

US EPA ARCHIVE DOCUMENT

SOLEC 2002



# BIOLOGICAL INTEGRITY

**DRAFT FOR DISCUSSION AT SOLEC 2002  
OCTOBER 2002**

## **NOTICE TO READER:**

***Many of the indicators cited in this background paper have been revised as a result of input received at the December, 2001 Biological Integrity Workshop that focused on non-native species as a stress. During two breakout sessions at SOLEC 2002 in Cleveland and the post-SOLEC 2002 comment period, the indicators listed in this paper, along with others from the complete Great Lakes suite, will be reviewed, modified and integrated with the goal of constructing a suite of indicators that will measure biological integrity. This integrated suite will be the basis for reporting the state of Great Lakes biological integrity at SOLEC 2004.***

***All indicators that have not yet undergone an evaluation based on the SOLEC criteria (i.e., new and revised indicators) will be reviewed over the next several months by expert panels using the established SOLEC criteria.***

***Please note that indicators relating to coastal wetlands were not available at the time of printing. These are being developed by the Great Lakes Coastal Wetlands Consortium, and will be incorporated into the suite of Biological Integrity indicators at a later date.***

# DRAFT FOR DISCUSSION AT SOLEC 2002

## EVALUATING BIOLOGICAL INTEGRITY IN THE GREAT LAKES ECOSYSTEM

### Table of Contents

1.	Introduction	3
2.	Biological Integrity Workshop	5
3.	Biological Integrity Survey of Experts	5
5.	Summary and emerging Issues	6

### Appendix A: Descriptions of the indicators identified through the Biological Integrity workshop process

# 6 Fish Habitat	8
# 8 Naturalized Salmon and Trout	11
# 9 Walleye	13
# 9a <i>Hexagenia</i>	15
# 17 Preyfish Populations	17
# 93 Lake trout	19
# 93a Scud ( <i>Diporeia</i> )	21
# 104 Benthic Biomass: Production Yield, Diversity and Abundance	23
# 116 Zooplankton Populations	25
# 8132 Land Use	27
NEW Health of Terrestrial Plant Communities	29
NEW Landscape Ecosystem Health	31
NEW Status and Protection of Special Places and Species	33

### Appendix B: Questions asked of the experts identified by the Lakewide Management Committees

35

### Appendix C: James Karr's Presentation at the Biological Integrity Workshop

36

# DRAFT FOR DISCUSSION AT SOLEC 2002

## 1. Introduction

The State of the Lakes Ecosystem Conference (SOLEC) has its roots in the Great Lakes Water Quality Agreement (GLWQA) and its overall purpose: “. . . to restore and maintain the chemical, physical and biological integrity of the waters of the Great Lakes Basin ecosystem.” Because the theme for SOLEC 2002 is Biological Integrity, SOLEC organizers have engaged many collaborators in a process since SOLEC 2000, to evaluate the effectiveness of the current suite of Great Lakes indicators to assess biological integrity in the Great Lakes ecosystem. This paper summarizes some of the efforts and thinking that has occurred to date regarding which indicators are useful, which might be revised, and what new ones should be added.

“Integrity” is not specifically defined in the Great Lakes Water Quality Agreement (GLWQA), therefore the following definition is used throughout this paper.

***“Biological integrity is the capacity to support and maintain a balanced, integrated and adaptive biological system having the full range of elements (the form) and processes (the function) expected in a region’s natural habitat.”***

- by James R. Karr, modified by Douglas P. Dodge.

This paper was prepared to stimulate discussion at the State of the Lakes Ecosystem Conference 2002 (SOLEC 2002), and the information and ideas should be considered **DRAFT** for discussion purposes. After SOLEC 2002, the proposed indicator suite for Biological Integrity will remain open for additional review and comment for a period to January 31, 2003. Experts engaged in the SOLEC process will then continue the review and refinement of the indicators using established SOLEC criteria. The resultant suite of indicators is expected to form the basis of reports on Biological Integrity for SOLEC 2004. The flow diagram below displays the intended process.

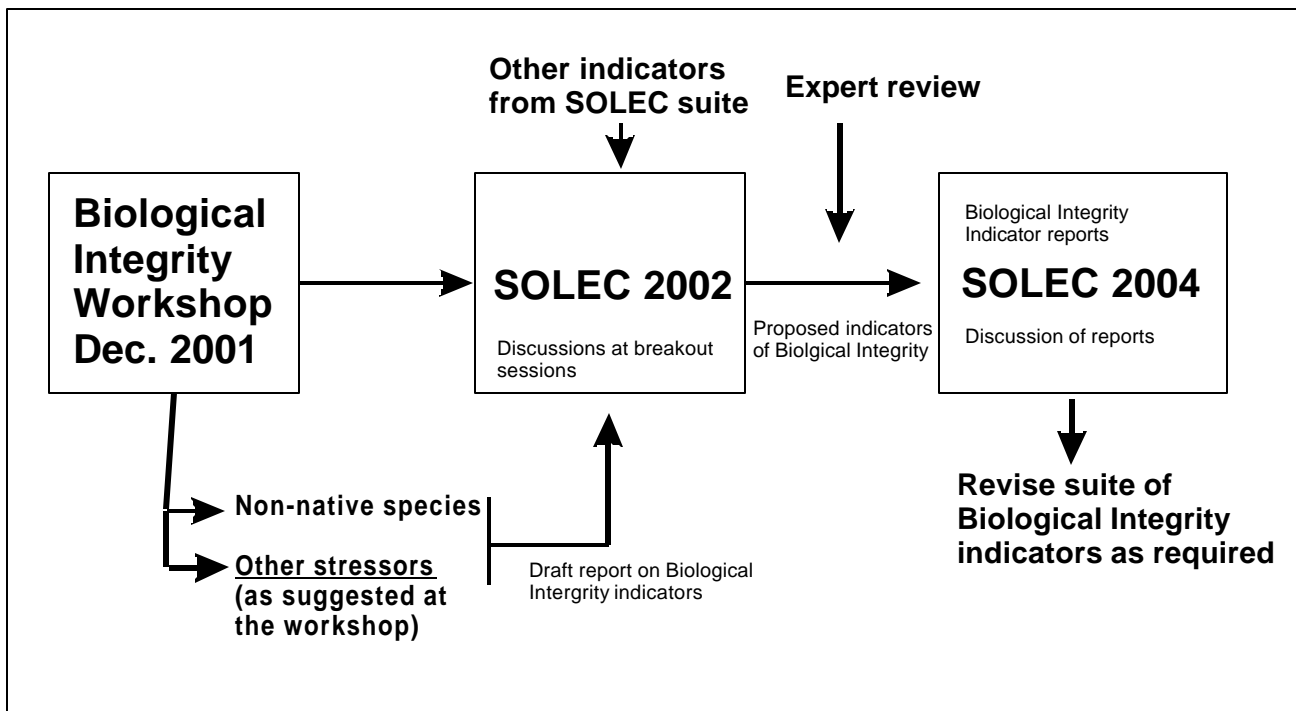


Figure 1

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There were two events conducted during 2001 – 2002 to advance the discussion about indicators of biological integrity in the Great Lakes basin ecosystem. A workshop of invited experts was conducted in December 2001 to consider indicators effective for assessing impacts of non-native species, and a project was conducted in summer 2002 during which identified experts were interviewed with a pre-established set of questions. Each event is discussed in more detail below.

The following table presents the indicators identified by experts associated with either event that appear to be relevant and useful for assessing biological integrity in the Great Lakes basin ecosystem. The number associated with most of the indicators relates to the SOLEC identification. The indicators have been grouped into topic areas for convenience of review.

Indicator Number	Name	Workshop-selected	Interview-selected
<b>Impacts from Non-Native Species</b>			
18	Sea Lamprey		X
4513	Presence, Abundance & Expansion of Invasive Plants		X
9002	Non-Native Species (Currently a SOLEC indicator under consideration)		X
<b>Changes in Communities at Different Trophic Levels</b>			
8	Salmon and Trout	X	X
9	Walleye	X	X
9a	<i>Hexagenia</i>	X	X
17	Preyfish Populations	X	X
68	Native Unionid Mussels		X
93	Lake Trout	X	X
93a	Scud ( <i>Diporeia</i> )	X	X
101	Deformities, Eroded Fins, Lesions and Tumours (DELT) in Nearshore Fish		X
104	Benthos Diversity and Abundance	X	X
109	Phytoplankton Populations		X
116	Zooplankton Populations	X	X
4507	Wetland-Dependent Bird Diversity & Abundance		X
8139	Community/Species Plans		X
New	Health of Terrestrial Plant Communities	X	
<b>Habitat Issues, Lake Levels, Wetland Losses</b>			
6	Fish Habitat	X	X
4510	Coastal Wetland Area by Type		X
4516	Sediment Flowing into Coastal Wetlands		X
4861	Water Level Fluctuations		X
7055	Habitat Adjacent to Coastal Wetlands		X
8114	Habitat Fragmentation		X
8132	Nearshore Land Use	X	
8136	Extent and Quality of Nearshore Natural Land Cover		X
8142	Sediment Available for Coastal Nourishment		X
8149	Protected Nearshore Areas		X
New	Landscape Ecosystem Health	X	
New	Status and Protection of Special Places and Species	X	
<b>Changes in Contaminants</b>			
113	Contaminants in Recreational Fish		X
114	Contaminants in Young-of-the-Year Spottail Shiners		X

## DRAFT FOR DISCUSSION AT SOLEC 2002

115	Contaminants in Colonial Nesting Water Birds		X
4083	Contaminants in Edible Fish Tissue		X
4506	Contaminants in Snapping Turtle Eggs		X
8135	Contaminants Affecting Productivity of Bald Eagles		X
8147	Contaminants Affecting the American Otter		X
<b>Changes in Nutrients</b>			
111	Phosphorus Concentrations and Loadings		X

### 2. Biological Integrity Workshop

In December 2001, a workshop was held that focussed on non-native species as one component of stress on biological integrity. Non-native species have been recognized as one of the key stresses affecting biological integrity in the Great Lakes basin ecosystem. The aim of the workshop was to test the robustness of the current suite of Great Lakes indicators to provide information about the integrity of the biological component of the Great Lakes Basin ecosystem, with reference to impacts of non-native species.

At the workshop, a series of case studies was considered, and the present set of 47 Great Lakes indicators related to the biological components of the ecosystem was reviewed, changes were suggested, and new indicators were nominated. Papers were also prepared to provide a more holistic overview of non-native species' impacts in the basin ecosystem from a First Nations / Tribal perspective. This focus offered participants an opportunity to examine the impact of non-native species on the health and resiliency of native species, and it also served to help identify other environmental factors, often acting in combinations with non-native species pressures, which impact biological integrity.

The indicators proposed in the case studies were evaluated during the workshop for their ability to be applied to other stresses (physical, chemical) in the basin and for feasibility of application based on data requirements versus availability. The consensus advice that was received during the workshop and subsequent to it was incorporated into existing indicator descriptions, or in some cases, new indicator descriptions were prepared. These proposed indicator descriptions are presented in Appendix A of this paper. Complete details of the workshop have been archived on CD and are available on request from [solec@ec.gc.ca](mailto:solec@ec.gc.ca)

### 3. Biological Integrity Survey of Experts

Subsequent to the Biological Integrity workshop, a group of some 40 Great Lakes experts, identified by Lakewide Management Plan Committees, was interviewed to get a basin-wide impression of other stressors on biological integrity (e.g., habitat loss, nutrients, toxic chemicals). These people were interviewed using the same set of issues and questions that was used for the case studies for the workshop (see Appendix B). The results of these interviews were meant to be a starting point for identification of the complete suite of biological integrity indicators. Some of the results of this survey are presented in this paper. Additional information will be presented at SOLEC 2002, and all the information will be available after SOLEC 2002 in CD ROM format.

The indicators shown in the table above were those identified by the experts surveyed. The objective of the survey was to get a quick overview of those indicators in the SOLEC suite that relate to aspects of biological integrity. This list, and that relating to non-native species, represents an initial starting point for further discussion. The opportunity to discuss the proposed indicators, and any other indicators of biological integrity in the SOLEC suite, exists at SOLEC 2002 and for a time beyond. The results from this discussion will be the basis for reporting the state of Great Lakes biological integrity at SOLEC 2004.

## DRAFT FOR DISCUSSION AT SOLEC 2002

### 4. Summary and Emerging Issues

The following summaries represent the key points raised by experts interviewed in each Lake basin or connecting channel. These statements are presented here to help stimulate discussion at SOLEC 2002.

- Non-native species pose a singularly powerful impediment to the restoration and maintenance of the biological integrity of the Great Lakes basin. In the catchment of each Great Lake, non-native species are directly and indirectly implicated in the deterioration and loss of many native species whether they be avian, terrestrial or aquatic. Non-native species are predators on, and competitors with native species; non-native species are changing trophic dynamics [pathways of energy transfer], nutrient availability, habitat, and the flow and sequestering of contaminants [subsequently, human health may come at risk]. These effects may also make native species more vulnerable to parasites and diseases.

- There appears to be no measure to anticipate which species may be the next immigrant to the basin, nor are there means to prepare for the usual resultant damage to the biological integrity of native and now naturalized species under management. In most instances, monitoring describes only changes, good or bad, in the biological integrity of the basin. Some agencies have data about non-native species captured near the front and side doors of the basin, the St Lawrence and Chicago rivers, respectively. For example, tench [*Tinca tinca*], a European fish species, has been introduced into the Richelieu River, a tributary to the St Lawrence, and Asian carp are known to be in the Chicago River. These species, and others, many unknown, are likely candidates to form the next wave of invaders.

- To change an old quote about species extinction being forever, the introduction of non-native species is also forever.

- Habitat modifications continue to affect communities of Great Lakes plants and animals. Direct losses result from changes in land use, from near shore and shore land alterations and from water levels that are dissimilar to natural fluctuations. Although smaller areas of suitable habitat may remain, these plots are often only unconnected fragments of inefficient shapes, so that both form and function of biological integrity are lost. As well, with these changes, the perturbed system becomes more vulnerable to the introduction of non-native species.

- Nutrient quality and quantity are important for primary production in any biological system. Although Great Lakes concentrations have decreased as the result of improved sewage treatment and other control measures, periodic inflows of high concentrations of nutrients associated with storm water run-off are compromising local embayments and streams and attracting non-native species. Changes caused by non-native species combine with sediment contamination and increases in pathogen concentrations to degrade the biological integrity of local benthic communities and may have ramifications for other trophic levels.

- Related to the storage, ebb and flow of nutrients in the Great Lakes ecosystem are chemical contaminants that use similar pathways. Chemical contaminants may reduce the reproductive success of some Great Lakes species, increase vulnerability to predation and, thus, contribute to population imbalances that result in decreased diversity.

- There is some concern for the apparent increase in the incidence of Type E botulism in birds, fish, and their predators and scavengers. Zebra mussels are suspect as one of the pathways for infection.

- Many Great Lakes indicators use data that relate to biological integrity. Most of these indicators were prepared to measure the state of a particular part of the health the Great Lakes ecosystem. Some also measure pressure and response. None was initially developed specifically to assess biological integrity. The proposed indicators are a first attempt at drafting a suite of indicators to describe biological



## DRAFT FOR DISCUSSION AT SOLEC 2002

integrity as it is affected by non-native species. The indicators proposed through the interview process support many of the indicators from the workshop and some additional indicators relating to other stresses are proposed for consideration.

- The challenge for SOLEC 2002 and beyond is identifying those indicators that integrate information collected at all trophic levels in the basin. It may be that combinations of indicators will lead to developing indices like those proposed by Karr in 1991.

### References Cited:

Karr, J.R. 1991. Biological integrity: A long-neglected aspect of water resource management. *Ecological Applications*, 1:66-84

## DRAFT FOR DISCUSSION AT SOLEC 2002

### Appendix A: Descriptions of the indicators identified through the Biological Integrity Workshop Process

**NOTE: The following indicator descriptions are revised versions of the existing indicators, based on comments received at the Biological Integrity workshop. Three indicators are NEW. None of the indicators here has undergone a review through the SOLEC criteria.**

#### Fish Habitat #6

**NOTE: This indicator has not received expert review, and has not undergone the SOLEC screening for necessary, sufficient and feasible. It is merely a place holder. It is expected that discussions at SOLEC 2002 and beyond will result in significant revision to this indicator.**

#### **Measure**

1) Quality, quantity (area), and distribution of aquatic habitat (e.g., shore, spawning shoals, tributaries, wetlands, etc.); 2) percent disturbed habitat and 3) population of sentinel fish species. For example, the measures for tributary quality could include the number of dams, number of miles of river channel that is impounded, number of miles of (formerly) high-gradient stream channel that is impounded, and the number of miles between the river mouth and the first dam. The number and location of fish passage facilities (up- and downstream) that could be used successfully by species or communities of concern (for example, lake sturgeon, or other anadromous fishes listed in FCGO) could also serve as measures.

#### **Purpose**

This indicator will assess the quality, quantity and location of aquatic habitat in the Great Lakes ecosystem, including the percent of habitat that has been disturbed or destroyed, and will be used to infer progress in rehabilitating degraded habitat and associated aquatic communities.

#### **Ecosystem Objective**

This indicator addresses the general Fish Community Goals and Objectives (FCGO) to protect and enhance fish habitat, achieve no net loss of the productive capacity of habitat supporting fish communities, and restore damaged habitats. Annex 2 of the GLWQA calls for the restoration of lost or damaged habitat. The indicator also supports the policy position of the Great Lakes Fishery Commission (GLFC), Habitat Advisory Board, presented in their 1998 Draft Binational Policy and Action Plan for the Protection and Enhancement of Aquatic Habitat in the Great Lakes.

#### **Endpoint**

The endpoints will need to be specific to habitat types and FCGO. In the Great Lakes and connecting channels, for example, the U.S. Environmental Protection Agency and Ontario Ministry of Environment numerical guidelines for dumping of contaminated dredged sediments can be used to protect aquatic habitat quality.

#### **Features**

This indicator will measure/calculate changes in aquatic habitat by area, by type, by location, by Lake. Significant losses and degradation of aquatic habitat have occurred in the Great Lakes aquatic ecosystem since the late 1800s when European settlement of the region was completed. Logging, navigation projects, dam construction, shoreline development, agriculture, urbanization, municipal and industrial waste disposal, and water withdrawal by power generation facilities for once-through cooling have all acted to reduce the amount and quality of aquatic habitat in the system. These affected habitats

## DRAFT FOR DISCUSSION AT SOLEC 2002

include the Great Lakes proper, their connecting channels and coastal wetlands, and the tributaries that provide linkages with inland aquatic habitats and terrestrial habitats via the surface water continuum.

Wetland losses in the region have been reasonably well documented and quantified, but losses of the other major habitat types have not. Recent efforts to relicense hydropower dams in the United States have led to a reconsideration of the habitat losses associated with these dams and a useful picture is emerging which allows an assessment of the adverse impacts of habitat fragmentation on anadromous and resident stream-fish communities. Data for tributary habitat are being developed in connection with FERC dam relicensing procedures in the United States. Data are presently available for Michigan, New York State, and Wisconsin.

Large volumes of water are withdrawn from the Great Lakes and their connecting channels for use by industry and municipalities. Steam-electric power plants using once-through cooling, and pumped-storage hydropower plants withdraw the greatest volumes of water. Fish of all sizes are entrained with this water and substantial mortality occurs basin-wide among the entrained population. Rates of water withdrawal and associated fish mortality rates are known for existing steam-electric power plants using once-through cooling and for pumped-storage hydropower plants. Reduction in water withdrawal rates or the addition of effective screening devices at existing facilities would reflect an improvement in fish habitat, and hence a reduction in fish entrainment mortality.

### ***Illustration***

Certain anadromous fish species e.g Atlantic salmon and walleye depend on unimpeded access to spawning habitats in streams. In many cases dams and other obstructions [e.g roads and culverts] prevent mature fish from reaching spawning habitat and thus compromise stock and species diversity, losses in annual recruitment and reduced production and harvests. In either case not even fish passing facilities will mitigate these effects because walleye cannot jump and even large female salmon are unable to use fishways. As well, many other stream-dwelling species of fish [e.g suckers and minnows] suffer discontinuity in their ranges because of barriers

### ***Limitations***

Restoration ecology is an emerging scientific discipline requiring an understanding of multiple disciplines and partnerships. Comprehensive, detailed habitat inventory, classification, and mapping of Great Lakes aquatic habitats has not been undertaken. Much more research will be required to recognize critical fish habitat and to understand the relationship between quantity of habitat and aquatic production. Interpretation of habitat measurements is confounded by issues such as interacting species and connectivity of habitat between life stages.

### ***Interpretation***

Dam removal, switching from peak-power generating flow mode to run-of-the-river flow mode, and provision of fully functional upstream and downstream fish passage facilities consistent with state management strategies or FCGO would be considered to be rehabilitation of habitat and beneficial to the riverine and anadromous fish communities using dammed tributaries.

### ***Comments***

Further development and ratification of the Great Lakes Fishery Commission, Habitat Advisory Board (***what's the update on this?***), 1998 Draft Binational Policy and Action Plan for the Protection and Enhancement of Aquatic Habitat in the Great Lakes should contribute significantly to furthering the goals of aquatic habitat protection and restoration in the Great Lakes basin. Indicators 4510 & 4511 contribute to this indicator, as does indicator 72. Sentinel species should be the same for each of these indicators.

## DRAFT FOR DISCUSSION AT SOLEC 2002

### *Unfinished Business*

- ▶ Need to develop a list of sentinel fish species.
- ▶ Quantifiable endpoints and/or reference values need further development work.
- ▶ The method of graphically displaying this indicator needs to be determined. Will bar graphs or maps be used to depict trends over time? What will appear on the graphs or maps?
- ▶ There needs to be more information added to help better understand the trends presented by this indicator.

### *Relevancies*

Indicator Type: state

Environmental Compartment(s): water, fish

Related Issue(s): habitat

SOLEC Grouping(s): **open waters, nearshore waters**, coastal wetlands

GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring

IJC Desired Outcome(s): 6: Biological community integrity and diversity, 9: Physical environmental integrity

GLFC Objective(s): Ontario, Erie, Huron, Michigan, Superior

Beneficial Use Impairment(s): 14: Loss of fish and wildlife habitat

### *Last Revised*

*July, 2002*

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## DRAFT FOR DISCUSSION AT SOLEC 2002

### # 8 Naturalized Salmon and Trout

#### **Measure**

1) Productivity, yield, or harvest of Pacific salmon, rainbow trout and brown trout individual stocks (need to explain this for non-fish people) using abundance (e.g., catch of each species in a given unit of sampling effort), or biomass metrics; and 2) populations of these stocked and naturally produced fish.

#### **Purpose**

This indicator will show trends in populations of introduced trout and salmon populations, as well as species diversity, and it will be used to evaluate the potential impacts on native trout and salmon populations and the preyfish populations that support them.

#### **Ecosystem Objective**

"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, cultural heritage, employment and income, and a healthy aquatic ecosystem. In addition, this indicator supports Annex 2 of the GLWQA.

#### **Endpoint**

The current Fish Community Goals and Objectives (FCGO) for introduced trout and salmon species establish harvest or yield targets consistent with FCGO for lake trout restoration, and in Lake Ontario, for Atlantic salmon restoration. The following index targets for introduced trout and salmon species were provided in the FCGO for the listed lake.

Lake Ontario (1999): *Salmon and trout catch rates in recreational fisheries continuing at early-1990s levels.*

Lake Erie (1999 draft – **is this still draft?**): *Manage the eastern basin to provide sustainable harvests of valued fish species, including . . . lake trout, rainbow trout and other salmonids.*

Lake Huron (1995): *A diverse salmonine community that can sustain an annual harvest of 2.4 million kg (5.3 million lb) with lake trout the dominant species and anadromous (stream-spawning) species also having a prominent place.*

Lake Michigan (**year?**): *A diverse salmonine community capable of sustaining an annual harvest of 2.7 to 6.8 million kg (6 to 15 million lb), of which 20-25% is lake trout.*

Lake Superior (1990): *Achieve . . . an unspecified yield of other salmonid predators, while maintaining a predator/prey balance which allows normal growth of lake trout.*

Salmonine abundance should be great enough to keep alewife abundance below levels associated with the suppression of native fishes, but should also be below levels where predatory demand threatens the forage base and the integrity of the system.

#### **Features**

This indicator will assess trends of Pacific salmon and rainbow and brown trout populations over time. These species were introduced into the Great Lakes ecosystem, are reproducing successfully in portions of the system, and can be considered to be permanent, "naturalized" components of the system. Stocking of these species continues to augment natural reproduction and enhance fishing opportunities, which is generally viewed favourably by the angling public. However, diversification of the salmonine

**DRAFT FOR DISCUSSION AT SOLEC 2002**

component of the fish community is a significant departure from the historic dominance by lake trout; the impacts of diversification on native species and ecosystem function is not yet fully understood.

***Illustration***

Rainbow trout stocks in the Lake Ontario Basin have declined in the last decade, with fewer fish in harvests and in spawning runs. Some stocks are from natural reproduction and others from regular fish plantings. Declines may be related to habitat changes, lower stream and lake productivity, losses/reductions of specific gene pools, over harvest, climate warming, drought, and/or groundwater withdrawals.

***Limitations***

The data for this indicator are collected annually by the states for certain segments of the fishery (e.g., Michigan's segment of the Lake Michigan charter boat fishery) and are available for reporting, but there is no coordinated, basin-wide data collection program. Reporting occurs as news releases and as reports to the Lake Committees of the Great Lakes Fishery Commission. More analysis of existing data and evaluation of management alternatives through mathematical modelling is needed before more detailed species-by-species harvest can be defined.

***Interpretation***

To be developed

***Comments***

Pacific salmon and rainbow and brown trout are introduced species. Some of these are now naturalized but stocking still occurs. Atlantic salmon, which were native to Lake Ontario, have been introduced at times to the other four Great Lakes. Atlantic salmon introductions to the upper four Great Lakes should be treated as potentially beneficial range extensions of the species within the basin. This valuable species is in decline in most of its historical Western Atlantic range, and the establishment of naturalized populations in the Great Lakes would help ensure the survival of the Western Atlantic gene pool. The salmonine community will consist of both wild and planted salmonines and exhibit increasing growth of, and reliance on, natural reproduction. Short-term restrictions of harvest may be required to achieve long-term goals of natural reproduction.

The measure of abundance of individual stocks will give a clue as to diversity within a species.

***Unfinished Business***

***Relevancies***

To be developed

***Sources***

GLFC SGLFMP; FCGO

<sup>1</sup> Great Lakes Fishery Commission. 1997. A Joint Strategic Plan for Management of Great Lakes Fisheries, Ann Arbor, Mi.

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## DRAFT FOR DISCUSSION AT SOLEC 2002

### # 9 Walleye

#### **Measure**

Relative abundance, biomass, or annual production of walleye populations in historical, warm-cool water, mesotrophic habitats of the Great Lakes.

#### **Purpose**

This indicator will show the status and trends in walleye populations in various Great Lakes' habitats, and it will be used in conjunction with the Hexagenia indicator, to infer the basic structure of warm-cool water predator and prey communities, the health of percid populations, and the health of the Great Lakes ecosystem.

#### **Ecosystem Objective**

Historical mesotrophic habitats should be maintained as balanced, stable, and productive elements of the Great Lakes ecosystem with walleye as the top aquatic predator of the warm-cool water community [and Hexagenia as a key benthic invertebrate organism in the food chain]. (Paraphrased from *Final Report of the Ecosystem Objectives Subcommittee*, 1990, to the IJC Great Lakes Science Advisory Board.) In addition, this indicator supports Annex 2 of the GLWQA.

#### **Endpoint**

Appropriate quantitative measures of relative abundance, yield, or biomass should be established as reference values for self-sustaining populations of walleye in mesotrophic habitats in each lake. The indicator for walleye can be based on the following index target abundances provided in the Fish Community Goals and Objectives:

Lake Huron (1995): *Reestablish and/or maintain walleye . . . with populations capable of sustaining a harvest of 0.7 million kg*

Lake Michigan (1995): *Expected annual yield: 0.1-0.2 million kg*

Lake Erie (1999): *Manage the western, central and eastern basin ecosystems to provide sustainable harvests of valued fish species, including walleye*

No reference values available for Lakes Superior and Ontario.

The walleye is a highly valued species that is usually heavily exploited by recreational and (where permitted) commercial fisheries, and harvest or yield reference values established for self-sustaining populations probably represent an attempt to fully utilize annual production; as a result, harvest or yield reference values for these populations can be taken as surrogates for production reference values.

#### **Features**

The historical dominance of walleye in mesotrophic habitats in the Great Lakes provides a good basis for a basin wide evaluation of ecosystem health. Maintaining or reestablishing historical levels of relative abundance, biomass, or production of self-sustaining populations of walleye throughout their native range in the basin will help ensure dominance of this species in the ecosystem and the maintenance of a desirable and balanced aquatic community in warm-cool water mesotrophic habitats. Historical data can be used to develop status and trend information on walleye populations. Commercial catch records for walleye in the Great Lakes extend back to the late 1800s; recreational catch data and assessment fishing data supplement these commercial catch records in some areas in recent years and are especially useful in areas where the commercial fishery for the species has been closed.

## DRAFT FOR DISCUSSION AT SOLEC 2002

### *Illustration*

To be developed

### *Limitations*

- Walleye abundance can be reduced by overfishing; harvest restrictions designed to promote sustained use are required if the species is to be used as an indicator of ecosystem health.
- The walleye indicator cannot reliably diagnose causes of degraded ecosystem health.
- Target reference values for the indicator have not been developed for Lakes Ontario and Superior.

### *Interpretation*

The desired trend is increasing dominance to historical levels of the indicator species in mesotrophic habitats throughout the basin. If the target values are met, the system can be assumed to be healthy; if the values are not met there is health impairment.

### *Comments*

To be developed

### *Unfinished Business*

The method of graphically displaying this indicator needs to be determined. For example, will bar graphs or maps be used to depict trends in walleye populations over time?

### *Relevancies*

Indicator Type: state

Environmental Compartment(s): biota, fish

Related Issue(s): contaminants & pathogens, nutrients, exotics, habitat

SOLEC Grouping(s): **open waters, nearshore waters**

GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring

IJC Desired Outcome(s): 6: Biological community integrity and diversity

GLFC Objective(s): Ontario, Erie, Huron

Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations, 6: Degradation of benthos

### *Last Revised*

*July, 2002*

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## DRAFT FOR DISCUSSION AT SOLEC 2002

### # 9a *Hexagenia*

#### **Measure**

Abundance, biomass, or annual production of burrowing mayfly (*Hexagenia* sp.) populations in historical, warm-cool water, mesotrophic habitats of the Great Lakes. Presence or absence of a *Hexagenia* mating flight (emergence) in late June early July in areas of historical abundance.

#### **Purpose**

This indicator will show the status and trends in *Hexagenia* populations, and will be used to infer the health of the *Hexagenia* populations and the Great Lakes ecosystem.

#### **Ecosystem Objective**

Historical mesotrophic habitats should be maintained as balanced, stable, and productive elements of the Great Lakes ecosystem with *Hexagenia* as the key benthic invertebrate organism in the food chain. (Paraphrased from **Final Report of the Ecosystem Objectives Subcommittee**, 1990, to the IJC Great Lakes Science Advisory Board.) In addition, this indicator supports Annex 2 of the GLWQA.

#### **Endpoint**

Appropriate quantitative measures of abundance, biomass, or production should be established as reference values for self-sustaining populations of *Hexagenia* in mesotrophic habitats in each lake.

#### **Features**

The historical dominance of *Hexagenia* in mesotrophic habitats in the Great Lakes provides a good basis for a basin-wide evaluation of ecosystem health. Maintaining or reestablishing historical levels of abundance, biomass, or production of *Hexagenia* throughout their native range in the basin will help ensure their dominance in the ecosystem and the maintenance of a desirable and balanced aquatic community in warm-cool water mesotrophic habitats. *Hexagenia* are a major integrator between detrital and higher levels in food web. *Hexagenia* are highly visible during emergence in June- July and the public can easily use the species as an indicator to judge ecosystem health in areas where it is now abundant or was historically abundant but now is absent. Historical data can be used to develop status and trend information on *Hexagenia* populations. Sediment cores from Lake Erie show major trends in abundance of *Hexagenia* extending back to about 1740 and other data are available to document more recent and present levels of abundance in Lake Erie and other parts of the basin.

#### **Illustration**

To be developed

#### **Limitations**

*Hexagenia* are extirpated at moderate levels of pollution, and more research is needed to develop data needed to show a graded response to pollution. Target reference values for the indicator are being developed for all major Great Lakes mesotrophic habitats.

#### **Interpretation**

The desired trend is increasing dominance to historical levels of the indicator species in mesotrophic habitats throughout the basin. If the target values are met, the system can be assumed to be healthy; if the values are not met there is health impairment. The presence of an annual *Hexagenia* mating flight (emergence) in late June-early July can also be used by the public and other non-technical observers as a specific indicator of good habitat quality, whereas the lack of a mating flight in areas where the species was historically abundant can be used as an indicator of degraded habitat. High *Hexagenia* abundance is strongly indicative of uncontaminated surficial sediments with adequate levels of dissolved oxygen in

**DRAFT FOR DISCUSSION AT SOLEC 2002**

the overlying water columns. Probable causative agents of impairment for *Hexagenia* include excess nutrients and pollution of surficial sediments with metals and oil.

**Comments**

*Hexagenia* were abundant in major mesotrophic Great Lakes habitats including Green Bay (Lake Michigan), Saginaw Bay (Lake Huron), Lake St. Clair, western and central basins of Lake Erie, Bay of Quinte (Lake Ontario), and portions of the Great Lakes connecting channels. Eutrophication and pollution with persistent toxic contaminants virtually extinguished *Hexagenia* populations throughout much of this habitat by the 1950s. Controls on phosphorus loadings resulted in a major recovery of *Hexagenia* in western Lake Erie in the 1990s. Reduction in pollutant loadings to Saginaw Bay has resulted in limited recovery of *Hexagenia* in portions of the Bay. *Hexagenia* production in upper Great Lakes connecting channels shows a graded response to heavy metals and oil pollution of surficial sediments.

*Hexagenia* should be used as a benthic indicator in all mesotrophic habitats with percid communities and percid FCGOs. Contaminant levels in sediment that meet USEPA and OMOE guidelines for "clean dredged sediment" and IJC criterion for sediment not polluted by oil and hydrocarbons will not impair *Hexagenia* populations. There will be a graded response to concentrations of metals and oil in sediment exceeding these guidelines for clean sediment. Reductions in phosphorus levels in formerly eutrophic habitats are usually accompanied by recolonisation by *Hexagenia*, if surficial sediments are otherwise uncontaminated.

**Unfinished Business**

Has a quantitative endpoint for *Hexagenia* populations been developed? If not, then further development work is necessary for this indicator.

The method of graphically displaying this indicator needs to be determined. For example, will bar graphs or maps be used to depict trends in walleye and *Hexagenia* populations over time?

**Relevancies**

- Indicator Type: state
- Environmental Compartment(s): biota, fish
- Related Issue(s): contaminants & pathogens, nutrients, exotics, habitat
- SOLEC Grouping(s): **open waters, nearshore waters**
- GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring
- IJC Desired Outcome(s): 6: Biological community integrity and diversity
- GLFC Objective(s): Ontario, Erie, Huron
- Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations, 6: Degradation of benthos

**Last Revised**

March 2002

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## DRAFT FOR DISCUSSION AT SOLEC 2002

### # 17 Preyfish Populations

#### **Measure**

Abundance and diversity, as well as age and size distribution, of preyfish species stocks (i.e., deepwater ciscoes, sculpins, lake herring, rainbow smelt, and alewives) in each lake.

#### **Purpose**

This indicator will assess the abundance and diversity of preyfish populations, and it will be used to infer the stability of predator species necessary to maintain the biological integrity of each lake.

#### **Ecosystem Objective**

To maintain a diverse array of preyfish populations to support healthy, productive populations of predator fishes as stated in the Fish Community Goals and Objectives (FCGOs) for each lake. For Lake Michigan, the Planktivore Objective (GLFC, 1995) states: *Maintain a diversity of prey (planktivore) species at population levels matched to primary production and to predator demands.* This indicator also relates to the 1997 Strategic Great Lakes Fisheries Management Plan Common Goal Statement for Great Lakes Fisheries Agencies and to Annex 2 of the GLWQA.

#### **Endpoint**

This indicator will refer to index target abundances for preyfish — the values used to regulate the amount of predator fish stocked in each lake — provided in the FCGO for each lake as quantitative reference values that represent the necessary diversity and structure of the preyfish community. Lakes Huron, Michigan and Superior provide general guidelines for prey species prioritizing species diversity and a return to historical population levels. Lake Michigan FCGO proposed a lakewide preyfish biomass of 0.5 to 0.8 billion kg (1.2 to 1.7 million lbs.). Lake Ontario FCGO proposed an average annual biomass of 110 kilogram/hectare for the production of top predators.

#### **Features**

An inadequate preyfish base might signal the need for reduction in predator species abundance by increasing harvest or reducing number of predator fish stocked. If preyfish populations also support a major recreational or commercial fishery, or are reduced significantly by entrainment mortality at water withdrawal sites in the Great Lakes, curtailment of these losses would be appropriate. Maintaining species diversity in the preyfish base may also require more detailed consideration and management of the predator species mix in the lake. Preyfish populations in each of the lakes is currently monitored on an annual basis. Changes in species composition, as well as changes in size and age composition of the major preyfish species, are available for review from long-term databases. Changes in prey fish biomasses and age distributions could also be early warnings of changes in quality and quantity of essential habitat.

#### **Illustration**

Lake-wide annual trends are displayed for each lake in bar chart format. A GIS-based reporting system is under development that will show annual trends at multiple sampling locations within each lake.

#### **Limitations**

Index target abundances, the quantitative reference values for this indicator, have not been established for all preyfish species in each lake.

**Question: Is it possible to have an endpoint for stock diversity?**

#### **Interpretation**

To be developed

## DRAFT FOR DISCUSSION AT SOLEC 2002

### *Comments*

Diversity in preyfish species imparts some overall stability to the forage base by minimizing the effects of year-to-year variations typically experienced by a single species; therefore, managing the preyfish resource for the exclusive benefit of a single preyfish species, such as alewife, is not recommended. A substantial component of native preyfish species should be maintained, especially if new research implicates thiaminase in introduced preyfish species, such as alewives and rainbow smelt, as a major factor contributing to reproductive failure in lake trout and Atlantic salmon in the Great Lakes. There is interest expressed in some FCGOs in protecting or reestablishing rare or extirpated deepwater cisco preyfish species in their historic habitats in the Great Lakes. This should be reflected in future reference values for affected lakes.

### *Unfinished Business*

- ▶ A discussion on how this indicator will be interpreted using the endpoint(s) is needed. For example, this indicator may need to be analyzed in conjunction with an indicator on primary production and/or predator species abundance and diversity.
  - Develop an endpoint for stock diversity (if possible).

### *Relevancies*

Indicator Type: state

Environmental Compartment(s): fish

Related Issue(s): contaminants & pathogens, nutrients, non-native species, habitat

SOLEC Grouping(s): **open waters, nearshore waters**

GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring IJC Desired Outcome(s): 6: Biological community integrity and diversity GLFC Objective(s):

Ontario, Erie, Huron, Michigan, Superior Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations.

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## DRAFT FOR DISCUSSION AT SOLEC 2002

### # 93 Lake Trout

#### **Measure**

Absolute abundance, relative abundance, yield, or biomass, and self-sustainability through natural reproduction of lake trout in coldwater habitats of the Great Lakes.

#### **Purpose**

To show the status and trends in lake trout populations, a major coldwater predator and subject of an international effort to rehabilitate populations to near historic levels of abundance.

#### **Ecosystem Objective**

The coldwater regions of the Great Lakes should be maintained as a balanced, stable, and productive ecosystem with self-sustaining lake trout populations as a major top predator.

#### **Endpoint**

Self-sustaining, naturally reproducing populations that support target yields to fisheries is the goal of the lake trout rehabilitation as established by the Fish Community Objectives drafted by the Great Lakes Fishery Commission. Target yields approximate historical levels of lake trout harvest or adjusted to accommodate stocked exotic predators such as Pacific salmon. These targets are 4 million pounds from Lake Superior, 2.5 million pounds from Lake Michigan, 2.0 million pounds from Lake Huron and 0.1 million pounds from Lake Erie. Lake Ontario has no specific yield objective but has a population objective of 0.5-1.0 million adult fish that produce 100,000 yearling recruits annually through natural reproduction. The lake trout is a highly valued species that is exploited by recreational and (where permitted) commercial fisheries, and harvest or yield reference values established for self-sustaining populations probably represent an attempt to fully utilize annual production; as a result, harvest or yield reference values for these populations can be taken as surrogates for production reference values.

#### **Features**

Self-sustainability of lake trout is measured in lakewide assessment programs carried out annually in each lake. The historical dominance of lake trout in oligotrophic waters in all of the Great Lakes provides a good basis for a basin-wide evaluation of ecosystem health. Maintaining or reestablishing historical levels of abundance, biomass, or production and reestablishing self-sustaining populations of lake trout throughout their native range in the basin will help ensure dominance in the ecosystem and the maintenance of a desirable aquatic community in oligotrophic, coldwater habitats. The desired trend is increasing dominance of the indicator species to historical levels in coldwater, oligotrophic habitats throughout the basin.

#### **Illustration**

For each lake, a graph with lake trout metrics including natural reproduction on the x-axis and year on the y-axis will be presented.

#### **Limitations**

The indicator is of greatest value in assessing ecosystem health in the oligotrophic, open-water portions of Lake Superior; it may be less useful in nearshore areas of the lake. Because the indicator includes only a single species, it may not reliably diagnose ecosystem health. Also, because lake trout abundance can be easily reduced by overfishing and sea lamprey predation, harvest restrictions designed to promote sustained use and enhanced sea lamprey control are required if the species is to be used as an indicator of ecosystem health. Annual interagency stock assessments measure changes in relative abundance, size and age structure, survival, and extent of natural reproduction but do not provide direct feedback to yield goals.

## DRAFT FOR DISCUSSION AT SOLEC 2002

### ***Interpretation***

Interpretation is direct and simple. If natural reproduction is observed and contributing significantly to the target values, the system can be assumed to be healthy; if the values are not met then causative agents of impairment are implicated and need to be addressed.

### ***Unfinished Business***

#### ***Relevancies***

Indicator Type: state

Environmental Compartment(s): biota, fish

Related Issue(s): toxics, nutrients, exotics, habitat

SOLEC Grouping(s): open waters

GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring

IJC Desired Outcome(s): 6: Biological community integrity and diversity

GLFC Objective(s): Ontario, Erie, Huron, Michigan, Superior, Erie

Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations

#### ***Last Revised***

August 2002

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## DRAFT FOR DISCUSSION AT SOLEC 2002

### 93a Scud (*Diporeia* spp.)

#### **Measure**

Abundance or biomass, and self-sustainability of *Diporeia* in cold, deepwater habitats of the Great Lakes.

#### **Purpose**

To show the status and trends in *Diporeia* populations, and to infer the basic structure of coldwater benthic communities and the general health of the ecosystem.

#### **Ecosystem Objective**

The cold, deepwater regions of the Great Lakes should be maintained as a balanced, stable, and productive oligotrophic ecosystem with *Diporeia* as one of the key organisms in the food chain. Relates to Annex 1 of the GLWQA.

#### **Endpoint**

In Lake Superior, *Diporeia* should be maintained throughout the lake at abundances of  $>200/m^2$  at depths  $<100m$  and  $>30/m^2$  at depths  $>100m$ . In the open waters of the other lakes, *Diporeia* should be maintained at abundances of  $>1,000/m^2$  at depths 30-100m and  $>200/m^2$  at depths  $>100m$ . These are conservative density estimates for these depths. Density estimates at depths  $<30m$  in all the lakes can be highly variable and subject to local conditions. Thus, densities at these shallower depths may not be a good indicator of lake-wide trends.

#### **Features**

*Diporeia* abundances are measured in assessment programs carried out annually in each lake. Other, more regional assessments occur less frequently. The historical dominance of *Diporeia* in cold, deepwater habitats in all of the Great Lakes provides a good basis for a basin-wide evaluation of ecosystem health..

#### **Illustration**

For each lake, a figure with *Diporeia* metrics on the y-axis and year on the x-axis will be presented. For less frequent but more spatially-intense regional assessments, a figure giving metric contours or isopleths will be presented.

#### **Limitations**

The indicator is of greatest value in assessing ecosystem health in the cold, open-water portions of the Great Lakes. It may also be useful when assessing long term trends within a specific lake region in the nearshore ( $<30m$ ), but its value is questionable if widely applied to nearshore areas over all the lakes.. Because this indicator consists of only one taxa, it may not reliably diagnose causes of degraded ecosystem health. A number of lakewide surveys and assessments of benthic invertebrate communities have been made over the past several decades in the Great Lakes and the current status of *Diporeia* populations is generally known, and an understanding of *the* changes related to the Dreissenid mussel invasion is emerging.

#### **Interpretation**

Target values are provided to evaluate abundances on a historic basis. Trends over time provide a means to assess indicator direction. On a more direct basis, if target values are met, the system can be assumed to be healthy; if the values are not met there is health impairment. Causative agents of impairment are not addressed by the indicator.

## DRAFT FOR DISCUSSION AT SOLEC 2002

### **Comments**

*Diporeia* is the dominant benthic macroinvertebrate in the cold, deepwater habitats of all the Great Lakes, comprising over 70% of benthic biomass in these regions. It feeds on material settled from the water column and, in turn, is fed upon by many species of fish. As such, it plays a key role in the food web of deepwater habitats. Among the fish species that are energetically linked to *Diporeia* is the lake trout. Young lake trout feed on *Diporeia* directly, while adult lake trout feed on sculpin, and sculpin feed heavily on *Diporeia*. Lake trout are a top predator in the deepwater habitat and abundances are another SOLEC Indicator. Therefore assessments of both *Diporeia* and lake trout provide an evaluation of lower and upper trophic levels in the cold, deepwater habitat.

### **Unfinished Business**

#### **Relevancies**

Indicator Type: state

Environmental Compartment(s): biota, fish

Related Issue(s): toxics, nutrients, exotics, habitat

SOLEC Grouping(s): open waters

GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring

IJC Desired Outcome(s): 6: Biological community integrity and diversity

GLFC Objective(s): Ontario, Erie, Huron, Michigan, Superior

Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations, 6: Degradation of benthos

#### **Last Revised**

July 2002

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## DRAFT FOR DISCUSSION AT SOLEC 2002

### # 104 Benthic Biomass: Production, Yield, Diversity and Abundance

#### **Measure**

Species diversity, abundance, production and yield over time and space in the aquatic benthic community.

#### **Purpose**

This indicator will assess trends in time and spatial distribution of species diversity, abundance, production and yield in the aquatic benthic community, and it will be used to infer the relative health of the benthic community, including the relative abundance of non-native species.

#### **Ecosystem Objective**

This indicator addresses the general Fish Community Goals and Objectives to protect and enhance fish habitat, achieve no net loss of the productive capacity of habitat supporting fish communities, and restore damaged habitats. This indicator supports Annex 2 of the GLWQA.

#### **Endpoint**

Appropriate quantitative measures of species abundance, production, yield and diversity should be established as reference values for a healthy, diverse benthic community.

#### **Features**

The aquatic benthic community has been used as one index to assess the relative health of the aquatic community in general. Benthic organisms are widespread and their abundances and species composition vary directly with the degree of nutrient enrichment and food supply. In addition, benthic species differ in their tolerances to polluted conditions. The desired trend is toward a diverse benthic community with inclusion of pollution-sensitive species.

#### **Illustration**

For each lake or sub basin, a graph showing the species composition and abundance of the representative benthic species community on the y-axis and years on the x-axis will be presented to illustrate the changes in species metrics over time. A map will be used to show the major, within lake, spatial-temporal differences.

#### **Limitations**

- Identifying benthic taxonomy is a highly specialized and time consuming activity that requires training and experience.
- Historical data are not housed in a data base.
- An endpoint for this indicator has not been established.

#### **Interpretation**

Abundant, pollution-tolerant benthic species indicate degraded habitats. Increasing species diversity and decreasing abundance of pollution-tolerant species indicate return to healthy habitats. Abundance and production of non-native species indicates a potentially unbalanced and degraded ecosystem.

#### **Comments**

This indicator measures the composition and production of the native and non-native benthic community over time and space. The relative abundance of non-native benthos such as zebra mussels, is indicative of a disrupted benthic community. Water depth has a strong effect on benthic community composition and should be standardized in any sampling design. Sampling design should also consider areas near sources of pollution as well as clean, offshore areas.

## DRAFT FOR DISCUSSION AT SOLEC 2002

### *Unfinished Business*

- ▶ May want to consider identifying specific species of interest to measure.
- ▶ Need to quantify “abundant”, “production”, “yield” and “diverse”.
- ▶ What will be the baseline to determine if species diversity is increasing or decreasing?

### *Relevancies*

Indicator Type: state

Environmental Compartment(s): biota

Related Issue(s): contaminants & pathogens, nutrients, habitat

SOLEC Grouping(s): **open waters, nearshore waters**

GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring

IJC Desired Outcome(s): 6: Biological community integrity and diversity

GLFC Objective(s):

Beneficial Use Impairment(s): 6: Degradation of benthos

### *Last Revised*

*July 2, 2002*

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## DRAFT FOR DISCUSSION AT SOLEC 2002

### # 116 Zooplankton Populations

#### **Measure**

Spatial and temporal trends in community composition; mean individual size; and biomass and production.

#### **Purpose**

This indicator will assess characteristics of the zooplankton community over time and space, and it will be used to infer changes over time in vertebrate or invertebrate predation, system productivity, energy transfer within the Great Lakes, or other food web dynamics.

#### **Ecosystem Objective**

Maintain the biological integrity of the Great Lakes and to support a healthy and diverse fishery as outlined by the Goals and Objectives of the LaMPs and Great Lakes Fishery Commission. This indicator supports Annex 2 of the GLWQA.

#### **Endpoint**

For mean individual size, Mills et al. (1987) suggest 0.8 mm as an optimal size when the water column is sampled with a 153- $\mu$ m mesh net. Endpoints for community composition and biomass and productivity depend on the desired trophic state and type of fish community. Zooplankton as indicators of plankton and ecosystem community health are still in the early stages of development. Some information on the variability in zooplankton mean length is presented in Mills et al. (1987), and Johannsson et al. (1999b,c). Empirical relationships can be found in the literature relating zooplankton biomass and production to other state variables, such as total phosphorus, chlorophyll a concentration, primary production and zooplankton mean length (Makarewicz and Likens 1979 (if rotifers are measured), (McCauley et al. 1980), Hanson and Peters 1984, Yan 1985, McQueen et al. 1986, Johannsson et al. 1999a). End points for community structure are not clear now that new non-native zooplankton (*Bythotrephes* and *Cercopagis*) have entered the lakes.

#### **Features**

This indicator tracks trends in zooplankton populations, including community composition, mean individual size, and biomass and production, over time and space. Some data are available for Lake Ontario from 1967, 1970, 1972 on composition and abundance. Composition, density, biomass and production data are available for 1981-1995 from the Canadian Department of Fisheries and Oceans Lake Ontario Long-Term Biological Monitoring (Bioindex) Program (Johannsson et al. 1998). Mean individual size was not measured for the community during these years, but could be obtained from archived samples. Zooplankton work on Lake Erie has been reviewed by Johannsson et al. (1999c).

#### **Illustration**

Zooplankton mean length, ratio of calanoids to cladocerans + cyclopoids and biomass can be presented as line graphs if trend data are available. Shifts in composition might be better tracked using factor analysis followed by multi-dimensional scaling to show how the community structure moves in a two-dimensional space.

#### **Limitations**

At this point, it is not possible to rate mean individual size of zooplankton if they do not equal 0.8 mm. It is unclear how different energy flow is if the mean size is 0.6 mm or 1.0 mm, and if 0.6 mm is equivalent to 1.0 mm.

#### **Interpretation**

Some of the other measures which would help with the interpretation of the zooplankton data would include, total phosphorus, chlorophyll a, temperature, oxygen (in some regions), and, if possible, primary production and phytoplankton composition and biomass.

## DRAFT FOR DISCUSSION AT SOLEC 2002

### *Comments*

Composition: Changes in composition indicate changes in food-web dynamics due to changes in vertebrate or invertebrate predation, and changes in system productivity. Ratios such as calanoids to cladocerans + cyclopoids have been used to track changes in trophic. This particular ratio may NOT work in dreissenid systems (Johannsson et al. 1999c).

Mean Individual Size: The mean individual size of the zooplankton indicates the type and intensity of predation. When the ratio of piscivores to planktivores is approximately 0.2, the mean size of the zooplankton is near 0.8 mm. These conditions are characteristic of a balanced fish community (Mills et al. 1987). There is a high degree of variability about this relationship and further work needs to be done to strengthen this indicator. Total biomass and possibly production decrease with decreases in the mean size of the zooplankton (Johannsson et al. 1999b).

Biomass and Productivity: Biomass can be used to calculate production using size and temperature dependent P/B ratios for each of the major zooplankton groups. Production is a much better indicator of energy transfer within a system than abundance or biomass.

Of these measures, composition and mean size are the most important. However, these factors provide the information needed to calculate biomass and production.

### *Relevancies*

Indicator Type: state

Environmental Compartment(s): biota

Related Issue(s): contaminants & pathogens, nutrients, exotics

SOLEC Grouping(s): **open waters, nearshore waters**

GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring

IJC Desired Outcome(s): 6: Biological community integrity and diversity

GLFC Objective(s):

Beneficial Use Impairment(s): 13: Degradation of phyto/zooplankton populations

### *Last Revised*

**July, 2002**

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## DRAFT FOR DISCUSSION AT SOLEC 2002

### # 8132 Land Use

***This indicator needs to be linked to #7002 Land Conversion – but we still need to be able to pull out data for 1 km along shore.***

#### ***Measure***

Land use types, and associated area, throughout the Basin. Land use types could include urban residential, commercial, and industrial, non-urban residential, intensive agriculture, extensive agricultural, abandoned agricultural, closed canopy forest, harvested forest, wetland and other natural area.

#### ***Purpose***

To assess the types and extent of major land uses throughout the Basin, and to identify real or potential impacts of land use on significant natural features or processes, including the twelve special lakeshore communities identified in the Biodiversity Investment Area work in SOLEC 1998-2000.

#### ***Ecosystem Objective***

Maintain diverse, self-sustaining terrestrial and aquatic communities. This indicator supports Annex 2 of the GLWQA.

#### ***Endpoint***

No net loss or alteration of significant natural features or processes from current conditions.

#### ***Features***

This indicator will track trends in land uses over time (ideally 5 to 10 year periods) and focus on identifying areas experiencing the greatest changes in land use intensity over time. To identify and map land uses, this indicator will rely on a variety of methods, including remote sensing; aerial photography; available land use planning data for areas identified as already experiencing rapid land use changes (e.g., urban areas and cottage development); municipal data on building permits; and official plan/zoning bylaw amendments. Subsequent yearly monitoring will establish an increase or decrease in the extent of major land use types. This indicator is related to indicator #8136, Nearshore Natural Land Cover and to #7002, Land Conversion.

#### ***Illustration***

For each lake basin, lake, jurisdiction, and ecoregion, a table or graph will display annual changes in the area and degree of interspersion of each land use (same as Land Conversion indicator).

#### ***Limitations***

Data collection may be difficult for many reasons. Collection of detailed data on a regular basis may be difficult due to the large area and the number of different jurisdictions to be examined. Differences in types of land use planning data collected by jurisdictions may also hamper the collection of consistent data to support this indicator. Some limited historical data are available on land use types, but these data are focused on specific areas. A few basin-wide studies have been conducted that would provide a basic description of land use trends (e.g., U.S. National Shoreline Inventory from the early 1970s and a recent IJC water levels reference study) but it may be difficult to compare these data due to differences in methodology and generalizations that may have been used.

#### ***Interpretation***

Developing a baseline for this indicator will require both a review of existing data sources to determine their usability, and a discussion among agencies to establish a common list of land use types and parameters. Computerized analysis of satellite imagery may provide a cost-effective means of data collection. A more detailed study and groundtruthing of selected areas, however, will be needed to assess the relationship of land use changes to the loss or alteration of significant natural features and processes. In particular, results from this indicator should be compared to results from indicator 8129,

## DRAFT FOR DISCUSSION AT SOLEC 2002

Area, Quality, and Protection of Special Lakeshore Communities, to assist in identifying land use change patterns that threaten natural habitats.

### *Comments*

The twelve special lakeshore communities are sand beaches, sand dunes, bedrock and cobble beaches, unconsolidated shore bluffs, coastal gneissic rocklands, limestone cliffs and talus slopes, lakeplain prairies, sand barrens, arctic-alpine disjunct communities, Atlantic coastal plain disjunct communities, shoreline alvars, and islands.

### *Unfinished Business*

### *Relevancies*

Indicator Type: state

Environmental Compartment(s): land

Related Issue(s): habitat

SOLEC Grouping(s): **nearshore terrestrial**, land use

GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring

IJC Desired Outcome(s): 6: Biological community integrity and diversity, 9: Physical environmental integrity

GLFC Objective(s):

Beneficial Use Impairment(s): 14: Loss of fish and wildlife habitat

*Last Revised* July 2, 2002

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## DRAFT FOR DISCUSSION AT SOLEC 2002

### # NEW Health of terrestrial plant communities

#### *Measure*

Trends in time and space of 1) non-native insect or disease infestation of plants and 2) plant mortality or damage (including deformities) throughout the Great Lakes basin.

#### *Purpose*

This indicator will assess the presence, abundance, distribution and trends over time of non-native insects and diseases infesting plants, and their impacts on plant mortality or damage (including deformities), as well as the impact of airborne and groundwater pollution on plant community health.

#### *Ecosystem Objective*

Healthy, diverse plant communities throughout the Great Lakes basin, providing habitat to support diverse communities of animals. Plants should be abundant and readily available for human medicinal, cultural and decorative use.

#### *Endpoint*

None at present, but presumably something such as "Absence or minimization of non-native disease or insect infestations of plants, also, minimization of airborne and groundwater pollution, and therefore absence or minimization of plant mortality or damage including deformities."

#### *Features*

Healthy native plant communities dominated the Great Lakes basin before European settlement. Many of these plants were used by First Nations / Tribes as an integral part of their culture. Some of these communities have sustained multiple ecological insults through non-native diseases, insect infestations and pollution from atmospheric and groundwater sources. Re-establishment of healthy plant communities means that appropriate habitat will be available for dependent animal communities as well. Human use of these plants can then occur at a sustainable rate throughout much of the basin.

#### *Illustration*

To be developed

#### *Limitations*

- Areal extent of insect and disease infestation on non-commercial plant communities.
- Areal extent of pollution impacts on plant communities.
- Control of the entry of non-native diseases and insects.

#### *Interpretation*

The target is an increase in areal extent of healthy plant communities, free of non-native insects, diseases and impacts due to pollution. If the target values are met, the system can be assumed to be healthy; if the values are not met then there is health impairment.

#### *Comments*

To be developed

#### *Unfinished Business*

To be developed

#### *Relevancies*

Indicator Type: state

Environmental Compartment(s): biota, plants

Related Issue(s): pathogens, non-native species, habitat, atmospheric pollution, ground water pollution

SOLEC Grouping(s): **terrestrial**

GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring; 15: Airborne toxic substance; 16: Pollution from contaminated groundwater

## DRAFT FOR DISCUSSION AT SOLEC 2002

IJC Desired Outcome(s): 6: Biological community integrity and diversity  
Beneficial Use Impairment(s): 14: Loss of (fish and) wildlife habitat

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## DRAFT FOR DISCUSSION AT SOLEC 2002

### NEW Landscape Ecosystem Health

#### **Measure**

The quantity, distribution and configuration of terrestrial natural cover, and the influence of adjacent land uses on the natural system.

#### **Purpose**

To describe the makeup of land cover, especially the natural cover, and evaluate the state of the terrestrial ecosystem and the effects of landscape changes over time on the terrestrial ecosystem.

#### **Ecosystem Objective**

This indicator supports Annex 2 of the GLWQA

#### **Endpoint**

A sustainable ratio of natural, agricultural and urban land cover, in a distribution and configuration which maximizes their function throughout the basin.

#### **Features**

This indicator will track changes in natural, agricultural and urban cover over time. It will look at their relative abundance (ratio) and distribution. It will look at the configuration of the natural system, in particular the size and shape of individual habitat patches (or habitat fragments). It will also look around individual patches to determine the influence of land uses adjacent to the natural system. In some measures the patches are evaluated individually but all results are reported as a value for the region (or the natural system). The parameters can include Quantity (percent natural cover), Distribution, Land Use Influence, Patch Size and Shape, and Connectivity (*this one we don't have a measure for as yet and we may decide that it is redundant given the other measures but we're still debating*). This reporting of landscape makeup will provide a summary or model of the function of the natural system in relation to how it looks from the air. It will determine how efficient we are with the land and where pressures are more than the terrestrial system can handle. This should correlate to water issues as well. Not only negative but also positive changes will be reported on, such as those occurring from restoration, reduction of intrusive land uses, or better conservation through official plans and policies.

#### **Illustration**

Individual habitat patches and broad land use categories are digitized using digital orthophotography or satellite imagery. Patches, and subsequently the natural system, are analyzed using landscape analysis, Geographical Information Systems (GIS), and a patch ranking system. Correlation of landscape mapping to field data on species informs the landscape analysis model. Maps are generated showing the natural system results for each measure.

#### **Limitations**

The landscape analysis provides some interpretation from the patch to the ecosystem scales despite the lack of field data. However, the accuracy of the model and therefore the interpretation of landscape health depends on the calibration to a valid field collected data sample. One question may be the regional differences in how species react to habitat patch size, for example, therefore models may need to be calibrated to ecoregions. Base mapping may be difficult to obtain uniformly across the entire nearshore area, either due to funding or source issues.

#### **Interpretation**

Even today, the comparison of patches and their land use context can offer some insights into how to make decisions at the landscape level. For example, we may see that isolated 10 hectare patches in urban settings cannot perform as well as 10 hectare patches in agricultural settings. We may find that 10 hectare patches generally do not occur in urban areas. Over time, we can compare temporally the effect of decisions on the landscape (we may find that the water management indicators are also correlated). The landscape measures (quantity, distribution, configuration and land use) are prescriptive and provide

## DRAFT FOR DISCUSSION AT SOLEC 2002

clear and concise suggestions such as "more habitat is needed here" or "improve the patch shape here". It assists in the comparison of past decisions (good official plan design between Areas of Concern, for example). Supported by field level species and community reporting, landscape reporting assists in providing simple, large-scale summaries and recommendations.

### **Comments**

This work lends itself well to developing targets for health, perhaps more than the field collected species and community indicators on which it is based. Clarity is important if information will feed the policy development process. The landscape model in a sense summarizes the field data and, although it cannot be looked at alone, provides a more simple means of predicting change, quantifying targets and generating specific actions. The field data is the "proof in the pudding".

### **Unfinished Business**

Decide on the calculations at the patch and ecosystem scales

### **Relevancies**

Indicator Type: state (and to some degree stress, in relation to the land use or matrix influence)

Environmental Compartment(s): biota

Related Issue(s): ??

SOLEC Grouping(s): nearshore terrestrial

GLWQA Annex(es): 2: Remedial Action Plans and Lakewide Management Plans, 11: Surveillance and monitoring

IJC Desired Outcome(s): 6: Biological community integrity and diversity

GLFC Objective(s): (percent natural cover at different scales??)

Beneficial Use Impairment(s): 3: Degraded fish and wildlife populations

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## DRAFT FOR DISCUSSION AT SOLEC 2002

### NEW Status and Protection of Special Places and Species

#### Should this be a societal indicator?

##### *Measure*

Area, quality, and protected status of special places at the landscape level, and counts of those species of special cultural or spiritual significance to peoples in the Great Lakes basin.

##### *Purpose*

To assess the status and degree of protection (at the landscape level) in area and quality of special places and special species of cultural and spiritual significance especially to First Nations/ Tribes. Special places include: ecologically unique areas e.g. rocky outcrops, large dead trees; and cultural treasures, e.g. burial grounds and areas where medicinal herbs grow. Special or iconic species are ones such as pileated woodpeckers, turtle, wolf, martens, medicinal herbs, bald eagles, American Otter, or rare species. Additionally this indicator will infer the success of management activities associated with the protection of areas and species.

##### *Ecosystem Objective*

This indicator supports the overall goal of the GLWQA: "...maintain...biological integrity of the Great Lakes basin." and Article IV,1,c "outstanding resource value" and Annex 2, 1(c) xiv & 4(a), iii

##### *Endpoint*

No net loss in area or quality of special places or of the number and abundance of special species.

##### *Features*

To be developed

##### *Illustration*

Colour mapping could show the size and distribution of each special place including trends over time (net losses or net gains). Graphs and maps could show population distributions of special species and trend in time information on populations.

##### *Limitations*

Data collection may be difficult because many of the special places may only be identified through cultural association. It may not be possible to use remote sensing, for example. Data collection will depend on individual memories. Special species counts may be easier, in that communities may be willing to provide volunteers to do the counts.

##### *Interpretation*

Baseline information, frequency of monitoring (suggest 3-5 years) – see #8129 for other points to add.

##### *Comments*

This indicator provides easily understood information on the status of special places and culturally significant species throughout the Great Lakes. The information conveyed by this indicator will help aboriginal peoples and others to focus attention and management efforts on preserving and / or rehabilitating these places and species.

##### *Unfinished Business*

To be developed

##### *Relevancies*

Indicator Type: state and societal response

Environmental Compartment(s): land, biota

Related Issue(s): habitat, societal response

## DRAFT FOR DISCUSSION AT SOLEC 2002

SOLEC Grouping(s): **societal**

GLWQA Annex(es): ??????

IJC Desired Outcome(s): 6: Biological community integrity and diversity, 9: Physical environmental integrity

GLFC Objective(s):

Beneficial Use Impairment(s): 14: Loss of fish and wildlife habitat

*Last Revised*

**July 2002**

## Appendix B: Questions asked of the experts identified by LaMP Committees

### Science Issues concerning extent and impact of [non-native species /other stressors]

- When (at what stage in the lifecycle) do the non-native species /other stressors interfere with native species?
- How does the non-native species /other stressor interfere? i.e. with other species or the habitat.
- How do the native species compensate, if at all?
- Do environmental conditions favour the success of the non-native species? Why? Are these conditions reversible? How?

### Indicators and Indices to monitor extent and impact of non-native species / other stressors

- How did you monitor the relationship between native species and non-native species / other stressors?
- Is there an appropriate Great Lakes indicator, or set of indicators, that could be used to monitor the biological integrity of the native species?
- Is it feasible to develop indices of biological integrity to better categorize or classify the state of the Great Lakes basin ecosystem? If yes, what are some possible indices of Biological Integrity?

### Supplementary Issues

The following questions were addressed at the Biological Integrity Workshop as time permitted. These discussions are included in the Biological Integrity Workshop Proceedings and will be revisited at SOLEC 2002.

### Managerial Actions

- What management actions need to be taken to protect or restore the biological integrity of the Great Lakes basin ecosystem? (With respect to non-native species / other stressors? With respect to Genetically Modified Organisms (GMOs)?)
- What action(s) would enable recovery of the native species?
- What action(s) would ensure the recovery was sustainable?

### Potential Invaders to the Great Lakes

- What are potential invaders to the Great Lakes? Are the effects of these invaders anticipated to be more deleterious than the non-native species that we have previously encountered?
- What research has been done on these potential invaders?
- What preventative measures exist to hinder this invasion of non-native species?
- Are there indicators/evidence to predict the number of non-native species that will enter the Great Lakes region?

## Appendix C: James Karr's Presentation at the Biological Integrity Workshop

Notes prepared to outline in some detail the points made in my impromptu comments at SOLEC Biological Integrity workshop at Windsor, Ontario, December 4-5, 2001 - James R. Karr

### 1. Need to tie several concepts together to make the framework and goals coherent. Those concepts are:

**Integrity:** the biological condition and character of sites with minimal human influence, ideally this is "wild nature"

**Biological condition:** the character of sites. Wild nature has a condition equal to biological integrity defined above.

**Healthy:** a human defined goal that specifies the desired condition at a site. It may diverge from integrity

**Unhealthy:** biological condition below some threshold that results in local or nearby degradation.

**Sustainable:** sites with biological integrity or above the healthy-unhealthy threshold are assumed by definition to be sustainable.

**Unsustainable:** sites below the threshold are both unhealthy and their use in that context or framework is unsustainable.

For more on the context of my use of these words, see figures and accompanying text as follows: Fig. 3, page 19 in Karr and Chu, *Restoring Life in Running Waters* (1999) and Fig. 12.1, page 213 in paper by Karr in Pimentel et al., *Ecological Integrity* (2000). Both of the cited documents are in books published by Island Press.

### 2. Think gradient.

Avoid the tendency to think in terms of sites that are impaired or unimpaired as if there are two classes. In reality, we are dealing with places that reflect a gradient of biological condition from undisturbed (biological integrity) to various levels of degradation. See figures cited above and premise 30, page 139 in Karr and Chu (cited above).

### 3. Understand the benchmark or baseline condition.

All sites have a biological condition expected in the absence of human activity (biological integrity) although few if any sites truly reflect that condition today because of the pervasive influence of human actions. But that benchmark condition still provides a stable base that can be used to evaluate sites with diverse human influence. That biological condition of integrity (or desired divergences from that condition as in healthy above) can serve as benchmark, guide, and goal for assessment and planning processes (see section of paper from *Ecological Integrity* book cited above on pages 214-215).

**4. Think integratively about the entire process from conception of the problem to development** of indicators through to the communication of the results to policymakers and citizens. I group these into 5 critical phases and no matter how good one step may be the system will fail unless attention is paid to all of them, including to moving all of them forward, at the same time. Those phases are conceptual, design, sampling, analytical, and communication. The lessons here include the importance of thinking in terms of all three levels of view (satellite, biplane, and canoe), for different kinds of environments (wetlands, lakes, uplands), organisms (birds, fish, bugs), and kinds of human influence (mining, agriculture, industrialization, point and non point sources, etc.). Failing to connect across these dimensions will, over the long-term, result in a flawed process. In short, don't spend an infinite amount of time on selecting indicators without giving attention to the other core and crucial issues.

**5. Understand the importance of two questions: What to measure? How to decide?**

The failure to develop a systematic approach to answering these two questions has derailed many monitoring and assessment programs before they get off the ground.

It is generally important to avoid the use of species as indicators. They are not widely distributed enough to provide strong signal in a wide diversity of circumstance. Moreover, population sizes of single species are often so naturally variable that it is difficult to sort out signal from noise.

Several other thoughts on this general topic. First, theory and logic are often not a good guide to metric selection. Empirical evidence of a consistent relationship across a gradient of human influence is crucial. When selecting measures be sure to pick measures that are relevant to the societal endpoints that encompass the primary goal. That goal is most often some framing of biological condition. Counts of bureaucratic activity (permits issued, fines levied, and other such bean counts) rarely directly connect to that biological condition. In streams, trophic dynamics are often mentioned as the best measures. Empirical evidence suggests otherwise. Here again don't trust theory and logic.

It is important to have multiple measures from diverse levels of biology (individual health, population, community, landscape, etc.) that reflect biological sensitivity to various human influences and over a range of spatial scales. (Note that the levels and the scales here are not the same although they are often confused.)

**6. Be careful about habitat goals.**

Scientists and managers often resort to language that says to restore habitat. Remember that the goal is biological and just as connections between permits issued or chemical water quality standards and biology are often not strong, our presumptions about the desired configuration of habitat is often not connected to the real habitat needs of species. Besides, the goal here is to protect biological or ecological integrity, not manage places to maximize the *presumed* optimal habitat of some narrowly defined species.

## DRAFT FOR DISCUSSION AT SOLEC 2002

### **7. The goal needs to be understanding of the importance of “whole things.”**

Here I quoted from my paper in the *Ecological Integrity* book mentioned above. The title of that paper is “Health, integrity, and biological assessment: The importance of measuring whole things” (pages 209-226).

### **8. Think carefully about organizing and framing indicators in new ways.**

Current discussions of indicator development focus on huge list of measures. Attempt to find the common measures or classes of measures that will boil the metrics down to 10 or 12, and discuss them as the same set of a dozen or so indicators, framed to convey biological character regardless of habitat type. We use the same set of indicators to assess the condition of small streams in areas as wide ranging as the Tennessee River system, the Pacific Northwest (Oregon, Washington, and Idaho), Rocky Mountains (Wyoming) and several regions in Japan. Rather than being buried in indicators, we select using the 2 questions listed above. We invoke a standard process of indicator evaluation and assessment. Low and behold, when this happens, a very similar set of measures emerges. The process of indicator development and selection should work harder to define that common ecological principle and context framework, as opposed to the current one which seems more attuned to making long lists, repetitively at sequential meetings.

### **9. Keep in mind that the goal is assessment, not monitoring.**

Biologists and water managers in a larger sense have monitored for most of the last century or more. It can be shown without much trouble that not much useful has come from much of that monitoring. A process that simply advocates more of the same “unguided or poorly guided monitoring” will not change the situation. Frame and form the process as one with an assessment goal, not a data collection (monitoring) goal. By doing that we refocus the energies and efforts to more effectively answer the two questions above as well as to place the task in the larger 5-phase process that I mentioned in item 4 above. That should both strengthen the intellectual foundations of the process as well as the probability that it will produce policy relevant information that can be communicated to diverse stakeholders.