GREAT LAKES FISHERY COMMISSION

2004 Project Completion Report[1]

Fish Communities of the Laurentian Great Lakes: The SCOL Tradition Revisited for the 21st Century

by:

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Completion Report:

Fish Communities of the Laurentian Great Lakes

The SCOL Tradition Revisited for the 21st Century

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Introduction

The first SCOL symposium, Salmonid Communities of Oligotrophic Lakes was convened in Geneva Park, Ontario, in July 1971, by Henry Regier and Ken Loftus. The symposium focused on effects of cultural eutrophication, fisheries exploitation, and non-native species on oligotrophic lakes of the world (not just North America). The symposium proceedings were published in the Journal of the Fisheries Board of Canada in June 1972 (Volume 29, Number 6).

The second SCOL initiative appeared as a pre-proposal by Randy Eshenroder to the Great Lakes Fishery Commission's Board of Technical Experts on 17 September 1997. Steve Kerr and Mike Hansen were named co-principal investigators on 9 March 1998. A steering committee for the task area was formed on 1 April 1998. The steering committee decided to proceed with the second SCOL initiative as a series of three workshops, rather than a single symposium, to (1) define the emergent patterns and processes in a first workshop, (2) define how those emergent patterns and processes compared among lakes in a second workshop, and (3) synthesize the findings of the first two workshops in a third workshop.

Project Objective

The SCOL2 Task Area was developed to organize, conduct, synthesize, and publish a series of workshops to focus on contemporary management needs affecting Great Lakes fish communities, and to determine future states of these ecosystems. Below, we define the project deliverables for the SCOL2 task area and our progress toward those deliverables.

Project Deliverables

- Perspectives of each lake submitted to CJFAS (Workshop I).
- Case histories of each lake submitted to GLFC (Workshop I).
- Cross-lake comparisons submitted to CJFAS (Workshop II).
- Synthesis of case histories and cross-lake comparisons submitted to CJFAS (Workshop III).

Progress toward Objectives and Deliverables

Workshop I – The first workshop was held at the University of Toronto at Mississauga on 18-20 May 2000 (Appendices: Workshop I Attendees, Agenda, Introduction, and Summary). At the first workshop, case studies of the Great Lakes were presented by Chuck Bronte (Superior), Chuck Madenjian (Michigan), Dave McLeish (Huron), Don MacClennan (St. Clair), Phil Ryan (Erie), and Ed Mills (Ontario). Deliverables from the first workshop, for each Great Lake, were intended to include a short Perspective to be published in the Canadian Journal of Fisheries and Aquatic Sciences (CJFAS) and a longer case history to be published as a Great Lakes Fishery Commission Technical Bulletin (GLFC).

- Perspectives of each lake submitted to CJFAS:
    - Lake Michigan was published by CJFAS (Madenjian et al. 2002).
    - Lake Ontario was published by CFJAS (Mills et al. 2003).
    - Lake Superior was published by CJFAS (Bronte et al. 2003).
    - Lake Huron was completed (Dobiesz et al., in review), sent to Hansen for review on 22 December 2003, returned to the authors for revision on 2 February 2004, and will be submitted to CJFAS for review on 1 March 2004.
    - Lake St. Clair case history was completed for Workshop I (see below; MacLennan et al., in review). MacLennan agreed to produce a manuscript for review by 1 April 2004.
    - Lake Erie case history was completed on 15 August 2003 (see below; Ryan et al., in review), submitted to Koonce and Bence for review, and reviewed by Bence on 1 October 2003. Koonce agreed to prepare the CJFAS Perspective from the draft case history by summer 2004.
- Case histories of each lake submitted to GLFC as Technical Reports:
    - Lake Ontario was submitted to GLFC (Mills et al., in press).
    - Lake Michigan was submitted to GLFC (Madenjian et al., in press).
    - Lake Superior was promised for 1 April 2004 (Bronte et al., in review).
    - Lake Huron was completed for Workshop I (McLeish et al., in review) and used by Norine Dobiesz to prepare the CJFAS Perspective (see above). Dave McLeish is committed to producing the case history.
    - Lake St. Clair case history was completed for Workshop I (see above; MacLennan et al., in review). MacLennan agreed to produce a manuscript for review after acceptance of the CJFAS Perspective.
    - Lake Erie was completed on 15 August 2003 (see above; Ryan et al., in review), submitted to Koonce and Bence for review, and reviewed by Bence on 1 October 2003.

Workshop II – The second workshop was held at Harkness Laboratory in Algonquin Park, Ontario, on 16-18 August 2001 (Appendices: Workshop II Attendees, Agenda, and Summary). At the second workshop, cross-lake comparisons were presented by Jim Bence (top-down effects), Joe Koonce (bottom-up effects), Doran Mason (food web structure and function), Mike Jones (climate change), and Gary Sprules (biomass size spectra). Deliverables from the second workshop were intended to be a module of manuscripts focusing on cross-lake comparisons of emergent patterns and processes in the Great Lakes.

- Authors of cross-lake comparisons attended a steering committee meeting in June 2002 and each promised draft manuscripts by August 2003, to serve as resource documents for Workshop III.

- The steering committee agreed to focus Workshop III on a review of each cross-lake comparison, to help synthesize patterns and processes within and among lakes, as an outline for a synthesis of Workshops I and II.

- The list of attendees was set to include primary authors for each case history, primary authors for each cross-lake comparison, the SCOL2 task area principal investigators, and GLFC participants.

- The agenda was developed to review cross-lake comparisons and to develop an outline for a manuscript that synthesizes emergent patterns and processes within and among the Great Lakes, for purposes of predicting future states of each lake.

Workshop III – The third workshop was held at Le Manoir du Lac Delage, Quebec, on 14-18 August 2003 (Appendices; Workshop III Attendees, Agenda, Introduction, and Summary). At the third workshop, cross-lake comparisons were updated by Jim Bence (top-down effects), Joe Koonce (bottom-up effects), Mike Jones (climate change), and Gary Sprules (biomass size spectra), and an outline for a SCOL2 synthesis manuscript was developed. Deliverables from the third workshop are intended to include a module of manuscripts on cross-lake comparisons (five papers) and a synthesis of the SCOL2 task area (one paper).

- Jim Bence produced a draft manuscript on top-down effects for the workshop and promised a draft for review by 15 December 2003.

- Joe Koonce produced a draft manuscript on bottom-up effects for the workshop and delivered a draft for review on 25 September 2003 (Koonce, in review).

- Mike Jones presented a review of climate-change effects at the workshop and promised a draft for review by 15 December 2003.

- Gary Sprules presented a review of biomass-size spectra among the Great Lakes at the workshop and promised a draft for review by 15 December 2003.

- Doran Mason canceled a review of food web structure and function at the last minute, but promised a manuscript for review by 15 December 2003.

- Participants developed a topic outline for a manuscript to synthesize the SCOL2 task area at the workshop, to be written by Hansen and Kerr after reviewing the associated lake case histories and cross-lake comparisons

AFS Symposium – Hansen solicited interest in a symposium on the SCOL2 task area for presentation at the 134th Annual Meeting of the American Fisheries Society in Madison, Wisconsin, 22-26 August 2004. A symposium proposal was then submitted and accepted for inclusion in the meeting (Appendix). The symposium will include all case histories originally presented at Workshop I, all cross-lake comparisons originally presented at Workshops II and III, and the synthesis that was outlined at Workshop III.

Anticipated Future Progress

- Perspectives of each lake submitted to CJFAS:
  - Lake Huron will be submitted to CJFAS by 1 March 2004 (Dobiesz et al., in review).
  - Lake St. Clair case history was completed for Workshop I (see above; MacLennan et al., in review). MacLennan agreed to produce a manuscript for review by 1 April 2004.
  - Lake Erie will be prepared by Koonce by summer 2004, reviewed by Hansen and Kerr by late summer 2004, and submitted to CJFAS by fall 2004.
- Case histories of each lake submitted to GLFC as Technical Reports:
  - Lake Ontario will be published by GLFC in 2004 (Mills et al., in press).
  - Lake Michigan will be published by GLFC in 2004 (Madenjian et al., in press).
  - Lake Superior will be published by GLFC in 2004 (Bronte et al. in review).
  - Lake Huron was completed for Workshop I (McLeish et al., in review) and used by Norine Dobiesz to prepare the CJFAS Perspective (Dobiesz et al., in review). McLeish agreed to prepare the GLFC Technical Report from his earlier manuscript and the CJFAS Perspective.
  - Lake St. Clair was completed for Workshop I (see above; MacLennan et al., in review). MacLennan agreed to produce a manuscript for review after the Perspective is accepted by CJFAS.
  - Lake Erie was completed in August 2003 (see above; Ryan et al., in review), submitted to Koonce and Bence for review, and reviewed by Bence in August 2003. Authors continue to express interest in producing a manuscript for consideration as a GLFC Technical Report.
- Module of cross-lake comparisons submitted to CJFAS:
  - A manuscript on top-down effects by Jim Bence was promised by 15 April 2004.
  - A manuscript on bottom-up effects by Joe Koonce was delivered on 25 September 2003 (Koonce, in review).
  - A manuscript on climate-change effects by Mike Jones was promised by 15 December 2003.
  - A manuscript on biomass-size spectra comparisons by Gary Sprules was promised by 15 December 2003.

- A manuscript on food-web structure and function by Doran Mason was promised by 15 December 2003.

- After receipt and review of manuscripts on cross-lake comparisons, Hansen and Kerr will draft a manuscript that synthesizes the SCOL2 task area, for inclusion in the module of manuscripts to be submitted to CJFAS.

- Symposium at AFS meeting in August 2004.

Manuscripts Submitted and Published

Bronte, C. R., M. P. Ebener, D. R. Schreiner, D. S. DeVault, M. M. Petzold, D. A. Jensen, C. Richards, and S. J. Lozano. 2003. Fish community change in Lake Superior, 1970-2000. Canadian Journal of Fisheries and Aquatic Sciences 60: 1552-1574.

Bronte, C. R., M. P. Ebener, D. R. Schreiner, D. S. DeVault, M. M. Petzold, D. A. Jensen, C. Richards, and S. J. Lozano. In review. A case history of the fish community of Lake Superior, 1970-2000: a restoration in progress. Great Lakes Fishery Commission, Technical Report, Ann Arbor, Michigan.

Dobiesz, N. E., D. A. McLeish, R. L. Eshendroder, J. R. Bence, B. A. Henderson, L. C. Mohr, M. P. Ebener, T. F. Nalepa, A. P. Woldt, J. E. Johnson, R. L. Argyle, and J. C. Makarewicz. In review. Ecology of the Lake Huron fish community 1970-1999. Canadian Journal of Fisheries and Aquatic Sciences.

Koonce, J. F. In review. Allocation of Benthic and Pelagic Production: A System Perspective on Primary Production in Great Lakes. Canadian Journal of Fisheries and Aquatic Sciences.

MacLennan, D. S., R. C. Haas, and M. V. Thomas. In review. Lake St. Clair: a case history of change 1970-1999. Great Lakes Fishery Commission, Technical Report, Ann Arbor, Michigan.

Madenjian, C. P., G. L. Fahnenstiel, T. H. Johengen, T. F. Nalepa, H. A. Vanderploeg, G. W. Fleischer, P. J. Schneeberger, D. M. Benjamin, E. B. Smith, J. R. Bence, E. R. Rutherford, D. S. Lavis, D. M. Robertson, D. J. Jude, and M. P. Ebener. 2002. Dynamics of the Lake Michigan Food Web, 1970-2000. Canadian Journal of Fisheries and Aquatic Sciences 59: 736-753.

Madenjian, C. P., G. L. Fahnenstiel, T. H. Johengen, T. F. Nalepa, H. A. Vanderploeg, G. W. Fleischer, P. J. Schneeberger, D. M. Benjamin, E. B. Smith, J. R. Bence, E. S. Rutherford, D. S. Lavis, D. M. Robertson, D. J. Jude, and M. P. Ebener. In press. Dynamics of the Lake Michigan food web, 1970-2000: learning through long-term research. Great Lakes Fishery Commission, Technical Report, Ann Arbor, Michigan.

McLeish, D. A., L. C. Mohr, B. A. Henderson, R. L. Eshendroder, M. P. Ebener, T. F. Nalepa, A. P. Woldt, J. E. Johnson, R. L. Argyle, G. L. Curtis, N. E. Dobiesz, J. R. Bence, and J. C. Makarewicz. In review. Ecology of the Lake Huron fish community 1970-1999. Great Lakes Fishery Commission, Technical Report, Ann Arbor, Michigan.

Mills, E. L., J. M. Casselman, R. Dermott, J. D. Fitzsimons, G. Gal, K. T. Holeck, J. A. Hoyle, O. E. Johannsson, B. F. Lantry, J. C. Makarewicz, E. S. Millard, I. F. Munawar, M. Munawar, R. O'Gorman, R. W. Owens, L. G. Rudstam, T. Schaner, and T. J. Stewart. 2003. Lake Ontario: food web dynamics in a changing ecosystem (1970-2000). Canadian Journal of Fisheries and Aquatic Sciences 60: 471-490.

Mills, E.L., J.M. Casselman, R. Dermott, J.D. Fitzsimons, G. Gal, K.T. Holeck, J.A. Hoyle, O.E. Johannsson, B.F. Lantry, J.C. Makarewicz, E.S. Millard, I.F. Munawar, M. Munawar, R. O'Gorman, R.W. Owens, L.G. Rudstam, T. Schaner, and T.J. Stewart. In press. A synthesis of ecological and fish community changes in Lake Ontario, 1970-2000. Great Lakes Fishery Commission, Technical Report, Ann Arbor, Michigan.

Ryan, P. A., R. Knight, E. Arnold, M. Bur, J. Ciborowski, T. P. Diggins, D. Einhouse, K. Fynn-Aikins, R. Haas, T. Johnson, K. Kayle, R. Kenyon, B. Locke, B. Shuter, M. Stapanian, J. Tyson, and M. Whittle. In review. The ecology of Lake Erie 1970-2000: a fisheries management perspective. Great Lakes Fishery Commission, Technical Report, Ann Arbor, Michigan.

SCOL2 Salmonid Communities in Oligotrophic Lakes -2

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May 18 - 20, 2000

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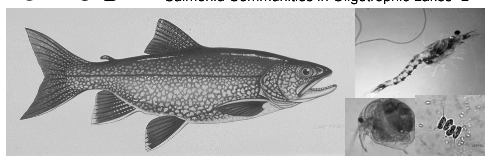
SCOL2 Salmonid Communities in Oligotrophic Lakes -2



SCOL2 – Workshop I – Agenda
University of Toronto at Mississauga
May 18 - 20, 2000

Thursday, 18 May 2000

12:00 - 1:00 pm	Light lunch
1:00 - 1:20	Introduction - Steve Kerr
1:20 - 1:50	Lake Superior Case History - Chuck Bronte
1:50 - 2:20	Lake Michigan Case History - Chuck Madenjian
2:20 - 2:50	Lake Huron Case History - Dave McLeish
2:50 - 3:20	Coffee Break
3:20 - 3:50	Lake St. Clair Case History - Don MacLennan
3:50 - 4:20	Lake Erie Case History - Phil Ryan
4:20 - 4:50	Lake Ontario Case History - Ed Mills
5:00 - 6:00	Plenary (Panel of Case History Authors)
6:30	Mixer/Barbecue

Friday, 19 May 2000

8:00 - 9:00 am	Breakfast
9:00 - 9:20	Review of yesterday - Mike Hansen
9:20 - 10:20	Plenary - patterns
10:20 - 10:40	Coffee Break
10:40 - 12:00	Breakout - patterns
12:00 - 1:00 pm	Lunch
1:00 - 2:00	Plenary - process
2:00 - 2:45	Breakout - process
2:45 - 3:15	Coffee Break
3:15 - 4:00	Breakout - process
4:00 - 5:00	Plenary with modelers
6:00 - 7:30	Dinner
7:30	Mixer

Saturday, 20 May 2000

8:00 - 9:00 am	Breakfast
9:00 - 9:20	Review of yesterday - Steve Kerr
9:20 - 9:40	Review Lake Superior models - Doran Mason
9:40 - 10:00	Review Lake Michigan models - Mike Jones
10:00 - 10:20	Review Lake Huron models - Jim Bence
10:20 - 10:50	Coffee Break
10:50 - 11:10	Review Lake Erie Models - Dave Atkinson
11:10 - 11:30	Review Lake Ontario models - Pat Sullivan
11:30 - 12:00 pm	Plenary - model themes
12:00 - 1:00	Lunch
1:00 - 2:15	Plenary - model themes
2:15 - 2:45	Breakout- model themes
2:45 - 3:15	Coffee Break
3:15 - 4:30	Breakout- model themes
4:30 - 5:00	Wrap-up and adjourn - Mike Hansen

SCOL2 Salmonid Communities in Oligotrophic Lakes -2

SCOL2 – Workshop I – Introduction
University of Toronto at Mississauga
May 18 - 20, 2000

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Welcome to Workshop 1 of SCOL-2. My name is Steve Kerr. It is my pleasure to welcome you to the proceedings. That I am standing here to welcome you, instead of my co-chair Mike Hansen, is entirely due to the fact that Mike was kind enough to insist upon it.

As I have learned from the nearly 2 years that we have worked together on this project, Mike is an astute observer of history, and of human foibles and many other things besides. From that perspective, he clearly judged that it would be at least poignant, and possibly even relevant, to have a participant in the original SCOL open its successor. So here I am, doing just that.

Mike did not initiate use of the term "old fart" in our various discussions, although I did note that he seized upon it with unbecoming alacrity when Henry Regier introduced it to our lexicon. I have since struggled to think of more attractive alternatives, but cannot. Old "fossil" initially seems kinder, but as pejorativeS go, I would rather settle for "old fart". At least that distinguishes those elder citizens in attendance such as Henry, Dick Ryder, and myself - and some others - from the usual predilection to associate fossils with dinosaurs, with all the entailments that evokes in common parlance.

I will introduce Mike to you in a few minutes. I will also introduce Randy Eshenroder, the prime instigator of these proceedings; not that either of these needs introduction. Before doing that however, let me trace a little history for you and add a few thoughts.

For starters, why have the organizers of this exercise had the seeming effrontery to label it as SCOL-2? Clearly, neither the format nor scope of the exercise is at all like the original SCOL. The original ran for two weeks in an intensive exercise that I think all or most of us would agree revolutionized our approach to the analysis of fisheries production systems, although I do not recall that we used the latter term very often in those days.

The first SCOL was explicitly empirical and comparative. It embodied a factorial design in which we considered the effects of exploitation, eutrophication and species introductions, which were then perceived as the major stressors, acting alone and in various combinations. We, or some of us, at least, were astonished at the time by the commonality of the effects.

The first SCOL was also much more global in its search for comparative material. This time around, we are more focused on the Great Lakes ecosystem. The current program also entails that we become more analytical, and ultimately, more explicitly focused on the management implications as our work unfolds.

The first SCOL was in fact a remarkable departure from the single-species paradigm that had characterized fisheries analysis to that point. It was the first such exercise I am aware of to have deliberate focus on community dynamics in the context of multiple stressors. The language it introduced at the time is still remarkably modern. It was the first to note, for example, that "where exploitation rates become excessive community transformations occur that are not predictable from population dynamics models of the component stocks" (Loftus and Regier, 1972). That was a novel conclusion at the time.

Nowadays, of course, our language has changed to the point where we comfortably speak in terms of complex, non-linear systems with emergent properties. More importantly, we appear to be on the verge of being able to make sensible and useful quantitative statements about such properties as their integration and self-organization. Time will soon tell if this will lead us to more powerful and appropriate management options.

This is not to argue that we must now abandon conventional population dynamics. Obviously, the conventional approach works very well in situations that are close to equilibrium (steady state). Where we have experienced the most difficulty, and this appears to be by far the more common situation, is where the system is far from equilibrium. This is true globally in many ecological production systems, not just in the Great Lakes ecosystem. In my view, and I know that many others share this perception, we have for too long been beguiled by the common perceptions of Lyell, Darwin and other giants of earlier western science; that change is uniform and gradual, and captured by the smooth, continuous, differentiable functions of Newton and Liebnitz. We now know that this perception works well for planetary motion, at least to a first approximation, but we also know that it does not work at all well for many situations in the biosphere where chaotic processes emerge from the complex, non-linear dynamics that cannot be ignored at the level of ecosystem function.

SCOL-1 therefore marked the first, decisive step away from the common supposition of smooth, continuous change in single-factor processes. We now know that complex, multi-factorial processes prevail in many instances. SCOL-1 of course had its various successors, in the form of ASPY, PERCIS, STOCS, and the like, all of which built upon this initial SCOL foundation and led to further, substantial successes. Our task here is to revisit the original SCOL and its successors, and determine what we can do to update the original analyses. More succinctly, our question is to determine "what is the future of the Great Lakes ecosystem"? In some measure, this is a different question than was posed by SCOL-1, but it is very much in its spirit.

SCOL-1 had two principle architects. Henry Regier is of course palpably with us today, much to our pleasure. Ken Loftus, unfortunately, is not. For that reason, Mike Hansen and I have decided that it is entirely appropriate to dedicate the proceedings of SCOL-2 to the memory of Ken Loftus. We do so for the obvious reason that he was a co-principal in the original SCOL. More importantly, in our view, we also do so because it recognizes one of the principal tenets that characterized Ken's professional career. Throughout, he was deeply concerned that management of our resources should benefit from the full and timely application of science, and that management be predicated solely on those premises, to the exclusion of those who argued for special benefits. This predilection is also reflected in his support of ASPY, STOCS, and all the other successful successors of SCOL-1. SCOL-2 is also dedicated to that aim, and for that reason in particular, we respectfully dedicate the proceedings of SCOL-2 to the memory of Kenneth H. Loftus, in the hope that he would have approved of our efforts.

SCOL2 Salmonid Communities in Oligotrophic Lakes -2

SCOL2 – Workshop I – Summary
University of Toronto at Mississauga
May 18 - 20, 2000

Case Studies

Chuck Bronte (Lake Superior) **–** Siscowet (*Salvelinus namaycush*, deepwater morphotype) and lake whitefish (*Coregonus clupeaformis*) stocks are at their highest levels of recorded abundance, and may be approaching ancestral states. Lake herring (*Coregonus artedi*) also made a recovery, but under conditions of sporadic recruitment that appear to be a product of density-independent causes. Contaminant levels declined in the water column and in fish tissue, and may be at levels in equilibrium with inputs. Toxaphene remains a problem with the highest levels reported in water and lake trout in the Great Lakes basin. Sea lamprey control, harvest restriction, and hatchery introductions fostered the recovery of lake trout (*Salvelinus namaycush*, lean morphotype), and the establishment of self-sustaining Pacific salmon (*Onchorynchus* sp.) and other salmonine populations eliminate the need for further stocking. Non-native salmonines support small but popular sport fisheries, but will likely remain minor components of the fish community. Forage biomass has shifted from dominance by rainbow smelt (*Osmerus mordax*), an exotic, to an array of native species, and high predation mortality will likely prevent recovery of rainbow smelt to former abundances. Without aggressive and continued sea lamprey control the recovery of native or intentional establishment of non-native salmonine populations would not have been possible. Unintentional introductions of exotic species have increased, and potentially threaten the recovering fish community in unknown ways, and therefore are threats to the ecosystem.

Chuck Madenjian (Lake Michigan) **–** Control of sea lamprey (*Petromyzon marinus*) and alewife (*Alosa pseudoharengus*) populations in Lake Michigan appeared to have profound effects on the food web. Dramatic recoveries of lake whitefish (*Coregonus clupeaformis*) and burbot (*Lota lota*) populations, and the spectacular buildup of salmonine populations, were attributable, at least in part, to sea lamprey control. Based on our analyses, salmonines, especially chinook salmon (*Oncorhynchus tshawytscha*), were primarily responsible for the substantial reduction in alewife abundance during the 1970s and early 1980s. In turn, control of the alewife population probably contributed toward recoveries of deepwater sculpin (*Myoxocephalus thompsoni*), yellow perch (*Perca flavescens*), and burbot populations during the late 1970s and 1980s. Decrease in the abundance of all three dominant benthic macroinvertebrate groups, including *Diporeia*, oligochaetes, and sphaeriids, during the 1980s in the nearshore ($\geq$50 m deep) waters of Lake Michigan was believed to be due to a decrease in primary production linked to a decline in phosphorus loadings between 1980 and 1987. In contrast, long-term data for spring total phosphorus and chlorophyll *a* concentration indicated that primary production in the offshore waters of Lake Michigan exhibited no trend between 1973 and 1998. Continued decrease in *Diporeia* abundance during the 1990s in nearshore waters of southern and southeastern Lake Michigan coincided with the establishment and spread of the zebra mussel (*Dreissena polymorpha*), but specific mechanisms for the zebra mussel invasion affecting *Diporeia* abundance remain unidentified. Overexploitation of fish populations appeared to play a relatively minor role in effecting changes within the Lake Michigan ecosystem during 1970-2000; though commercial harvest of yellow perch during the 1990s may have contributed to the prolonged period of low recruitment to the yellow perch population. Bans on the use of pesticides and polychlorinated biphenyls (PCBs) led to substantial decreases in contaminant concentrations of Lake Michigan biota between 1970 and 2000, and consequently to a rapid increase in the double-crested cormorant (*Phalacrocorax auritus*) population size during the late 1980s and 1990s. Finally, the rise and fall in bloater (*Coregonus hoyi*) abundance during the 1980s and 1990s may have represented natural oscillations in bloater population size, which were largely independent of human activities and interactions with other species of fish.

Dave McLeish (Lake Huron) – The status of the Lake Huron fish community between 1970 and 1999 was reviewed and effects of key stressors were explored. Offshore waters changed little in terms of enrichment, while phosphorus levels declined in inner Saginaw Bay. Introduced mussels, *Dreissena* spp., proliferated and may have caused a decline of the *Diporeia* population in outer Saginaw Bay. The exotic zooplankter, *Bythotrephes*, is now common in the lake and may be responsible for a compositional shift of zooplankton from bosminids to daphnids. Sea lampreys (*Petromyzon marinus*) remain prevalent, but intensive control efforts on the St. Marys River in the late 1990s may reduce the impacts of their predation on salmonines. Over fishing is less of a problem than in the past with the exception of the native lake trout (*Salvelinus namaycush*), planted for rehabilitation purposes, and *Coregonus hoyi*, which is sensitive to fishing when its cyclic recruitment is low. Massive stocking programs increased the abundance of top predators, but lake trout (*Salvelinus namaycush*) have been rehabilitated in only one area. Management for Pacific salmon fisheries and rehabilitation of lake trout may not be compatible.

Don MacClennan (Lake St. Clair) – Changes in the Lake St. Clair aquatic ecosystem since 1970 were described. The west of the lake is like Lake Huron, whereas the east side of the lake is like Lake Erie. A decline in water levels in 1987-1988 increased the photic zone. Zebra mussels caused water transparency to double, and might yet cause a trophic cascade. Phytoplankton production, as indexed by Chlorophyll concentration, declined dramatically (66%). Marcophytes increased as water transparency increased, which favored fish recruitment. Zebra mussels have virtually eliminated native mussels. Walleye declined in the 1990s, and walleye stocks now exhibit increased mean age, high survival, and low exploitation. Walleye from Lake St. Clair tend to spend more time in Lake Huron than in Lake Erie. Walleye recruitment may have been reduced by zebra mussels. Muskellunge and smallmouth bass both increased by 2-3 times in the 1980s, perhaps because of changes in macrophyte density.

Phil Ryan (Lake Erie) – Changes in the Lake Erie ecosystem since 1970 were described. Phosphorus loading declined from 25,000 MT in 1968 to only 11,000 MT in the 1990s. Phosphorus and chlorophyll concentrations exhibit a declining trend from west to east that caused water transparency to increase through time. As a consequence, Lake Erie has moved from a mesotrophic state to oligotrophic state. Yellow perch declined as walleye increased after the mid-1970s, which facilitated white perch to increase. Walleye are now at record levels of abundance, whereas yellow perch productivity fell to record low levels. Rainbow smelt predominate in the eastern basin. Lake herring, once the most productive species in the lake, are still absent.

Ed Mills (Lake Ontario) – Stressors that led to profound ecological changes in the Lake Ontario ecosystem and its fish community since 1970 were examined. Most notable have been reductions in phosphorus loading, invasion by *Dreissena* spp., fisheries management through stocking of exotic salmonids and control of sea lamprey (*Petromyzon marinus*), and fish harvest by anglers and double-crested cormorants. The stressor response to these driving forces has resulted in: 1) declines in both algal photosynthesis and epilimnetic zooplankton production; 2) decreases in alewife (*Alosa pseudoharengus*) abundance; 3) declines in native *Diporeia* and lake whitefish (*Coregonus clupeaformis*); 4) behavioral shifts in alewife spatial distribution that has benefited native lake trout (*Salvelinus namaycush*), three-spine stickleback (*Gasterosteus aculeatus*), and emerald shiner (*Notropis atherinoides*) populations; 5) dramatic increases in water clarity; 6) predation impacts by cormorants (*Phalacrocorax auritus*) on select fish species; and 7) lake trout recruitment bottlenecks associated with alewife induced thiamine deficiency. Stressor responses associated with anthropogenic forces like exotic species invasions and global climate warming should continue to impact the Lake Ontario ecosystem in the future, and continuous long-term ecological studies will be required for both scientific understanding and management of this important resource.

Patterns and Processes

Nutrients – Phosphorus loading decreased throughout the basin, which caused the N:P ratio to increase. As a consequence, phytoplankton production has declined, which is evident as increased light penetration and deeper thermocline. Monitoring of phosphorus loading should be improved, to facilitate modeling. Is there continuing data on anthropogenic inputs (EPA)? Are phosphorus loadings stabilized? We need to methods of analysis or nutrient models that treat the whole Great Lakes ecosystem as a unit. In addition, models need to incorporate mussels. The new model should then be used to determine whether offshore phosphorus in the upper lakes will still take a long time to reach equilibrium. A decrease in non-point pollution may decrease total nutrient loads, so the effects on near shore community and total nutrient loads must be examined. Are there lags in the effect of phosphorus loading on the system? A cross-lake comparison could examine phosphorus concentrations, N:P ratio, light penetration, and macrophyte time-series through abatement to look for time lags. How would future nutrient changes affect the food web? Impacts of decreased phosphorus may be stronger in more oligotrophic systems, so may need to retrieve data on silica-diatom dynamics. We need to develop mechanistic insight into V_s: $[P] = \frac{Wload}{Q + (Area_s \times V_s)}$; where H_o: degraded food webs have high V_s through loss of detritivores and benthic species that migrate up into the water column. Test by comparison of V_s from Lake Erie with other degraded lakes outside the Great Lakes basin. Such changes may decrease the ability of exotics to colonize a lake. Consult existing literature for trophic history of lakes from sediment cores.

Dreissena – Increased density of zebra mussels causes increased water clarity, lower phytoplankton biomass, changed phytoplankton community structure to very small greens and large/colonials, and decreased diatoms. How abundant do *Dreissina spp.* have to become before phosphorus and chlorophyll decouple? A cross-lake comparison could compare primary production rate against total phosphorus. Few changes in the zooplankton community are associated with zebra mussel invasion, though fewer nauplii and rotifers are present when zebra mussels are abundant. Zebra mussels cause large changes in the benthos, including loss of native mussels, disappearance of *Diporeia*, sporadic recovery of *Hexagenia*, and increases in *Gammarus*. A cross-lake comparison could compare pre/low and post/high mussel areas to determine effects on benthic community structure and function. Zebra mussels cause changes in habitat, including fish egg incubation, droils, Cladophora, and potentially, fish recruitment and growth. What is the possible maximum range of zebra mussels in the Great Lakes? Limits of depth, temperature (overwinter), calcium, and oxygen should be determined. Analysis of existing data and a literature review of *Dreissena* physiology can be used to determine limits to distribution. Analysis of physical models of currents and substrates may help to predict the rate and range of colonization. A cross-lake comparison may yield an estimate of the rate of colonization. Do zebra mussels increase phosphorus transport to sediments? What is the effect on birds? How is contaminant transport changed by mussels? Compare food density gradients across lakes. Compare effects in Lake St. Clair, eastern Lake Erie, and western Lake Huron.

Predators – What is to be expected with changing stocking levels? Changes in predator stocking practices (decreasing numbers) may lead to changes in the size distribution of prey species, as in Lake Huron (i.e. smaller alewives), or no change, as in Lake Michigan. Abundant predators may be over-suppressing prey species in some lakes, as with lake trout in Lake Superior, Chinook salmon in Lake Ontario and Lake Michigan, and walleye in Lake Erie. Are some Great Lakes ecosystems returning to the previous state, in terms of their structure, as evident by the recovery of burbot, whitefish, and cisco in several lakes? A trophic cascade is evident through changes in zooplankton (i.e. cladocera) that are coincident with declines in alewives, and increases in exotic zooplankton species like *Bythotrephes* and *Cercopagis*. The loss of *Diporeia* offshore will likely affect predator species through bottom-up effects. The influence of lake trout on burbot is evident in Lake Superior, Lake Huron, and Lake Michigan, where burbot decreased as lake trout increased. Predator-prey systems range from diverse in Lake Superior (i.e. many species of prey and predators) to simple in Lake Huron and Lake Michigan (i.e. only two prey species; alewife and rainbow smelt). Deep-water chubs seem to cycle in abundance through density dependent changes in femaleness, which increases as abundance decreases. Prey fishes sometimes exhibit changes in behavior (i.e. change in Alewife behavior in Lake Ontario, as when they stay offshore until later in year) or size structure (i.e. rainbow smelt decrease in size in all Lakes). In all lakes, a loss of structure and diversity in deep water fish communities are evident. Analyses need to include both temporal and spatial variation, so could include other large lakes of the world. Predator-prey models are already being parameterized to examine qualitative changes in prey/predator community structure over time and among lakes. Mechanistic models could be constructed with data from all lakes. Also, the Thieubeux Dickie model could be used to examine biomass size-spectra of aquatic food webs (i.e. from primary producers up to top predators) among the Great Lakes.

Climate change – What effects on fish habitat might result from changing water levels? We could examine historical patterns of lake-level change for association with temporal patterns of change in fish abundance (i.e. walleye, centrachids). We could contrast similar embayment areas in different lakes, to see if some lakes (i.e. Superior, Ontario) exhibit smaller fluctuations than other lakes (i.e. Michigan, Huron, St. Clair and Erie). Fishery data for short historic periods (i.e. 20-40 years back) could be examined for changes in recruitment patterns. Sediment cores for longer historic periods (i.e. 100-150 year back) could be examined for water level and fish history. We could use GIS models to compare changes in available habitat at different lake levels, but would likely need thermal and wind factors (e.g. Minns' Lake Erie habitat supply model). We could use archival data sets (e.g. scales) to explore associations between regional climactic events and biological events. How might warmer conditions affect alewife winter survival? To answer this question, we could compare alewife die-off events to historic temperature data. Also, we could compare condition and lipid levels in alewives in fall and spring as an indication of alewife susceptibility to increasing temperature. Will warmer conditions lead to reduced tendency for lakes to turn over? Will riverine thermal and hydrological conditions become more variable? Analyses would require alignment of time-series reconstructions from case studies to document existence of synchronous events (i.e. would support regional driving forces). Water-column temperature data are probably lacking for most lakes.

Potpourri – Lake whitefish increased in all Great Lakes except Lake Erie. As lake whitefish populations increased, they generally decreased in body condition, possibly coincident with density dependence or loss of food supply (*Diporeia*). Gobies are now increasing in all lakes. Zooplankton production declined in Lakes Erie and Michigan, particularly inshore. Smallmouth bass increased in Lakes Erie and St. Clair. Lake trout still do not reproduce widely in Lakes Ontario, Erie, Huron, and Michigan, possibly because of early mortality syndrome (EMS). Exotic species will likely increase in all Great Lakes. Contaminants will likely persist for many years, but no one seems able to document solid effects on aquatic food webs, though endocrine disrupters may be problematic. Planktivore biomass is currently reduced in some lakes. The number of species in commercial catches is reduced in some lakes. What are the effects of increasing shoreline development? How will reduced TFM use affect fisheries in the lakes? Few changes in zooplankton communities are evident. Fishing effort has declined, but is still too high in some areas of the lakes. Will reduced zooplankton production lead to reduced larval fish recruitment? What will be the future trajectory of goby-mussel associations? What is the importance of behavioral adaptations to avoiding predation on community dynamics? Are phosphorus and zebra mussel changes separable? How have inshore changes affected fish recruitment and habitat? Can we predict the effects of exotic invaders? Is there a relationship between changes in the nearshore zone and the offshore fish community (e.g. spawning areas for forage fish)? What is the spatial and temporal distribution of carrying and productive capacity across the lakes? How stable are the current system states? What is important in promoting system stability? Has the productive capacity of the system changed over time? Are systems with full functional groups more resistant to pertrbations? Is there a single K or does it vary as you change the community?

SCOL2 Salmonid Communities in Oligotrophic Lakes -2

SCOL2 – Workshop II – Participants
Harkness Laboratory, Algonquin Park, Ontario
August 16 - 18, 2001

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SCOL2 Salmonid Communities in Oligotrophic Lakes -2

SCOL2 – Workshop II – Agenda
Harkness Laboratory, Algonquin Park, Ontario
August 16 - 18, 2001

Thursday, 16 August 2001

7:00 – 8:00 am	Breakfast
8:00 – 8:30	Welcome and Introductions – Steve Kerr
8:30 – 9:30	Top Down – Jim Bence
9:30 – 10:30	Bottom Up – Joe Koonce
10:30 – 11:00	Coffee Break
11:00 – 12:00	Food Web Structure – Doran Mason
12:00 – 1:00 pm	Lunch
1:00 – 3:00	Panel Discussion – Lead authors identify mechanisms that demonstrably account for patterns of change among fishes in each Great Lake.
3:00 – 3:30	Coffee Break
3:30 – 5:30	Breakout Groups – Discuss and develop topics from panel discussion to reach consensus on mechanisms that are most likely and those that are not likely.
5:30 – 6:00	Rest Period
6:00 – 7:30	Dinner

Friday, 17 August 2001

7:00 – 8:00 am	Breakfast
8:00 – 8:30	Review Progress – Mike Hansen
8:30 – 9:30	Ecosystem Health and Integrity – Randy Eshenroder
9:30 – 10:30	Climate Change – Mike Jones
10:30 – 11:00	Coffee Break
11:00 – 12:00	Ecosystem Function and Structure – Gary Sprules and Steve Kerr
12:00 – 1:00 pm	Lunch
1:00 – 1:30	A SCOL2 Ecosystem Approach Deconstructed – Henry Regier
1:30 – 3:00	Panel Discussion – Lead authors identify mechanisms that demonstrably account for patterns of change among fishes in each Great Lake
3:00 – 3:30	Coffee Break
3:30 – 5:30	Breakout Groups – Discuss and develop topics from panel discussion to reach consensus on mechanisms that are most likely and those that are not likely.
5:30 – 6:00	Rest Period
6:00 – 7:30	Dinner

Saturday, 18 August 2001

7:00 – 8:00 am	Breakfast
8:00 – 8:30	Review Progress – Steve Kerr
8:30 – 10:30	Breakout Groups – Finalize list of mechanisms
10:30 – 11:00	Coffee Break
11:00 – 12:00	Plenary – Breakout Group Reports
12:00 – 1:00 pm	Lunch
1:00 – 3:00	Plenary – Breakout Group Reports (continued)
3:00 – 3:30	Coffee Break
3:30 – 6:00	Wrap-Up – Steve Kerr and Mike Hansen (Where do we go from here?)
6:00 – 7:30	Dinner

SCOL2 Salmonid Communities in Oligotrophic Lakes -2

SCOL2 – Workshop II – Summary
Harkness Laboratory, Algonquin Park, Ontario
August 16 - 18, 2001

Jim Bence – Top-Down Effects

Top-down effects on TP and Chlorophyll-1 by Daphnia are not evident for any of the Great Lakes (though Lake Erie was included in the analysis). Lake Ontario and Lake Superior lack moderate sized plankton, an effect of intense planktivory, or in the case of Lake Superior, a lack of nutrients. A large fraction of zooplankton biomass Lake Huron is in the size range 1-2.5 mm. High levels of phaophyton are evident, which may be an indicator of algae under stress. A 3-fold difference in TP and a 11-fold difference in alewife recruitment between Lake Huron and Lake Ontario suggest alewife may collapse in Lake Ontario. Alewives are the main prey fish in Lake Ontario, while the remaining lakes have other prey fish species. Alewives grow fastest in Lake Michigan, while alewives in Lake Ontario grow little after age 3. In Lake Michigan, alewife recruitment did not decline as abundance of older fish declined, but as predator biomass increased, age 2+ alewives declined. The top-down effect is not extending down to the age classes responsible for most of the total consumption: 50% of consumption is by age-0 alewives. Lake Ontario has more prey biomass than the other lakes, but most is concentrated in age 0-1 alewives. In Lake Ontario, less biomass is tied up in chinook salmon and lake trout, but these two species account for 70-80% of prey consumption. Lake Superior has 50-60 kg per ha of predator biomass tied up in longer-lived species such as siscowet, whereas Lakes Michigan, Huron and Ontario have less than 10 kg per ha. Chinook salmon exhibit the fastest growth in Lake Ontario. In Lake Superior, lake trout size at age-10 declined; lake trout are half as big (kg) as they were in the 1970s, which is consistent with increased biomass. Lake Erie needs to be added to the analysis. Anomalous observations, such as the high levels of piscivores in Lake Superior and alewives in Lake Ontario, need to be examined, as do the departure of lakes from the TP-chl a relationship. Bythotrephes abundance needs to be included as a measure of top-down planktivory influence. Indirect effects need to be examined, including: (1) Perch, burbot, deepwater sculpin recovery may be linked to decreased alewife abundance; (2) Contrast between TP and YOY alewife vs. TP and total forage fish; (3) Dampening of effects by abundance of age 0 alewife; and (4) Effect of decline in abundance of sea lamprey.

Joe Koonce – Bottom-Up Effects

Many ecosystem models are not operating on the correct temporal and spatial scales for examining bottom-up effects. Plankton requires the use of fine spatial and temporal scales; however, the models used are operating on large spatial and temporal scales. Trophic status affects whether the production occurs in the benthic or pelagic. The pattern of TP versus Chlorophyll-a varies in Lake Erie, which suggests something is occurring; the major difference with time is the presence of zebra mussels. System primary production is poorly understood; all production in the system is not being considered. Bottom-up effects may affect system productivity less than the distribution of productivity. Pelagic food webs are limited; much of the organic production that organisms can utilize if they change their distribution has been missed. The existing hypotheses and models are incomplete; the system must be thought of as a more complex model. The allocation of system production needs to be expanded to examine how much production plankton consumes and how much benthos consumes. The crossover between macrophyte-benthic production and pelagic production needs to be explored. We also need to examine the relationship between Chlorphyll-a and TP.

Doran Mason & Ann Krause – Food Web Structure and Function

Objectives of the analysis were to quantify changes in the structure and energy flow in food webs and relate these changes to the fish community. ECOPATH was used to balance the food web, ECOSIM was used to fit the food web to time series data and simulate the potential impacts of species invasions, and NETWORK analysis was used to model perturbations in the ecosystem. Modeling scenarios included: 1984 (baseline), 1996 (zebra mussels, *Bythotrephes* and *Diporeia*), zebra mussels only, *Bythotrephes* only, and *Diporeia* decline only. The food web was compartmentalized into 36 live compartments and detritus; these compartments are still being modified. The time series model fits the data reasonably well, but does not capture annual fluctuations; the model did capture major increases and declines. Trophic efficiency was examined for each of the scenarios: food chain length increased for the 1996 scenario and transfer efficiencies changed between levels; food chain length decreased dramatically for zebra mussels only transfer efficiencies changed between levels; food chain length increased for *Bythotrephes* only; *Diporeia* only was similar to the 1984 scenario. The zebra mussels only scenario showed the greatest amount of material recycled through the system when compared to baseline conditions. Sea lamprey and detritus dominated all scenarios, except zebra mussels only, where juvenile lake trout and lake trout dominated, possibly because lake trout become the dominant predator if sea lamprey are gone from the system,. Zebra mussels affect the system by increasing fish dependency on bluegreen and green algal groups, while decreasing dependency on diatoms. The number of effective trophic levels decreased, and trophic efficiency decreased. The number of cycles decreased, whereas the quantity of material recycled increases. System activity (flows) and system organization decreased, which could result in a decrease in the ability of a system to respond to a perturbation.

Ann Krause – Quantifying Ecosystem Health

Network analysis, in conjunction with Ecopath and Ecosim models, can be used to quantify ecosystem health in the Great Lakes. Network analysis offers an integrated perspective of food webs and can be used to explore and interpret trends in indices of biotic integrity over time. Ecosystem health is referenced, but is often vaguely defined, in many Great Lakes policy documents. Callicott defined ecosystem health as "linked ecological processes that compose ecosystems that are occurring naturally – that is, as they occurred historically." Several definitions of ecosystem health have been proposed. Ulanowicz defined ecosystem function as "overall level of activity in processing material and energy" and ecosystem structure as "how effectively its various processes are linked to each other." Network analysis includes input-output, trophic level, cycle, and information analyses, each of which includes measures that can be related to ecosystem health. Information analysis is based on the equation, Capacity = Ascendancy + Overhead. Capacity is defined as the capacity for development. Ascendancy is defined as healthy performance. Overhead is defined as resilience and creativity. Ecosystem health and integrity should have a social component; so network analysis needs to integrate with public policy. Network analysis can help to quantify ecosystem health in the Great Lakes.

Randy Eshenroder – Policy Exercise and Application of SCOL II

Great Lakes policy makers need a better definition of ecosystem health and integrity. Ecosystem health involves keeping the processes intact as they were historically, and needs to consider human use of the system. Ecosystem integrity is usually used when protecting undisturbed, pristine systems that do not have much human disturbance. Those involved in SOLEC and Chesapeake Bay developed indicators of ecosystem health that may be of value in the Great Lakes. Policy exercises need to be undertaken; the policy must appeal to managers, be adaptive, and involve stakeholders. Goals should include assessing the robustness of Lake Superior's presumed integrity and quantifying a minimum state of health for each of the lower Great Lakes. Ecosystem integrity may not be the issue, as stakeholders are not interested in returning Great Lakes ecosystems to previous integrity if it means losing preferred species or money. Partitioning lakes to meet the expectations of all groups has been shown not to work in Lake Huron; however, managing for different user groups may have been what has helped slow the degradation of the Great Lakes. For the lower Great Lakes, it may be necessary to quantify a minimum consensus state for each lake, not a minimum state of health. What role does SCOL2 play? And, should we enlist other agencies to assist instead of relying on fisheries agencies?

Mike Jones & Brian Shuter – Climate Change and Great Lakes Fisheries

What might the effects of future climate-related changes be for Great Lakes Fisheries? What are the hypothesized effects of climate change? Climate change models CGCM1 and HadCM2 were used to forecast conditions for a base period (1961-1990) and future decades (Present-2090). Air temperature is much warmer: CGCM1 predicted a 5-6°C increase (greatest in Lake Erie), HadCM2 predicted a 2.5-3°C (greatest in Lake Superior). Increased air temperature is predicted to greatly affect water temperature and ice cover; ice cover could decrease 9-fold. Much wetter conditions are predicted: CGCM1 predicted that temperature and precipitation changes would lead to lower water levels, and HadCM2 predicted modest declines to increases in water levels. The effects of altered lake levels in Lake Superior would include changes in the percentage of good spawning habitat for fishes. Western Lake Erie could see a 300% increase in spawning habitat shallower than 3 meters if water levels drop 1 meter, a complete loss of habitat deeper than 7 meters, and a 900% increase in habitat less than 3 meters deep if water levels drop 2 meters. Water temperatures will likely rise significantly; the main effect will likely be on winter water temperatures. Large-scale climatic factors appear to be affecting recruitment of walleye. Local and regional climatic factors appear to be affecting Lake Erie walleye: higher recruitment has occurred in warmer years. Studies in Lake Ontario suggest that climate has a big effect on fisheries. Future research should focus on temperature effects on embayments and on lake-level effects on near shore areas.

Gary Sprules & Steve Kerr – Ecosystem Function and Structure

Biomass size spectra include internal information on trophic positions at periodic intervals, with the periods based on body size. Fish domes persist through time despite many internal changes, and give an indication of overall health status. Dome shapes are remarkably similar between marine systems and Great Lakes, although there can be substantial variation in parts of the same system. Fish domes can be used to estimate production inexpensively because overall density is expressed as a function of body size interval. Several types of ecosystem change can be diagnosed using fish domes. Changes in fish size at the extremes of the dome indicate excessive fishing mortality or reduced recruitment. Changes in overall abundance are indicated by changes in the y-axis. Changes in overall body size of the fish assemblage are indicated by changes in location of the dome along the x-axis. Changes in curvature are caused by complex changes in growth and predation within the fish assemblage. Changes in residuals over time indicate changes in ecosystem structure.

Phil Ryan – Lake Erie Verbal Narrative

Lake Erie has three basins, each with multiple stocks of fish and differences in trophic state, nutrient inputs, and food web structure. Rainbow smelt in the Central basin increased as walleye and blue pike abundance decreased. A strong fishery for rainbow smelt was developed with high quotas in the mid-1980s. The fishery currently has lower quotas, but is not constrained by quotas. The lake whitefish population was reduced by rainbow-smelt predation; the release from predation by increased walleye recruitment allowed the fishery to begin to recover in the mid-1980s. Rainbow smelt are a major prey species in the Eastern basin. With the introduction of zebra mussels, rainbow smelt declined in abundance and condition. Changes in the prey fish community have been reflected in predator growth, fecundity, and mortality. Walleye changed the composition of the prey community after the mid-1980s. Yellow perch density differs across the lake: abundance decreases from west to east. Poor recruitment and other factors such as zebra mussels caused a large decline in abundance in the mid-1980s. Fish community structure has been most greatly affected by strong walleye recruitment, over-fishing of walleye, and predation on planktivores.

Plenary Discussion – Common mechanisms driving change across the Great Lakes

Great Lakes ecosystems are most stable when biomass is in large, long-lived predators. High predator biomass dampens changes in the system. The systems tend to move toward a biomass that is dominated by large, long-lived predators, but introductions and harvest impedes such movement. Top-down and bottom-up effects are difficult to separate; bottom-up effects are often less prevalent and overshadowed by top-down effects. The systems appear to be exhibiting transient behavior. We lack the ability to detect cascades from data; measurement error is related to the scale used. Currently, small system techniques are being applied to larger systems; we should be using techniques used in marine systems. Lakes that retained mostly native predators and prey have recovered fastest. Juvenile life stages of predators may be crucial for controlling age-0 alewives and other planktivores. Near shore components may be crucial areas for fish recruitment, but are most susceptible to climate change and human influence. Near shore areas are important for energy flow in the system, so destruction or change of only a few near shore areas may be detrimental. Why is Lake Ontario such an anomaly?

Steering Committee – Workshop 3

Workshop 3 will rely on *written narratives* of each lake as models for evaluating the reasonableness of fish community objectives (FCOs). Each *written narrative* will synthesize the history and science of how and why each Great Lake changed. Case history authors from Workshop 1 were asked to lead narrative teams for all lakes, except for Lake Huron and Lake Erie. Chuck Bronte agreed to lead the Lake Superior team, Chuck Madenjian agreed to lead the lake Michigan team, Don MacLennan agreed to lead the Lake St. Clair team, and Roger Knight agreed to lead the Lake Erie team. Ed Mills will be asked to lead the Lake Ontario team and either Dave Reid or Mark Ebener will be asked to lead the Lake Huron team. Jim Bence will also be asked to serve on the Lake Huron team. All of the analysts from Workshop 2 agreed to be part of the lake teams. At Workshop 3, the FCOs for each lake will be vetted in light of the written narratives, with the involvement of key fishery managers for each lake. The workshop will be held in late summer (July or August), 2002, at either Harkness Laboratory (Ontario), Isle Royale (Lake Superior), Stone Lab (Lake Erie), or Wingspread (Racine, Wisconsin).

SCOL2 Salmonid Communities in Oligotrophic Lakes -2

SCOL2 – Workshop III – Participants
Le Manoir du Lac DeLage, Quebec
August 14 – 18, 2003

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SCOL2 Salmonid Communities in Oligotrophic Lakes -2

SCOL2 – Workshop III – Agenda
Le Manoir du Lac DeLage, Quebec
August 14 – 18, 2003

Thursday, August 14

Afternoon – Participants arrive
6:00 PM – Cocktails with Hors d'oeuvre (meeting room)

Friday, August 15

8:00 AM – Breakfast Buffet (dining room)
9:00 AM – Introduction – Kerr and Hansen
- Overview of workshop objectives
- Synthesis of workshops I and II
- Objectives and outline for synthesis paper

9:45 AM – Modeling papers (break at 10:45-11:00 AM)
- Top-down effects – Bence
- Bottom-up effects – Koonce

12:00 PM – Working Lunch
1:00 PM – Modeling papers (break at 2:00-2:15 PM)
- Climate change effects – Jones
- Food web effects – Mason

3:15 PM – Wrap-up discussion
- Where are the lakes going?
- What are recommendations or implications for future management?

5:00 PM – Dinner (dining room)

Saturday, August 16

8:00 AM – Breakfast Buffet (dining room)
9:00 AM – Round-table discussion (break at 10:30-10:45 AM)
- What are commonalities among modeling papers?
- What are contradictions among modeling papers?

12:00 PM – Working Lunch
1:00 PM – Plenary synthesis session (break at 3:00-3:15 PM)
- Develop rough outline for synthesis paper
- Outline serves as topics for breakout groups Sunday AM

5:00 PM – Dinner (dining room)

Sunday, August 17

8:00 AM – Breakfast Buffet (dining room)
9:00 AM – Breakout groups (break at 10:30-10:45 AM)
- Develop topic sentences for outline of synthesis paper

12:00 PM – Working Lunch
1:00 PM – Plenary session (break at 3:00-3:15 PM)
- Finalize topic sentences for outline of synthesis paper

4:00 PM – Summary – Kerr and Hansen
5:00 PM – Dinner (dining room)

Monday, August 18

8:00 AM – Breakfast Buffet & Departure

SCOL2 Salmonid Communities in Oligotrophic Lakes -2

SCOL2 – Workshop III – Summary
Le Manoir du Lac DeLage, Quebec
August 14 – 18, 2003

Mike Hansen (Brief History of SCOL2) – The first SCOL symposium, Salmonid Communities of Oligotrophic Lakes was convened in Geneva Park, Ontario, in July 1971, by Henry Regier and Ken Loftus. The symposium focused on effects of cultural eutrophication, fisheries exploitation, and non-native species on oligotrophic lakes of the world (not just North America). The symposium proceedings were published in the Journal of the Fisheries Board of Canada in June 1972 (Volume 29, Number 6). The second SCOL initiative appeared as a pre-proposal by Randy Eshenroder to the GLFC BOTE on 17 September 1997. Steve Kerr and Mike Hansen were named co-principal investigators on 9 March 1998. A steering committee for the task area was formed on 1 April 1998. The first workshop was held at the University of Toronto at Mississauga on 18-20 May 2000. Case studies of the Great Lakes were presented by Chuck Bronte (Superior), Chuck Madenjian (Michigan), Dave McLeish (Huron), Don MacClennan (St. Clair), Phil Ryan (Erie), and Ed Mills (Ontario). The second workshop was held at Harkness Laboratory on 16-18 August 2001. Cross-lake comparisons were presented by Jim Bence (top-down effects), Joe Koonce (bottom-up effects), Doran Mason (food web structure and function), Mike Jones (climate change), and Gary Sprules (biomass size spectra).

Mike Hansen (Status of Publications from Workshop 1) – The intent of the first workshop was to publish case studies of each lake in two forms, including a short perspective in the Canadian Journal of Fisheries and Aquatic Sciences and a long case history in the Technical Reports of the Great Lakes Fishery Commission. For Lake Superior, the short paper is virtually completed and the long paper will be completed by fall 2003. For Lake Michigan, the short paper is published and the long paper is in review at GLFC. For Lake Huron, the short paper is in final preparation and the long paper is not being prepared (i.e. future is uncertain for the long paper). For Lake Erie, the long paper is in the final stages of writing and the short paper is not being prepared (i.e. future is uncertain for the short paper). For Lake Ontario, the short paper is published and the long paper is in review at GLFC.

Steve Kerr (Overview of the History of the Great Lakes) – When human technology interacts with ecosystems, humans win. Human technology is unfolding exponentially with direct and indirect effects on ecosystems. Impacts may be global (e.g., non-point contaminants, climate change) or local (e.g., species introductions, eutrophication). We need to anticipate the unanticipated. Since SCOL1, technological impacts expanded to coastal ecosystems, cod were lost, global oceans are now at risk, and large-bodied species are being rapidly fished up. How best can we cope with local effects of global factors? Genetic manipulation may result in what could be considered a possible bio-error. Bio-terror is an applied bio-errror. Jones stated that it is relatively easy to understand the linkage between stressors and ecosystems (e.g., exploitation, cultural eutrophication). With current stressors like global climate change, it is not as easy to see direct linkages between insult and impact.

Jim Bence (Top-Down Effects) – Chinook size at age 3, as an index of growth, declined in lakes Huron and Michigan. Greater differences between lakes Ontario, Michigan, and Huron. Lake trout size at age 10 declined in Lake Superior, perhaps due to lower prey fish biomass in Lake Superior than in Lakes Huron or Michigan. In Lake Michigan, alewife exhibit compensation, because abundance of age-0 alewife fluctuates widely, but the fluctuation is not related to adult stock decline. Across lakes, size of age-3 alewife was 168 in Lake Michigan, 158 in Lake Huron, and 153 in Lake Ontario. Prey fish biomass is related to spring total phosphorus, though the relationship differs among lakes. Physical characteristics of lakes are related to the growth efficiency of predators. In years with high *Bythotrephes*, light penetration is low, which leads to little or no overlap between predators and prey. In Lake Ontario, large zooplankters are scarce, so alewives grow slowly. Algal biomass is difficult to quantify with one cruise, so we need broader spatial and temporal coverage. In Lake Michigan, bloater population fluctuations may not be related to alewife. Whitefish recruitment is not synchronous with the timing of the stocking program. In Lake Huron, rainbow smelt existed before lake whitefish recruitment increased. Top-down effects may not be as great due to compensatory recruitment. Why is there so much alewife recruitment in Lake Ontario? Can we expect top-down effects if we lump trophic levels? Is it possible to balance the needs of Pacific salmon (e.g. lots of alewife) and restoration (e.g., few alewife)?

Joe Koonce (Bottom-Up Effects) – Evidence for bottom-up effects on aquatic food webs include a strong exponential relationships between phosphorus loading and phosphorus concentration, phosphorus concentration and chlorophyll concentration, and chlorophyll concentration and fish production. Food web structure is also related to primary production. Theories of trophic cascade, particle size spectra, and productive capacity also derive from bottom-up principles. Empirical relationships suggest that yield is strongly related to phosphorus, chlorophyll, and primary production. Primary production is a property of the system, so comparing primary production among systems can be useful for understanding how primary production regulates system structure and function. However, in any system, primary production may be allocated between benthic and pelagic components differently, which may confound simple comparisons among systems. Based on a production allocation model, as total phosphorus concentration increases, production by phytoplankton increases asymptotically, whereas macrophyte production decreases asymptotically. However, the trade-off between phytoplankton and macrophyte production results in lower sensitivity of total system production to changes in total phosphorus concentration. Using the same model to examine the effect of lake morphology, with lake area constant and maximum depth varied, primary production increases as lake depth decreases, for the same total phosphorus concentration. For Lake Erie, where the littoral zone is a small part of the total area of the lake, primary production from macrophytes is not as large as in small lakes, and increases in total phosphorus have a larger effect on total primary production. In general, system primary production is poorly understood, existing theories and models are incomplete, bottom-up effects may have less effect on productivity than the distribution of productivity, and the distribution of primary production is more fundamental to fish community structure.

Mike Jones (Climate Change Effects) – Numerous lines of evidence in the Great Lakes basin suggest that climate has changed significantly since the 1960s and will continue to change in the next several decades. Models suggest that warmer climate will create more habitat volume for all thermal guilds of fishes, which should increase overall fish production, with disproportionately greater benefits for warm-water fishes. Some species will increase their ranges northward into the Great Lakes region, from more southern locations. For river-spawning walleye, climate change may increase recruitment through changes in river discharge, but variation in recruitment will be large. For lake-spawning lake trout and walleye, climate change will alter the distribution of habitat at suitable depths through changes in lake levels, but the availability of suitable habitat will not be greatly altered. For juvenile and adult walleye, climate change will alter the amount of habitat by changing the distribution of light and temperature, but the net effect on growth and survival will be hard to predict. In conclusion, effects of climate change are likely to more complex than can be easily predicted from existing models of habitat supply, though modeling will likely be helpful for exploring potential effects.

Gary Sprules (Biomass Size Spectrum) – Use normalized biomass size-spectra as a monitoring tool for indexing ecosystem change. Living biomass exhibits regularity in patterns of logarithmic intervals of body size. Patterns reflect ecological and physiological processes, so changes in parameters (patterns) may indicate changes in environmental conditions. Good for monitoring. Spatial patterning of organisms can affect food web patterns.

Lars Rudstam (Pivotal Event Summary) – Pivotal events for the Great Lakes basin and for each Great Lake were summarized by a graduate student of Ed Mills. Steve Kerr solicited the summary of pivotal events to provide a means of organizing past events, which may help to organize thinking about the last 20 years. In addition, we need a chronology of major disturbances during the 1970-2000 period of primary interest to our SCOL2 initiative. The summary of pivotal events would be stronger if it included historical human events prior to European settlement and a longer ecological history, perhaps based on reviews of paleo-limnological samples. Kerr and Hansen will use the summary for their synthesis, if necessary.

Synthesis Outline – The synthesis outline was prepared initially by brain-storming a list of forcing functions and then discussing those forcing functions within upper-lake (Superior, Michigan and Huron) and lower-lake (Erie and Ontario) groups. In plenary, each group reported on their discussions of forcing functions and then agreed on an outline for the synthesis manuscript. Kerr and Hansen will write the synthesis manuscript using the prospective outline, but relying on cross-lake comparison manuscripts and within-lake case histories. Therefore, the synthesis manuscript cannot be completed until these other manuscripts are available for scrutiny by Kerr and Hansen.

- Introduction (History of SCOL, SCOL2, and objective of SCOL2 synthesis workshop).
- Demographic/Political context for the future.
- Assess the potential futures of the GLFC systems ("Looking Forward"; forcing functions).
    - Nutrients.
    - Exploitation.
    - Species introductions and emerging diseases.
    - Stocking.
    - Pest control.
    - Loss of key species.
    - Effects of climate change.
    - Effects of landscape change.
    - Effects of navigation "improvements".
    - Impacts of aquaculture.
    - Contaminants (fish and algae).
    - Changes in water quality.
- Major Findings.
- Implications for Joint Strategic Plan.
- Predictions.
    - Lakes.
    - Basin.

Symposium Title: Salmonid Communities of the Great Lakes: What Does the Future Hold for the Laurentian Great Lakes?

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Description: Fish communities of the Laurentian Great Lakes exhibited dramatic functional and structural changes in decades preceding the 1971 Salmonid Communities in Oligotrophic Lakes (SCOL) Symposium, which was later published as a special volume of the Journal of the Fisheries Research Board of Canada (Volume 29, Number 6, June 1972). Since SCOL, fish communities of the Laurentian Great Lakes continued to change in ways that were not anticipated by SCOL participants. Over that period, many new sources of ecosystem stress were recognized and more was learned about effects of old stresses on Great Lakes fish communities. We organized a sequence of three workshops that focused on contemporary scientific issues and management needs affecting fish communities of Great Lakes ecosystems, to determine if we could better anticipate the future of Great Lakes fish communities. This symposium will consolidate and integrate products of those three workshops into a single session, to enhance communication of our findings to North American fisheries professionals.

Format: A full day session with 12 speakers.

Moderator: Michael J. Hansen

Audiovisual Needs: Laptop computer with LCD projector.

Speakers and Topics:

TIME	SPEAKER	TITLE
8:20 AM	Michael J. Hansen	Introduction to SCOL2
8:40 AM	Charles R. Bronte	Fish Community Changes in Lake Superior, 1970-2000
9:20 AM	Charles P. Madenjian	Dynamics of the Food Web in Lake Michigan, 1970-2000
10:00 AM	Break	
10:20 AM	Norine E. Dobiesz	Ecology of the Fish Community in Lake Huron, 1970-2000
11:00 AM	Brian Locke	Fish Community Response to Ecological Change in Lake St. Clair, 1970-2000
12:00 PM	Lunch	
1:00 PM	Roger L. Knight	A Fisheries Management Perspective on the Ecology of Lake Erie, 1970-2000
1:40 PM	Edward L. Mills	Ecological and Fish Community Changes in Lake Ontario, 1970-2000
2:20 PM	James R. Bence	Salmonines and Prey Fish: The Role of Top Predators and Contrasting Stories among the Great Lakes
2:40 PM	Break	

3:00 PM	Joseph F. Koonce	Allocation of Benthic and Pelagic Production: A System Perspective on Primary Production in Great Lakes
3:20 PM	Brian J. Shuter	Potential Impact of Climate Change on Great Lakes Aquatic Environments and Implications for Fish and Fisheries
3:40 PM	Doran M. Mason	Food-Web Disruption: A Comparison of Lakes Michigan and Huron
4:00 PM	W. Gary Sprules	The Use of Shape Parameters from the Normalized Zooplankton Biomass Size Spectrum as an Index of Community Change in the Laurentian Great Lakes
4:20 PM	Michael J. Hansen	A Synthesis of Patterns and Processes Causing Change in Great Lakes Food Webs during 1970-2000 and Prospects for Future Change
4:40 PM	Adjourn	

Sponsor:

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