrestrial Wildlife

Indicator	Purpose of Indicator	Illustration of Indicator	Interpretation of Indicator
1. Breeding Birds (50+ species)	To monitor diversity, relative abundance & distribution of birds;	No. of taxa, relative abundance & relative distribution of over 50 breeding bird species;	Indicator provides evidence of effects of habitat change on avian communities;
2. Amphibian Populations	To monitor the diversity & relative abundance of selected amphibian species within the lake basin;	Relative abundance of amphibian species through frog/toad call surveys;	Indicator will track declines which may indicate a problem;
3. Rare & Important Plants (G_1, G_2 of TNC list)	To measure the relative abundance of rare & important plants over time;	Relative abundance of rare & important plants;	Indicator will track declines which may indicate a problem;

Indicator	Purpose of Indicator	Illustration of Indicator	Interpretation of Indicator
4. Land Use Change	To measure land use change over time (i.e., forest type, edge density, age structure, landscape characteristics & forest structure);	Land use patterns measured at a level not coarser than 200 x 200 m. resolution at 5-yr. intervals;	Indicator provides evidence of habitat change;
5. Micro & Invertebrate Soil Organisms	To measure changes in the relative density & abundance of soil organisms over time;	Relative density & abundance of soil organisms over time;	Indicator will track declines which may indicate a problem;
6. Tree Swallows	To measure contaminant levels in tree swallows;	Trend in body-burdens of contaminants in tree swallows over time;	Indicator will show changes in levels of contaminant in nearby water;
7. Snapping Turtles	To measure contaminant levels in snapping turtles;	Trends in body-burdens of contaminants in snapping turtles over time;	Indicator will show changes in rates of contaminant bioaccumulation in turtles;
8. Colonial Birds	To measure relative abundance, distribution & contaminant levels in colonial birds;	Trends in relative abundance, distribution maps & contaminant levels in colonial bird populations;	Indicator will show changes in population levels which may indicate a problem, & changes in rates of contaminant concentrations over time;
9. Nocturnal Owls	To measure the relative distribution & abundance of nocturnal owl species;	Trends in relative distribution & abundance of nocturnal owl species;	Indicator will show changes in population levels & distributions which may indicate a problem;
10. Federally Listed Threatened & Endangered (T&E) Species	To measure the relative distribution & abundance of T&E species;	Trends in relative distribution & abundance of T&E species;	Indicator will show changes in distribution & abundance which may indicate a problem;
11. Exotic Plants & Terrestrial Animals (i.e., Gypsy Moth)	To measure the relative distribution & abundance of exotic plants & animals;	Trends in relative distribution & abundance of exotic plants & terrestrial animals;	Indicator will show increases which may indicate a worsening situation;
12. Medium-sized Carnivores	To measure the relative distribution & abundance of carnivores;	Trends in relative distribution & abundance of medium-sized carnivores;	Indicator will show declines which may indicate a problem;
13. White-tailed Deer	To measure the relative abundance of deer;	Trends in relative abundance of deer;	Indicator will show population impacts;
14. Ruffed Grouse	To measure the relative distribution & abundance of grouse;	Trends in relative distribution & abundance of grouse;	Indicator will show declines which may indicate a problem;

Indicator	Purpose of Indicator	Illustration of Indicator	Interpretation of Indicator
15. Lichens/ Mosses/Fungi	To measure the relative distribution, abundance and growth of lichens, mosses & fungi;	Trends in relative distribution, abundance and growth of lichens, mosses, fungi;	Indicator will show declines in population/growth which may indicate a problem;
16. Common Loons	To measure productivity & contaminant levels in common loons;	Trends in population productivity & contaminant levels in common loons;	Indicator will show levels of mercury bioaccumulation, & effects of habitat alteration;

D. Habitat

Indicator	Purpose of Indicator	Illustration of Indicator	Interpretation of Indicator
1. Stream Flow/Sedimentation	To monitor stream flows & sediment transport to track changes in land use patterns;	Line graphs of mean discharge; stream base flow, peak-to-low ration & sediment loading for streams on annual basis;	Changes in these parameters (e.g., increased frequency of peaking; increased sediment transport) indicate watershed degradation;
2. Benthic Invertebrates	To monitor trends in density & species richness of benthic invertebrate communities in streams, estuaries, inland lakes;	Graphical illustration of benthic community measures (density, taxonomic richness, diversity indices) & physical properties (pH, turbidity, nutrients) for comparison between site and temporal patterns;	Water quality & status of benthic invertebrate communities to detect problem sources and indicate need for mitigation measures;
3. Inland Lake Transparencies	To monitor clarity of inland lakes to determine changes in water quality over time;	Maps of secchi depth readings for lakes to indicate changes in water clarity over time;	Changes in water clarity may provide an indication of the overall ecosystem health of inland lakes;
4. Forest Fragmentation	To monitor patterns of landscape composition & pattern to track forest fragmentation;	Bar or line graphs of metrics including class area, mean patch size, patch size variability, total forest edge, nearest-neighbor distance etc. to indicate changes over time;	Decreases in forested area, mean patch size, increases in nearest-neighbor distance & patch edge indicate increase forest fragmentation, and the potential for forest species declines;

Indicator	Purpose of Indicator	Illustration of Indicator	Interpretation of Indicator
5. Accessible Stream Length	To monitor increases in total wetland area & accessible stream length to track habitat rehabilitation and protection efforts.	GIS-based system providing maps & graphs of changes in wetland area and accessible stream length.	Increases in wetland area, accessible stream length will provide indicators in positive change in lake's ability to produce fish & other aquatic life.

E. Human Health

Indicator	Purpose of Indicator	Illustration of Indicator	Interpretation of Indicator
1. Fish Contaminants	To monitor levels of contaminants in fish to provide information on human exposure;	Bar graphs showing fluctuation of contaminants over time & space; Contaminants will be summed to provide overall indicator of fish contamination;	Data will be used to monitor changes in contaminant levels for remedial plans, & for the issuing of contaminant advisories to public re: consumption limits;
2. Drinking Water Quality	To monitor quality of raw, treated and distributed water for comparison to water quality objectives & guidelines;	Bar graphs of geometric averages of contaminant concentrations (lead, trihalomethanes, nitrates, benzo[a]pyrene, mercury, etc.) in raw, treated & distributed levels to show trends over time;	Indicator would reveal trends in contaminant levels in water in various locations throughout the lake;
3. Recreational Water Quality	To monitor beach postings and *E. coli* counts spatially & temporally throughout the lake;	Bar graphs showing trends over time for *E. coli*, beach closures & contaminant levels;	Data will show seasonal and local trends in recreational water quality to aid in beach management & prediction of poor water quality episodes;
4. Air Quality	To monitor concentrations of 9 contaminants at 99 sites throughout the lake to provide an index of air quality;	Bar graphs of geometric means showing trends for each pollutant & air quality index over time;	Data will show overall air quality trends & allow regulatory agencies to monitor the effects of remedial plans;
5. Radionuclides	To monitor concentrations of whole milk for radionuclides;	Bar graphs of cesium & strontium concentrations in milk over time; Bar & line graphs showing total radiation as a percent of MAC;	Indicator will provide a measure of the overall exposure to the population to radionuclides from weapons fallout;

Indicator	Purpose of Indicator	Illustration of Indicator	Interpretation of Indicator
6. Body Burdens	To monitor concentrations of toxic contaminants in human tissue to determine delivered doses of chemicals;	Methods for illustrating trends in contaminants in human tissue to be determined; May measure contaminant levels in mother's milk;	Body burden information is useful to delineate potential from actually delivered doses of chemicals;
7. Health Effects	To monitor the occurrence or change in rate of adverse health outcomes directly linked to contaminant effects;	Measures such as birth weight, gestational age & malformations of infants will be plotted over time;	Trends in such measures may indicate contaminant effects, or changes in prenatal care;
8. Cohort Indicator of Exposure and Effects	To repeatedly monitor cohort of people within the basin for exposure indicators & expression of health effects;	Epidemiological techniques will be used to illustrate trends in exposure and health effects;	Indicator will help link human health outcomes to levels of contaminant exposure;

F. Developing Sustainability

Indicator	Purpose of Indicator	Illustration of Indicator	Interpretation of Indicator
1. Reinvestment in Natural Capital	To monitor balance between what is extracted from social & natural basis for life, & what is returned to the land & society; To promote projects designed to facilitate an equitable balance in future;	Measures include: amount of sustainable forestry, extent of watershed management & restoration programs, native fisheries & wildlife stocking, exotic species control & native plan repatriation, reclamation of mines and industrial sites, replacement of wetlands & biotic diversity;	
2. Quality of Human Life	To measure a range of social indicators to indicate the quality of life in the basin;	Measures include: incidence of crime; migration demographics, demands for social services, transportation infrastructure status, recreational & cultural opportunities, citizen involvement in decision making, public access to lakeshores, population density;	

Indicator	Purpose of Indicator	Illustration of Indicator	Interpretation of Indicator
3. Resource Consumption Pattern	To monitor types & quantities of resources consumed in basin, such as energy, water use & waste stream loadings;	Measures include: recycling programs, forest & mining resources remaining in basin, types of electric power generation, quality & volume of aquifers, tourism, depletion of wildlife and fisheries, landfill capacity & incineration volume, urban sprawl, loss of native flora;	
4. Awareness of Capacity for Sustainability	To implement a range of educational programs focusing on sustainability & to assess social conduct;	Measures include: environmental & sustainability education in schools, promotion of resource conservation programs, incorporation of ecological design into building codes, zoning regimes, popular support for environmental regulations, community outreach programs by natural resource agencies, media coverage of sustainability-related issues;	
5. Economic Vitality Measures	To understand the threats & opportunities to economic health of watershed, & implement projects to demonstrate sustainable alliance between environmental & economic sectors.	Measures include: per capita income, cost of living, extent of poverty, local employment trends, regional trade balance, diversity of communities economies, facilitation of transitional economies, value-added industry, regional & local tax bases.	

3.3 ECOSYSTEM GOALS

In order to achieve our vision of Lake Superior and in order to preserve, protect, and enhance healthy, sustainable ecosystems, the following ecosystem goals were established. In many ways, these goals describe the elements we wish to accomplish in the coming years (see Chapter 6 for additional details). We believe that, if we accomplish these elements, we will achieve the overall vision of Lake Superior.

OVERALL GOALS

- Diverse and healthy native plant and animal communities exist in the Lake Superior Basin.
- A program is in place to monitor the abundance, distribution, and health of plant and animal populations and communities in the Lake Superior Basin.
- Species at risk or species of concern are recovered if populations are too low, or controlled if populations are too large.
- A system of representative, high-quality habitats is established, and these areas are protected.
- No further extirpation of native species occurs in the Lake Superior Basin.
- No non-native species will be introduced into the Lake Superior Basin.
- An interagency effort to restore and protect critical habitats will be organized and initiated.
- Partnerships among natural resources management agencies, environmental agencies, and non-agency stakeholders are strengthened and broadened.

In 2003, the Binational Program workgroup ecosystem committees developed more detailed goals. These draft goals can be found below, in Table 3-3. These draft goals will be discussed at upcoming Superior Work Group meetings, and will be presented to the Lake Superior Task Force for their review and approval. These goals will be further refined by these groups, the Forum, and other interested stakeholders.

Table 3-3. Draft Ecosystem Goals for Habitat and Wildlife (Lake Superior Binational Program Work Group 2003)

#	DRAFT GOAL	DRAFT SUB-GOAL
1	Develop ecologically based integrated watershed management plans for all watersheds within the Lake Superior Basin (LSB).	
		Determine which watersheds have existing plans.
		Develop a list of watersheds that need a new or revised plan.
		Prioritize watershed list.
		Develop watershed plans for highest priority watersheds
2	Develop and establish a unified, binational GIS database that includes the most current and functioning basin-wide data and decision support models needed for ecosystem/watershed management. Develop and establish methods for providing data access and distribution - at a scale and in a format that supports Lake Superior Basin planning and watershed management.	
		Develop formal agreements (e.g., MOU/MOA's) for data sharing, participation, and support.
		Establish a mechanism to maintain shareable data once collected.
3	Develop information and educational material for local land use decision makers to implement Binational Program (BNP) goals through land use planning.	
		Have a BNP educator on staff to present material to local governments and decision makers highlighting linkages between land use and ecosystem health.
4	Provide an annual public and technical forum to provide opportunities for researchers and resource managers and public to exchange information. Build Lake Superior track into 2003 Society for Conservation Biology meeting in Duluth, MN.	

#	DRAFT GOAL	DRAFT SUB-GOAL
5	Protect important habitat sites in the Lake Superior Basin.	
		Publicly owned important habitat protected with special designations.
		Educate landowners regarding important habitat.
		Protection of public land important habitat sites.
6	Complete a biological/biophysical inventory for the entire basin.	
		Complete comprehensive, systematic Natural Heritage Inventory/biological surveys in the watershed to identify remaining high-quality natural communities and locations of rare plants and animals.
		Inventory extent of exotic, invasive, and terrestrial wildlife species.
		Inventory degraded habitats and communities on which terrestrial wildlife depend.
7	Inform and educate decision makers on how their actions move the basin toward a healthy Lake Superior vision.	
		Develop communications plan for # 7 above.
8	No new invasive exotics.	
9	Establish and implement Best Management Practices for a range of forestry, recreation, and intra-lake shipping procedures to prevent the introduction and spread of exotics.	
10	Complete inventory and control plan for priority existing exotic species at the scale of the Lake Superior Basin.	
		All agencies will institute treatment programs for priority species.
11	Institute a long-term Lake Superior Basin wide program to monitor ecosystem health utilizing standardized methodology.	
		Explore the development of an inventory, monitoring, assessment and reporting (IMAR) system for the basin and how it might be implemented.
		Develop, test, and implement standardized monitoring protocols, sampling procedures, and data handling for ecological indicators to enable BNP agencies to report on the status of the basin's ecosystem health (# of implemented indicators).
		Neotropical Migratory Birds
		Reptiles and Amphibians
		Soil Invertebrates
		Medium-Sized Carnivores
		Land Use Change
		Exotic and Invasive Species
		Rare Resources
		Culturally Important Resources
		Over Abundant Species
		Indicators of Contaminants in the Environment
12	Identify and restore ecologically-important areas which are degraded.	
13	Assess impacts to habitat at a basinwide scale from current and historic sources of degradation.	
14	Incorporate existing information about important habitat into the existing database.	
15	Restore 25 percent of degraded wetland acres in the Lake Superior Basin.	
16	Develop and distribute a GIS map of coastal wetland acres, types, and condition and areas where restoration can occur.	
17	Have in place a policy that results in zero loss of wetland acres and function.	
18	Restore or protect (e.g., via conservation easement) 25 percent of riparian conifer forest acres.	

#	DRAFT GOAL	DRAFT SUB-GOAL
19	Develop a guidance document for agencies' vegetation restoration for projects in the Lake Superior Basin.	
20	Encourage the appropriate use of native species for all projects requiring vegetation restoration.	
		Develop sources of native plants and seeds in an ecologically appropriate manner throughout the Lake Superior Basin for use in vegetation restoration.
		Establish standards of native species propagation and use as well as definitions of seed zones.
		Develop a list of critical native species that are regionally / habitat specific and ecologically appropriate.
		Educate citizens in the Lake Superior Basin about the importance and appropriate use of local native plants in restoration and landscaping projects.
21	Complete a Lake Superior IMAX film.	
22	Obtain the web site www.lakesuperior.info for our use.	
23	Eliminate biological impacts of contaminants in terrestrial wildlife.	
24	Determine which species are most impacted by contaminants.	

3.4 FISH COMMUNITY OBJECTIVES (2003)

The development of fish-community objectives for each lake is mandated by *"A Joint Strategic Plan for Management of Great Lakes Fisheries"* (Great Lakes Fishery Commission 1997). This multi-agency agreement also reflects a commitment to habitat protection and restoration through the following statement:

> *The Parties must exercise their full authority and influence in every available arena to meet the ecological, chemical, and physical needs of desired fish communities.*

Accordingly, these fish-community objectives highlight habitat issues. Table 3-4 presents fish community objectives by indicator or species (Horns et al. 2003).

Table 3-4. Fish Community Objectives (2003)

Indicator/Species	Objective
Overall Objective	Achieve no net loss of the productive capacity of habitat supporting Lake Superior fishes. Where feasible, restore habitats that have been degraded and have lost their capacity for fish production. Reduce contaminants so that all fish are safe to eat. Develop comprehensive and detailed inventories of habitats.
Prey Species	A self-sustaining assemblage of prey dominated by indigenous species at population levels capable of supporting desired populations of predators and a managed commercial fishery.
Lake Trout	Achieve and maintain genetically diverse self-sustaining populations of lake trout that are similar to those found in the lake prior to 1940, with lean lake trout being the dominant form in nearshore waters, siscowet lake trout the

Indicator/Species	Objective
	dominant form in offshore waters, and humper lake trout a common form in eastern waters and around Isle Royale.
Lake Whitefish	Maintain self-sustaining populations of lake whitefish within the range of abundance observed during 1990-99.
Walleye	Maintain, enhance, and rehabilitate self-sustaining populations of walleye and their habitat over their historical range.
Lake Sturgeon	Rehabilitate and maintain spawning populations of lake sturgeon that are self-sustaining throughout their native range
Brook Trout	Maintain widely distributed, self-sustaining populations in as many of the historical habitats as is practical.
Pacific Salmon, Rainbow Trout, and Brown Trout	Manage populations of Pacific salmon, rainbow trout, and brown trout that are predominantly self-sustaining but that may be supplemented by stocking that is compatible with restoration and management goals established for indigenous fish species.
Sea Lamprey	Suppress sea lampreys to population levels that cause only insignificant mortality on adult lake trout.
Nuisance Species	Objective 1: Prevent the introduction of any non-indigenous aquatic species that is not currently established in Lake Superior. Objective 2: Prevent or delay the spread of non-indigenous nuisance species, where feasible. Objective 3: Eliminate or reduce populations of non-indigenous nuisance species, where feasible.
Species Diversity	Protect and sustain the diverse community of indigenous fish species not specifically mentioned earlier (burbot, minnows, yellow perch, northern pike, and suckers). These species add to the richness of the fish community and should be recognized for their ecological importance and cultural, social, and economic value.

The fish-community objectives were developed in conformity with twelve guiding principles that summarize the values and practical realities that constrain or guide fisheries management on Lake Superior. Additional objectives pertain to prey species, lake trout (*Salvelinus namaycush*), lake whitefish (*Coregonus clupeaformis*), walleye (*Stizostedion vitreum vitreum*), lake sturgeon (*Acipenser fulvescens*), brook trout (*Salvelinus fontinalis*), pacific salmon (*Oncorhynchus spp*.), and trout (*Salmonidae spp*.), sea lamprey (*Petromyzon marinus*), nuisance species, and species diversity. Habitat issues impeding achievement of any objective are described. The most-pressing habitat concerns are in streams and embayments, and accordingly affect:

- Tributary-spawning species, including brook trout, walleye, and lake sturgeon
- Warm- or cool-water species, including yellow perch (*Perca flavescens*), northern pike (*Esox lucius*), and smallmouth bass (*Micropterus dolomieu*)

Although numerous non-native species have invaded Lake Superior, with the effective control of sea lamprey, the offshore fish community has returned to a condition broadly similar to that which existed prior to the modern era. The agencies envision an offshore fish community dominated by lake trout as the top predator and requiring the continued control or eradication of sea lamprey.

The Binational Program adopted the following overall objective for the aquatic community of Lake Superior:

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

Consistent with those goals, the Lake Superior fishery-management agencies adopt the following fish-community goal:

> To rehabilitate and maintain a diverse, healthy, and self-regulating fish community, dominated by indigenous species and supporting sustainable fisheries.

Along with agreement on the overall goals, complex fishery management requires agreement on specific principles to guide the development of policies and programs. A combination of fisheries science, management experience, and public participation has led to the development of a number of widely accepted management concepts that are essential for establishing a consistent, cooperative management approach for Lake Superior.

3.5 COOPERATIVE MONITORING OF LAKE SUPERIOR INITIATED IN 2005

In 2001, U.S. and Canadian government agencies identified a need to improve coordination of Great Lakes monitoring activities. Great Lakes managers from Canada and the United States discussed the issues at a series of workshops and developed a set of recommendations for improvement. Based on these recommendations, a Great Lakes Cooperative Monitoring program was established.

The Cooperative Monitoring approach is above and beyond the routine monitoring programs that agencies normally conduct. It is a binational effort that focuses on one lake each year, with the goal of filling key information gaps as identified through the lakewide management programs. It complements and builds on other monitoring and research projects being conducted on the lake in the same year.

In 2004, a rotational cycle for Cooperative Monitoring was endorsed, with Lake Superior being the focus for both 2005 and 2006. The Lake Superior LaMP Work Group identified the following key information gaps: atmospheric and open lake concentrations of LaMP pollutants; screening of tributaries to identify sources of LaMP pollutants; status of the lower food web; a better understanding of the comparability of fish tissue contaminant data among agencies; herptile distribution and abundance in the Basin; and a method for measuring and reporting on land use change. In response, during the spring, summer and fall of 2005, numerous stations in the open lake and nearshore were sampled for LaMP pollutants and the lower foodweb;

additional air and precipitation samplers were installed at Sibley and Eagle Harbor; Canadian and U.S. tributaries have been sampled for LaMP pollutants. In 2006, a multi-agency intercomparison study is being launched to assess differences in fish tissue contaminant results as well as a pilot project to establish a herptile monitoring protocol. The projects conducted over these two years involve federal, state and provincial agencies, First Nations/Tribes and academia.

Sampling efforts conducted in 2005 have been completed and we are currently awaiting preliminary results. The information collected through the Cooperative Monitoring effort will be shared amongst the principal investigators in order to address LaMP priorities.

The Great Lakes Monitoring inventory of current monitoring and research programs on the Great Lakes was established and will allow a one-window access point to facilitate better cooperation and coordination.

3.5.1 Lake Superior Cooperative Monitoring Programs

In 2005 and 2006, Lake Superior is the focus of Cooperative Monitoring, addressing key information needs identified by the Lake Superior Binational Program Working Group. Numerous scientists from both the U.S. and Canada are participating, both in terms of providing input to the design of the programs, as well as conducting sampling, laboratory analysis, and data interpretation. There are many projects being undertaken, and although each one is independent, they each contribute to the bigger picture: a better understanding of Lake Superior. Below is a brief description of the activities to be undertaken in the Lake Superior Basin.

1. <u>Chemical Concentrations in the Lake Superior Basin</u>

Various media were sampled and analyzed for LaMP pollutants, including new and emerging compounds. This will provide updated information on current concentrations, as well as atmospheric loading estimates to the lake.

Water/Air: Three open lake cruises were conducted in Lake Superior in which water concentrations were measured for LaMP pollutants with an expanded list that included emerging compounds. Air samples were also collected to determine concentrations for selected compounds and air/water exchange for selected compounds was studied.

Air**:** Samples were taken during each of the three open lake cruises. An additional air sampler was co-located at Eagle Harbor that will sample for new and emerging compounds. This sampler has been refitted to remove all Teflon parts. This work will complement the existing IADN sampler at Eagle Harbor.

Precipitation: an additional precipitation sampler has been co-located at Sibley to sample for new and emerging compounds. This sampler has been refitted to remove all Teflon parts. This work will complement the existing IADN sampler at Sibley. The duration of this program will be one year.

Sediment: During the spring open lake cruise, bottom surficial sediments were sampled at every station for organic contaminants, including some new and emerging chemicals. Superior has been sampled for bottom sediments in the past and this will provide a spatial and temporal "snapshot" of the chemicals in 2005. Also, samples were taken for methyl mercury analysis. At some nearshore stations, core samples have been collected.

Fish: Currently, DFO has fish archives from 2004, and more fish were caught in 2005. These fish will be analyzed for the LaMP chemicals, including new and emerging compounds.

Lower Food Web: Net hauls were conducted on each of the three open lake cruises for zooplankton and mysids. Also, large volumes of water were filtered to capture bacteria. The resultant catch will be analyzed for the same list of compounds as fish.

Lake Siskiwet, Isle Royale: Bottom sediment, cores, water, fish and net hauls for lower food web were sampled for most LaMP and emerging chemicals. Samples from this site will be used as a reference samples as the area is impacted only by atmospheric inputs.

2. Fish Contaminants Intercomparison Study

The Chemical Committee also identified a need to better understand the differences in fish tissue contaminant data. In response to this, a phased-in multi-agency intercomparison program is being initiated. Phase 1 will collect information from all participating agencies on their field and analytical methodologies, as well as current concentration data; this will be reviewed for differences. The next two phases will compare laboratory variability. Phase 2 requires that each participating agency analyze an injection-ready reference standard (DFO is supplying the reference standard), while Phase 3 requires that each lab analyze a composite sample. At each Phase, discussions will be held to review the results.

3. Tributary Sampling for Source Trackdown

Since the Lake Superior Binational Program includes a commitment to Zero Discharge, the Chemical Committee identified a need to confirm the absence of inputs from tributaries. Sediment in the depositional zone of every accessible tributary (US and Canadian) that drains into Lake Superior was sampled for the LaMP chemicals, as well as metals and emerging contaminants.

4. Status of the Lower Food Web

The Aquatics Committee, in cooperation with the Lake Superior Technical Committee, identified a need for information on the status of the lower food web. In response to this, workshops were held with experts from both sides of the border to identify specific questions to be addressed, and to develop a comprehensive lakewide lower food web program as part of this cooperative monitoring initiative.

Open Lake Sampling: During the three open lake cruises scheduled for 2005, sampling was conducted at approximately 11 stations to determine biomass estimates of the lower food web. Net hauls were conducted to sample zooplankton, mysids and diporeia; ponars were used to sample benthic invertebrates; and water samples were collected for microbial food web. Additional boxcores were taken for amphipods, worms, and other invertebrates for stable isotopes and lipids. Also, nutrient samples (TP, TFP, Silica and chlorophyll a) were taken during all three cruises to supplement the lower food web information.

Nearshore Sampling by USGS and US EPA: Sampling for the lower food web was conducted during the regular fish trawls by USGS. Hydroacoustic surveys conducted by US EPA in summer 2005 proved useful as a new technology for lower food web sampling.

Nearshore Sampling (Impacted vs Unimpacted): Sampling was conducted by OMNR during the spring, summer and fall of 2005 at four sites. The sites chosen (Duluth, Thunder Bay, Apostle Islands, and Nipigon Bay) represent two sites from each country, with one site being impacted and the other site unimpacted. Net hauls were supplemented by sampling for nutrients.

5. Land-use Change

Several Lake Superior Committees (Sustainability, Habitat, Terrestrial Wildlife) identified a need for a protocol to measure and report on land-use change in the Basin, including monitoring recommendations. A breakout session at the 2004 SOLEC conference brought together experts in the field to initiate this discussion, however, further discussion at the Work Group level is required to define the questions to be addressed.

6. Herptile Monitoring - Pilot Program

The Terrestrial Wildlife Committee requested that herptile indicator monitoring be initiated in the Basin. A pilot scale monitoring program funded by GLNPO has begun and will continue through 2007.

7. Value-added Science

In addition to key information needs identified by the Lake Superior LaMP, additional science initiatives are being supported that will complement existing programs insofar as they can be accommodated. For example, meteorological buoys, radiation and temperature moorings will be deployed during the open lake cruises in support of a Climate Change project that will model the impact of climate on lake-atmosphere heat exchange, and the lake thermal and hydrodynamic response.

3.6 IMPAIRED BENEFICIAL USES (DUE TO CHEMICAL POLLUTANTS)

Annex 2 of the Great Lakes Water Quality Agreement requires that each LaMP assess impairment to14 beneficial water resource uses as the first step in identifying restoration and protection actions for each of the Great Lakes. The Lake Superior LaMP also recognizes that more than just these 14 beneficial use impairments will need to be addressed before Lake Superior can be fully restored. These other issues, or stressors, are discussed in other sections of the LaMP document.

For example, the 1991 Lake Superior Binational Program sets a goal of zero discharge for designated PBT substances. The Stage I LaMP identified six beneficial uses as impaired due to critical pollutants (Table 3-5 below). Impairments were noted for open-lake and nearshore areas. Data from Areas of Concern (AOC), their Remedial Action Plans (RAPs) and other nearshore areas were used together with data for open-lake areas. When an impaired beneficial use is identified, it means that impairment is occurring somewhere in that basin, not necessarily throughout the entire basin. The removal of use impairments is proposed as an environmental goal for all critical pollutants.

However, nine of the 23 critical pollutants were targeted for zero discharge. The Stage 2 LaMP (1999) sets load reduction targets for the nine zero discharge chemicals up to 2020. The other chemicals require remediation so that they are no longer critical (i.e., restoring beneficial uses through the RAP process or meeting lake ecosystem objectives). The critical pollutant focus of the LaMP therefore shifted to the nine zero discharge chemicals. While these nine contribute to beneficial use impairments, remediation would in most cases be insufficient to meet zero discharge goals. The emphasis in the LaMP therefore is on source reductions of chemicals including emissions and discharges in manufacture or as by-products, and proper disposal of products containing any of these nine substances.

As the ecosystem of Lake Superior changes over time, periodic assessments of each beneficial use will be needed. The LaMP hopes to have all beneficial use impairments assessed in future.

Table 3-5. Beneficial Use Impairments Associated with Critical Pollutants (Lake Superior Binational Program Work Group 1995)

Beneficial Use Impairments[a]	Status[b,c]	Indicators of Impairment
1. Restrictions on fish and wildlife consumption	Impaired due to PCBs, Hg, chlordane, toxaphene, dieldrin, DDE, and dioxin and furans.	Contaminants at levels at which agency or jurisdiction issues advisories to limit consumption
4. Fish tumors or other deformities	Impaired, associated with general contamination in Thunder Bay and Jackfish Bay, possibility of impairments in St. Louis River RAP Area of Concern.	Tumor frequency elevated
5. Bird or animal deformities or reproduction problems	Impaired reproduction (terns, bald eagles), associated with PCBs, Hg, DDE, dieldrin, and toxaphene. Also, habitat factors are likely important for lowered reproduction rates.	Reproduction below inland levels
6. Degradation of benthos	Impaired in most U.S. and Canadian RAP areas and other nearshore areas due to heavy metals (Cu, Pb, Cr, Zn, As, Ni, and Hg), PCBs, PAHs, dioxins, furans. Also, habitat factors are likely important.	Population structure "degraded"
7. Impacts on dredging; materials require special handling	Restrictions in St. Louis River, St. Mary's River, Chequamegon, Thunder Bay, Nipigon Bay, and Peninsula Harbor. Elevated concentrations of PCBs, PAHs, Hg, Cd, Cu, Pb, Zn, Cr, Ni, As, Fe, Mn, or HCB.	Contaminants in sediment prompt special handling requirements for dredged materials
8. Eutrophication	Impaired in Nipigon Bay, and excessive phosphorus loading to St. Louis River.	Phosphorus or other indicators of eutrophication[d]

[a] Numbering corresponds to the order used in the Great Lakes Water Quality Agreement. A missing number indicates that the beneficial use is not impaired.
[b] The determinations are based on Remedial Action Plan (RAP) and other work summarized in the Stage 1 LaMP.
[c] This column includes the compounds causing the impairments. PCBs: polychlorinated biphenyl; PAHs: polyaromatic hydrocarbons; DDE: dichlorodiphenylethane; Hg: mercury; Cd: cadmium; Cu: copper; Pb: lead; Zn: zinc; Cr: chromium; Ni: nickel; As: arsenic; Fe: iron; Mn: manganese; and HCB: hexachlorobenzene.
[d] Phosphorus loading and eutrophication are problems in particular RAP areas. These issues are being addressed through the appropriate RAPs rather than through the LaMP.

3.7 REFERENCES

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