Lake Winnipeg Science Workshop, November 29-30, 2004

Edited by

G. Burton Ayles and David M. Rosenberg

for

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FOREWORD

The Lake Winnipeg Science Workshop was organized by an *ad hoc* Steering Committee at the request of the Provincial Minister of Water Stewardship and the Federal Ministers of Fisheries and Oceans Canada (DFO) and Environment Canada (EC).

Members of the Steering Committee, in alphabetical order, were: Vic Cairns (DFO, Burlington), Kevin Cash (EC, Saskatoon), Robert Fudge (DFO, Winnipeg), Keith Kristofferson (DFO, Winnipeg), Joe O'Connor (Water Stewardship, Winnipeg), Peter Thompson (DFO, Sarnia), and Dwight Williamson (Water Stewardship, Winnipeg). The work of the Steering Committee was supported by Burton Ayles (Consultant, Winnipeg) and David Rosenberg (Consultant, Winnipeg) who also chaired and facilitated the workshop.

The workshop report was drafted by Burton Ayles and David Rosenberg and was reviewed by the Steering Committee. The recommendations were prepared after the workshop and were based on the workshop results and discussions.[1] They were approved by the Steering Committee as the outcomes of the workshop but they do not necessarily reflect the positions of the government departments involved.

[1] The Steering Committee was aided by a verbatim report, prepared by a court reporter, of the proceedings of the second day of the workshop.

ABSTRACT

Lake Winnipeg is the tenth largest freshwater lake in the world and the third largest lake wholly within Canadian boundaries. It supports important commercial, recreational and subsistence fisheries, is a centre for significant cottage and on-water recreational activities, and is the primary reservoir for Manitoba's hydro-electric production system. It is of critical environmental, social and economic importance for the province of Manitoba

Scientific findings indicate that the Lake Winnipeg ecosystem is deteriorating mainly because of increased loading of nutrients. Thus, the Manitoba government announced the Lake Winnipeg Action Plan in 2003. It was recognized that strong science was needed to support both implementation of the Lake Winnipeg Action Plan as well as to ensure development and implementation of other measures to sustain the Lake's ecosystem over the long term. Manitoba has asked federal departments (Fisheries and Oceans Canada [DFO] and Environment Canada [EC]) to collaborate with the implementation of this science plan.

As an important step in that process, the Lake Winnipeg Science Workshop (LWSW) was held November 29–30, 2004 at the Freshwater Institute in Winnipeg, Manitoba. The primary goal of the workshop was:

> *To identify science priorities and research needs for Water Quality and Nutrients, Fish Communities and Fish Habitat in Lake Winnipeg in support of current and emerging management issues as identified by the agencies directly responsible for the Lake's aquatic resources.*

The workshop was organized by the Department of Water Stewardship, DFO and EC. Participation included, amongst others, individuals from federal and provincial departments, Manitoba Hydro, City of Winnipeg, University of Manitoba, Lake Winnipeg Research Consortium, First Nations, and Canadian and US members of the Ecosystem Health Committee of the International Joint Commission's International Red River Board.

The workshop addressed three themes: water quality and nutrients, fish communities and fish habitat. There were four sessions: 1. an opening introductory plenary that addressed management issues in Lake Winnipeg and lessons learned from experiences in the Great Lakes; 2. a session to address science needs and develop proposals within each of the three themes; 3. a session to address interactions and connections between the proposals developed in the second session; and 4. a concluding session to review the proposals and identify priorities.

From the presentations and discussions it was clear that Lake Winnipeg is an aquatic ecosystem under stress. Furthermore, although the causes of the problems are understood in general, our scientific knowledge of the Lake is limited and insufficient to answer some of the specific questions posed by Lake managers.

The primary recommendation[2] from the workshop addressed the specific objective to identify science priorities and research needs in support of current and emerging management issues:

1. *The Departments should develop an integrated science program proposal for funding within each Department, based on the research proposals described in this workshop.*

Government agencies have tended to narrowly focus their support of aquatic environmental science programs. Thus, individual programs considered fish without habitat, and lakes without the rivers, streams and watersheds that they depend on. In the future, a whole-watershed approach will be necessary to develop the scientific knowledge and understanding to support aquatic ecosystem-based management for Lake Winnipeg. The priority research proposals are identified within the three workshop themes but the importance of integration between disciplines and between agencies is critical.

For the theme of “water quality and nutrients” priority proposals focused on developing a better understanding of the relationship between Lake Winnipeg watersheds and water quantity and quality in the Lake and of the relationship between water quantity and quality and Lake biota:

- Identification of key biological endpoints, benchmarks and acceptable levels of change for key components of the ecosystem (e.g. critical fish populations, algal levels, etc.) and their relationship with nitrogen and phosphorous concentrations.
- Development of computer models of water movements within Lake Winnipeg and of the quantity and timing of water flows into Lake Winnipeg.
- Development of a computer-based model of landuse practices and landscapes and their effect on nitrogen and phosphorous inputs to Lake Winnipeg, and the improvement of precision and accuracy of estimates of nutrient loading in the Lake.

Other proposals included development of better knowledge of the causes of high bacterial levels at recreational beaches and the relationship between nutrient management and carbon sequestration in Lake Winnipeg.

For the theme of “fish communities” it was emphasized that effective management decisions depend on knowledge and understanding of fish populations (e.g. relative abundance, growth rates, year-class strengths, etc.). The highest priority proposal was:

- Establishment of an ongoing and extensive (broad temporally and geographically) standardized survey netting program to develop fish community indices for critical fish species and their variation over time and space.

Other proposals included:

- Determination of the effects of invasive species on the Lake Winnipeg ecosystem (a similar proposal was identified under the fish habitat theme).

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[2] The recommendations were prepared after the workshop and were based on the workshop results and discussions. They were approved by the Steering Committee as the outcomes of the workshop but they do not necessarily reflect the positions of the government departments involved.

- Determination of sources of fish mortality other than the commercial harvest (e.g. recreational and subsistence harvests, fish and bird predation, toxic algal blooms).
- Collection of Traditional Ecological Knowledge (TEK) and other local knowledge from elders and fishers on what is known about the fisheries and the ecosystem of Lake Winnipeg. (This proposal would also link to, and support, many of the other proposals from the workshop.)
- Determination of the genetic stock structure of commercial species (walleye, sauger, whitefish).
- Analysis of the potential effects of climate and climate change on the aquatic ecosystem.
- Establishment of routine tracking of contaminant levels in Lake Winnipeg fish, water and sediments.
- Development of an ecosystem model to understand the impact of changes in foodweb structure on fisheries productivity.

For the theme of "fish habitat" it was recognized that the protection of fish habitats is critical for the protection of the Lake Winnipeg ecosystem and that protection of these habitats depends on understanding their geographical extent and their use by fish and other components of the food chain. Four linked proposals addressed the priority need for baseline information on critical habitats:

- An aerial inventory of habitats in the North Basin and channel areas.
- Development of a fish habitat classification system for the South Basin.
- An assessment of use of tributaries and reefs by fish.
- An assessment of causes of the decline in wetland habitat.

Other proposals included:

- Development of a better understanding of the relevant importance of nutrients, light and temperature to the algal community of Lake Winnipeg.
- Collation of existing landuse information and river nutrient concentrations and nutrient load information into an integrated database.
- Determination of the causes and consequences of declines in zoobenthos communities in the Lake.
- Definition and description of critical habitat for SARA (federal Species at Risk Act) species.

Acting on these proposals should be but the first step in the development of an ongoing comprehensive science program for Lake Winnipeg. In addition, the LWSW Steering Committee made four special recommendations for the longer term. These recommendations came from an overall assessment of the keynote presentations, the results of the breakout discussions, comments from the Minister of Water Stewardship and the general discussions in plenary, and go beyond specific research studies:

2. *The Departments should develop an overarching administrative framework, similar to the Lakewide Management Plans developed under the Great Lakes Water Quality Agreement, for their joint management responsibilities for the Lake Winnipeg aquatic ecosystem.*

3. *The Departments should support ongoing governance mechanisms and initiate new mechanisms to ensure coordination of scientific activities on the Lake and its watershed to ensure that those activities address stated management needs.*

4. *The Departments should initiate triennial "State of Lake Winnipeg Conferences" to inform the public and the scientific community of the "health" of the system. As a first step to the establishment of regular conferences, the Departments should immediately begin the preparation of a "State of the Lake" report for Lake Winnipeg to provide a baseline for future progress against which to measure achievement of goals to improve the condition of the Lake.*

5. *The Departments should develop a comprehensive program of integrated monitoring of the biological, chemical and physical components of the Lake Winnipeg ecosystem and its watershed based on management objectives and science-based ecosystem indictors.*

There are serious knowledge gaps that hamper management of Lake Winnipeg and its fisheries. Managers and researchers can benefit significantly from experiences gained from other systems that have been studied more extensively, but the long-term health of Lake Winnipeg and its fisheries depends on a strong local science program. Implementation of the recommendations from this report will provide Lake managers with the tools they need for effective management of Lake Winnipeg.

Key words: Lake Winnipeg, freshwater ecology, fishery resources, water quality, fish habitat, aquatic ecosystem, biological stress, eutrophication, research proposals, management needs.

RÉSUMÉ

Le lac Winnipeg est la dixième plus grande étendue d’eau douce au monde et le troisième plus grand lac se trouvant complètement à l’intérieur des frontières canadiennes. Il supporte d’importantes pêches commerciales, récréatives et de subsistance, est un centre d’activités significatives de loisirs et de sports liés à la vie de chalet et aux activités sur l’eau, et représente le principal réservoir du système de production hydro-électrique du Manitoba. Il est d’une importance environnementale, sociale et économique cruciale pour la province du Manitoba.

Des conclusions scientifiques indiquent que l’écosystème du lac Winnipeg se détériore principalement à cause de l’augmentation de la charge d’éléments nutritifs. Conséquemment, le gouvernement du Manitoba a annoncé le Plan d’action pour le lac Winnipeg en 2003. On a reconnu qu’il fallait de forts éléments scientifiques pour appuyer la mise en œuvre du Plan d’action pour le lac Winnipeg et pour assurer l’élaboration et la mise en oeuvre d’autres mesures pour maintenir l’écosystème du lac à long terme. Le Manitoba a demandé à des ministères fédéraux (Pêches et Océans Canada [MPO] et Environnement Canada [EC]) de collaborer à la mise en oeuvre de ce plan scientifique.

Une des étapes importantes dans ce processus a été la tenue d’un atelier scientifique sur le lac Winnipeg, le 29 et 30 novembre 2004, à l’institut Freshwater à Winnipeg au Manitoba. Voici quel était le principal but de cet atelier :

> *Déterminer les priorités scientifiques et les besoins en recherche pour la qualité de l’eau et les substances nutritives, les communautés de poissons et l’habitat des poissons du lac Winnipeg en appuie aux questions de gestions courantes et nouvelles telles que déterminées par les agences directement responsables des ressources aquatiques du lac.*

L’atelier a été organisé par le *Department of Water Stewardship*, le MPO et EC. Parmi les participants se trouvaient, entre autres, des personnes de ministères fédéraux et provinciaux, Manitoba Hydro, la ville de Winnipeg, l’université du Manitoba, le *Lake Winnipeg Research Consortium*, les Premières Nations et des membres canadiens et américains du comité sur la santé des écosystèmes du conseil international de la rivière Rouge de la Commission mixte internationale.

L’atelier a abordé trois thèmes : la qualité de l’eau et les éléments nutritifs, les communautés de poissons et l’habitat des poissons. Il a eu quatre séances : 1. une plénière d’ouverture et d’introduction qui a traité de question de gestion du lac Winnipeg et des leçons apprises des expériences dans les Grands Lacs; 2. une session pour aborder les besoins en science et pour développer des propositions se rapportant à chacun des trois thèmes; 3. une séance pour aborder les interactions et les connections entre les propositions développer au cours de la deuxième session; et 4. une séance de clôture pour examiner les propositions et déterminer les priorités.

Selon les exposés et les discussions, il était clair que le lac Winnipeg est un écosystème aquatique qui subit des stress. De plus, bien qu'on comprenne en général les causes des problèmes, notre connaissance scientifique du lac est limitée et insuffisante pour répondre aux questions posées par les gestionnaires du lac.

La principale recommandation[3] de l'atelier traite de l'objectif spécifique qui est d'identifier les priorités scientifiques et les besoins en recherche en appui aux questions de gestions courantes et émergentes :

6. *Les ministères devraient développer une proposition pour un programme scientifique intégré, fondé sur les propositions de recherche décrites dans cet atelier.*

Les organismes gouvernementaux ont eu tendance à axer étroitement leur appui aux programmes de science de l'environnement aquatique. Il s'ensuit que des programmes particuliers étudiaient le poisson sans son habitat, les lacs sans les rivières, les cours d'eau sans les bassins versants dont ils dépendent. Dans l'avenir, une approche englobant l'ensemble des bassins versants sera nécessaire pour développer la connaissance et la compréhension scientifiques pour appuyer une gestion du lac Winnipeg fondée sur un écosystème aquatique. Les propositions concernant les recherches prioritaires sont identifiées dans les trois thèmes de l'atelier, mais l'importance de l'intégration entre les disciplines et entre les organismes est cruciale.

Sous le thème « qualité de l'eau et éléments nutritifs », les propositions prioritaires étaient axées sur le développement d'une meilleure compréhension de la relation entre les bassins versants du lac Winnipeg et la relation entre la quantité et la qualité de l'eau du lac et le biote du lac :

- Identification des principaux résultats biologiques, des points de repères et des niveaux acceptables de changement de l'écosystème (p. ex., les populations halieutiques essentielles, les niveaux des algacés, etc.) et leur relation avec les concentrations d'azote et de phosphore.
- Développement de modèles informatiques des mouvements de l'eau dans le lac Winnipeg et de la quantité et du rythme des débits d'eau dans le lac Winnipeg.
- Développement d'un modèle informatisé des pratiques de l'utilisation du sol et de l'aménagement paysagé et de leur effet sur les apports d'azote et de phosphore dans le lac Winnipeg, et l'amélioration de la précision et de l'exactitude des prévisions de la charge d'éléments nutritifs dans le lac.

D'autres propositions comprenaient le développement d'une meilleure connaissance des causes du haut niveau de bactéries aux plages de plaisance et la relation entre la gestion des éléments nutritifs et le piégeage du carbone dans le lac Winnipeg.

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[3] Les recommandations ont été préparées après l'atelier et sont fondées sur les résultats et les discussions des ateliers. Elles ont été approuvées par le Comité directeur comme résultats de l'atelier, mais ne reflètent pas nécessairement les positions des ministères gouvernementaux impliqués.

Sous le thème « communautés de poissons », on a mis l'accent sur le fait que les décision de gestions efficaces dépendent de la connaissance et de la compréhension des populations de poissons (p. ex., l'abondance relative, le taux de croissance, l'importance des classes d'âge, etc.). Voici la proposition ayant la plus grande priorité :

- Établissement d'un programme d'enquête standardisé de pêche au filet continu et approfondi (vaste en termes temporels et géographiques) afin de développer des indices sur la communauté des poissons pour les espèces fondamentales de poissons et leur variation au fil du temps et de l'espace.

Voici certaines autres propositions :

- Déterminer les effets des espèces invasives sur l'écosystème du lac Winnipeg (une proposition similaire a été identifiée sous le thème de l'habitat du poisson).
- Détermination des sources de mortalité des poissons, autre que la pêche commerciale (p. ex., la pêche de loisir, la pêche de subsistance, la prédation par des poissons ou des oiseaux, les fleurs d'eau toxiques).
- Cueillette du savoir écologique traditionnel et d'autres connaissances locales provenant des aînés et des pêcheurs sur ce qu'on sait sur la pêche et l'écosystème du lac Winnipeg. (Cette proposition serait également reliée à beaucoup d'autres propositions provenant de l'atelier, et les appuierait.)
- Détermination de la structure des stocks génétiques des espèces commerciales (doré jaune, doré noir, grand corégone).
- Analyse des effets potentiels du climat et du changement climatique sur l'écosystème aquatique.
- Établissement d'une routine de repérage des niveaux de contaminants dans les poissons, l'eau et les sédiments du lac Winnipeg.
- Développement d'un modèle d'écosystème pour comprendre l'impact des changements dans la structure du réseau trophique sur la productivité des pêcheries.

Sous le thème « habitat des poissons » on a reconnu que la protection des habitats des poissons était essentielle à la protection de l'écosystème du lac Winnipeg et que la protection de ces habitats consiste à comprendre l'étendue géographique et l'utilisation qu'en font les poissons et autres élément de la chaîne alimentaire :

- Un inventaire aérien des habitats dans le bassin nord et dans les zones de canaux.
- Élaboration d'un système de classification des habitats de poissons pour le bassin sud.
- Une évaluation de l'utilisation que les poissons font des affluents et des récifs.
- Une évaluation des causes du déclin de l'habitat marécageux.

Voici d'autres propositions :

- Développer une meilleure compréhension de l'importance pertinente des éléments nutritifs, de la lumière et de la température sur la communauté des algacés du lac Winnipeg.
- Rassembler les renseignements existants sur l'utilisation du sol et sur les concentrations d'éléments nutritifs et des charges d'éléments nutritifs dans une base de données intégrée.

- Déterminer les causes et les conséquences du déclin des communautés de zoobenthos dans le lac.
- Définir et décrire les habitats critiques des espèces de la LSED (*Loi fédérale sur les espèces en péril*).

L'exécution de ces propositions ne serait qu'un premier pas dans le développement d'un programme scientifique global continu pour le lac Winnipeg. De plus, le comité directeur de l'atelier scientifique sur le lac Winnipeg a présenté quatre recommandations spéciales pour le long terme. Ces recommandations découlent d'une évaluation des principaux exposés, des résultats des discussions en groupe, des commentaires du ministre responsable des eaux et des discussions générales en plénières, et elles vont au-delà de projets de recherche précis :

7. *Les ministères devraient élaborer un cadre administratif global, semblable aux plans d'aménagement panlacustre élaborés en vertu de l'Accord relatif à la qualité de l'eau dans les Grands Lacs, afin d'avoir une responsabilité commune envers l'écosystème aquatique du lac Winnipeg.*

8. *Les ministères devraient appuyer les mécanismes courants de gouvernance et lancer de nouvelles initiatives afin d'assurer la coordination des activités scientifiques sur le lac et ses bassins versants et de s'assurer que ces activités répondent à des besoins énoncés par la gestion.*

9. *Les ministères devraient lancer des « Conférences sur l'état du lac Winnipeg » tous les trois ans afin d'informer le public et la communauté scientifique sur la « santé » du système. Comme première étape vers l'établissement de conférences régulières, les ministères devraient commencer immédiatement la préparation d'un rapport sur « l'état du lac » pour le lac Winnipeg afin de fournir une base sur laquelle mesurer les progrès futurs dans l'atteinte des buts visant à améliorer la condition du lac.*

10. *Les ministères devraient développer un programme global d'éléments de surveillance biologique, chimique et physique intégrée de l'écosystème du lac Winnipeg et de ses bassins versants fondé sur les objectifs de gestion et les indicateurs scientifiques de l'écosystème.*

Il existe de graves lacunes dans le savoir qui nuisent à la gestion du lac Winnipeg et de la pêche qui s'y fait. Les gestionnaires et les chercheurs peuvent profiter considérablement des expériences obtenues d'autres systèmes qui ont été étudiés plus en profondeur, mais la santé à long terme du lac Winnipeg et de ses poissons dépend d'un programme scientifique local solide. La mise en oeuvre des recommandations de ce rapport donnera aux gestionnaires du lac les outils dont ils ont besoins pour gérer efficacement le lac Winnipeg.

Mots-clés: lac Winnipeg, écologie d'eau douce, ressources de la pêcherie, qualité de l'eau, habitat du poisson, écosystème aquatique, stress biologique, eutrophisation, projets des recherches, besoins de gestion.

INTRODUCTION

Lake Winnipeg is the tenth largest freshwater lake in the world and the third largest lake wholly within Canadian boundaries. It supports important commercial, recreational and subsistence fisheries, is a centre for significant cottage and on-water recreational activities, and is the primary reservoir for Manitoba's hydro-electric production system. It is of critical environmental, social and economic importance for the province of Manitoba

Scientific findings indicate that the Lake Winnipeg ecosystem is deteriorating mainly because of increased loading of nutrients, so the Manitoba government announced, in 2003, a Lake Winnipeg Action Plan. It was recognized that strong science was needed to support both implementation of the Lake Winnipeg Action Plan as well as to ensure development and implementation of other measures to sustain the Lake's ecosystem over the long term. Manitoba asked federal departments of Fisheries and Oceans Canada (DFO) and Environment Canada (EC) to collaborate with the implementation of this science plan. This workshop is a direct result of an exchange in April 2004 between the Minister of Water Stewardship for Manitoba and the Minister of DFO, and subsequent correspondence with the Minister of EC. In their meetings and correspondence, the Ministers addressed issues related to the state of Lake Winnipeg and the Lake Winnipeg Action Plan. The Ministers further concurred that a fall science workshop would be an important step in establishing the scientific and management priorities required to conserve the ecological integrity of Lake Winnipeg. In August, the three agencies established the Lake Winnipeg Science Workshop Steering Committee to organize the workshop.

The Lake Winnipeg Science Workshop (LWSW) was held November 29–30, 2004 at the Freshwater Institute in Winnipeg, Manitoba. The primary goal of the workshop was:

> *To identify science priorities and research needs for Water Quality and Nutrients, Fish Communities and Fish Habitat in Lake Winnipeg in support of current and emerging management issues as identified by the agencies directly responsible for the Lake's aquatic resources.*

The workshop was officially opened by The Honourable Steve Ashton, the Minister of Water Stewardship for Manitoba. There were a series of keynote presentations outlining management issues in three theme areas: water quality and nutrients, fish communities, and fish habitat, each followed by lessons learned from other jurisdictions. There were then a series of breakout sessions to discuss science requirements to address the management issues. Participation included, amongst others, individuals from federal and provincial departments, Manitoba Hydro, City of Winnipeg, University of Manitoba, Lake Winnipeg Research Consortium, First Nations, and Canadian and US members of the Ecosystem Health Committee of the International Joint Commission's International Red River Board (Appendix I). The emphasis on participation was focused more on scientific expertise than on strict representation of individual stakeholder organizations.

The results of the workshop will be the basis for discussions between Manitoba and Canada intended to identify the individual and joint roles of Manitoba and Canada concerning Lake

Winnipeg. This report summarizes the workshop structure, a general description of the Lake and its watershed, management organizations and environmental issues for the Lake. The workshop results include brief descriptions of priority science proposals to address the issues, and general recommendations to improve scientific support for management of Lake Winnipeg. Appendices include summaries of the keynote presentations and details of the science proposals. An enclosed CD-ROM includes copies of all keynote presentations in Adobe.pdf format, and the presentations from each of the breakout sessions.

STRUCTURE OF THE LAKE WINNIPEG SCIENCE WORKSHOP

The workshop addressed three themes: water quality and nutrients, fish communities and fish habitat. There were four sessions as follows: 1. an opening introductory plenary; 2. a breakout session to address science needs within each theme; 3. a breakout session to address interactions and connections; and 4. a concluding summary panel in plenary.

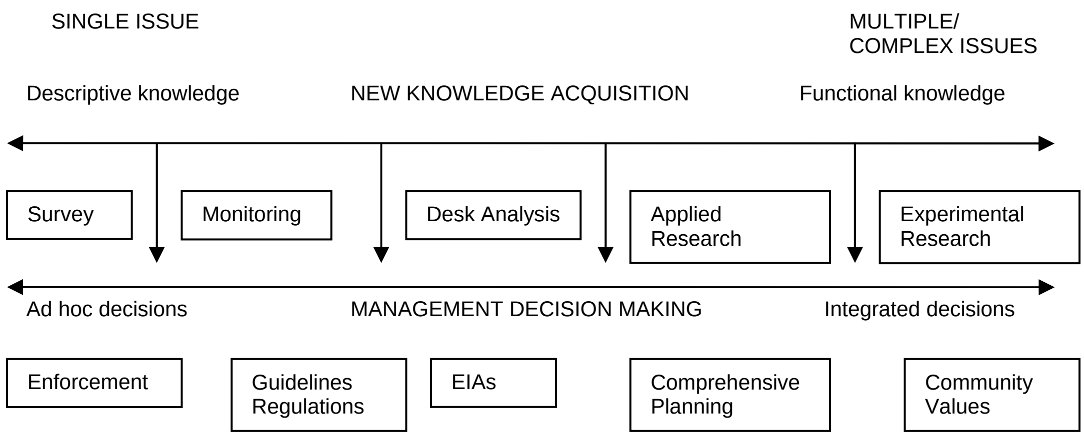
The purpose of Session 1 was to provide the participants with a common background on Lake Winnipeg and identify the key management issues that the science discussions that followed would be expected to address. The session consisted of seven solicited presentations. First, there was a background paper on the history, geography, and issues for Lake Winnipeg to set the scene for presentations on the three themes. For each theme there was then a presentation on the current status of the Lake followed by a presentation on lessons learned from elsewhere. Presentations were as follows:

- Background
  "An Overview of Lake Winnipeg" – G. Burton Ayles
- Theme 1. Water Quality and Nutrients
  "Lake Winnipeg Water Quality: History, Current and Future State, and Management Needs" – Dwight Williamson
  "Lake Erie and the Lake Winnipeg Situation" – Murray Charlton
- Theme 2. Fish Communities
  "Lake Winnipeg's Fish and Fisheries" – Walter Lysack
  "Fish and Fisheries of Lake Ontario: A Case History" – John M. Casselman
- Theme 3. Fish Habitat
  "Lake Winnipeg Habitat Impacts, Past, Present and Future"– Keith Kristofferson
  "Lessons Learned from the Great Lakes: Habitat Science Experience" – Robert G. Randall

Summaries of the presentations are in Appendix V. Copies of the Power Point presentations of each of the keynote addresses are in Appendix VII on the CD-ROM distributed with this report.

The purpose of Session 2 was to develop some specific ideas for the acquisition of new knowledge and understanding for water quality and nutrients, fish communities and fish habitat that meet the needs of management on the Lake. The session consisted of structured breakout group discussions. There were three breakout groups viz., water quality and nutrients, fish communities and fish habitat, to discuss the individual themes. The discussions were structured to ensure that all the elements of a comprehensive, integrated aquatic science plan for the lake were considered. In a complex system such as Lake Winnipeg, a full spectrum of management decision-making is required as is a full spectrum of new knowledge acquisition. In the LWSW we used a model (Figure 1) developed by the Westwater Institute, University of British Columbia, to describe acquisition of knowledge and understanding (research) to support management decision making for Lake Winnipeg (Dorcey and Hall 1981). This model was developed for the Fraser River estuary but can be applied to environmental research in general as a conceptual view of how different kinds of research contribute to management. Issues related to aquatic environments range from simple/single issues to multiple/complex issues. Management decision making is a continuum from *ad hoc* decisions to integrated decisions, from enforcement to comprehensive planning and changes in community values. Similarly, the acquisition of new knowledge can be seen as a continuum, which flows from left to right from simple data collection to comprehensive understanding. New knowledge and information contributes to management decision making along those continua. In a complex system such as Lake Winnipeg, the full spectrum of management decision making is required as is the full spectrum of new knowledge acquisition.

Figure 1. A model for the acquisition of aquatic science and technology to support management decision making on Lake Winnipeg.



Each breakout group was asked to identify and describe research needs (acquisition of knowledge and understanding) under five categories viz., Inventory, Monitoring, Desk Analysis, Applied Research[4] and Experimental Research. They were asked to identify at least one research idea under each of these categories but were to develop as many more as they agreed were appropriate. It was emphasized that both scientific knowledge and traditional or local knowledge are valid and both can be captured in the model.

A common template was provided and each research idea was documented using the following elements:

- workshop theme (water quality and nutrients, fish communities, fish habitat),
- the knowledge continuum (inventory, monitoring, desk analysis, applied research, experimental research),
- title,
- management issue,

[4] Dorcey and Hall (1981) use the term "Experimental Management" to describe knowledge gathering that that involves designing an experiment that enables an hypothesis to be tested by the implementation of a management decision. For this workshop we used the term "Applied Research" but the meaning is essentially the same.

- description of the idea (includes hypothesis, methods, equipment, timelines, etc.),
- deliverables,
- facility and infrastructure support requirements, and
- possible researchers.

At the end of the discussions there were plenary presentations of the results.
The purpose of Session 3 was to refine the ideas for new knowledge prepared in Session 2 by determining linkages between ideas from the different themes that would lead to a more integrated research program, and to identify gaps and omissions from the earlier discussions. The session began with a presentation on ecosystem integration models so that participants would have a clearer idea of what was expected:

- “Models as Tools for Data Integration and Management” – Marten A. Koops and Scott Millard (see Appendix V and Appendix VII on the CD-ROM)

There were three breakout groups to discuss integration and three integration categories to consider: water quality and fish populations, water quality and fish habitat, and fish populations and fish habitats. The breakout group discussions were led by the same facilitators and rapporteurs as the groups in the previous breakouts but group participation was assigned at random to ensure a diversity of knowledge within each group. The results from the earlier breakout session provided the basis for the discussions. Groups examined the proposed research for commonalities and possible interactions, and identified gap areas that were not considered earlier. At the end of the discussions there was a plenary presentation of the results.

The purpose of Session 4 was to establish a list of integrated research ideas to address identified management issues for Lake Winnipeg. This final synthesis session consisted of panel presentations, plenary discussions and a priority setting session. The two keynote presenters for each “theme” presentation and for the integration session gave their assessments of the discussions and the proposals presented. This was followed by a brief discussion period. Participants were then asked to rate the proposals. This was followed by an open discussion to identify the key recommendations on priorities for the acquisition of new science and understanding to support current and emerging management issues for Lake Winnipeg.

LAKE WINNIPEG OVERVIEW

This section provides a brief physical description of Lake Winnipeg and its watersheds, the history of the use of the Lake, and an outline of major organizations that are involved with the management and protection of the aquatic resources of the Lake.

Lake Winnipeg Physical Geography

Lake Winnipeg, like the Laurentian Great Lakes and the other great lakes of North America, Great Bear, Great Slave and Athabasca, is an ice-scour lake on the border of the Canadian Shield. It is a result of repeated glaciation and the scraping away of relatively soft Paleozoic sediments along the margin of the Canadian Shield.

Lake Winnipeg is flanked by Precambrian (Kenoran Orogeny >2.5 Ga) rocks on its eastern and northern shores and Paleozoic carbonate rocks (primarily Ordovician, Silurian and Devonian dolomite, limestone and sandstones) of the Williston Basin to the west and south. The axis of the lake follows the contact between the Precambrian and Paleozoic rocks. Lake Winnipeg and the other large Manitoba lakes to the west, are the remnants of glacial Lake Agassiz. Lake Agassiz was the largest of all the glacial lakes in North America, extending over a total area of almost 950,000 km^2 in Saskatchewan, Manitoba and Ontario, and south into North Dakota and Minnesota, though not in all provinces or states at any one time (Trenhalle 1990).

With an area of 24,400 km^2, Lake Winnipeg is 25% larger than Lake Ontario and just slightly smaller than Lake Erie. However, the total volume of Lake Winnipeg is considerably less, some 127 km^3 compared with 1,710 km^3 and 545 km^3 for the two Laurentian lakes, respectively (Korzun 1974). Lake Winnipeg is divided into the South and North Basins separated by The Narrows, an area of islands and narrow passages only a few kilometres wide. The Lake is 430 km long, the North Basin is up to 100 km wide and the South Basin reaches 40 km in width. The Lake is very shallow, mean depths of the North Basin, The Narrows and the South Basin are 13.3 m, 7.2 m and 9.7 m, respectively (Brunskill et al. 1980). Its outlet is through the Nelson River in the north-east and this is a controlled outflow. Major inflows are from the Winnipeg River to the south-east (mean monthly flow 771 $m^3\,s^{-1}$), the Saskatchewan River from southern Alberta and central Saskatchewan (667 $m^3\,s^{-1}$), the Red River from southern Manitoba and the nearby United States (159 $m^3\,s^{-1}$), Dauphin River from the interlake area (57 $m^3\,s^{-1}$) and other smaller streams (Lewis and Todd 1996).

The Lake Winnipeg watershed covers about 10% of Canada’s surface area and includes parts of four provinces (Alberta, Saskatchewan, Manitoba and Ontario) and four states (Montana, North Dakota, South Dakota and Minnesota). The population in the watershed is approximately 5.5 M and there are over 200 M head of livestock. The rivers draining the markedly different subwatersheds of Lake Winnipeg have different chemical and biological characteristics, and they have very different effects upon the limnology of the Lake Winnipeg (Environment Canada 2004).

The eastern and south-eastern subwatersheds of Lake Winnipeg are part of the Boreal Shield Ecozone and they are overlain with variable thicknesses of glacial Lake Agassiz-derived soils, muskegs and boreal forests. The area supports mining and forest industries, little agriculture, and few large communities. The population in these watersheds remains low, less than 75,000. The Winnipeg River is the major system in these watersheds and it provides as much as 40% of the total inflow to the Lake but less than 27% of the phosphorus input.

The southern subwatersheds are overlain with considerable thicknesses of glacial Lake Agassiz sediments, with well-developed soils. The Red River is the major system to the south and south-west of Lake Winnipeg and its watershed extends well into North Dakota, Minnesota and South Dakota. Corn, spring wheat, oilseeds, hay and livestock production are common, depending on local conditions. Hog farming, in particular, has been increasing in the region. The area includes Winnipeg, Grand Forks and Fargo–Moorehead, and several other small centres with considerable industrial activity and a population of close to 800,000 in Canada. The Red provides less than 10% of the inflow to the lake but almost 60% of the phosphorus input.

The subwatersheds to the west and north-west of Lake Winnipeg are part of the Boreal Plains and Prairies Ecozones and the Saskatchewan River is the major inflow. The Prairies Ecozone is the most human-altered region in Canada. Agriculture is the dominant land use, and the Ecozone contains over 60% of Canada's cropland and 80% of its rangeland and pasture. Major economic activities include mining (coal, potash, mineral and aggregates), forestry and oil and gas production. The total population in the watershed is over 3.0 million. The Saskatchewan contributes over 20% of the flow but just over 10% of the phosphorus input. A water deficit situation is characteristic of the Prairies Ecozone.

Pre-Historical and Historical Importance of Lake Winnipeg

Before European contact, the lake was important for fisheries and as a transportation route for the people in the area. The Laurel people (200 BC–1000 AD) consumed pike (Esocidae), sturgeon (*Acipenser fulvescen*s), sucker (Catostomidae), walleye (*Sander vitreum*) and bass (Centrarchidae) The Blackduck culture at the grassland–forest edge and the Selkirk culture further north, which moved into the Region around 800 AD, showed an increasing reliance on fish (MacDonald 1993).

Lake Winnipeg was the centre of the fur trade and transportation in the 18th and 19th centuries; it was the crossroads between the east and the west and the link from the south to the north. The first permanent European community on the lake was comprised of Icelandic colonists in 1875 who settled in the area of Gimli, which was the start of commercial fishing on the Lake.

The commercial fisheries of Lake Winnipeg continue to be amongst the most successful in inland waters of Canada and are second only to Lake Erie in terms of total landed value. The importance of the fur trade and transportation has declined significantly while two other industries, recreation and hydro-electric development, have grown in importance.

Recreational use of the Lake began in the first two decades of the last century, and cottage use and recreational boating continues to expand. The Manitoba Department of Tourism estimates recreational expenditures exceed $100 million annually. Beginning in the late 1960s, the Lake has been increasingly important for hydro-electric production. Lake Winnipeg is now a reservoir and 60% of its inflow is regulated. Downstream of the outflow of the Lake, the Nelson River has a series of dams that generate electricity as the water from over 10% of Canada spills off the Shield, and across the Hudson Bay Lowlands into the ocean. Export sales of electricity are between $350 and $580 million per year.

Lake Winnipeg Water Management and Coordination Organizations

Manitoba Water Stewardship: The Manitoba Department of Water Stewardship was created in November 2003. Manitoba was the first jurisdiction in Canada to create a stand-alone department dedicated to water management. The Ecological Services Division is responsible for planning and coordination, transboundary issues, water science and management, fisheries and drinking water. The Infrastructure and Operations Division is responsible for water licencing, water control infrastructure and regional operations. Since the Department's formation, the Water Protection Act has been tabled in the legislature. This important legislation will govern water in Manitoba into the future, allowing for stricter water-quality standards, regulation of water-quality management zones for nutrients and control of invasive species through regulation. The Act will provide a comprehensive framework for integrated watershed management.

Lake Winnipeg Stewardship Board: The Lake Winnipeg Stewardship Board (Water Stewardship Manitoba 2004) was announced by the Government of Manitoba in February 2003 as one of six actions under the Lake Winnipeg Action Plan. The role of the Board is to assist the Government of Manitoba to achieve the main commitments in the Lake Winnipeg Action Plan: reducing phosphorus and nitrogen in the lake to pre-1970 levels. Board members represent a variety of interests, including fishing; agriculture; urban land use; First Nations; federal, provincial and municipal governments; and non-governmental organizations. The Board reports through its Chair to the Minister of Water Stewardship.

Fisheries and Oceans Canada (DFO): Until 1930, Canada was fully responsible for day-to-day management of the fisheries of the Prairie Provinces. That changed as a result of various Natural Resources Transfer Agreements. DFO responsibilities for Lake Winnipeg are limited to maintaining fishing harbours; producing and maintaining navigational charts; deploying aids to navigation and maintaining marine communication; protecting fish habitat; and protecting aquatic species at risk and their critical habitat. Under the terms of a science Memorandum of Understanding with the Prairie Provinces and as a partner in the Lake Winnipeg Research Consortium, DFO has been involved in some science activities on Lake Winnipeg, specifically investigating habitat degradation, aquatic invasive species, species at risk and climate change issues.

Environment Canada (EC): EC has limited responsibilities for aquatic research and monitoring in Lake Winnipeg. EC has few activities in the Lake itself but has ongoing water-quality monitoring programs in a number of major tributaries to the Lake. Under the Canadian Environmental Protection Act (CEPA), the Minister of the Environment "shall" undertake monitoring to ensure no adverse impacts from pollutants in the environment. There is no monitoring in Lake Winnipeg under CEPA at the moment. EC has recently been involved in a remote sensing study to assess the frequency (spatial and temporal) and extent of algal blooms in the North Basin. This is a one-off study and not part of a larger EC initiative.

EC is involved in a number of "Large Ecosystem Initiatives" (e.g. Great Lakes Action Plan) and other research initiatives to address issues of national concern (e.g. climate change impacts). None involve Lake Winnipeg at the moment but this could represent a mechanism to get involved in Lake studies should a federal program for the Lake be justified and resources made available.

International Joint Commission (IJC) and the International Red River Board(IRRB) Ecosystem Subcommittee: The IJC was established by the Canada–USA Boundary Waters Treaty of 1909 to deal with the apportionment, conservation and development of water resources along the international boundary. Four Boards of the IJC have responsibilities that can potentially affect Lake Winnipeg: the Rainy Lake Board of Control, the Rainy River Water Pollution Board, the Lake of the Woods Control Board, and the IRRB. The mandate of the IRRB is to assist the IJC in preventing and resolving transboundary disputes regarding the waters and aquatic ecosystem of the Red River and its tributaries. The IRRB's activities focus on factors that affect the Red River's water quality, water quantity, water levels and aquatic ecological integrity.

The Lake Winnipeg Research Consortium (LWRC): The LWRC was founded in 1998 and incorporated in 2001. Its membership is diverse and includes commercial and recreational fishing organizations, the universities of Manitoba and Winnipeg, aboriginal groups, many different NGOs, and federal and provincial agencies, amongst others. The LWRC has no formal management responsibility for Lake Winnipeg. It was initially formed to seek funding for, and to coordinate scientific cruises of, the research vessel Namao, under a Memorandum of Understanding with the Canadian Coast Guard. Its objectives are to facilitate multi-disciplinary scientific research and educational opportunities on Lake Winnipeg; expedite information exchange and foster co-operation among all stakeholders; protect and sustain the lake ecosystem; and provide a dedicated and capable vessel as a platform for research on the lake.

CRITICAL AQUATIC ISSUES FOR LAKE WINNIPEG

A number of Lake Winnipeg issues are at the forefront of public attention. The keynote presentations addressed water quality and nutrients, fish communities and habitat issues from a management perspective and discussed similarities with the Great Lakes. This section summarizes the primary environmental issues. For further background and details the reader is directed to Appendix VI (Summaries of Keynote Presentations) and to the CD-ROM in Appendix VII, which contains Adobe.pdf files of the keynote presentations.

Although the issues, often seen in the popular press, are presented below as single issues, it should be recognized that they are all intimately interconnected. For example, amongst other effects, climate change is liable to lead to changes in water flows, altered eutrophication, fewer cold-water species and more invasive species. Similar multiple impacts are liable to happen with the destruction of physical habitat. Such losses may affect spawning of certain species and survival of the forage fish on which these species feed and, at the same time, benefit possible exotic competitors, which may in turn affect algal blooms. The workshop participants did not discuss priorities for these issues and the issues are presented in alphabetical order. The lack of prioritization does not mean the issues have equal priority for management action or for scientific study.

Aquatic Issues

Climate Change: Climate change is a significant long-term threat to prairie ecosystems. Surface temperatures in the South Basin have increased over time but there are insufficient long-term data to observe lakewide climate warming effects (Kristofferson, Appendix V and VII). However, there are broad concerns regarding the potential impact of climate change on many aspects of the Lake Winnipeg ecosystem. Climate change in Lake Winnipeg, in most global climate modelling scenarios, will entail lower water levels and higher temperatures.

Climate change is a major issue of concern in the Great Lakes (Casselman, Appendix V and VII; Randall, Appendix V and VII). Large-scale, multi-partner habitat science projects are underway to predict the impacts of climate change and changes in water level to fish habitat (Randall, Appendix V and VII). The change in habitat availability and quality in particular wetlands across the lower Great Lakes indicates potential changes to Lake Winnipeg systems under a changed climate. Similar studies would benefit Lake Winnipeg aquatic management. Great Lakes studies on the effects of temperature on recruitment and growth of typical warm-water (e.g. smallmouth bass [*Micropterus dolomieu*]), cool-water (e.g. northern pike [*Esox lucius*]), and cold-water species (e.g. lake whitefish [*Coregonus clupeaformis*]) have shown that warm-water species are increasing substantially, but at a predictable pace, given temperature increases over the past three decades (Casselman, Appendix V and VII). The implication for Lake Winnipeg is that climate warming will directly impact cold-water species such as lake whitefish.

Climate warming may compound the impacts of eutrophication on Lake Winnipeg by stressing foodweb structure and function through changes in watershed hydrology (Ayles,

Appendix V and VII). Management actions implemented to reduce nutrient contributions to Lake Winnipeg will increase the resiliency of the lake and its watershed to better withstand and to minimize the impacts of climate change (Williamson, Appendix V and VII).

Bacteria: Recreational beaches of Lake Winnipeg have experienced closures arising from elevated fecal coliform levels. Past studies focused on the obvious large domestic sewage discharges from the City of Winnipeg, nonpoint-source run-off from livestock operations, and natural wildlife populations throughout the region, but these studies failed to identify either single or combined sources of bacteria that could account for the infrequent, but relatively high densities observed at several of the Lake Winnipeg beaches (Williamson et al. 2004). It is now known that elevated densities of *E. coli* are present in the surficial water underlying sand in the foreshore beach region of many Lake Winnipeg beaches, that these bacterial populations are being transferred periodically to bathing water with wind-induced water level changes, and that the majority of *E. coli* originates from animal sources rather than humans, with gulls and terns being the largest single animal contributors (Williamson et al. 2004). Similar observations have been made in Lake Michigan beaches but solutions remain problematic (Whitman and Nevers 2003). There are a number of management needs related to the *E. coli* issue. These include the need to continue work towards developing a model that can successfully predict when meteorological conditions are most likely to transport indicator bacteria from the foreshore sand to the bathing water, the need to understand whether or not indicator bacteria are replicating in the wet beach sand, and the need to gain an understanding of the health risks facing bathers through epidemiological studies arising from exposure to *E. coli* (Williamson, Appendix V and VII).

Chemical Contaminants: Chemical contaminants have been a major public concern in Canada for many decades. There are concerns for Lake Winnipeg that contaminants such as PCBs, organochlorine pesticides and hormones may increase as an outcome of increased cattle and hog production, and result in increased wastes in the watershed (Ayles, Appendix V and VII). Long-range atmospheric transport can mean the introduction of pesticides, such as toxaphene, which are banned throughout North America (Williamson, Appendix V and VII). In the future, inter-basin transfers of water into the Lake Winnipeg watershed could increase chemical contamination. Periodic floods can also add contaminants to the Lake. For example, the 1997 flood resulted in elevated contaminant levels, in particular toxaphene, in predatory fish species.

In the Great Lakes, contaminants have come from multiple sources such as industrial pollution, municipal wastes, sewage plants, run-off and long-range air transport (Charlton, Appendix V and VII). These contaminants affect fish, bird and human health. The issues are numerous and complex, from taste and odour of water and in fish flesh, to disruption of growth and reproduction in fish, birds and possibly people, to death of individuals and loss of populations of birds and fish. Canada and the US maintain fish contaminant monitoring programs to detect spatial and temporal trends in toxic chemical levels in Great Lakes biota. Although the human population and industry in the Lake Winnipeg watershed are smaller than in the Great Lakes, based on the Great Lakes experiences, these materials can have human health implications and can create unpredictable changes in community structure and function (Charlton, Appendix V and VII). There are no long-term monitoring programs on Lake Winnipeg, similar to those in the Great Lakes, to determine if contaminant levels are changing or if there are impacts on fish and fisheries.

Species at Risk: There are concerns about the survival of components of the aquatic ecosystem. There are 60 native fish species in Lake Winnipeg (Stewart and Watkinson 2004), and uncounted numbers of other aquatic species that could face extirpation as conditions in the Lake change. In Lake Winnipeg, *Physa winnipegensis*, an endemic, endangered snail has been proposed for COSEWIC listing, a remnant population of shortjaw cisco (*Coregonus zenithicus*) is threatened, and other fish species (bigmouth buffalo [*Ictiobus cyprinellus*] special concern, carmine shiner [*Notropis percobromus*] threatened, chestnut lamprey [*Icthyomyzon castaneus*] special concern, silver chub [*Macrhybopsis storeriana*] special concern and lake sturgeon [*Acipenser fulvescens*] endangered) are also under stress.

There are 157 fish species native to the Great Lakes watershed. Eight of those species have been extirpated from the watershed, two species that were endemic to the lakes are now extinct and two more species (one of them being the shortjaw cisco) have been extirpated from all lakes except Lake Superior (Coon 1999). Overfishing, loss of spawning and rearing habitat, and competition from introduced species have all been implicated in the loss of fish from the Great Lakes (Coon 1999). The Federal Government's Species at Risk Act provides a mechanism for developing strategic plans for rehabilitation of aquatic species at risk (Kristofferson, Appendix V and VII). Habitat rehabilitation experiences from the Great Lakes may also be of value in Lake Winnipeg.

Eutrophication: Eutrophication in Lake Winnipeg has increased in the past several decades and is now one of the most important water-quality challenges facing the Lake. Input of nitrogen and phosphorus from rivers has increased and levels of nitrogen and phosphorus in the Lake have also increased (Kristofferson, Appendix V and VII; Williamson, Appendix V and VII). The incidence and severity of algal bloom formation appears to be increasing. Data suggest that blooms of nitrogen-fixing cyanobacteria are more common at the present time than earlier in the century. All of the Lake's other major water-quality issues are manifestations of the same cause—excess loadings of nutrients. These other issues include clogging of commercial fishers' nets, thus increasing effort and reducing economic return; alterations to the structure and function of aquatic biotic communities; fouling of beaches with large mats of decomposing algae, thus creating unpleasant conditions for cottagers and bathers; reduction of dissolved oxygen due to decomposing of senescing blooms; and production of toxins from cyanobacteria that may result in fish die-off and bathing advisories. Increasing human populations and lack of tertiary sewage treatment; intensive cropping and increased use of fertilizers; and increased cattle and hog production and resultant increased wastes in the watershed have all been identified as potential causative factors of eutrophication. As well, the 1997 flood resulted in substantial increases in water column nutrients.

Many lessons may be learned from the eutrophication experience in the Great Lakes (Charlton, Appendix V and VII). Lake Winnipeg is similar to much of Lake Erie; the South Basin of Lake Winnipeg is more similar to Lake Erie's west basin, which receives the most pollution. Growing concern about the quality of water in the Great Lakes led to the "Great Lakes Water Quality Agreement" between Canada and the US in 1972. The international scientific literature, including research at the Experimental Lakes Area in northwestern Ontario, pointed to phosphorus as being the major factor in eutrophication, and the primary focus of the Agreement was on the reduction of phosphorus. The emphasis was on reducing phosphorus in detergents and reducing phosphorous output from sewage plants. The phosphorus load was reduced by 50% in Lake Erie and Lake Ontario. The majority of the improvement resulted from better treatment of point-source discharges such as improved treatment of municipal sewage, combined sewer overflows and control of major point sources in the watershed. Based on the Great Lakes experience, phosphorus in sewage, agricultural fertilizers and feedlot waste was mostly available to grow algae, whereas river-borne phosphorus may be largely attached to eroded soils and is less available biologically. As well, shallow lakes, such as Lake Erie and Lake Winnipeg, are known to recycle phosphorus better than deeper lakes (Charlton, Appendix V and VII). The use of phosphorus models developed for the Great Lakes may help to increase understanding of how the Lake Winnipeg ecosystem may function and to explore options (Koops, (Appendix V and VII) and Millard, (Appendix V and VII). The recovery of Lake Erie indicates that recovery of a large lake is possible with the correct management actions.

Aquatic Invasive Species: There are concerns that invasive species are disrupting the food web of the Lake. At least eight introduced freshwater fish species occur in Lake Winnipeg (Stewart and Watkinson 2004). The major ones are common carp *(Cyprinus carpio)* introduced to Manitoba in 1886 and spread to Lake Winnipeg in the 1940s; white bass *(Morone chrysops)*, which first appeared in the mid 1960s and in the 1990s was the most common perch-like fish in the South Basin; and rainbow smelt *(Osmerus mordax*) which first appeared in 1991and is now well established in the North Basin. A cladoceran zooplankter *(Eubosmina coregoni)* is already well established and another zooplankter (*Bythotrephes cederstroemi*), recently detected in Saganaga Lake in the Winnipeg River sub-watershed, will require surveillance (Kristofferson, Appendix V and VII). Exotic species have entered the Lake Winnipeg watershed through planned government introductions, unauthorized introductions by individuals, inadvertent bait bucket transfers, and accidental introductions on recreational vessels and equipment. Future inter-basin transfers of water could introduce further problematic invasive species to the Lake (e.g. gizzard shad [*Dorosoma cepedianum*] and pike perch [*Sander leuceoperca*]). Climate warming will also increase the likelihood of other invasive species surviving in the Nelson River/Lake Winnipeg watershed (Casselman, Appendix V and VII).

Invasive species have been a serious problem in the Great Lakes: 139 species (25 fishes, 28 invertebrates, 59 plants, 24 algae and 3 parasites or disease pathogens) have become successfully established in the Great Lakes watershed since the early 1980s (Leach et al. 1999). Lessons from the Great Lakes demonstrate that the impacts of exotic species can be significant and that these impacts can be compounded by other factors that are important for Lake Winnipeg (overfishing, eutrophication and siltation). For example, lake trout

(*Salvelinus namaycush*) virtually disappeared in Lake Ontario in the middle decades of the last century as a result of overfishing, predation from the exotic sea lamprey (*Petromyzon marinus*) and spawning-substrate degradation from eutrophication and siltation (Casselman, Appendix V and VII). As a result of the absence of lake trout predation, large rainbow smelt became increasingly abundant. The increase in large smelt coincided with a dramatic decline in lake herring (*Coregonus* sp.) recruitment. With reduced recruitment and continued commercial fishing pressure, the lake herring population declined drastically and has never recovered to its former level. Predator–prey interactions among lake trout, smelt, lake herring and whitefish confirmed that large smelt in Lake Ontario directly affect whitefish recruitment and dynamics (Casselman, Appendix V and VII). The primary lessons from the Great Lakes are that invasive species can have significant economic and ecological impacts and control of most invasives is virtually impossible once they have entered the drainage basin.

Overfishing: Lake Winnipeg has been commercially gillnetted since the 1880s. There are ongoing concerns that the fish populations are subject to present or future overfishing (Lysack, Appendix V and VII). A number of fish stocks have been significantly depleted in the past (e.g. sturgeon, lake trout and large lake whitefish) and there is concern that fishing pressure in combination with other environmental changes may result in further declines in the future. Whitefish abundance has declined erratically over the long term. Annual yields of whitefish were highest in the 1920s and declined until the mercury closure in 1970. After the mercury closure, whitefish yields again increased until the mid-1980s and then declined erratically primarily as a result of price declines because of poor markets (Lysack, Appendix V and VII). Walleye and sauger (*Sander canadensis*) yields were highest after whitefish first began declining. Sauger yields declined from the mid-1980s to the present. Walleye yields increased until the mid-1980s, declined until the mid-1990s and increased to their highest levels in 2003 (Lysack, Appendix V and VII). The maintenance of numbers of large pike at low abundance levels has allowed sucker abundance to continue increasing (Lysack, Appendix V and VII).

The fisheries of the Great Lakes have shown a similar pattern of dramatic changes and overall declines. The major destabilizers have been overfishing, exotic species, eutrophication, and habitat alteration (Cassleman, Appendix V and VII). In the first half of the 20th century, commercial fisheries targeted mainly large-bodied species, particularly lake herring, lake trout, lake whitefish, and walleye. Declines of these large-bodied commercial species became apparent in the 1940s through the 1960s, and extirpation became common (e.g. deepwater ciscoes) (Casselman, Appendix V and VII).

A long-term fish community index fishing program in Lake Ontario is providing insights into the primary stressors, impacts, influences, and processes that affect fish population abundance and community dynamics and structure (Casselman, Appendix V and VII). Since the 1970s, the most profound ecological changes in the Lake Ontario ecosystem and its fish communities have been reductions in phosphorus loading, fish harvest by anglers, invasion by dreissenid mussels, predation by double-crested cormorants and fisheries management through stocking of exotic salmonids and control of sea lamprey (Casselman, Appendix V and VII). In contrast, the Lake Winnipeg annual stock monitoring program was standardized in 1979, reduced during the late 1990s and ended after 2003. As well, there are no measurements of catch and effort data from the "special permit" fishery or the "subsistence" fishery and no estimates of predation from birds and fish (Lysack, Appendix V and VII).

Sediment Levels: There are concerns about the altered suspended sediment regime in the Lake. As a result of the construction of the Grand Rapids dam, sediment from the Saskatchewan River is trapped by Cedar Lake and the clarity of the North Basin increased significantly in years after 1969 (Kristofferson, Appendix V and VII). This may now be changing. Increased erosion, sediments and nutrients, in part from increased runoff due to drainage and agricultural land clearing, are especially evident in the Red River subwatershed. These additional sediments from the Red and Assiniboine Rivers are increasingly being transported into the North Basin, in part by large wind-caused seiche events (Kristofferson, Appendix V and VII). Changes in sediment levels can significantly affect benthic invertebrates, resulting in unpredictable changes in the fish community.

Shoreline Disturbance: There are concerns for the loss of fish habitat as a result of shoreline disturbance from recreational cottage development and from natural and controlled changes in lake levels. The east- and west-side shorelines in the South Basin have been extensively modified by land owners and recreational cottagers through a combination of shoreline stabilization developments and beach creation activities using rock groynes (Kristofferson, Appendix V and VII). Some works are of considerable size, removing rocky shorelines and riparian habitat. The cumulative effect of many individual projects is major alterations of valuable fish spawning, rearing and nursery habitat in the littoral zone. Historical habitat value in the areas has been documented in index trawl catches in these areas from 1976 to 1983 (Kristofferson, Appendix V and VII). Although portions of the South Basin are prone to erosion due to underlying geologic and hydrologic conditions, many landowners continue to apply these practices in other areas as well and considerable cumulative damage has already been done to the natural habitat.

The Great Lakes are experiencing similar problems (Randall, Appendix V and VII) and there are several lessons for Lake Winnipeg habitat science: GIS-based habitat inventories are invaluable; fish-habitat suitability databases for freshwater fishes in central Canada are available and can be revised and updated for new applications; fish-habitat suitability and productive capacity models are becoming increasingly sophisticated and useful; coarse-resolution fish habitat classifications for large coastal areas are useful to managers; and multi-partner and multi-agency projects are becoming common and lead to synergistic products for ecosystem-based management (Randall, Appendix V and VII).

Water Control: Since completion of the control structures at the outlet into the Nelson River in 1976, Lake Winnipeg has been operated as a reservoir, where water is held back during the open-water months and discharged during the winter months as power requirements increase at this time of year. There are several concerns regarding the shift in flow from summer to winter and the resulting changes in water levels at different times of the year. Although mean monthly water levels pre- and post-hydro regulation from 1914–2003 appear to have changed very little, this information is based on a lakewide average and corrected for wind setup. There has been a dampening in amplitude and frequency of the water-level fluctuations (as indicated in a change in annual winter and summer outflows from 1915 to 1998), which may have impacted the productive capacity of littoral zones and wetlands. Potential impacts range from changes in migration patterns of fish, to retention of nutrients, to loss of spawning habitat to disruption of cottage shorelines, amongst others (Kristofferson, Appendix V and VII).

Scientific Knowledge and Understanding of Lake Winnipeg Issues

Although there may be general agreement on many of the environmental issues, and even agreement on the general actions that need to be taken, there is insufficient scientific knowledge and understanding of the Lake Winnipeg ecosystem and its watershed to provide lake managers with established science-based objectives that will lead to the Minister's goal to "Go back to 1970 in terms of water quality" (Ashton, Appendix V).

The extent of our current scientific knowledge of Lake Winnipeg is illustrated by the literature data presented in Table 1.

Table 1. Comparison of number of publications on fisheries and aquatic sciences from the large lakes of North America and Africa.[5]

Lake	**Aquatic Science and Fisheries Abstracts (1978–2002)**	**Environmental Sciences and Pollution Management (1981–2003)**
Michigan	1816	3085
Ontario	1764	2590
Erie	1712	2578
Superior	1050	1543
Huron	622	907
Victoria	756	343
Malawi	398	159
Great Slave	79	57
Winnipeg	71	73
Great Bear	22	22

Lake Winnipeg has been understudied when compared to the other large lakes of North America and the world. Only Great Bear Lake in Canada's far north has received less attention. Clearly, compared to other large lakes, there is a lack of knowledge about Lake Winnipeg and its management.

[5] Information on numbers of publications courtesy of the Lake Winnipeg Research Consortium.

Minister Ashton noted that Lake Winnipeg is not the same as Lake Erie (Ashton, Appendix V) but the keynote presentations on lessons learned from elsewhere and the discussions during those presentations indicated that Lake Winnipeg researchers can benefit significantly from experiences gained from other systems that have been studied more extensively. In particular, the discussions emphasized the importance of looking at the entire ecosystem, not just the issues of current interest or issues related to the mandate of individual government departments. In the past, government agencies have tended to narrowly focus their support of aquatic environmental science programs. Thus, individual programs considered fish without habitat, and lakes without the rivers, streams and watersheds that they depend on. In the future, a whole-watershed approach will be necessary to develop the scientific knowledge and understanding to support aquatic ecosystem-based management for Lake Winnipeg. The presentations by Koops (Appendix V and VII) and Millard (Appendix V and VII) pointed out the importance of models to assist in the integration of different disciplines to form useful understandings, and to integrate data and inform management decisions. Management is best served through the integration of research, and models are the tools by which research and monitoring data can be brought together to provide input to management. Significant effort has been made in developing models in the Great Lakes and elsewhere, and similar approaches should be of significance to Lake Winnipeg. Koops and Millard made the point that there may already be enough scientific data on Lake Winnipeg (water quality) to begin using an ecosystem model to inform management decisions (impact of phosporus reductions on algae production and fisheries) and identify research needs.

Establishment by the Great Lakes Fishery Commission (www.GLFC.org) and the IJC (www.IJC.org) of a number of committees to coordinate management and scientific activities on the Great Lakes has significantly advanced the inter-agency coordination that is necessary for successful integrated ecosystem management (Casselman, Appendix V and VII, Charlton, Appendix V and VII). It was emphasized by several participants that similar mechanisms could be of benefit to the integration of scientific and management activities on Lake Winnipeg.

WORKSHOP RESULTS

In the breakout sessions, the participants first discussed management issues within their theme area. The management issues formed the basis for development of individual research proposals; a statement of the issue is found with each proposal in Appendix VI and in the breakout presentations in Appendix VIII on the CD-ROM attached to this report. Participants identified and described 24 proposals in all, seven under the theme of Water Quality and Nutrients, eight under the theme of Fish Communities and nine under the theme of Fish Habitat. Detailed descriptions for each proposal are contained in Appendix VI. In this section, we briefly describe the extent of linkages or integration between research proposals, the categorization of proposals within the knowledge continuum described in the section on workshop structure, and requirements for vessel support. We also provide short descriptions of each proposal.

Although presented as projects under a specific theme, the workshop emphasized the integration of projects across disciplines and departmental mandates; Session 3 was set up to specifically look at linkages between proposals. Table 2 lists the titles of the proposals and identifies linkages to other proposals.

Table 2. Lake Winnipeg Science Workshop, November 29–30, 2004. Index of titles of research proposals and linkages to other proposals.

Research Proposal Number and Title	Linkages to Other Proposals[6]
Water Quality and Nutrients	
Water 1: Bacteria Levels at Recreational Beaches	W6
Water 2: Carbon Cycling/Carbon Sequestering	F4, W4, W5, W6
Water 3: Land Use: Lake Winnipeg Sustainability	F2, F4, H3, H4, H5, W4, W5
Water 4: Watershed Hydrology Model	F3, H4, H6, W3, W5, W6, W7
Water 5: Improvement of Nutrient Loading Estimates for the Lake Winnipeg Basin	H4, H5, W3, W4, W7
Water 6: Physical Model for Lake Winnipeg	F2, F5, H2, H4, W1, W2, W3, W4, W5, W7
Water 7: Relating Nutrients and Biological Endpoints for Setting Ecological Objectives for Lake Winnipeg	F4, F5, H5, H7, H9, W6
Fish Communities	
Fish 1: Fish Community Index Sampling Programs	F3, F7, H3, H8

[6] Legend for research proposal numbers: W = Water Quality and Nutrients, F = Fish Communities, H = Fish Habitat.

Research Proposal Number and Title	**Linkages to Other Proposals**[6]
Fish 2: Partitioning Sources of Fish Mortality, other than the Commercial Harvest	F1, F4, F5 (added after workshop)
Fish 3: Subpopulation Structure of Commercial Species (Walleye, Sauger, Whitefish)	F1, F4, F5, H3, H9, W6
Fish 4: Effects of Exotic Species on the Lake Winnipeg Ecosystem	H1, H6, H7, H8, H9, W2, W5
Fish 5: Traditional and Local Knowledge	F1, F2, F3, F4, F6, H4, H5, H6, H9, W3, W6, W7
Fish 6: Effect of Climate and Climate Change on the Aquatic Ecosystem: Monitoring and Analysis	F4, F5, H3, H4, H6, H9, W5, W6
Fish 7: Contaminant Levels in Lake Winnipeg Biota	F1, F2 (added after workshop)
Fish 8: An Ecosystem Model to Understand the Impact of Changes in Foodweb Structure on Fisheries Productivity	F1, F2, H7, H8, W5, W7
Fish Habitat	
Habitat 1: Aerial Inventory of North Basin and Channel Areas	H3, H4 (as identified in plenary)
Habitat 2: Fish Habitat Classification for South Basin	F3, F6, H1, H3, H4
Habitat 3: Assessment of Use of Tributaries and Reefs by Fish	F1, F3, F5
Habitat 4: Decline in Wetland Habitat	F4, H9
Habitat 5: Correlation of Land Use and Watershed Nutrient Databases	H3, W3, W4
Habitat 6: Define, Describe Critical Habitat for SARA Species	F1
Habitat 7: Develop a Better Understanding of Relevant Importance of Nutrients, Light, and Temperature to Algal Community of Lake Winnipeg	F3, H2, H3, H8, W3, W4, W6,
Habitat 8: Causes and Consequences of Decline in Zoobenthos Communities	F4, H9, W7,
Habitat 9: Invasion of Exotics and Consequences on the Fish Community	F1, F4, W7

The close integration between projects is evidenced by the observation that, on average, proponents of each proposal identified five other projects that it should be linked to or that it depended on. The linkages were not just within a theme but extended equally to the other two themes. The proposals that the participants felt had the greatest number of linkages with other proposals were “Fish 5: Traditional and Local Knowledge”, “Water 6: Physical

Model for Lake Winnipeg" and "Fish 6: Effect of Climate and Climate Change on the Aquatic Ecosystem: Monitoring and Analysis".

In a complex system such as Lake Winnipeg, a full spectrum of management decision making is required and it needs to be supported by a full spectrum of new knowledge acquisition. In this workshop, we asked participants to identify and describe research needs under five categories viz., Survey, Monitoring, Desk Analysis, Experimental Management and Experimental Research (Table 3).

Table 3. Identification of research proposals in relation to the knowledge acquisition continuum used during the workshop.

Workshop Theme	Knowledge Acquisition Continuum				
	Inventory	**Monitoring**	**Desk Analysis**	**Applied Research**	**Experimental Research**
Water Quality and Nutrients	W1 ,W2, W4, W5, W6	W2, W4, W5, W6, W7	W2, W3, W5, W6, W7	W3, W4	W7
Fish Communities	F2, F3, F4, F5, F6, F7	F1, F4, F6, F7	F1, F4, F8	F5	
Fish Habitat	H1, H2, H3, H4	H8, H9	H2, H4, H5, H6, H7, H9	H2, H4, H6, H8	H8

The knowledge continuum categories are not discrete, and 16 of the 24 research ideas described involved studies in more than one of the five categories. The majority of the research ideas proposed were directed at the acquisition of descriptive knowledge rather than functional knowledge, i.e. inventorying and monitoring rather than applied or experimental research. As well, there was no distinction between themes with respect to the kinds of knowledge that were needed, e.g. there were project proposals for basic inventories for water quality and nutrients, fish communities and fish habitat in the Lake.

The purpose of the workshop was to identify science priorities and research needs in a broad sense and the template used to document individual research ideas was not designed to assess detailed requirements of the research. Nevertheless, in the descriptions of research proposals, participants were asked to identify requirements for special expertise and requirements for special infrastructure. In general, the assessment was that expertise was currently available within the region, although not necessarily working on Lake Winnipeg. Greater participation would be needed from DFO, EC and university staff for a number of projects if these projects were to proceed. Also identified was a need to participate with fishers, community members and First Nations for a number of proposals.

There was also a requirement for modeling expertise, which is not currently available in the region.

In general, special equipment or facilities were not required for the execution of the majority of the proposals. Access to special equipment was needed by some of the projects, including GIS facilities and special DNA analysis. Access to aircraft for aerial habitat surveys and to satellites for water quality, nutrient and habitat surveys was also identified.

The one clear requirement for special infrastructure was for access to both large and small vessels for key work related to all three themes (Table 4).

Table 4. Assessment of vessel requirements of research proposals.

Workshop Theme	Vessel Requirement			
	No Vessel Requirements	Small Vessel/Yawl Required	Large Vessel Required	Other
Water Quality and Nutrients	W1, W3, W4		W2, W5, W6, W7	W6 (vessels of opportunity)
Fish Communities	F8	F1, F3, F5	F1, F2, F4, F6, F7	
Fish Habitat	H1, H4, H5, H7, H9	H2, H3, H6	H2, H3, H6, H8	

Thirteen of the 24 research ideas described at the workshop would require a large vessel, six would require a small vessel and nine would not require vessel support. Four of the proposals would require both large and small vessel support. Each of the research theme areas had projects that required large vessel support. Four of seven Water Quality and Nutrients proposals, five of eight Fish Community proposals and four of seven Fish Habitat proposals required large vessel support. The two proposals rated highest priority (see following section for priorities) by the participants, F1 (Fish Community Index Sampling Programs) and W7 (Relating Nutrients and Biological Endpoints for Setting Ecological Objectives for Lake Winnipeg) would both require large vessel support. Considering the four Fish Habitat inventory proposals (H1, H2, H3, H4) as a single project and the two exotic species proposals (F4, H9) as a single project, five of the seven top-rated projects require large vessel support. A specific vessel was not identified but it would need to accommodate a wide range of aquatic sampling equipment, from fish trawls to sediment samplers to water and zooplankton samplers.

Descriptions of Prioritized Research Proposals

This section contains short, prioritized[7] descriptions of each proposal. Details for each proposal are in Appendix VI. It should be emphasized that all of the proposals were considered important and necessary for a more complete understanding of the Lake Winnipeg aquatic ecosystem. The prioritization represents the results of the workshop but the specific scores were not discussed or challenged during the workshop. Further, they do not necessarily represent the priorities of the Departments involved in the workshop.

F1: Fish Community Index Sampling Programs. Score: 42

Effective fisheries management decisions depend on knowledge and understanding of the fish populations (e.g. relative abundance, growth rates, year-class strengths, etc.).

This proposal would use standard, bottom-set multi-mesh gillnets to establish relative abundance indices and achieve better understanding of community structure and dynamics. The surveys need to be standardized to include all species and should be extensive (many locations). The abundance-index surveys would be supplemented with offshore trawling, a small inshore program (e.g. electrofishing), and spawning stock surveys in the spring and fall.

W7: Relating Nutrients and Biological Endpoints for Setting Ecological Objectives for Lake Winnipeg. Score: 38

Management of water quality in Lake Winnipeg will depend on broad management objectives, protection goals and management/monitoring of biological-indicator endpoints developed and agreed to by all stakeholders. To be effective, these ecological objectives need to be strongly science-based.

This proposal would first identify key biological endpoints, benchmarks and acceptable levels of change for key components of the ecosystem (e.g. critical fish populations, algal levels, zooplankton abundance, etc.). It would then address the relationships between these critical biological endpoints and nitrogen and phosphorous concentrations. In essence, this proposal would determine whether the biological endpoints are a predictable function of nutrient concentrations and, thus, what changes might be required in nitrogen and phosphorous inputs to maintain the ecological integrity of the Lake. This would be primarily a desk analysis with some specific experimental research requirements and long-term monitoring as a follow-up.

[7] Process for prioritization: Titles and brief descriptions of each research idea were posted on the walls of plenary room. Participants were each given five sticky dots and told to apply them to the projects they considered to be of priority. Participants could place more than one dot on a research idea. The score is the simple total of all dots assigned to a given project.

W6: Physical Model for Lake Winnipeg. Score: 21

Development of long-term objectives for the management of Lake Winnipeg depends on understanding the relationship between sediments, nutrients, carbon and algae. Key to this understanding is knowledge of how water circulates within the lake.

This proposal would develop an appropriate computer model of water movements in Lake Winnipeg. A wide range of components would need to be considered, including wind velocity, temperature, bathymetry, currents, and water velocity. The project would depend on a buoy network, and make optimum use of existing resources (ferries, fishermen, freighters, Namao). This would be a three- to five-year project but preliminary information would be available after the first year for input to the nutrient models. Model development is a specialized field and local expertise in physical limnology is limited. Collaboration with specialists from outside the region will be essential.

H1, H2, H3, H4: Habitat Inventories. Score: 19 (includes H2, H3, H4)

Protection of fish habitats is critical for the protection of the Lake Winnipeg ecosystem. Protection of these habitats depends on understanding their geographical extent and their use by fishes and other components of the food chain. The following four research proposals address some key gaps in the knowledge and understanding of Lake Winnipeg fish habitats.

H1: Aerial Inventory of North Basin and Channel Areas. There is no baseline physical inventory of critical fish habitats in the North Basin and channel areas against which anthropogenic and natural change can be assessed.

This proposal would involve a current and historical survey (satellite imagery and air photos) of the North Basin and the channel areas. It would provide physical descriptions of various habitat types, and classification and measurements of those habitats. It would also provide baseline indications of habitat status for critical functions (spawning, rearing, food supply). It would involve fixed-wing aircraft collection of digital GPS photos at optimal altitude, seasons and water levels based on a stratified sampling regime as determined from suitable sources (e.g. orthos, satellite imagery). It would also involve analysis of historical archival data. The outcome of this study would be a geo-referenced, digital, photographic, habitat inventory, which would be used to assess existing and future habitat impacts and to reference and plan additional research activities.

H2: Fish Habitat Classification for South Basin. There is a lack of understanding of watershed impacts and of shoreline developments on fish habitats.

This proposal would collect the necessary data to apply existing fish-habitat models developed for the Great Lakes. Data required will include the following: bathymetry (will require support from the Canadian Hydrographic Service using ROXANN to determine substrate types), fetch (from GIS-based maps) and cover (from aerial photos, sonar and stratified field surveys). The proposal would also involve the development of a fish-habitat suitability database using current literature, including depth preferences by life stage of critical species, and thermal preferences and habitat structures, amongst others. This study would provide a documented database, maps of habitat classifications and shorelines, and would directly support a fish-habitat management plan for the South Basin.

H3: Assessment of Use of Tributaries and Reefs by Fish. Tributary rivers and streams and reefs are known to be critical habitats for fishes in large lakes but there is little knowledge of their specific use in Lake Winnipeg, especially for species at risk.

This proposal would determine which tributaries and reefs are important habitats for Lake Winnipeg fishes. It would involve extensive surveys by small vessels using boat and backpack electrofishers. It would also involve mark and recapture techniques, egg sampling devices and larval fish emergence traps. This study would provide a habitat-use inventory as a tool for protecting tributary and reef fish habitats in the Lake.

H4: Decline in Wetland Habitat. Wetland habitats on the margins of Lake Winnipeg have declined. Protection and mitigation or possible restoration of these wetland habitats depends on understanding the causes of their decline.

This proposal would determine whether wetland habitat decline is related to water regulation, nutrients and turbidity, or invading species. The Province and DFO would participate in monitoring and would support ongoing research by the University of Manitoba and Ducks Unlimited to address the above causes. The proposal would conduct research in existing marshes connected to Lake Winnipeg to identify potential adverse effects such as turbidity, carp biomass, and water-level regulation (timing, magnitude, duration, frequency, annual cycles). The proposal would also determine whether fish passage past Hydro facilities is a major factor affecting the fish community of Lake Winnipeg, which would involve sampling below Hydro facilities to identify potential fish movement. The study would identify the main factors responsible for wetland loss and potential mitigation options to recover wetlands (e.g. carp exclusion, artificial water-level manipulation).

<u>W4: Watershed Hydrology Model.</u> Score: 19

Development of Best Management Practices (greatest return for a level of investment) for control of nutrient input into the Lake depends on an understanding of the delivery of water and nutrients to the Lake.

This proposal would develop a hydrologic model of the quantity and timing of water flows into Lake Winnipeg. It would involve an understanding of basin-wide inputs and outputs including: seasonal variability and transport of flow; spring runoff/snow melt; groundwater inflow; withdrawals for irrigation; runoff characteristics/farm practices; and travel time due to instream controls (e.g. Lockport, Winnipeg floodway, other controls on the Winnipeg River and Saskatchewan River). The model would also have to consider issues of scale, e.g. large basin-wide vs. reach-specific accuracy, and the monitoring required for calibration of available models. Interprovincial and international coordination would be important.

H7: Develop a Better Understanding of Relevant Importance of Nutrients, Light, and Temperature to the Algal Community of Lake Winnipeg. Score: 19

Development of Best Management Practices (greatest return for a level of investment) for control of nutrient inputs into Lake Winnipeg depends on an understanding of the effects of potential nutrient-reducing land-management decisions on algal communities, especially the development of bluegreen algae.

This proposal would provide a description of the current state of knowledge of nutrients, sediment loads and temperature to the algal community of the Lake Winnipeg ecosystem. It would involve completion of the analysis of existing data on Lake Winnipeg so that practitioners could bring their understanding of the Lake ecosystem up to date in terms of data already collected. The analyses would be enhanced by adding a modeler to the team to develop models of algal productivity and use these models to test sensitivity of the algal community to significant factors.

F4 and H9: Effects of Aquatic Invasive Species. Score: 18

Invasive species can have unanticipated impacts on food webs, valuable commercial fisheries and wetlands. A critical management objective for Lake Winnipeg is preventing the introduction of exotic species of fish, vertebrates, plants, viruses, etc. into the Lake ecosystem. These two studies would provide an evaluation of changes in biodiversity and future changes in ecosystem structure and function, and could provide potential preventive or mitigative actions for management. The two projects address different aspects of the issue of exotic species.

F4: Effects of Aquatic Invasive species on the Lake Winnipeg Ecosystem. This proposal would address a number of critical questions regarding exotic species that have invaded, or could invade, Lake Winnipeg. Specific issues include the following: routes and modes of transfer; effects of exotic species on Lake Winnipeg community structure and function (nutrient cycling , foodweb structure); impacts of exotic species on contaminant/toxin transfer through the food chain; and effect of exotic species on quality, taste, texture, disease and condition of fish flesh. The proposal would involve surveys to assess current and emerging exotic species; monitoring to assess establishment and growth of exotic species; and desk analyses to evaluate existing databases and develop an historical perspective on exotic species.

H9: Invasion of Exotics and Consequences on the Fish Community. This proposal would be a risk assessment of the effects potential invasive species would have on the Lake Winnipeg ecosystem. Ecological requirements of potential invaders (fish, invertebrates, plants or viruses) would be matched with existing conditions in Lake Winnipeg.

W3: Land Use: Lake Winnipeg Sustainability. Score: 15

Land use (i.e. land use refers to all aspects of land cover, physiography, soils, geology, etc.) and landscapes affect nutrient loadings to Lake Winnipeg. Management actions need to be based on an understanding of how land use (mature forest, clear cut, pastureland, field crops, etc.) and soil type contribute to nitrogen and phosphorous enrichment of the Lake.

This proposal would develop a computer-based model using existing databases (APF linkages). The model would be linked to nutrient mass balance models and hydrologic/hydraulic models. The model could also be used to analyze future land use and climate change scenarios. The model would help to identify landuse practices that would be of greatest relevance to nitrogen and phosphorus reductions, and it would help to determine the role of wetlands, riparian and other landscape uses. The model would also contribute to a landuse inventory, a decision-support model and to the development of reach-specific action plans for the Lake.

H5: Correlation of Land Use and Watershed Nutrient Databases. Score: 10

Management of watershed land use depends, in part, on how changes in use affect water quality of runoff. Existing databases on land use and on watershed nutrient levels need to be integrated.

This proposal would assemble existing landuse information and river nutrient concentrations and load information into an integrated GIS database. The proposal would test for correlations between land use and nutrient concentrations, and loadings in downstream runoff.

F2: Partitioning Sources of Fish Mortality other than the Commercial Harvest. Score: 10

Effective management of the Lake Winnipeg fisheries depends not only on knowledge of the total commercial harvest of fish but also on knowledge of other factors that might cause mortalities of critical commercial fish.

This proposal would address all sources of mortality, including fish harvesting, predation, foodweb interactions, harmful algal blooms, toxins and oxygen depletion. Specific issues would include: commercial harvesting; unrecorded commercial harvest (special permits, bushing/discarding); subsistence fishery harvesting; sport fishing; impacts of exotic predator fishes; impacts of cormorants and other birds on survival of commercial species; effect of algal blooms on young-of-the-year and/or adult fishes; and impact of water regulation on survival of fishes.

H8: Causes and Consequences of Decline in Zoobenthos Communities.
Score: 7

Zoobenthos are a critical component of the food web supporting fish production in Lake Winnipeg but the extent to which fish in Lake Winnipeg rely on zoobenthos as a food resource is not well understood. Of concern for managers is the observation that zoobenthic abundance and production are declining. The causes of the declines and the consequences of these declines for future fish productivity are unclear.

This proposal would examine the following possible causes of zoobenthic decline: hypoxia in the North Basin related to changes in thermal stratification and eutrophication; sedimentation changes; nutrients and contaminants; and fish predation. The approach would be as follows: examine the relationship between spatial and temporal distribution of zoobenthic taxa relative to oxygen, water quality and sediment conditions; collect sediment cores to reconstruct short- and long-term changes in benthic community structure and geochemical indicators of anoxia and sedimentation rates; assess fish feeding through both gut content and stable isotope analysis; and extend past surveys of zoobenthos to shallow waters.

W5: Improvement of Nutrient Loading Estimates for the Lake Winnipeg Basin. Score: 6

Improving the levels of precision and accuracy of the nutrient budgets for Lake Winnipeg will allow improved management decision making on control levels or methods.

This proposal would develop a nutrient budget with known precision and accuracy (i.e. a power analysis). The first phase would be an analysis of existing data and identification of gaps and shortfalls. The second phase would be the development of a more comprehensive program of monitoring of flow and water quality so that more precise annual averages with confidence limits can be determined.

F5: Traditional and Local Knowledge. Score: 5

Traditional ecological knowledge (TEK) can contribute significantly to many aspects of management decisions for the aquatic environment. TEK is the first step to a better understanding of the ecosystem. This knowledge and information can help to focus scientific studies, identify additional management issues and determine potential causes of problems and their solutions. Current studies of Lake Winnipeg are primarily scientific studies; they do not make use of TEK and are too narrowly focused.

This proposal would collect local and TEK from fishers and local elders on what is known about the fisheries and the ecosystem of Lake Winnipeg. It would be carried out through non-structured visits and interviews. It is important that the information be collected in the field in a non-academic/scientific setting for there to be full participation by the interviewees. This project would also be designed to contribute significant local information to several of the other water, habitat and fish assessment and classification studies.

F3: Subpopulation Structure of Commercial Species (Walleye, Sauger, Whitefish). Score: 5

Current fisheries management decision making for Lake Winnipeg is based on the assumption that all of the fish from a single species are part of a homogenous single stock distributed throughout the Lake. This is problematic for effective management. Stock structure is, in fact, unknown. If there are several stocks, as is likely given the situation in other great lakes, managing a species as a single stock could potentially lead to overharvesting and eventual extirpation of stocks adapted to specific geographic areas or environmental conditions in the Lake.

This proposal would determine whether there are separate stocks of commercial species and if the presumptive discrete stocks show fidelity of spawning, i.e. do they return to spawn in the same area year after year? Mitochondrial DNA analyses would be used to determine whether fish using different areas are genetically different. The plan would be to sample and genetically analyze fish in late winter offshore in the North Basin (Grand Rapids), the narrows (Berens River/Matheson Island) and the South Basin (Gimli), and then repeat the sampling in the summer in the same areas to determine if there are changes in the genetic structure of the stocks. Sampling of spring spawning percids would be carried out in rivers around the Lake (large and small systems, east and west shores, North and South Basins).

F6: Effect of Climate and Climate Change on the Aquatic Ecosystem: Monitoring and Analysis (developed in Session 3 to address identified gap). Score: 5

Climate change will significantly impact all aspects of Lake Winnipeg including runoff, nutrient and sediment supply from the watershed, and productivity of fish and other biota. Understanding the thermal regime in the Lake is essential to an understanding of population abundance, community dynamics and community structure at all trophic levels and is critical to understanding problems related to species at risk and aquatic invasive species.

This proposal would involve integrating historic data sets (water buoys, Gimli pier, Grand Rapids Reservoir, cruise surveys and air temperatures in the Lake and Basin). Temperature profiles would be measured at multiple stations in three seasons. Long-term standardized stations for surface and water-column temperature monitoring (utilizing at least three buoys) or continuous-flow pumps on shore would be established. Remote sensing would be used to calibrate AVHRR surface temperatures locally and develop historical SST maps for the whole lake.

H6: Define, Describe Critical Habitat for SARA Species. Score: 5

Managers are responsible for protection of critical habitat for species at risk, as defined under the federal Species at Risk Act (SARA) or associated policy.

This proposal would locate and describe critical habitat for SARA species through aerial surveys (geo-referenced digital aerial photos) and vessel surveys (sampling of nearshore/offshore sites). The studies would provide the support necessary for experts to peer review known information regarding critical habitat descriptions as developed under National or Zonal Action Plans, and develop a schedule and timetable of studies required to identify basic habitat requirements.

F7: Contaminant Levels in Lake Winnipeg Biota (developed in Session 3 to address identified gap). Score: 4

Proactive management and protection of the ecosystem and resource users from the effects of contaminants requires an early warning system for potential problems.

This proposal would establish a routine reporting structure to track changes in contaminant levels in fish, water and sediments. This reporting structure would depend on ongoing programs such as those operated for the commercial fishery by the Canadian Food Inspection Agency, other ongoing and periodic monitoring by other Canadian and US agencies, and by additional contaminant surveys and monitoring in Lake Winnipeg as required.

F8: Ecosystem Model to Understand the Impact of Changes in Foodweb Structure on Fisheries Productivity (developed in Session 3 to address identified gap). Score: 3

Overall management of the aquatic ecosystem of Lake Winnipeg includes the management of a number of different but interrelated components, including nutrients, fish harvests, fish habitats and exotic species. The management strategies for each are quite different and it is problematic to assess alternative strategies for different components.

This proposal would assess the combined and separate effects of various management strategies using an ecosystem model. It is proposed to accumulate the necessary data and develop an ecosystem model (e.g. ECOPATH) of the Lake Winnipeg food web. Relevant questions that would be addressed by the use of the model include the following: How will changes in nutrient loading affect fisheries productivity? How will changes in foodweb structure caused by exotic species affect fisheries productivity? Which management strategies will be most effective for minimizing detrimental effects on the fisheries? This model would also be used to identify knowledge gaps and guide future research on the lake. Model development is a specialized field and local expertise in ecosystem model development is limited. Collaboration with specialists from outside the Lake Winnipeg Basin will be essential.

W1: Bacteria Levels at Recreational Beaches. Score: 3

Knowledge of bacterial levels at recreational beaches is critical for the public and the recreational service industry. Present management practices would be improved by the development of best management practices and options for beach management.

This proposal would develop a predictive model relating exposure/risk (source-dependent) with wind/water and changing bacterial counts. It would necessitate identification of unknown sources of bacteria, development of a DNA reference bank, understanding the ecology of pathogens in sand through laboratory culturing and field experiments to determine the size of the bacterial reservoir and whether or not it is expanding.

W2: Carbon Cycling/Carbon Sequestering. Score: 0

This proposal would examine the consequences of proposed nutrient management for carbon sequestration in Lake Winnipeg and, in turn, the implication for carbon credits under the Kyoto Agreement. This proposal would address whether decreased nutrient inputs will change carbon sequestration rates. Specific issues to be addressed would be: sedimentation rates; carbon fixation and respiration rates; the carbon budget for Lake Winnipeg; and carbon deposition and suspension zones. The proposal would involve taking core samples and determining sedimentation rates in Lake Winnipeg. The approach would involve a review/analysis of historical data, and analysis of satellite imaging to determine areas of intense blooms of phytoplankton.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This workshop was the first formal Federal–Provincial science workshop specifically on Lake Winnipeg in recent memory. There was a Red–Assiniboine River Basin Planning workshop held in 1991 (Dominion Ecological Consulting 1991) and the Red River Basin Institute in the United States recently organized a multi-agency workshop to identify research objectives and priorities in the Red River subwatershed (Red River Basin Institute 2004). These workshops identified many of the same issues that led to the organization of this workshop, and some of the proposals are complementary. However, the earlier workshops focused on only one of the major Lake Winnipeg subwatersheds and did not address science needs for the Lake itself.

From the presentations and discussions it is clear that Lake Winnipeg is an aquatic ecosystem that is under stress. Furthermore, although the causes of problems are understood in general, our scientific knowledge of the Lake is limited and insufficient to answer some of the major questions that Lake managers need to have answered.

The discussions during the workshop went beyond the descriptions of new research projects and priorities. Participants recognized that this workshop was an important opportunity because, in the past, government agencies tended to focus on their narrow mandates and support aquatic environmental science programs in the same way. The Province of Manitoba, the IJC and multi-lateral groups such as the Prairie Provinces Water Board and the Lake Winnipeg Research Consortium have all recognized the importance of the watershed approach to resource management. The Province of Manitoba Department of Water Stewardship and the Federal EC and DFO all have responsibilities for the protection and management of Lake Winnipeg; actions in the US and in other provinces can directly impact the Lake. This workshop was seen as the first step in greater Federal–Provincial–US cooperation to develop the scientific knowledge and understanding to support aquatic ecosystem-based management of Lake Winnipeg.

As participants heard from the keynote speakers, from the US participants and from those with experience on the Lake and elsewhere, there are many things that can be learned from others. Researchers in DFO, EC and the three Manitoba universities have knowledge and expertise that could contribute to scientific understanding of the Lake. These researchers have not been involved because of other priorities and lack of funding but they could be active in the future. Fishers, First Nations people and community members on the Lake have much to contribute in terms of local and traditional knowledge, and could be involved in many aspects of monitoring the health of the Lake. Researchers from the Great Lakes could be called upon for certain expertise, particularly with respect to the development of ecosystem models. Researchers and managers working on the Lake Winnipeg watershed in Saskatchewan, Alberta, Ontario and the US have information and knowledge that should contribute to an overall understanding of the Lake. As well as scientific information, other jurisdictions have developed common objectives and governance mechanisms that assist in the cooperative management of aquatic ecosystems.

News reports (Ayles, Appendix V and VII) and recent general interest books on Lake Winnipeg and other lakes and rivers in the Lake Winnipeg watershed (MacDonald 2000, Russell 2004) have expressed public concern about the state of Lake Winnipeg. It has taken decades for the deterioration to occur. It will take knowledge, action and time to restore the Lake, but it is important to start now. The prioritized descriptions of science proposals in the previous sections address the specific objectives for the workshop, i.e. to identify science priorities and research needs. This is a good start and should form the basis for federal and provincial program managers to begin their internal and cooperative work-planning and coordination processes and to seek the additional resources necessary to support significant new scientific studies on the Lake or in its watershed.

Recommendations

Individual concepts and ideas were discussed during the workshop, but there was no attempt to reach a consensus on recommendations, other than to prioritize individual research proposals. The recommendations in this section were developed by the authors and the Steering Committee and are provided to assist the Department of Water Stewardship, DFO and EC (hereinafter referred to as the Departments) develop a scientific program to support the aquatic management needs of Lake Winnipeg and its watershed. The recommendations were prepared after the workshop and were based on the workshop results and discussions. They were approved by the Steering Committee as the outcomes of the workshop but they do not necessarily reflect the positions of the government departments involved.

The first recommendation, addresses the specific objective of the workshop to identify science priorities and research needs in support of current and emerging management issues.

1. *The Departments should develop an integrated science program proposal for funding within each Department, based on the research proposals described in this workshop.*

Managers from the individual Departments stated clearly that, at the time of the workshop, there were no confirmed additional financial resources for scientific activities on Lake Winnipeg. They further emphasized that it would be their responsibility to take the recommendations forward within their specific jurisdictions to seek those resources. They should do so but the funding proposals should be prepared in an integrated and coordinated manner to ensure that needs of the entire ecosystem are addressed, not just the narrow, mandated responsibilities of a single agency. Agencies will need to address agency priorities and will need to consult with their individual partners and clients within and outside their own organization, e.g. the Lake Winnipeg Stewardship Board, First Nations and the Lake Winnipeg Research Consortium, to name just a few, and this consultation should also be done with all relevant agencies participating. It was pointed out during the workshop that a small science workshop, such as this one, was the first step in the development of the Great Lakes Water Quality Agreement. It was also emphasized that without additional resources the momentum for further cooperative action will be lost.

The purpose of the workshop was to identify science priorities and research needs in a broad sense, and the template used to document individual research ideas was not designed to assess detailed vessel requirements. Nevertheless, participants were asked to consider vessel needs in general, and the proposals clearly indicate that vessel support will be necessary for many of the programs required on Lake Winnipeg. The Departments must develop a coordinated approach to ongoing vessel support if a comprehensive monitoring and scientific program is to be developed and maintained.

Acting on the proposals developed during the workshop should be but the first step in the development of an ongoing comprehensive research program for Lake Winnipeg. In addition, the authors of this report and the LWSW Steering Committee have made four special recommendations for the long term. These recommendations come from an overall assessment of the keynote presentations, the results of the breakout discussions, comments from the Minister of Water Stewardship and the general discussions in plenary, and go beyond specific research studies:

2. *The Departments should develop an overarching administrative framework, similar to the Lakewide Management Plans developed under the Great Lakes Water Quality Agreement, for their joint management responsibilities for the Lake Winnipeg aquatic ecosystem.*

The Department of Water Stewardship and the Federal EC and DFO all have responsibilities for the protection and management of Lake Winnipeg. These responsibilities are defined by federal and provincial legislation, and by policies and priorities of the individual departments. The aquatic ecosystem of the Lake is not organized around federal or provincial legislation. Fish are not independent of fish habitat and fish habitat is not independent of water quality—they are interdependent and their management needs to take this into consideration. Management needs to be integrated and common goals have to be established. Canada and the US are signatories to the Great Lakes Water Quality Agreement (GLWQA). The purpose of the Agreement is “to restore and maintain the physical, chemical, and biological integrity of the Great Lakes Basin”. The GLWQA has provided a Lakewide Management Planning (LaMP)[8] framework for coordinating water-quality research and management in the Great Lakes and, expanded to include fisheries and fish habitat, could serve as a model for Lake Winnipeg.

3. *The Departments should support ongoing governance mechanisms and initiate new mechanisms to ensure coordination of scientific activities on the Lake and its watershed to ensure that those activities address stated management needs.*

This workshop was seen as the first step in greater Federal–Provincial–US cooperation to develop the scientific knowledge and understanding to support aquatic ecosystem-based

[8] The LaMPs identify impaired beneficial uses (lost fisheries, habitat, biodiversity, access or economic value, etc.), their state of impairment and target levels for recovery.

management for Lake Winnipeg. The Lake Winnipeg Stewardship Board and the Lake Winnipeg Research Consortium are positive initiatives. However, the former is responsible to only the Manitoba government and the latter is a self-reporting co-ordinating group with no formal reporting mechanism to any agency. Both the provincial and the federal governments have mandated responsibilities on the Lake and need to be formally involved in coordinating scientific activities to support management decisions. Development of the new coordination mechanisms should also consider relationships with international boards such as the International Red River Board and the Rainy River and Lake of the Woods Control Boards, with US coordinating organizations such as the Red River Basin Institute and with agencies in the Prairie Provinces and Ontario that have aquatic resource responsibilities in the Lake Winnipeg watershed. The Great Lakes Fishery Commission and the IJC have established coordinated planning mechanisms on the Great Lakes, which have significantly enhanced science, management and environmental conditions in the Great Lakes. Similar mechanisms could do the same for Lake Winnipeg. There are also other mechanisms that could be used as models, or that could be built upon; e.g. DFO has a Science Memorandum of Understanding with the Prairie Provinces aimed at developing science initiatives of mutual interest and there is a Canada–Manitoba agreement under which EC carries out water-quality monitoring in tributaries to Lake Winnipeg.

> *4. The Departments should initiate triennial "State of Lake Winnipeg Conferences" to inform the public and the scientific community of the "health" of the system. As a first step to the establishment of regular conferences, the Departments should immediately begin the preparation of a "State of the Lake" report for Lake Winnipeg to provide a baseline for future progress to measure achievement of goals to improve the condition of the Lake.*

It became clear during the workshop that considerable data were available for Lake Winnipeg but that the information had never been consolidated into a single comprehensive scientific assessment. This comprehensive assessment needs to be prepared now and ongoing mechanisms developed for the continued updating and reporting of progress towards the overall goals for the Lake. Under the auspices of the GLWQA, a State of the Lakes Ecosystem Conference (SOLEC) is held every two years. Its purpose is to report of the state of the Great Lakes ecosystem and the major factors impacting it, and to provide a forum for exchange of this information amongst Great Lakes decision makers. The first conference, held in 1994, addressed the health of the entire system and, for each conference, an integration paper is prepared bringing all topics together (e.g. Environment Canada 2005, Environmental Protection Agency 2005). The immediate preparation of a comprehensive State of the Lake report for Lake Winnipeg would provide a clear assessment of the current status and a baseline for reporting progress on a periodic basis in the future.

> *5. The Departments should develop a comprehensive program of integrated monitoring of the biological, chemical and physical components of the Lake Winnipeg ecosystem and its watershed based on management objectives and science-based ecosystem indictors.*

The Great Lakes SOLEC of 1998 developed a formalized suite of easily understood indicators that objectively represent the condition of components of the Great Lakes ecosystem. These indicators inform the conference participants and the public and report on progress in achieving the goals of the GLWQA. The priorities placed on new surveys and monitoring by the participants at the present workshop indicate that such data are not available for Lake Winnipeg. A comprehensive monitoring program should be developed as soon as possible, with the recognition that the process will evolve as new knowledge and understanding become available from the research studies elaborated here. The results of the monitoring should be reported through future State of Lake Winnipeg conferences.

In conclusion, there are serious knowledge gaps that hamper management of Lake Winnipeg and its fisheries. Managers and researchers can benefit significantly from experiences gained from other systems that have been studied more extensively, but the long-term health of Lake Winnipeg and its fisheries depends on a strong local science program. Implementation of the recommendations from this report will provide Lake managers with the tools they need for effective management of Lake Winnipeg.

ACKNOWLEDGEMENTS

The LWSW Steering Committee would like to acknowledge the Provincial Minister of Water Stewardship and the Federal Ministers of Fisheries and Oceans Canada and Environment Canada for their foresight in directing the organization of this workshop.

The Steering Committee would also like to recognize the participants for their hard work during the workshop, their ideas and contributions to the discussions and their role in establishing priorities for the research proposals.

Special thanks should go to the keynote speakers: Minister Steve Ashton, Dr. Burton Ayles, Dr. John Casselman, Mr. Murray Charlton, Mr. Keith Kristofferson, Mr. Walter Lysack, Dr. Marten Koops, Mr. Scott Millard, Dr. Robert Randall and Mr. Dwight Williamson. Their contributions were critical for setting the stage for discussions and for bringing new ideas to the workshop.

The Steering Committee would also like to thank the chairs and rapporteurs of the breakout sessions, Ms. Nicole Armstrong, Dr. Drew Bodaly, Dr. Kevin Cash, Mr. Joel Hunt, Ms. Laureen Janusz, Mr. Gary Swanson and Mr. Peter Thompson. Their leadership was essential for the development of the individual science proposals and establishing linkages between proposals.

The Steering Committee especially acknowledges the individuals in the Freshwater Institute who coordinated the planning and local arrangements for the workshop, Mr. Robert Fudge, Mr. Terry Shortt, Ms. Camille Campbell and Dr. Karen Scott.

BIBLIOGRAPHY

Brunskill, G.J., Campbell, P. and Elliott, S.E.M. 1980. Morphology, hydrology and watershed data pertinent to the limnology of Lake Winnipeg. Canadian Fisheries and Marine Service Manuscript Report 1556. 32 p.

Coon, T.G. 1999. Icthyofauna of the Great Lakes Basin. Pages 55–72 *in* Taylor, W.W. and Ferreri, C.P., eds. Great Lakes fisheries policy and management. Michigan State University Press, East Lansing, MI.

Dominion Ecological Consulting. 1991. The Red – Assiniboine River Basin Initiative Planning Workshop Report. Draft report of a workshop held in Winnipeg, MB, April 22–24, 1991 by Environment Canada. 54 p. plus appendices. (Report available from Regional Director Environment and Conservation, Environment Canada, Edmonton, AB.)

Dorcey, A.H.J. and Hall, K.J. 1981. Setting ecological research priorities for management: The art of the impossible in the Fraser estuary. Westwater Research Centre, University of British Columbia, Vancouver, BC. 78 p.

Environment Canada. 2004. Narrative descriptions of terrestrial ecozones and ecoregions of Canada. http://www.ec.gc.ca/soer-ree/english/framework/nardesc/default.cfm. (Date accessed: October 26, 2004.)

Environment Canada. 2005. State of the Lakes Ecosystem Conference. Environment Canada website http://on.ec.gc.ca/solec/what-is.html. (Date accessed: February 1, 2005.)

Environmental Protection Agency. 2005. State of the Lakes Ecosystem Conference. United States Environmental Protection Agency website http://www.epa.gov/glnpo/solec/ (Date accessed: February 1, 2005.)

Korzun, V.I. 1974. ed. World water balance and water resources of the earth. Translated from Russian by UNESCO 1978. UNESCO, Paris, France. 664 p.

Leach, J.H., Mills, E.L., and Dochoda, M.R. 1999. Non-indigenous species in the Great Lakes Basin. Pages 185–205 *in* Taylor, W.W. and Ferreri, C.P., eds. Great Lakes fisheries policy and management. Michigan State University Press, East Lansing, MI.

Lewis, C.F. and Todd, B.J. 1996. Lithology and seismostratigraphy of long cores, and a reconstruction of Lake Winnipeg water history. Pages 161–201 *in* Todd, B.J., Lewis, C.F., Thorleifson, L.H., and Nielsen, E., eds. Lake Winnipeg Project: Cruise report and scientific results. Geological Survey of Canada Open File 3113. Geological Survey of Canada. Ottawa, ON. 655 p.

MacDonald, J. 1993. Land of the north wind. Pages 28-52 *in* Shilliday, G., ed. Manitoba 125 – A history. Volume one, Rupert’s Land to Riel (pre-1870). Great Plains Publications, Winnipeg, MB. 238 p.

Macdonald, J. 2000. ed. The lake: An illustrated history of Manitoba's cottage country. Great Plains Publications, Winnipeg, MB. 157 p.

Red River Basin Institute. 2004. Red River Basin applied research needs development meeting. Report of a workshop held in Moorhead, MN, August 3–4, 2004. 14 p. Report available fromr Red River Basin Institute, North Dakota State University, 1805 Research and Technology Park, Fargo, ND, 58105 USA.

Russell, F. 2004. Mistehay Sakahegan, the Great Lake: The beauty and the treachery of Lake Winnipeg. Heartland Associates Inc., Winnipeg, MB. 184 p.

Stewart, K.W. and Watkinson, D.A. 2004. The freshwater fishes of Manitoba. University of Manitoba Press, Winnipeg, MB. 274 p.

Trenhalle, A.S. 1990. The geomorphology of Canada. Oxford University Press, Don Mills, ON. 240 p.

Water Stewardship Manitoba. 2004. Water Stewardship Manitoba website http//www.gov.mb.ca/waterstewardship/. (Date accessed: October 26, 2004.)

Whitman, R.L. and Nevers, M.B. 2003. Foreshore sand as a source of *Escherichia coli* in nearshore water of a Lake Michigan beach. Applied Environmental Microbiology 69: 5555–5562.

Williamson, D., Ralley, W., Bourne, N., Fortin, R., and Hughes, C. 2004. Principal factors affecting *Escherichia coli* at Lake Winnipeg beaches, Manitoba, Canada. Manitoba Water Stewardship Report No. 2004-01. (Available at http://www.gov.mb.ca/conservation/watres/lkwpg_beach_report_interim-040129.pdf)

APPENDIX I. AGENDA

AGENDA
Lake Winnipeg Science Workshop
November 29–30, 2004
Freshwater Institute, 501 University Crescent
Winnipeg, MB R3T 2N6

Date/Time	Event
Mon, Nov 29th 2004	**Day 1**
	Registration, Welcome and Introduction
07:45–08:30	Workshop Registration
08:30–08:40	Opening of the workshop and welcome to the Freshwater Institute – Dr. Redmond Clarke, Regional Director, Habitat, Fisheries and Oceans Management, DFO, Central and Arctic Region
08:40–09:00	Introduction and description of workshop structure – Dr. Burton Ayles, Facilitator
	Session 1. Aquatic Management Issues for Lake Winnipeg
09:00–09:15	*General Overview of Lake Winnipeg* – Presentation by Dr. Burton Ayles
09:15–09:45	Theme 1 - *Water Quality and Nutrients* – Conditions in Lake Winnipeg Presentation by Mr. Dwight Williamson, Manitoba Dept. of Water Stewardship
09:45–10:15	Theme 1 – *Water Quality and Nutrients* – Lake Erie and the Lake Winnipeg Situation Presentation by Mr. Murray Charlton, DOE, CCIW Burlington, ON
10:15–10:30	Health Break
10:30–11:00	Theme 2 – *Fish Communities* – Lake Winnipeg's Fish and Fisheries Presentation by Mr. Walt Lysack, Manitoba Dept. of Water Stewardship
11:00–11:30	Theme 2 – *Fish Communities* – Fish and Fisheries of Lake Ontario: A Case History Presentation by Dr. John Casselman, Ontario Ministry of Natural Resources
11:30–12:00	Theme 3 – *Fish Habitat* – Lake Winnipeg Habitat Issues Presentation by Mr. Keith Kristofferson, DFO Habitat Management
12:00–12:30	Theme 3 – *Fish Habitat* – Habitat Lessons Learned from the Great Lakes: Habitat Science Experience Presentation by Dr. Robert Randall and Susan Doka, DFO, Great Lakes Laboratory for Fisheries and Aquatic Sciences (GLLFAS), Burlington, ON
12:30–13:30	Break for lunch
	Session 2. Development of Science to Address Management Issues
13:30–13:45	Description of next sessions – Overview by Dr. Burton Ayles, Facilitator
13:45–16:45	Breakout sessions for three theme areas *Water Quality and Nutrients*, *Fish Communities* and *Fish Habitat*
15:00–15:15	Health Break – Coffee served in Small Seminar Room
16:45	End of Day 1 – Meeting of review team to discuss progress and summarize information for next session. Rapporteurs to prepare presentations on theme discussions for presentation to plenary in morning.

Date/Time	Event
18:30–21:00	Reception and Dinner at the University Club, Pembina Hall, University of Manitoba Campus
Tue, Nov 30th 2004	**Day 2**
08:00–08:30	Address by Minister Steve Ashton, Minister for Manitoba Water Stewardship
08:30–09:30	Plenary reports from Session 2, 15 min each and 15 min for discussion
	Session 3. Integration of Proposals from Session 2
09:30–10:15	Models as Tools for Data Integration and Management: Presentations on *Phosphorus Modelling* – Mr. Scott Millard and *Ecosystem Modelling* – Dr. Marten Koops. Both with the DFO, GLLFAS
10:15–10:30	Health break
10:30–10:45	Instructions for breakout sessions on integration of proposed programs
10:45–12:00	Breakouts for integration of proposed programs
12:00–13:00	Break for lunch
13:00–13:45	Plenary reports from Session 3, 15 min each including discussion
	Session 4. Conclusion Session in Plenary
13:45–15:00	Final plenary panel discussion/comments from outside speakers
15:00–15:15	Health break
15:15–16:00	Participants establish priorities
16:00–16:30	Final Conclusions and next steps
16:30	Close Workshop

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APPENDIX III. TEMPLATE FOR PREPARATION OF RESEARCH PROPOSALS
Lake Winnipeg Science Workshop
Nov 29–30, 2004
Description of Ideas for New Knowledge for Lake Winnipeg

Workshop Theme (Water Quality and Nutrients, Fish Communities, Fish Habitat)

Enter text within this box. It will expand.

Title

Enter text within this box. It will expand.

Knowledge Continuum (Inventory, Monitoring, Desk Analysis, Applied Research, Experimental Research)

Enter text within this box. It will expand.

Management Issue (Management issue as identified in the keynote presentations in Session 1 or as identified within the breakout group, i.e. what is the rationale behind the idea?)

Enter text within this box. It will expand.

Description of Idea (To include the hypothesis(es) to be tested or question to be answered, methods to be used, including data repositories/sharing and equipment/facilities required and timelines for completion of research.)

Enter text within this box. It will expand.

Deliverables (Identify the expected products or outputs of the research and how they would be used and include the timelines for completion.)

Enter text within this box. It will expand.

Facility And Infrastructure Support Requirements (To include the nature of facilities, analytical equipment and vessels needed, including estimates of time, place and season for the work.)

Enter text within this box. It will expand.

Possible Researchers (To include names of individuals or agencies that have the technical and intellectual capacity to carry out this research, e.g. government agencies, universities, communities, fishermen, aboriginal groups, etc. Should also indicate what the individuals or group would bring to the research.)

Enter text within this box. It will expand.

Session 3 Linkage to Other Ideas for New Knowledge (To be completed during Session 3. Identify Themes and Titles of other proposals and briefly describe synergies. Groups will have the descriptions the research ideas developed in Session 2 and will expand or add new descriptions as appropriate.)

Enter text within this box. It will expand.

APPENDIX IV. BIOGRAPHIES OF KEYNOTE SPEAKERS

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In recent years, he has specialized in studying the effects of climate and climate change on fish-population dynamics and community structure, particularly predictions for the effects of global warming on various thermal guilds of Great Lakes fish. He has published numerous papers on various species, such as smallmouth bass, northern pike, yellow perch, lake whitefish and lake trout. Other recent research includes the impact of invasive species (e.g. smelt and rock bass), setting size limits on a biological basis, the impact of cormorants on fish and fisheries, and effects of long-term water-level dynamics, stabilization and impoundment.

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Murray's research has spanned the St. Lawrence River, Bay of Quinte and all the Great Lakes except Michigan. He has specialized in Lake Erie since the mid 1970s and much of the available data come from his research studies on water quality. He is the author or co-author of 50 publications. Murray has spearheaded much of the trend research on the response of Hamilton Harbour to remedial actions. He chairs several committees including the Remedial Action Plan Technical Team, which is the main interface between scientists and the public and implementers. In 2003, he received a recognition award for "exceptional contributions to the Hamilton Harbour Remedial Action Plan and to the community's understanding of water quality" from the Bay Area Restoration Council.

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Walter Lysack is the Manitoba fisheries biologist with primary responsibility for survey design and fish stock data analysis on Lake Winnipeg. As a summer student, Walt worked with the Ontario Ministry of Natural Resources geological survey in 1971 and with Dr. Roger Green on Lake Manitoba in 1973. He studied *Chaoborus* productivity in West Blue Lake and received his M.Sc. in Zoology from the University of Manitoba in 1976. He began working with Manitoba Fisheries Branch in 1977 on the northern lake pulse fishing program. Walt has initiated a number of important scientific and data collection programs in support of the management of Manitoba's fisheries including: the standardized annual fish stock monitoring programs on Lake Winnipeg and Cedar Lake in 1979; a Red River creel survey and bait fish study in the early 1980s; perch surveys in Duck Mountain lakes in the mid-1980s; and the Lake Winnipegosis stock survey in 1987, amongst others. Throughout his career he has been very active in establishing data management systems for Manitoba's fisheries including: setting up the first regional fisheries computer network and head office LAN in the Manitoba Fisheries Branch in 1988–1990 and the first data transfer system from the Freshwater Fish Marketing Corporation in 1991; writing the first index and commercial catch data analysis software in 1987−1988 and writing the first creel survey data analysis software in 1991. He has written over 20 technical reports on Manitoba fisheries and completed stock surveys on 54 Manitoba lakes.

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Scott’s personal scientific interests have been contaminant dynamics in model ecosystems, phytoplankton production in the Great Lakes, nutrient dynamics, impacts of phosphorus control on ecosystem productivity and, more recently, ecosystem modelling with the software Ecopath with Ecosim.

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Dwight has worked with the Province of Manitoba for 30 years in the water quality sector and is presently the Acting Director of the Water Science and Management Branch for the new Department of Water Stewardship. Dwight has contributed to over 50 publications mainly comprised of Departmental technical reports but also including several peer-reviewed, journal articles.

Dwight presently sits on a number of inter-provincial and international committees related to water quality: International Joint Commission's (IJC) International Red River Board; Health Canada's National Working Group on Recreational Water Quality Guidelines; Prairie Provinces Water Board's Committee on Water Quality; Souris River Bilateral Water Quality Monitoring Group; Canadian Council of Ministers of the Environment's (CCME) Water Quality Task Group; United States/Canada Garrison Joint Technical Committee.

APPENDIX V. SUMMARIES OF KEYNOTE PRESENTATIONS

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OVERVIEW OF LAKE WINNIPEG
Presentation by: G. Burton Ayles

Introduction

This presentation provides a brief physical description of Lake Winnipeg and its watersheds, an outline of major organizations that are involved with the management and protection of the aquatic resources of the Lake and overviews of some of the environmental issues critical to the Lake.

Lake Winnipeg History and Physical Description

Lake Winnipeg, like the Laurentian Great Lakes and the other great lakes of North America, Great Bear, Great Slave and Athabasca, is an ice-scour lake on the border of the Canadian Shield. It is a result of repeated glaciation and the scraping away of relatively soft Paleozoic sediments along the margin of the Canadian Shield.

Lake Winnipeg is flanked by Precambrian (Kenoran Orogeny >2.5 Ga) rocks on its eastern and northern shores and Paleozoic carbonate rocks (primarily Ordovician, Silurian and Devonian dolomite, limestone and sandstones) of the Williston Basin to the west and south. The axis of the lake follows the contact between the Precambrian and Paleozoic rocks. Lake Winnipeg and the other large Manitoba lakes to the west, are the remnants of glacial Lake Agassiz. Lake Agassiz was the largest of all the glacial lakes in North America, extending over a total area of almost 950,000 km^2 in Saskatchewan, Manitoba and Ontario, and south into North Dakota and Minnesota, although not all at any one time (Trenhalle 1990).

At 24,400 km^2 Lake Winnipeg is 25% larger than Lake Ontario and just slightly smaller than Lake Erie. However, the total volume of Lake Winnipeg is considerably less, some 127 km^3 compared with 1,710 km^3 and 545 km^3 for the two Laurentian lakes (Korzun 1974). Lake Winnipeg is divided into the South and North Basins separated by The Narrows, an area of islands and narrow passages only a few kilometres wide, a region of islands and constricted passages. The Lake is 430 km long while the North Basin is up to 100 km wide and the South Basin reaches 40 km in width. The Lake is very shallow, the mean depths of the North Basin, The Narrows and the South Basin are 13.3 m, 7.2 m and 9.7 m, respectively (Brunskill et al. 1980). Its outlet is through the Nelson River in the north-east and this is a controlled outflow. Major inflows are from the Winnipeg River to the south-east (mean monthly flow 771 $m^3 s^{-1}$), the Saskatchewan River from southern Alberta and central Saskatchewan (667 $m^3 s^{-1}$), the Red River from southern Manitoba and nearby United States (159 $m^3 s^{-1}$), Dauphin River from the interlake area (57 $m^3 s^{-1}$) and other smaller streams (Lewis and Todd 1996).

Lake Winnipeg Watersheds

The Lake Winnipeg watershed covers approximately 950,000 km^2, about 10% of Canada's surface area. The population in the watershed is approximately 5.5 M and there are over

200 M head of livestock. The rivers draining the markedly different watersheds of Lake Winnipeg have different chemical and biological characteristics, and they have very different effects upon the limnology of the Lake Winnipeg. (Descriptions of the watersheds are from Environment Canada 2004.)

The eastern and south-eastern watersheds of Lake Winnipeg are part of the Boreal Shield Ecozone and they are overlain with variable thicknesses of glacial Lake Agassiz-derived soils, muskegs and boreal forests. The area supports mining and forest industries, little agriculture and few large communities. The population in these watersheds remains low, less than 75,000. The Winnipeg River is the major system in these watersheds and it provides as much as 40% of the total inflow to the Lake but less than 27% of the phosphorous input.

The southern watersheds are overlain with considerable thickness of glacial Lake Agassiz sediments, with well-developed soils. The Red River is the major drainage system to the south and southwest of Lake Winnipeg and its watershed extends well into North Dakota and Minnesota. Corn, spring wheat, oilseeds, hay and livestock production are common, depending on local conditions. Hog farming, in particular, has been growing in the region. The area includes Winnipeg, Grand Forks, and Fargo–Moorehead, several other small centres with considerable industrial activity and a large population of close to 800,000 in Canada. The Red provides less than 10% of the inflow to the lake but almost 60% of the phosphorous input.

The watersheds to the west and north-west of Lake Winnipeg are part of the Boreal Plains and Prairies Ecozones and the Saskatchewan River is the major source of inputs. The Prairies Ecozone is the most human-altered region in Canada. Agriculture is the dominant land use and the Ecozone contains over 60% of Canada's cropland and 80% of its rangeland and pasture. Major economic activities include mining (coal, potash, mineral and aggregates) and oil and gas production. The total population in the watershed is over 3.0 million. The Saskatchewan contributes over 20% of the flow but just over 10% of the phosphorous input. A water deficit situation is a characteristic of the Prairies Ecozone.

Historical and Pre-Historical Importance of Lake Winnipeg

Before European contact, the Lake was important for fisheries and as a transportation route for the people in the area. The Laurel people (200 BC–1000 AD) consumed pike, sturgeon, sucker, walleye and bass. The Blackduck culture at the grassland–forest edge and the Selkirk culture further north, which moved into the Region around 800 AD, showed an increasing reliance on fish (MacDonald 1993).

Lake Winnipeg was the centre of the fur trade and transportation in the 18th and 19th centuries; it was the crossroads between the east and the west and the link from the south to the north. The first permanent European community on the Lake was Icelandic colonists in 1875 who settled in the area of Gimli, and that was the start of commercial fisheries on the Lake.

The commercial fisheries of Lake Winnipeg continue to be amongst the most successful in inland waters of Canada and are second only to Lake Erie. However, the importance of the fur trade and transportation have declined significantly while two other industries, recreation and hydro-electric development, have grown in importance. Recreational use of the Lake began in the first two decades of the last century and cottage use and recreational boating continue to expand. The Manitoba Department of Tourism estimates recreational expenditures exceed $100 M annually. Beginning in the late 1960s, the Lake has been increasingly important for hydro-electric production. Lake Winnipeg is now a reservoir and 60% of the inflow is regulated. Downstream, the Nelson River has a series of dams that generate electricity as the water from over 10% of the country spills off the Shield, and across the Hudson Bay Lowlands into the ocean. Export sales are between $350 and $580 M per year

Agencies With Coordinations and Management Responsibilities for Lake Winnipeg

Manitoba Water Stewardship

The Manitoba Department of Water Stewardship was created in November 2003. Manitoba was the first jurisdiction in Canada to create a stand-alone department dedicated to water management. The Ecological Services Division is responsible for planning and coordination, transboundary issues, water science and management, fisheries, and drinking water. The Infrastructure and Operations Division is responsible for water licencing, water control infrastructure, and regional operations. Since the Department's formation, the Water Protection Act was tabled in the legislature. This important legislation will govern water in Manitoba into the future, allowing for stricter water-quality standards, regulation of water-quality management zones for nutrients, and control of invasive species through regulation. Also, it will provide a comprehensive framework for integrated management.

Lake Winnipeg Stewardship Board

The Lake Winnipeg Stewardship Board (Water Stewardship Manitoba 2004) was announced by the government of Manitoba in February 2003 as one of the actions under the Lake Winnipeg Action Plan. The role of the Board is to assist the government of Manitoba to achieve the main commitments in the Lake Winnipeg Action Plan: reducing phosphorus and nitrogen in the Lake to pre-1970 levels. Board members represent a variety of interests, including fishing, agriculture, urban land use, First Nations, federal, provincial and municipal government, and non-governmental organizations. The Board reports through the Chair to the Minister of Water Stewardship.

Department of Fisheries and Oceans (DFO)

Until 1930, Canada was fully responsible for day-to-day management of the fisheries of the Prairie Provinces. That changed as a result of various Natural Resources Transfer Agreements. DFO-mandated responsibilities for Lake Winnipeg are limited to maintaining fishing harbours; producing and maintaining navigational charts; deploying aids to navigation and maintaining marine communication; and protecting fish habitat and endangered or threatened aquatic species and their critical habitats. Under the terms of a science Memorandum of Understanding with the Prairie Provinces and as a partner in the Lake Winnipeg Research Consortium, DFO has been involved in some science activities on Lake Winnipeg, specifically investigating habitat degradation, aquatic invasive species, species at risk and climate change issues.

Department of the Environment (EC)

EC has limited mandated responsibilities for aquatic research and monitoring in Lake Winnipeg. The Department has few activities in the Lake itself but has ongoing water-quality monitoring programs in a number of major tributaries to the Lake. In addition, there are mechanisms by which the Department could become involved in Lake studies should the program justify it and resources allow it.

International Joint Commission and the International Red River Board Ecosystem Subcommittee

The International Joint Commission (IJC) was established by the Canada–USA Boundary Waters Treaty of 1909 to deal with the apportionment, conservation and development of water resources along the international boundary. Four Boards of the IJC have responsibilities that can potentially affect Lake Winnipeg: the Rainy Lake Board of Control; the Rainy River Water Pollution Board; the Lake of the Woods Control Board; and the International Red River Board (IRRB). The mandate of the IRRB is to assist the Commission in preventing and resolving transboundary disputes regarding the waters and aquatic ecosystem of the Red River and its tributaries. The Board's activities focus on those factors that affect the Red River's water quality, water quantity, water levels and aquatic ecological integrity.

Lake Winnipeg Research Consortium (LWRC)

The Lake Winnipeg Research Consortium was founded in 1998 and incorporated in 2001. Its membership is extremely diverse and includes commercial and recreational fishers organizations, the universities of Manitoba and Winnipeg, aboriginal groups, many different NGOs, and federal and provincial agencies, amongst others. Its objectives are to facilitate multi-disciplinary scientific research and educational opportunities on Lake Winnipeg; expedite information exchange and foster co-operation among all stakeholders; protect and sustain the Lake ecosystem; and provide a dedicated and capable platform for research on the Lake.

Lake Winnipeg Aquatic Issues

The following is a listing of Lake Winnipeg issues that are at the forefront of public attention. They are in alphabetical order, not order of priority nor are they independent.

- **Climate change:** There is a concern that the impacts of eutrophication on Lake Winnipeg may be compounded by an increasing potential for climate warming that could stress foodweb structure and function through changes in watershed hydrology.

- **Biological contaminants:** There are concerns that recreational beaches of Lake Winnipeg have experienced increasing numbers of closures arising from elevated fecal coliform levels.
- **Chemical contaminants:** There are concerns that contaminants such as PCBs, organo-chlorine pesticides and hormones may rise as an outcome of increased cattle and hog production and increased wastes in the watershed.
- **Endangered species:** There are concerns about the survival of components of the aquatic ecosystem. In Lake Winnipeg, *Physa winnipegensis*, an endemic, endangered snail has been proposed for COSEWIC listing, a remnant population of shortjaw cisco (*Coregonus zenithicus*) is threatened, and other fish species (bigmouth buffalo [*Ictiobus cyprinellus*] special concern, carmine shiner [*Notropis percobromus*] threatened, chestnut lamprey [*Icthyomyzon castaneus*] special concern, silver chub [*Macrhybopsis storeriana*] special concern and lake sturgeon [*Acipenser fulvescens*] endangered) are also under stress.
- **Eutrophication:** There are concerns that levels of eutrophication in Lake Winnipeg are reaching dangerous levels. Input of N and P from rivers is increasing. Levels of N and P in the Lake are increasing. The incidence and severity of algal bloom formation seem to be increasing. Algal populations in the Lake are shifting to nitrogen-fixing bluegreens.
- **Exotic species:** There are concerns that exotic species are disrupting the food web of the lake. In particular, *Eubosmina coregoni* (cladoceran zooplankton) and *Osmerus mordax* (rainbow smelt) are already well established.
- **Floods:** There are concerns about the impact of periodic floods on the Lake. The 1997 flood resulted in substantial increases in water column nutrient and suspended sediment loads, biological community restructuring and elevated contaminant levels in predatory fish species.
- **Inter-basin transfers:** There are concerns that interbasin transfers of water will bring increased chemical contamination and introduce problematic exotic species to the Lake.
- **Overfishing:** There are ongoing concerns that the fish populations are subject to present or future overfishing. A number of fish stocks have been significantly depleted in the past and there is concern that fishing pressure in combination with other environmental changes may result in further declines in the future.
- **Sediment levels:** There are concerns rates of sedimentation in the North Basin are increasing as a result of increased erosion in the watersheds surrounding the Lake.
- **Shoreline disturbance:** There are concerns for the loss of fish habitat as a result of shoreline disturbance from recreational cottage development and from natural and controlled changes in Lake levels.
- **Water control:** There are several concerns regarding the shift in flow from summer to winter and the resulting changes in water levels at different times of the year. Potential impacts range from changes in migration patterns of fish to loss of spawning habitat to disruption of cottage shorelines, amongst others.

Bibliography

Brunskill, G.J., Campbell, P. and Elliott, S.E.M. 1980. Morphology, hydrology and watershed data pertinent to the limnology of Lake Winnipeg. Canadian Fisheries and Marine Service Manuscript Report 1556. 32 p.

Environment Canada. 2004. Narrative descriptions of terrestrial ecozones and ecoregions of Canada. http://www.ec.gc.ca/soer-ree/english/framework/nardesc/default.cfm. (Date accessed: October 26, 2004.)

Korzun, V.I. 1974. ed. World water balance and water resources of the earth. Translated from Russian by UNESCO 1978. UNESCO, Paris, France. 664 p.

Lewis, C.F. and Todd, B.J. 1996. Lithology and seismostratigraphy of long cores, and a reconstruction of Lake Winnipeg water history. Pages 161–201 *in* Todd, B.J., Lewis, C.F.M., Thorleifson, L.H., and Nielsen, E., eds. Lake Winnipeg Project: Cruise report and scientific results. Geological Survey of Canada Open File 3113. Geological Survey of Canada. 655 p.

MacDonald, J. 1993. Land of the north wind. Pages 28-52 *in* Shilliday, G., ed. Manitoba 125 – A history. Volume one, Rupert’s Land to Riel (pre-1870). Great Plains Publications, Winnipeg, MB. 238 p.

Trenhalle, A.S. 1990. The geomorphology of Canada. Oxford University Press, Don Mills, ON. 240 p.

Water Stewardship Manitoba. 2004. Water Stewardship Manitoba website http//www.gov.mb.ca/waterstewardship/. (Date accessed: October 26, 2004.)

PRESENTATION TO THE LAKE WINNIPEG SCIENCE WORKSHOP
Presentation by: Steve Ashton[9]

I want to actually start by giving you a quick sense of what I think our collective vision is for water in this province. Very simply put, we can't take the quality or even the quantity of our water for granted. Unless we act now we're going to see further degradation of water quality and, in some areas of the province, quantity issues and we will end up in a very difficult situation. I also want to start with a very basic reality and that is water is pretty essential to us as Canadians. It's not just a part of our reality, it's also part of our identity. We have a fair amount of it, although I think we often tend to over estimate how much of that is accessible. We have 20 percent of the surface fresh water in the world but probably only about seven percent of the annual water flow, depending on the figures you use.

We use a lot of water. I think everybody in this room probably is aware of that, but 343 litres per person, per day is the second highest use rate in the world. Here in Manitoba we're number one in Canada. Not where you want to be. I think it's important to note just how our sense of scale is out of whack with a lot of areas of the world. In most of the developing world 20 litres per day of good quality water is considered an adequate supply. In Canada we use 18 litres every time we flush a toilet. As well, we are one of the few areas in the world where we take water, we treat it to drinking water standards and then we wash our cars and water our lawns with it. Such is Canada.

Now I want to deal with the quality issue as well, because I also think it's important to put a lot of the issues we're dealing with into perspective. Here in Manitoba we probably have a greater diversity of aquatic ecosystems than any other jurisdiction in Canada. Coming from northern Manitoba, I see the difference, for example, between the Churchill River and any of the prairie watersheds. On the whole, however, compared to many areas of the world, we have relatively good quality water. But that doesn't mean that our lakes and rivers aren't under stress; it means that there are many areas of the world where there are dead and dying lakes, rivers and streams. I've had the opportunity to talk to people who have worked throughout the world and what they come back with in terms of their experience in different parts of the world is often a renewed sense of making sure that here in Canada we avoid getting to that stage.

That doesn’t mean we don’t have significant water-quality issues. Lake Winnipeg is probably one of the most visible and clearest examples of that. Although Lake Winnipeg is a lake under stress, it's not a dead lake and we don't believe it's a dying lake. However, the reality is, and there are all sorts of examples throughout the world and even here in Canada, that it's not that difficult to move from stressed to dying and to dead.

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[9] This is an edited summary of the presentation by Minister of Water Stewardship, Steve Ashton, to the Lake Winnipeg Science Workshop, November 30, 2004. The presentation was recorded verbatim and edited by the authors of this report.

Lake Winnipeg is under stress. We all know there's been a significant increase in nutrients. Levels have not gone up exponentially or geometrically but they have gone up by 10% and that is significant. We're already seeing the impact on the lake in terms of eutrophication.

One of the key things I want to emphasize is the trend line. It's not the change from one year to another, it's the trend over several years in terms of the extent of algal blooms and the types of algal blooms. That can vary from year to year with water conditions and weather conditions, but the trend is certainly there. And that is why our vision for Lake Winnipeg is to turn back the clock. In this world, where we're always looking ahead, our goal is to go back to 1970 levels in terms of water quality. This is an ambitious vision for Lake Winnipeg and we have started to address this vision in a number of ways. In 2000 we established a nutrient management strategy and a water strategy, and one of the first areas that we made a real commitment to was Lake Winnipeg. We've established the Lake Winnipeg Stewardship Board on the premise that, if we're going to achieve our goal, we have to look not just at point sources, but throughout the watershed. I would also remind people that Lake Winnipeg is symbolic of other areas of the province as well, because similar situations exist elsewhere.

Unfortunately, a lot of people are disconnected from the fact that they are part of the problem. For example, the City of Winnipeg wastewater system produces about six percent of the nutrients in Lake Winnipeg. It can vary according to the cycle, by the way, and probably in the 1980s and early 1990s it was a higher percentage. But in terms of Lake Winnipeg and other water-related challenges the reality is we have 1.1 million sources in Manitoba. That's everybody in this province. Of course we also have the challenge of other jurisdictions contributing to the problem through the Winnipeg River system in Ontario; through the Red River and Assiniboine in the United States and Saskatchewan; and the Saskatchewan River through Saskatchewan and Alberta.

Now I start with the premise that everybody is involved because some people say, "Well, we can't do anything", and they'll start finger-pointing; "Hey, I may be part of the problem, but that other person or sector is a much bigger part of the problem than I am". I've heard this wherever I've gone. I have had meetings throughout rural Manitoba, where a lot of the people have said, "It’s the City of Winnipeg. Raw sewage from Winnipeg in the Red River". And it's true. Most people here would be aware that 25-30 times a year the City of Winnipeg wastewater system dumps raw sewage into the Red River because of the combined sewer overflow system, so it’s true.

Another part of the blame game is often agriculture. And agriculture does contribute on the nutrient side. I think if you were to combine actual agricultural activities, runoff, etc., about 17 percent of the nutrients flowing into Lake Winnipeg come from agricultural activities. Then people will blame outside jurisdictions. Quite true. About 30 percent of the nutrients probably come from the US.

Now the reason I emphasize those numbers is because when you're into the blame game and you get the actual contributions on the table people start to realize that we're all part of the problem. And all have to be part of the solution as well. Unlike some examples of large-scale water pollution where it's possible to blame a single large company or industry there are very few single large contributors to the problem. With Lake Winnipeg and its watershed it's more complicated. But, because there are greater complications, we shouldn't say we can't do anything. In fact it's quite the opposite. Remember the 10 percent reduction target as a general benchmark and see how everybody can be part of the solution.

Let's take the City of Winnipeg wastewater facilities, for example. There was a maintenance failure in 2002 that resulted in significant release of raw sewage into the Red River. Following that incident we put in place Clean Environment Commission hearings. As Minister I received and adopted the report, which resulted in two major changes. First the City will be required to go from a 50-year replacement cycle for combined sewer down to a 20-year cycle. Second the City will be required to bring nutrient removal to its wastewater facilities. In September 2004 the west end facility was issued the first licence as part of that process. What it's going to mean is that the six percent figure that the City currently contributes to Lake Winnipeg will probably be down to less than two percent. So, through the licencing process of one significant source, as part of the overall strategy of reducing nutrients, we are now going to end up with a significant part of that 10 percent reduction target coming from the City of Winnipeg. It is expensive, $600 million plus, but that $600 million could make a significant difference in terms of the health of Lake Winnipeg.

Out-of-province sources could also be reduced. Through the International Joint Commission's Red River Board there is a commitment between Manitoba, North Dakota and Minnesota for a 10 percent reduction of nutrients. I mentioned that perhaps 30 percent of the nutrients flowing into Lake Winnipeg come from the US. I recognize that these numbers are not precise, and are subject to verification, but if you take 30 percent as the accepted number coming from the US and reduce it by 10 percent that is three percent of the overall amount. We are now quite a bit closer to the 10 percent target and you can see that it's something we can accomplish. By the way, in the US they are going through the same thing we are. The State of Minnesota, in particular, has moved very aggressively in terms of nutrient reductions. Thanks to federal support, Minnesota has some very significant programs of habitat preservation and restoration targeted towards water quality and nutrients.

We can also look at the agricultural side. We have already taken a number of actions in terms of manure management. But what's also interesting on the farm side are some new concepts which have been put forward. Concepts such as one that is based on the recognition that farmers aren't strictly farmers, they're land managers. This leads to the recognition that there are all sorts of decisions that can be made, and all sorts of incentives and disincentives that can be put in place to bring about the desired end result. We also have a better sense of some of the things that could be done: better landuse practices; and better treatment and new technology for wastewater. The Maple Leaf plant in Brandon is an example. If it goes to a second shift it will actually result in improved wastewater quality coming from that plant. Now that sounds improbable but it's really a recognition of some new technology, some tighter new licencing requirements and the fact that in the 1990s there was, in my view, inadequate environmental licencing at Maple Leaf due to the fact that we essentially did not have proper hearings. I'm a great believer in the Clean Environment Commission's processes and I think we've seen, both in terms of the City of Winnipeg and the Maple Leaf plant, a significant difference.

As a result of the CEC I wanted to mention these examples because, when you start to discuss solutions, there are a couple of things that become pretty clear. First is that the blame game doesn't work because, if you blame someone else, it provides a great excuse to do little or nothing yourself. Second is that there is room for optimism.

So, we've got better knowledge, we have better technology, but we also have a better understanding of the role of proper land management. As I look ahead over the next 10 or 20 or 30 years, I see a fork in the river. We have two streams we can follow. If we follow one, people will look back and they'll say, "You know, that generation, they knew what the problem was, you know, they kind of argued over who was responsible, they kept pointing fingers. They did a little bit here and there around the edges, but essentially what happened is while they were arguing over who was responsible it got worse, and those lakes under stress, like Lake Winnipeg, became dead lakes". If we follow the other fork, people looking back on us 50 or 60 years from now will say, "You know, they knew what the problem was and they did something unique. They actually said, 'We're all part of the problem, we all have to be part of the solution', and they took actions that not only slowed down the deterioration of water quality, but reversed it". They would be saying that we were the first generation in some time to leave the quality of water, the quality of our environment, in better shape than we found it.

For many years people lived in harmony with nature, but certainly for the last number of generations it has been quite the opposite. My view of the environment and our water system is it's not a resource always to be exploited. It is a natural wealth, natural capital, and we should only use the interest. In many cases, leaving an environment in a natural state has a value in and of itself. And when you look at how much we rely on our water for fishing and tourism, etc., that brings home the point of why it's so important to choose that one fork that leads to improved water quality and fisheries, because I think we owe it to future generations. It's a hugely important natural asset that we have an opportunity now to leave in better shape than we found it.

That is the vision; we are at a fork in the river and we can make things better for the future. What this workshop is doing is an important part of this overall vision of a better environment because science is hugely important in identifying the problem, benchmarking the problem and finding solutions. I look forward to a new five-year plan for science. I'm very excited by the collaboration between the Department of Fisheries and Oceans, Environment Canada, and the Ministry of Water Stewardship. I've talked to the two Federal Ministers, and they're also quite excited by this process. This science plan will be part of that legacy, that fork in the river that I believe we should select. If you can come up with an ambitious, perhaps even aggressive, science plan that will challenge us politically, challenge all of us in Manitoba and challenge all levels of government, I think you will be doing a great service. You will be really contributing towards leaving Manitoba's water and Lake Winnipeg's water in better quality than we found it.

Thanks for listening to me and I really look forward to seeing your report.

WATER QUALITY AND NUTRIENTS: CONDITIONS IN LAKE WINNIPEG
Presentation by: Dwight Williamson

Lake Winnipeg faces a number of significant water-quality challenges at the present time, while other potential threats can be predicted to emerge in the future. The development and implementation of rational and appropriate strategies, policies and regulations need to be well-informed by the best available science. At the same time, managers are often faced with difficult but real choices—when must timely action be taken even in the absence of complete scientific understanding where risks of inaction are too great, and when must action await further discovery where the action itself may be inappropriate or too costly? The following is an overview of the two principal water-quality issues facing water-quality managers on Lake Winnipeg at the present time, along with a list of several other present and reasonably foreseeable future issues.

First, there is strong evidence that nutrient loading to Lake Winnipeg has increased over the last three decades or more and that resulting blooms of nuisance, harmful and toxic algae are occurring more frequently and with greater intensity. Statistical assessment done on long-term water-quality monitoring data from streams draining to Lake Winnipeg indicates that nitrogen has increased by about 13% since the early 1970s and phosphorus has increased by about 10% during this same period (see trend report prepared by Jones and Armstrong 2001 at http://www.gov.mb.ca/conservation/watres/trend_report.pdf). Subsequent work by Bourne et al. (2002) estimated overall contributions to Lake Winnipeg during the period 1993 to 2001 (Table 1) (see http://www.gov.mb.ca/conservation/watres/nutrient_loading_report_2002-04_november_2002.pdf).

As a result of the initial science work conducted as part of Manitoba's Nutrient Management Strategy (see http://www.gov.mb.ca/conservation/watres/nutrmgt.pdf), the Lake Winnipeg Action Plan was announced on February 18, 2003 (see http://www.gov.mb.ca/chc/press/top/2003/02/2003-02-18-01.html). The Lake Winnipeg Action Plan is a commitment to return the loadings of nitrogen and phosphorus to what they once were prior to the 1970s.

It is recognized that the commitments identified in the Lake Winnipeg Action Plan represent interim targets. It is necessary for work to continue on the development of long-term water-quality objectives for nutrients in Lake Winnipeg based upon ecologically sensitive end-points. Development of such water-quality objectives represents a significant challenge but is necessary for the long-term successful management of nutrients in Lake Winnipeg and its contributing watershed. To assist in the implementation of these water-quality objectives, it will also be necessary to develop a working water-quality model for the lake. This, too, represents a significant challenge, but is necessary for the sound management of this important resource.

Table 1. Average contributions of nitrogen and phosphorus to Lake Winnipeg during the period 1993 to 2001 (modified from Bourne et al. 2002). Values are shown for both mass loading (tonnes/year) and percent contributions.

Category	Average Total Nitrogen (tonnes/yr)	% Total Nitrogen	Average Total Phosphorus (tonnes/yr)	% Total Phosphorus
Overall annual nutrient load to Lake Winnipeg	67,273	100.00	6,571	100.00
Upstream jurisdictions	45,269	67.29	3,893	59.25
United States (Red River)	18,983	28.22	2,537	38.61
United States (Souris River)	1,130	1.68	209	3.18
Saskatchewan and Alberta (Assiniboine and Saskatchewan rivers)	8,339	12.40	359	5.46
Ontario (Winnipeg River)	16,817	25.00	788	11.99
Manitoba Sources	22,004	32.71	2,678	40.75
Manitoba Point Sources (i.e. effluents)	5,014	7.45	645	9.82
City of Winnipeg	3,591	5.34	390	5.94
All others	1,423	2.12	255	3.88
Manitoba Watershed Processes (i.e. runoff from the landscape)	7,490	11.13	1,557	23.70
Estimated natural background	5,168	7.68	639	9.72
Present day agriculture	2,322	3.45	919	13.98
Atmospheric deposition (Row added after Workshop)		14%		7%

It is important to note that successful management of nutrient loading to Lake Winnipeg will remedy many but not all of the Lake's other major water-quality issues, since all are related and are manifestations of the same cause—excess loadings of nutrients. These include clogging commercial fishers' nets thus increasing effort and reducing economic return, alterations to the structure and function of aquatic life communities, fouling of beaches with large mats of decomposing algae, reduction of dissolved oxygen due to decomposing of senescing blooms, and production of toxins from cyanobacteria.

Second, elevated densities of *Escherichia coli* bacteria have been observed occasionally each summer at the major Lake Winnipeg beaches since beach monitoring began in the early 1980s. Because of elevated densities in the late fall of 1993, and again in the summer of 2003, several beaches were posted with advisory signs.

Intensive efforts beginning largely in 2003 and continuing through 2004 led to gaining a significant and important understanding of the reservoir of *E. coli* available for dispersion to Lake Winnipeg beaches and the factors responsible for transport from the reservoir to bathing water. While considerable work had been done in past years to identify the source of the occasional occurrences of elevated *E. coli* densities at the Lake Winnipeg beaches, these efforts were largely unsuccessful. The focus of past studies was directed to the obvious large domestic sewage discharges from the City of Winnipeg, non-point source run-off from livestock operations and natural wildlife populations throughout the region, but these failed to identify either single or combined sources of bacteria that could account for the infrequent, but relatively high, densities observed at several of the Lake Winnipeg beaches (see http://www.gov.mb.ca/conservation/watres/lkwpg_beach_report_interim-040129.pdf).

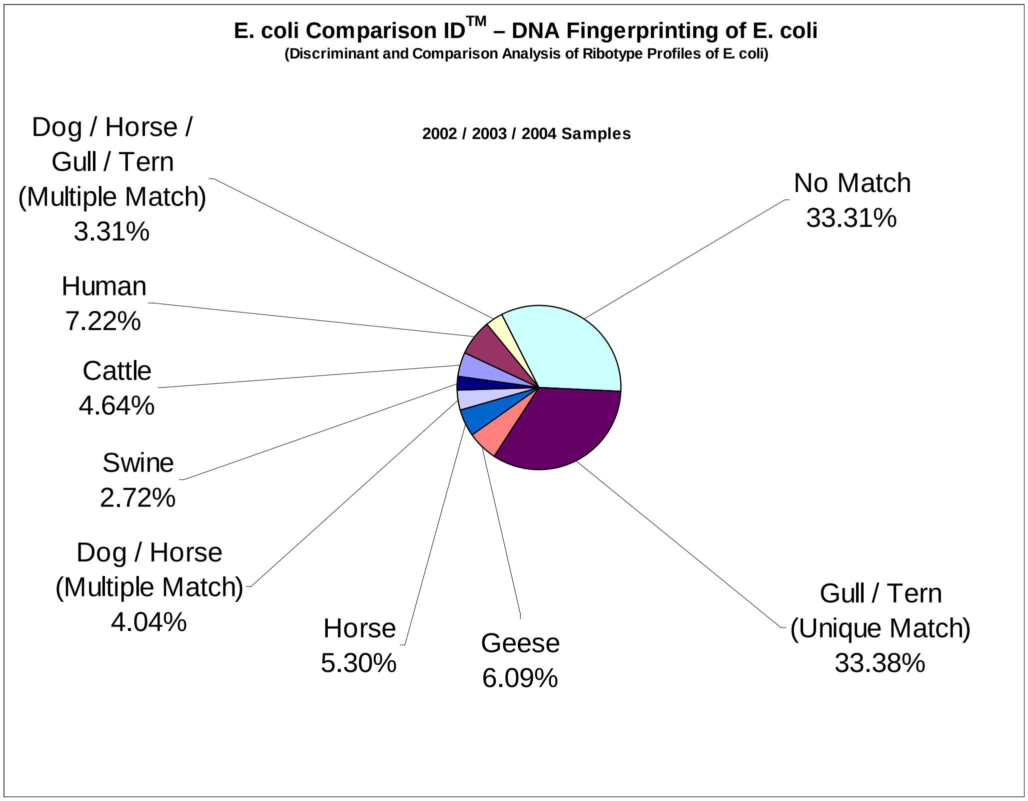
As a result of this recent work, it is now known that elevated densities of *E. coli* are present in the surficial water underlying sand in the foreshore beach region at many Lake Winnipeg beaches, that these bacteria populations are being transferred periodically to bathing water with wind-induced water level changes, and that the majority of *E. coli* originates from animal sources rather than humans, with gulls and terns being the largest single animal contributors. There was strong presumptive evidence in both 2003 and 2004 to indicate that the *E. coli* population in both the foreshore beach region and bathing water arises from bacterial re-growth and that this re-growth likely occurs in the wet sand underlying the foreshore beach region. Densities of *E. coli* bacteria have been correlated with wind-induced water level changes in the South Basin of Lake Winnipeg, with short-term water level changes accounting for approximately 40% of the observed variability in bacteria densities at Gimli and West Grand beaches. This identified mechanism of transport from the foreshore beach region to bathing water is likely an important mechanism only in large lakes such as Lake Winnipeg because of the absence of significant wave action and associated daily water level fluctuations in smaller recreational lakes.

Findings in 2003 showed that humans contributed about 8% of the *E. coli* with the remainder being from animal sources (with some being unmatched to either). Of the animal sources, gulls and terns contributed about 13% and were the largest single identified source. However, about 80% remained unmatched to any animal or bird. Findings in 2004 showed that humans contributed less than 1%, that gulls and terns contributed about 45% and, when combined, gulls, terns and geese contributed about 50%. The unmatched animal sources were reduced from 80% in 2003 to 34% in 2004. There were no hogs matched with *E. coli* in 2004. All of the samples from 2002, 2003 and 2004 were re-analyzed. The combined findings from the last three years are displayed in the attached graph (Figure 1).

The overall conclusions following completion of the 2004 work remain the same as in 2003 but are now strengthened with more conclusive data. It is clear that, indeed, gulls and terns are the single largest contributors. Unfortunately, not all *E. coli* samples were successfully matched to animal sources but the number of unknown matches was significantly reduced from about 80% in 2003 to about 34% in 2004. The data from 2004 also indicate that *E. coli* survived through the winter in the beach sand at some beaches.

There are a number of management needs related to the *E. coli* issue. These include the need to continue work towards developing a model that can successfully predict when meteorological conditions are most likely to be present that are responsible for transport of indicator bacteria from the foreshore sand to the bathing water; the need to understand whether or not indicator bacteria are replicating in the wet beach sand; the need to gain an understanding of the health risks facing bathers through epidemiological studies arising from exposure to largely bird sources of indicator bacteria rather than humans, since most existing relationships between bather-related illnesses and indicator densities are assumed to arise from exposure to human sources of fecal material; and the need to implement programs to reduce contributions of fecal material, particularly from shore birds to foreshore sand.

Figure 1. Sources of *Escherichia coli* at Lake Winnipeg beaches from 2003 to 2004 following application of DNA ribotyping source tracking techniques.



Finally, there are a number of other water-quality issues that challenge managers of Lake Winnipeg. These include tracking the fate of toxaphene accidentally contributed to Lake Winnipeg during the flood of 1997, understanding the consequences of the present small complement of exotic species in Lake Winnipeg and preventing further introductions, undertaking measures to assure resilience in advance of climate change, plus others.

As a closing comment, I note that management actions implemented to reduce nutrient contributions to Lake Winnipeg will increase the resiliency of the lake and its watershed to better withstand and to minimize the impacts from future stressors such as climate change.

WATER QUALITY AND NUTRIENTS: LAKE ERIE AND THE LAKE WINNIPEG SITUATION
Presentation by: Murray Charlton

Lake Erie has had a plethora of management issues since the 1920s. The earliest on record were fisheries problems. The issues have increased in complexity but no issue has dropped off the list. The list of issues keeps growing while the research and management funds do not grow.

Growing concern led to the Great Lakes Water Quality Agreement (GLWQA) between Canada and the US in 1972. The GLWQA featured the following goals:

- Decrease phosphorus loads by about 50%
- Decrease algal problems
- Year-round aerobic conditions in Central Basin hypolimnion
- Later versions called for Remedial Action Plans and restoration of "Ecosystem Integrity"
- 25% of load to the lake was from detergents—ban phosphorus from detergents
- Large portion of load was municipal sewage
- Control sewage to 1 mg P/L for all the largest sewage plants—technologically based target would reduce load by half
- Control non-point sources.

The results were:

- Phosphorus load reduced by 50% in Lake Erie and Lake Ontario
- Phosphorus concentrations decreased by 50% in western Lake Erie and Lake Ontario
- The majority of the improvement was caused by better sewage treatment
- Non-point sources hardly changed.

Phosphorus concentration and bioavailability determines the importance of a phosphorus load. This point is often missed in the engineering approach to P load management but is explicit in the OECD/Vollenweider models.

The hypolimnion oxygen goals of the GLWQA have not been achieved—early analyses were flawed and based on little data or understanding. Oxygen is a tempting selling point but is often misused and can bring a lack of credibility. For example, no sooner had the EPA whipped up a hysterical frenzy about Lake Erie's "DeadZone" than we had 2 good years for oxygen. They deal with short term data—I don't. On the other hand, the public understands suffocation and oxygen in survival terms so the kafuffle was good for grants.

Walleye were almost killed off by commercial fishing in Erie. They began their recovery when fishing was stopped at the time of highest nutrient pollution and have continued their recovery. Commercial fishing is a large structuring force in Erie and other lake ecosystems.

Recently, alien mussels seem to have caused otherwise inexplicable perturbations in Lake Erie's phosphorus concentrations. Again, the alarm was raised instead of a responsible wait and see stance.

Lake Winnipeg is similar to much of Lake Erie. The South Basin of Lake Winnipeg is similar to Lake Erie's west basin, which receives the most pollution.

Shallow lakes tend to have higher rates of hypolimnion oxygen depletion—this was known in the late 1920s.

Shallow lakes will exhibit a high degree of variability in oxygen depletion due only to variable inter-annual weather variations.

Sewage plants may achieve 0.3 mg P/L. These are recent techniques for a conventional secondary plant with phosphorus precipitation. How well do Manitoba plants do in comparison?

Municipal waste is the easiest to control and to monitor. Detergents accounted for 25% of the P load to Lake Erie. That load is gone now. Is yours?

There are only a few lake management "levers". Is the research applied to decision making about these levers?

"We cannot understand phosphorus dynamics unless we know whether carbon gets into protozoa by diffusion or ingestion so give me a juicy grant" (A.N. Unknown 2002). BUT is that understanding needed for any decision making? What research is actually needed to apply against the management levers?

A big item is the concentration and bioavailability of phosphorus loads.

FISH COMMUNITIES: LAKE WINNIPEG'S FISH AND FISHERIES
Presentation by: Walter Lysack

Lake Winnipeg has been commercially gillnetted since the 1880s. Sturgeon was the first species to collapse due to its biological inability to cope with excessive fishing effort. Annual yields of whitefish were highest in the 1920s and declined until the mercury closure in 1970. After the mercury closure, whitefish yields again increased until the mid-1980s and then declined erratically. The harvest of whitefish roe increased during the mid-1990s. Walleye and sauger yields were highest after whitefish first began declining. They declined erratically until the mercury closure and then increased again until the mid-1980s. Sauger yields declined from the mid-1980s to the present while walleye yields attained a historical maximum in 2000. (Until 1970, yields were recorded as marketed weight. After 1970, yields were recorded as round equivalent weight by the Freshwater Fish Marketing Corporation [FFMC]).

An annual quota of 6,400,000 kg is currently applied to the combined commercial fishery yield of walleye, sauger and whitefish. Walleye provide the greatest financial value and whitefish provide the least value. Quota entitlements were created in 1985. There are about 1649 quota entitlements for the summer, fall and winter commercial fisheries. Quotas can be "rolled" forward and backward. The current annual quota has never been attained. A temporally increasing number of "special dealer" permits allow fishers to sell their catch directly to consumers or retailers. Domestic and illegal fishing activities produce unknown amounts of fish.

Cotton and linen gillnets were replaced by multifilament nylon nets in the early 1950s. Nylon nets were replaced by monofilament nets in the early 1990s. This has quadrupled the efficiency of a typical gillnet. Both trap nets and gillnets were permitted during the late 1960s. Minimum commercial mesh sizes range from 3 inch (stretched measure) in the South Basin to 3.75 inches in the North Basin. The minimum mesh size in the North Basin was 4.25 inches until 1991. Since 1992, the summer fishery in the South Basin does not commence until 80% of the walleye have spawned. Whitefish spawning does not control the opening date of the fall fishery.

Walleye yield density declined after each time that it surpassed 1 kg ha^{-1} (1950 and 1985). This is probably the upper limit of sustainable walleye yield in Lake Winnipeg. The sustainable yield formula developed by Baccante and Colby (1996) estimates that Lake Winnipeg can sustain an annual walleye harvest of 0.66 kg ha^{-1}. Annual walleye yields are related to annual fishing effort.

From 1979 to 2003, maturity ages of all three quota species have generally tended to shift towards younger ages and display increasing rates. The parameters of Ricker stock-recruitment curves for walleye and sauger are strongly affected by the choice of age class used to indicate abundance of recruits. The trawling program that attempted to estimate annual abundance of young-of-the-year (YOY) walleye and sauger failed because an arbitrary body length was chosen to discriminate between YOY and age-1 fish. Otolith ages of YOY and age-1+ walleye revealed that their body length distributions overlap.

Indices of whitefish spawning stock and recruitment fit poorly to both Beverton–Holt and Ricker stock-recruitment curves.

Median values of abundance indices from the annual monitoring program (1979–2003) indicated that:

1. Whitefish abundance and mature female whitefish abundance have declined erratically over the long term.
2. Sauger abundance declined slowly from 1979–1996. Sauger data after 1999 are not reliable because they were poorly collected. The abundance of mature female saugers increased during the latter part of the 1990s.
3. Walleye abundance increased until the mid-1980s, then declined until the mid-1990s and has increased to its highest level in 2003. The abundance of mature female walleyes remained relatively low and constant until the late 1990s when it began to rapidly increase.

In years that the mean value of an abundance index is greater than the median value, the majority of fish were caught in relatively few gangs and many gangs caught fewer fish. Temporal changes in the FFMC abundance index and the Fisheries Branch abundance index were well related for walleye and less related for sauger and whitefish.

Walleye grow faster and attain greater maximum body sizes than whitefish. Sauger grow relatively slowly and attain the smallest maximum body size of the three quota species. Both minimum and maximum annual body sizes of walleye increased from 1979–2003. Maximum annual body sizes of whitefish and saugers decreased during this period. Minimum body sizes of whitefish and sauger increased. This may indicate increasingly poor recruitment of whitefish and sauger. Weight:length ratios of whitefish declined slowly from 1979–1995. After the steepest decline in 1996, whitefish weight:length ratios began increasing again. Walleye weight:length ratios increased erratically from 1979–1995, declined sharply in 1996 and began increasing again. Sauger weight:length ratios have increased since 1979.

Mortality rates of successive walleye cohorts from the 1971–1981 cohorts were more variable than those of sauger cohorts. Mortality rates of successive walleye cohorts from 1981–1992 have steadily increased while sauger cohort mortality remained relatively constant. Annual mortality rates of whitefish have declined slowly and erratically from 1979–2003.

The summer commercial fishery tends to select walleye that are older than those selected by the fall fishery. Mean ages at 50% maturity have ranged from 4–8 years. Since the open water fisheries select relatively few walleyes aged 8+ and since walleyes grow relatively fast and attain large maximum body sizes, the prime spawning females remain largely unexploited. This partly explains why the walleye abundance index has increased. The other reason is the change to a new and abundant prey, smelt, in the northern basin. A Gavaris ADAPT virtual population analysis depicts the recovery of a large spawning stock of walleyes after 1991 (after the North Basin minimum commercial mesh size was changed from 4.25 inches to 3.75 inches).

The summer and fall commercial fisheries select similar age ranges of whitefish. In contrast to walleye, a larger segment of females past the age of 50% maturity are still exploited. The slower growth of whitefish keeps them susceptible to the commercial gillnets until age 9+. This has caused a decline in the whitefish abundance index.

This scenario is exaggerated for sauger. Summer fisheries select 3–12 year old sauger. Fall fisheries select younger sauger. A larger segment of fish much older than the age of 50% maturity are still selected by commercial gillnets. Slow growth and a small maximum body size make prime spawning sauger more vulnerable to exploitation. This has caused a marked decline in the sauger abundance index. The same problem has also occurred in the Lake Manitoba commercial fishery.

Small (40–60 cm) pike are present in all Manitoba commercial fisheries. Pike larger than 60 cm were cropped years ago. Pike mature at 40 cm and maintain themselves between 40–60 cm in the face of continuous fishing effort. Pike in this size range prey on suckers in the 20–25 cm range of body sizes. Once sucker have surpassed this size range, their mortality declines since large pike are not present to prey on them. The extremely rapid growth of suckers does not expose them to the vulnerable 20–25 cm size range for very long. The high fecundity of larger sucker females maintains a high recruitment of small suckers. The removal of large pike and pike's ability to maintain itself in the 40–60 cm size range has caused sucker abundance to increase dramatically in all Manitoba commercial fisheries.

The survival of young whitefish is negatively affected by high chlorophyll concentrations during their birth year (age 0). Environment affects early (age 0–3) survival of walleye so that about 2 strong cohorts are recruited to the fishery per decade. The temporal patterns of age 3 walleye recruitment also vary spatially from the South to the North Basin. Fewer strong cohorts of sauger are recruited per decade. This is more a function of declining spawning stock size especially in the George Island–Berens River area. Spawning stock size is weakly related to recruitment of all three quota species. A trawling program that properly identifies age 0 walleye and sauger is required to improve stock-recruitment curves. Using abundance of older fish as a recruitment index does not work well.

Sturgeon, trout and large whitefish were present in the late 1880s. Sturgeon and trout stocks collapsed at the turn of the century. Whitefish abundance declined before 1930. Percids became dominant as whitefish abundance declined. Walleye, sauger and whitefish stocks collapsed during the 1960s and declined again in the late 1980s. Recently, whitefish stocks have stabilized at a low level, sauger continues to decline and walleye have shown a marked increase in abundance. The maintenance of a "hammer handle" pike stock at low abundance levels has allowed sucker abundance to continue increasing. Exotic species were introduced in the 1940s (carp), 1964 (white bass), 1980s? (black crappie) and 1990 (smelt).

The annual stock monitoring program that was standardized in 1979 eroded during the late 1990s and stopped after 2003. From a fish stock monitoring perspective, we need trawling data for accurately identified YOY walleye, sauger and whitefish to be used to annually adjust future quotas. We need temporal changes in abundance of other gillnetted species. We need gut content data. We need catch and effort data from the “special permit” fishery. We need catch and effort data from the “domestic” fishery.

Bibliography

Baccante, D.A. and Colby, P.J. 1996. Harvest, density and reproductive characteristics of North American walleye populations. Annales Zoological Fennici 33: 601–615.

FISH COMMUNITIES: FISH AND FISHERIES OF LAKE ONTARIO: A CASE HISTORY
Presentation by: John M. Casselman

Commercial and recreational fisheries of Lake Ontario combine with the others of the Great Lakes to be among the largest in the world. In the first half of the 20th century, commercial fisheries targeted mainly large-bodied species, particularly lake herring, cisco, lake trout, lake whitefish and walleye. Declines of these large-bodied commercial species became apparent in the 1940s through the 1960s, and extirpation became common (e.g. deepwater ciscoes). This left, in the extreme, only small-bodied exotics abundant, e.g. Lake Ontario—alewife, rainbow smelt and white perch. The major destabilizers were overfishing, exotic invaders, particularly sea lamprey, eutrophication and habitat alteration. This created challenges that produced positive international co-operative initiatives, creating the Great Lakes Fishery Commission (1955) and the Great Lakes Water Quality Agreement (1972). These fostered effective lamprey control, reduced nutrient loading, co-operative ecosystem-based fisheries management, and establishment of long-term fish community indexing programs that commenced in Lake Ontario in 1958.

For 30 years, fisheries have benefited from these initiatives and from more effective management. However, recently we have seen dramatic ecosystem changes, fish-community dynamics, and declines. With the extirpation of lake trout in the late 1940s, rehabilitative stocking was initiated, in earnest, in the mid-1970s. This was conducted in association with lamprey control and intensive stocking of exotic salmonids to increase fishing opportunity. One hundred years of total harvest statistics are available for Lake Ontario. Prior to the 1950s, harvest was almost exclusively commercial. But in the past several decades, it has been equally proportioned between recreational and commercial, although substantially reduced compared with the earlier period. The establishment of long-term indexing programs almost five decades ago provided valuable quantitative indices for assessing population and fish-community dynamics and structure. These provide valuable insights into the many stressors and influencing factors, such as exploitation, invasive species, changes in trophic conditions (ranging from hyper-eutrophication to induced oligotrophication), water-level dynamics and stabilization, climate and climate change, and habitat alteration.

Exploitation was an important early factor in influencing fish abundance and community structure. Its impact was most apparent when other stressors occurred in concert. A specific example is the dramatic decline of the commercial lake herring fishery in the early 1950s. This occurred when fishing pressure remained high while abundance of lake trout, another important commercial species, decreased dramatically. Lake trout were also exposed to increasing lamprey abundance and spawning-substrate degradation (eutrophication and siltation). One of the primary factors in lake herring declines was the interrelationship between decreased lake trout abundance and reduced predation pressure on smelt. Smelt, an early invader, first appeared in the 1920s and dramatically increased in the 1940s. In the absence of lake trout predation, large smelt became increasingly abundant—so much so that, in the late 1940s, they supported a commercial fishery. Large smelt are substantial larval piscivores. The increase in large smelt coincided with the dramatic decline in lake herring recruitment. In the presence of reduced recruitment and continued commercial fishing pressure, the lake herring population declined drastically and has never recovered to its former level, mainly because of community restructuring. Intensive rehabilitative stocking of lake trout in the mid-1970s dramatically reduced the abundance of large smelt. This change was associated with a coincidental resurgence in whitefish recruitment in the late 1970s. Predator–prey interactions among lake trout, smelt, and lake herring, as well as whitefish, confirm that large smelt in Lake Ontario directly affect coregonine recruitment and dynamics.

Two other exotic species, alewife and white perch, are also important predators on larval native fishes (e.g. walleye and yellow perch). These exotics are thermally ill-adapted to Lake Ontario and, as a result, have gone through extreme dynamics, best exemplified by the catastrophic winterkills in the late 1970s. With the aid of long-term community indexing programs, the roles of these exotics, as both predator and prey, are also well documented.

Long-term indexing emphasizes the importance of climate on fish-community dynamics and structure and provides the ability to predict responses to global climate change. Detailed studies into the effects of temperature on recruitment and growth of typical warm-water (e.g. smallmouth bass), cool-water (e.g. northern pike), and cold-water species (e.g. lake trout) have been quantified. Warm-water species are increasing substantially, but at a predictable pace, given temperature increases over the past three decades. These temperature changes match and confirm global climate change. Recruitment changes with a 1º to 3º increase in water temperature indicate that, in Lake Ontario, recruitment of cold-water species will decrease substantially, as will cool-water species but to a lesser extent, while recruitment of warm-water species will increase dramatically. Relative to the rest of the fish community, recruitment of the warm-water assemblage will increase by 2.1-fold with an increase of 1ºC and 2.8-fold with a 2ºC increase.

The long-term community indexing of the Bay of Quinte makes it possible to study the effects of nutrient loading and phosphorus control both temporally and spatially. Two stocks of whitefish exist in Lake Ontario—a “bay” and a “lake” stock. The bay stock virtually disappeared in the mid-1970s with increased phosphorus loading, heavy fishing pressure and increasing thermal conditions. With phosphorus control and more favourable temperature conditions, the bay stock re-established from a resurging remnant lake stock. Resurgence of both stocks, particularly the bay, occurred in the 1980s, partially as a result of more ideal spawning conditions (cold falls and winters) and decreased smelt abundance and associated larval predation.

Recruitment of both whitefish stocks has decreased substantially in the past decade (1990s), mainly because of invasion and colonization by dreissenids and their impact on *Diporeia*, a preferred whitefish prey, which has virtually disappeared from the inshore waters. Warm falls and winters have also created less favourable spawning and recruitment conditions. Habitat changes caused by dreissenid colonization are substantial. They have induced oligotrophication, substantially increased transparency, and altered and infilled substrate.

During the 1980s and 1990s, fish communities in eastern Lake Ontario and the Bay of Quinte underwent changes of a magnitude not documented for more than four decades, including during catastrophic winterkills in the late 1970s. Rehabilitative stocking of lake trout commencing in the mid-1970s, as well as stocking of other salmonids, restructured the cold-water community. Native whitefish and walleye resurged after recruitment increased substantially in 1977–78, influenced by more favourable thermal conditions (cold falls followed by warm springs and summers) and reduced larval predation (decreased abundance of exotic smelt, alewife, and white perch). Large species reached record-high levels in the late 1980s and early 1990s, creating increasing prey demand that required maximum prey production, possible in the abnormally warm period in the early 1990s. In the 1990s, average fish weight reached a three-decade high. After peaking, overall abundance declined by two-thirds, followed by biomass by one-half. Small prey, particularly alewife and smelt, reached record-high levels, then declined precipitously; slimy sculpins reached record-low levels. Large species such as lake trout, whitefish and walleye reached record-high levels a few years later and then also declined abruptly. Decreased abundance, which began during the pivotal 1991 to 1993 period, coinciding with a major low-temperature perturbation (1992) caused by the eruption of Mount Pinatubo, was sustained by complete dreissenid colonization (1994) and associated biological oligotrophication and declining phosphorus levels.

Coincidentally, native lake trout, lake sturgeon and deepwater sculpin have reappeared, along with chinook recruitment, originating from the 1992 to 1995 year-classes. Recruitment of the catadromous American eel has virtually ceased, causing a substantial decline from record-high levels in the late 1970s. In the 1990s, yellow perch in the bay increased to record-high levels, and because of dreissenid-induced increased transparency, walleye left the Bay of Quinte and the fish community started reverting from one of walleye–alewife to yellow perch–northern pike–centrarchids reminiscent of the 1930s to 1950s. Inshore water temperatures have increased significantly over the past five decades, matching global warming. If this continues, community structure will be dramatically altered and warm-water species will become significantly more abundant. Recent studies on the effects of water-level dynamics and stabilization on long-term recruitment of northern pike and yellow perch confirm the negative effects of stabilization and water-level alteration. Exotics that will alter and destabilize the fish community have appeared; round gobies are colonizing the inshore waters. Cormorants, acting like invaders, have increased substantially over the past two decades and are now competing for, and influencing, fish resources.

The long-term community indexing program in Lake Ontario and its associated embayments provides considerable insights into the primary stressors, impacts, influences and processes that affect fish population abundance and community dynamics and structure. The most profound ecological changes in the Lake Ontario ecosystem and its fish communities since the 1970s are reductions in phosphorus loading, invasion by dreissenids, fisheries management through stocking of exotic salmonids and control of lamprey, and fish harvest by anglers and double-crested cormorants. Stressor responses associated with anthropogenic forces, such as exotic species invasions and global climate warming, will significantly influence the Lake Ontario ecosystem in the future. Continuous long-term ecological studies and indexing are recommended to enhance the scientific understanding and management of these important resources.

Selected References for Further Reading

Casselman, J.M. 2002. Effects of temperature, global extremes, and climate change on year-class production of warmwater, coolwater, and coldwater fishes in the Great Lakes Basin. Pages 39–59 *in* McGinn, N.A., ed. Fisheries in a changing climate. Proceedings of American Fisheries Society Symposium 32. American Fisheries Society, Bethesda, MD. 295 p.

Casselman, J.M. and Scott, K.A. 2003. Fish-community dynamics of Lake Ontario—Long-term trends in the fish populations of eastern Lake Ontario and the Bay of Quinte. Pages 349–383 *in* Munawar, M., ed. State of Lake Ontario: Past, present and future. Ecovision World Monograph Series. Aquatic Ecosystem Health and Management. Society. 664 p.

Casselman, J.M., Scott, K.A., Brown, D.M., and Robinson, C.J. 1999. Changes in relative abundance, variability, and stability of fish assemblages of eastern Lake Ontario and the Bay of Quinte—The value of long-term community sampling. Aquatic Ecosystem and Health Management 2: 255–269.

Hoyle, J.A., Casselman, J.M., Dermott, R., and Schaner, T. 2003. Resurgence and decline of lake whitefish (*Coregonus clupeaformis*) stocks in eastern Lake Ontario, 1972 to 1999. Pages 475–491 *in* Munawar, M., ed. State of Lake Ontario: Past, present and future. Ecovision World Monograph Series. Aquatic Ecosystem Health and Management Society. 664 p.

Mills, E.L., Casselman, J.M., Dermott, R., Fitzsimons, J.D., Gal, G., Hoyle, J.A., Johannsson, O., Lantry, B.F., Makarewicz, J.C., Millard, S., Munawar, M., Munawar, I.F., O'Gorman, R., Owens, R.W., Rudstam, L.G., Schaner, T., and Stewart, T.J. 2002. Lake Ontario: Food web dynamics in a changing ecosystem (1970–2000). Salmonid Communities in Oligotrophic Lakes—SCOL II. Canadian Journal of Fisheries and Aquatic Sciences (submitted).

Munawar, M. ed. 2003. State of Lake Ontario: Past, present and future. Ecovision World Monograph Series. Aquatic Ecosystem Health and Management Society. 664 p.

Vander Zanden, M.J., Wilson, K.A., Casselman, J.M., and Yan, N.D. 2004. Species introductions and their impacts in North American Shield lakes. Pages 239–263 *in* Gunn, J.M., Steedman, R.J., and Ryder, R.A., eds. Boreal Shield watersheds. CRC Press, Boca Raton, Florida.

FISH HABITAT: HABITAT IMPACTS AND ALTERATIONS PAST, PRESENT AND FUTURE

Presentation by: Keith Kristofferson

Introduction and Background

DFO's Mandate: Strengthening fish habitat protection in Canada's inland provinces. Many fish stocks are declining due to pressure on fish habitat. Habitat conservation is critical to ensure continuation of Canada's commercial, recreational and subsistence fisheries. The commercial resource is valued at more than $13 billion annually in Canada and $30 million annually in Manitoba. Simply put: no habitat, no fish.

DFO's Vision: Safe, healthy, productive waters and aquatic ecosystems, for the benefit of present and future generations.

Fisheries Act definition of fish habitat: "Spawning grounds and nursery, rearing, food supply, migration and any other areas on which fish depend directly or indirectly in order to carry out their life processes". It includes lakes, rivers, streams, creeks, intermittent watercourses, man-made drains and wetlands. Fish habitat consists of the many parameters that comprise the life stage requirements of fish and aquatic organisms for spawning, feeding rearing, overwintering and migration. This would include water quantity and quality, riparian vegetation, and aquatic plants and food. As such, the definition is very broadly based and can be applied to Lake Winnipeg habitat impacts on both a macro and micro scale.

Fisheries Act relevant sections: The two major sections of the Fisheries Act that are used by the Habitat Management Branch are: Section 35(1), which prohibits works or undertakings that could result in the harmful alteration, disruption or destruction of fish habitat, and Section 36(3) which prohibits the deposit of a deleterious substance in waters frequented by fish.

Environment Canada is responsible for enforcing violations of section 36(3) as they pertain to pesticides, herbicides and other chemical alterations, and DFO Habitat Management is responsible for the deposition of sediment. Again, the potentially broad application of Section 35 of the Fisheries Act includes any "Harmful Alteration, Disruption or Destruction (HADD)" of fish habitat, which is defined as: "Any change to the physical, biological, or chemical attributes of habitat that adversely affects the habitat's ability to provide the basic life requisites (spawning, rearing, nursery, overwintering, feeding, migration)".

Macro-habitat Characteristics of Lake Winnipeg—Geographic, Geologic, Ecologic and Hydrologic Settings

The lake lies along the boundary between two physiographic and climatic zones. East: Precambrian Shield with high rainfall and water yield; west: Paleozoic sediments with low rainfall and water yield. Bathymetry characteristics: The North Basin is larger and deeper at 17,520 km^2 and averaging 13.3 m depth. The South Basin (including The Narrows) is smaller and shallower at 6,230 km^2 and averaging 8.3 m depth. The deepest part of the lake is a hole near Black Island 36 m (118 ft) deep. The Lake Winnipeg watershed is 39 times its surface area and includes Saskatchewan, Alberta, North Dakota and Minnesota. By comparison, the Lake Erie Watershed is only 3 times its surface area. There are three dominant inflows to the lake: Saskatchewan River 22%, Winnipeg River 40%, Red River 8%. All other tributaries comprise 19%, and precipitation comprises 11% of flow contributions. There is one outflow, the Nelson River. The ecological zones that characterize Lake Winnipeg shorelines include the boreal forest to the east, aspen parkland and boreal forest to the west, and northwest and prairie landscapes to the south and southwest. This sets the stage for examining any historical, present or potential habitat impacts on Lake Winnipeg.

Lake Winnipeg Macro-habitat Impacts—Water Quality, Quantity (Flow) and Productive Capacity Alterations

Although mean monthly water levels pre- and post-hydro regulation from 1914–2003 appear to have changed very little, this information is based on a lakewide average and corrected for wind setup. After regulation, Lake Winnipeg is operated as a reservoir, where water is held back during the open-water months and discharged during the winter months because power requirements increase at this time of year. This has resulted in a dampening in amplitude and frequency of water-level fluctuations, which may have impacted the productive capacity of littoral zones and wetlands as indicated by a change in annual winter and summer outflows from 1915 to 1998. Surface temperature changes show some increase in the South Basin over time but there is no long-term data set to make any conclusive observations lakewide. Nutrient input increases have occurred (N and P) as have sedimentation rates in both North and South Basins as a result of changes in agricultural land drainage increases and practices.

The biological response is reflected in algal bloom increases, an algal species composition shift to blue greens, phosphorous input from rivers, transparency changes (especially in the North Basin), and changes in species composition and abundance in phytoplankton, crustaceans and zoobenthos.

Lake Winnipeg Invasive, Exotic and Endangered Species

The newly proclaimed Species at Risk Act (SARA) and COSEWIC status reports have targeted the following species for review: carmine shiner, silver chub, short jaw cisco, bigmouth buffalo, chestnut lamprey and the *Physa* snail. Exotic species introductions currently include carp, rainbow smelt, white bass, smallmouth bass and the exotic zooplanktor *Eubosmina coregoni*.

Micro-habitat Alterations to the South Basin Shoreline

Extensive modifications have been made to the east- and west-side shorelines in the South Basin by land owners and recreational cottagers through a combination of shoreline stabilization developments and beach creation developments using rock groynes. This has resulted in a major alteration of valuable fish spawning, rearing and nursery habitat in the littoral zone. Historical habitat value in the areas has been documented in index trawl catches in these areas from 1976 to 1983. While portions of the South Basin are prone to erosion due to underlying geologic and hydrologic conditions, many landowners continue to apply these practices outside of these zones of vulnerability and considerable cumulative damage has already been done to the natural habitat.

Summary and Conclusions

Numerous existing and potential macro impacts on the productive capacity of fish habitat may be occurring as a result of changes in hydrological flow regime, nutrient loading and sedimentation rate increases. In addition, the biological response appears to include changes in species composition and abundance in phytoplankton, zooplankton and zoobenthos. Interpretation of these impacts has been additionally complicated by increases in exotic and invasive species introductions and abundance. Micro impacts to the alteration of shoreline in the South Basin of Lake Winnipeg have also occurred, with the cumulative impact lakewide of an alteration in the productive capacity of fish habitat.

What Needs To Be Done?

Identify research and information gaps to develop a Lake Winnipeg ecosystem model. Conduct research in a comprehensive and collaborative manner. Establish linkages of perturbations to existing or potential impacts on fish habitat. Identify and inventory productive capacity of Lake Winnipeg in an ecological context. Eliminate, mitigate and rehabilitate any damage to the ecosystem.

Research Needs

Inventory representative habitat classes, e.g. using sonar mapping technology (DFO). Use historical satellite imagery to establish linkages relating the optical quality of the water column to pelagic and benthic components using trawls and benthic grabs, as currently being examined by DFO and CEOS.

Ongoing Research

Expand the benthic sampling program of Dr. Brenda Hann from the Department of Zoology at the University of Manitoba. Refine our understanding of productive capacity by measuring carbon and nitrogen fixation and planktonic community structure by DFO. Determine the status of COSEWIC-listed species (DFO).

FISH HABITAT: LESSONS LEARNED FROM THE GREAT LAKES: HABITAT SCIENCE EXPERIENCE

Presentation by: Robert G. Randall and Susan Doka

Introduction

The large spatial scale of the Great Lakes presents a challenge for providing science support for the management of fish habitat. To introduce and illustrate some of the approaches adopted in the Great Lakes, three topics are described: 1) the science basis for a regional fish habitat management plan; 2) the use of field data to develop and validate empirical predictive models of the productive capacity of coastal habitat; and 3) large scale multi-partner projects to predict the impacts of climate change and changes in water level to fish habitat. Details of topics one and two can be obtained from published information; topic three is an ongoing and expanding program in the Great Lakes (websites provided below).

Regional Fish Habitat Management Plan

Severn Sound, Georgian Bay, was identified by the International Joint Commission as one of 17 Areas of Concern in the Ontario Great Lakes region. In addition to water-quality issues, the degradation of fish populations and fish habitat was a key concern in this area. As part of the Severn Sound Remedial Action Plan, an interim fish habitat management plan was developed using a 'panel of experts' approach in 1993. Subsequently, a scientifically defensible approach and methodology for classifying coastal habitat in Severn Sound was developed by Ken Minns (Minns et al. 1999; Canadian Manuscript Report of Fisheries and Aquatic Sciences 2490). The abstract from this report is reproduced below:

> *This report documents the GIS database assembled for the littoral habitat areas of Severn Sound, Georgian Bay, and describes the methods used to devise a fish habitat classification model for those littoral areas. Development of the classification model was undertaken to provide the implementers of the Remedial Action Plan in Severn Sound with a scientifically defensible update for their interim fish habitat management plan. The interim plan was prepared as a guidance document for local and regional planning authorities to promote increased regard for fish habitat and the legislated responsibilities where proposed developments impinge on littoral habitat. In that plan, a group of local fish habitat experts had classified shoreline lengths into one of three classes, Red, Yellow or Green. The different colours signalled different levels of importance of littoral areas as fish habitat and the lists of allowable and excluded activities were linked to the colour-codes. Most of the littoral habitat in Severn Sound between 0 and 1.5 metre depth was inventoried over a period of several years. Depth, substrate, and vegetation areas were mapped by field crews for much of the littoral zone. The data were digitized and brought into a geographic information system (GIS). The GIS database provided the foundation for the development of a new fish habitat classification model. The fish habitat model considered four types of information: 1) Composite suitability index values derived for all species and life stages of the*

fish assembly present in Severn Sound using the Defensible Methods suitability indexing model; 2) Identification of rare habitat types specific to particular thermal-life stage-trophic guilds of fish species; 3) Wetlands identified through Ontario's provincial wetland classification system; and 4) Local expert identification of important habitat areas for particular fish species and life stages. For the composite and rarity components of the model, method development and validation results are described. Each component was implemented as a map layer in the GIS database. The classification model separates of habitat units into three classes, low, medium, and high, using composite suitability indices. Then the rarity, wetland, and expert layers are used to override low and medium class memberships, reassigning them to the high class. The final high, medium, and low classes are then renamed Red, Yellow and Green. The results of the classification steps are illustrated. The complete GIS database including full implementation of the classification model are available on an enclosed CD-ROM. The limitations of the source data and the classification model are assessed and future steps required for iterative improvement are identified.

Empirical Field Data: The Development of Predictive Models, Model Validation and Experimental Field Research

As noted in the above abstract, field data were used to validate the Fish Habitat Classification Model for Severn Sound. If collected using a standardized survey protocol, field data can also be used to develop and validate empirical models for predicting the productive capacity of nearshore fish habitat. In large lakes, shoreline habitat and the associated fish community is influenced by coastal exposure. Using a large database from the lower Great Lakes, Randall et al. (CSAS Research Document 2004/087) developed a predictive model to determine habitat productive capacity for extensive coastline areas. The abstract from the report is reproduced below:

Regression tree classification with coastal exposure (fetch distance) as a predictor of fish abundance was used to evaluate the productive capacity of near shore habitat in the Great Lakes. Coastal habitat characteristics that influence fish distribution, including the occurrence and abundance of submersed macrophytes, water temperature and substrate characteristics, were related to maximum fetch distance. Three classes of macrophyte density (absent, moderate and dense cover), were predicted from substrate size and fetch distance: plant cover was highest where the dominant substrate size was fine (silt) and maximum fetch was < 12.6 km. Fetch was a significant predictor of the biomass of both individual species and two fish community metrics, the Index of Biotic Integrity (IBI, a measure of species richness and assemblage composition) and a Habitat Productivity Index (HPI, a product of site biomass and P/B). For all response variables, classification was improved if fetch was used together with the other habitat attributes as predictors. The degree of resolution of habitat classification (number of classes that were discernible) was limited to 2 to 4 classes, depending on the fish response variable. Proportional reduction in error for the regression trees ranged between 0.30 and 0.76. Four classes of Lepomis gibbosus habitat were determined and validated, but *the number of habitat classes for Perca flavescens and Alosa pseudoharengus was less. For the whole fish assemblage, four habitat classes were identified using IBI as the dependent index of productive capacity, and fetch, water temperature and HPI as predictors. Knowledge of site exposure and the underlying habitat-fish linkages can be used to determine and map first-order estimates of coastal habitat productive capacity in the Great Lakes.*

Experimental field research is invaluable for evaluating fish-habitat linkages and for making inferences about population production at a whole-lake scale. At a recent Technology Transfer workshop involving both the Science and Habitat Management Sectors, results of field experiments at inland lakes (Sault Ste. Marie and Experimental Lakes Area) were used to address several key science issues, including the investigation of habitat-specific process rates and fish production; non-linear or threshold responses to habitat alteration; effectiveness of compensation and mitigation projects; and the need for risk management. Many of the results from these whole lake studies can be extrapolated to large lakes. Further details are available in Randall et al. (CSAS Proceedings Series 2004/010).

Large-Scale Studies

<u>IJC Lake Ontario–St. Lawrence River Water Levels Study:</u> This is a large international undertaking that involves many different levels of integrated research to address the issue of changing water regulation practices at the Moses–Saunders dam at Cornwall, ON, that affect levels and flows in the Lake Ontario and St. Lawrence system (LOSL). A multi-agency task group has been established to look at the effects of water regulation on aquatic biota, particularly in sensitive coastal habitats. DFO Burlington has been tasked with addressing fish and fish habitat impacts under the current regulation scheme as compared to proposed schemes and simulated run-of-the-river conditions.

We have taken 3 approaches to assessing the impacts: 1) habitat supply calculations for different guilds of the nearshore fish community; 2) an assessment of representative fisheries species (northern pike, yellow perch, smallmouth bass and largemouth bass) and their population dynamics based on life stage habitat requirements; and 3) an assessment of two species at risk (bridle shiner, pugnose shiner) and their habitat supply in areas where they are present in the LOSL system.

The guilds were selected based on spawning preferences, which included shallow water, four different thermal windows, and vegetation versus open water spawning. Models use a detailed habitat database for the Lake Ontario and Upper St. Lawrence system generated using a GIS and habitat models, where necessary, to capture information on elevation, bathymetry, temperature, substrate type and aquatic vegetation. Population models use habitat supply in density-dependent functions.

The final assessment model compares weighted suitable area output, population abundance or recruitment metrics over 100-year time series based on lake and river temperatures and water levels that are generated for different regulation schemes. Baseline conditions, both current regulation practices and run-of-the-river scenarios, are used to assess the impact on fish and fish habitat in the LOSL system, both upstream and downstream of the dam, by comparison to new plans. Only the most sensitive and representative indicators, from the environmental assessment and other interest groups will be used to determine the best regulation scheme that does not harm the environment nor disproportionately harm one sector. Please see http://www.losl.org/ for more information on the study.

CCIAP Coastal Wetlands Vulnerability and Adaptation Strategy

Assessment: Partners on the project include CWS Downsview and the Adaptations and Impact Research Group of EC. DFO's responsibilities include the coordination of fish modelling for climate change impacts and the field work component for dyked and undyked marsh comparisons. The goal of this project is to assess the vulnerability to climate change of three biotic communities (aquatic vegetation, birds and fish) in coastal wetlands. Climate change in the Great Lakes, in most global climate scenarios, entails lower water levels and higher temperatures. Project partners are assessing the vegetation community response in different wetlands of the lower Great Lakes to historical water-level fluctuations. Using these models, future vegetation extent and community composition are predicted. The combination of water depth, substrate type, and vegetation present in wetlands is used to predict the habitat supply for different fish species that use these areas for spawning, nursery and adult stages. The change in habitat availability and quality in particular wetlands across the lower Great Lakes give an indication of potential changes to these systems under a changed climate.

Conversely, landuse practices may change because of water levels and the location of currently developed infrastructure. In wetlands, dyking may become more prevalent and this 'adaptation strategy' was also evaluated as part of this study. A field survey of selected paired wetlands in the lower Great Lakes assessed fish community and habitat differences between open and barrier or dyked systems. DFO ccoordinated fish and habitat data gathering for 12 coastal wetlands in Lake Ontario, Lake Erie and Lake St. Clair. Both spring and fall fish usage of wetland habitats were assessed. Initial results indicate that species richness is generally higher in open systems but some species at risk may persist in closed systems likely because of accessibility. The thermal regime of dyked and open systems is also altered. Fish habitat supply in open and barrier systems will be evaluated under climate change conditions to assess the utility of this strategy for both the current fish assemblage and a community that includes new invaders due to climatic warming. Reports will advise Great Lakes managers regarding the vulnerability of different areas to climate change and the potential risks of different adaptation strategies. Please see http://www.fes.uwaterloo.ca/research/airg/ for more information.

Lessons Learned

Although different in scales and timeframes, all three topics were interconnected and had similar messages for applied habitat science: 1) GIS-based habitat inventories are invaluable; 2) fish-habitat suitability databases for freshwater fishes in central Canada are available and can be revised and updated for new applications; 3) fish-habitat suitability and productive capacity models are becoming increasingly sophisticated and useful; 4) coarse resolution fish habitat classifications for large coastal areas are useful to managers; 5) multi-partner and multi-agency projects are becoming common and lead to synergetic products for ecosystem-based management; and 6) effective and continuing communication between Science, Fish Habitat Management and other management agencies are paramount. To address the need for better communication, a Habitat Science Advisory Group needs to be established.

INTEGRATION OF SCIENCE PROPOSALS: MODELS AS TOOLS FOR DATA INTEGRATION AND MANAGEMENT
Presentation by: Marten A. Koops and Scott Millard

Introduction

"*All models are wrong ...but some are useful*." – G.E.P. Box

Models are representations of how we think a system works. This is true for verbal models, graphical models, mathematical or computer models. No model, however, can fully represent a complex system such as an ecosystem, so all models are going to be wrong in some respects. Luckily, models do not need to fully represent the system to be useful. Instead, we should view models as tools that represent a view or aspect of the ecosystem. As long as the tool is useful, it can and should be used, but then refined or discarded based on its performance.

The process of formalizing models has a number of benefits, including:

- Explicit assumptions can be evaluated and help to define the limits of the model. Without explicit assumptions, it is easy to overlook key assumptions that affect the conclusions drawn from the model results.
- Interdisciplinary collaborations are needed to build ecosystem models since no one individual has the expertise or data required for all aspects of the ecosystem. This tends to be less true of simpler models that only deal with a single issue.
- Data mobilization and standardization to build models on the best available data also allows for synthesis and the identification of knowledge gaps.
- Identifying knowledge gaps can stimulate additional research and evaluate ongoing programs.
- Simultaneous evaluation of factors can lead to unexpected discoveries of structure and function and/or increased management options.
- Scenario explorations are used to evaluate hypotheses about how the ecosystem may function, to increase understanding of how the ecosystem operates, and to explore management options.

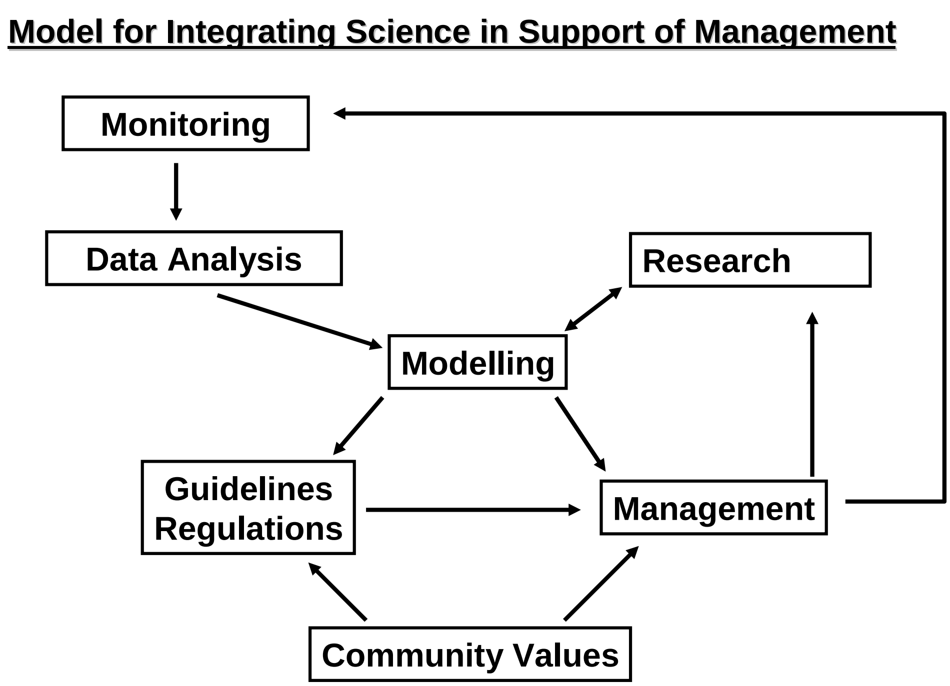
Why Use Models?

Models are built for a variety of reasons. For the purposes of the Lake Winnipeg Science Workshop, we will consider the use of models to integrate data and inform management decisions (Figure 1). Data, whether they are from the analysis of surveys and monitoring or from research, can be integrated through models. Without the integration of data from multiple sources, there is the potential for management to respond to the latest research without an understanding of the relative importance of these findings. By integrating research results, it is possible to evaluate the relative impact of multiple factors on the operation of an ecosystem, and the relative performance of alternative management options. Management is best informed through the integration of research, and models are the tool by which research and monitoring data can be integrated to provide input to management.

Models can also provide input to research through model predictions and the identification of knowledge gaps.

Below we outline two examples of the use of modelling in the Bay of Quinte, Lake Ontario, to illustrate some of these points. The first example is of phosphorus modelling, identifying a surprising effect of zebra mussel (*Dreissena polymorpha*) colonization and consequent increase in macrophyte growth on sediment phosphorus reflux. The second example is of ongoing ecosystem modelling and some of the realized benefits and lessons learned from the process of building Ecopath models.

Figure 1. A model for the integration of monitoring data and science research, through modelling, to inform management decisions.



Phosphorus Modelling

The Bay of Quinte, an embayment at the northeastern end of Lake Ontario, had undergone major eutrophication in the 1950s and 1960s. In the early 1970s, the Bay of Quinte became one of many targets for point source phosphorus control around the Great Lakes. In 1972, a multi-agency group initiated Project Quinte, a long-term study of phosphorus load management and associated consequences for major biotic components in the Bay of Quinte. Phosphorus removal at sewage treatment plants discharging treated effluent to the Bay of Quinte was instituted in the winter of 1977–78. In 1986, the Project Quinte group published a collection of papers documenting ecosystem changes in the period 1972 to 1981 (Minns et al. 1986a). Included in that publication were estimates and analysis of nutrient budgets for the Bay of Quinte covering the period 1965–81 (Minns et al. 1986b).

Since the major reductions in point source phosphorus inputs of 1977–78, significant further reductions in point source loading have been achieved through refinement of sewage treatment plant (STP) operations. The work of the Project Quinte group has continued, and in recent years has expanded its focus as dreissenid mussels became established in the mid-1990s. The purpose of this paper is to present an updated analysis of nutrient loadings and their effects on *in situ* nutrient concentrations in the Bay, covering the period 1972 to 2001.

The results and analyses in contained in two reports, one on phosphorus budgets (Minns et al. 2004) and a companion report on modelling future conditions (Minns and Moore 2004) provided the Bay of Quinte Restoration Council, and its associated local, provincial and federal agencies (Environment Canada, through their Sustainability Fund, and Ontario Ministry of Environment, under the Canada–Ontario Agreement, funded this work), with the tools to develop a phosphorus management strategy for the Bay of Quinte.

Phosphorus Budget Report

This report describes the assembly and analysis of data for nutrient loads and budgets for the Bay of Quinte covering the period 1972 to 2001. The methods closely follow those used by Minns et al. (1986b) in an earlier study of the Bay covering the period 1965 to 1981. Changes in the frequency and spatial cover of sampling made some simplifications of the methods necessary. Loads and budgets were estimated by month and by bay section (upper, middle, and lower) for total phosphorus (P), total nitrogen (N), and chloride (Cl). Point source loading of P have declined dramatically with decreases continuing to the present. Point source N loads are unchanged while Cl loads have increased. Analyses of whole Bay and sectional budgets showed there have been shifts in retention and estimated sediment P reflux in line with expectated declines in reflux after point source load reductions were implemented. The colonization of dreissenid mussels in the mid-1990s and the associated increases in macrophyte cover and density have altered the nutrient budgets, thereby increasing upper bay concentrations. Recommendations for the future include more rigorous collection of nutrient and flow data for the major rivers and point sources, allowing refinement of certain components of the Bay of Quinte nutrient budgets. The budget results provide a basis for future development of a model simulating P dynamics over the period 1972 to 2001 and predicting future conditions under alternate hydrologic regimes, ecosystem conditions, and P management in the Bay of Quinte.

Phosphorus Model

A simple input-output phosphorus model was developed and implemented for the Bay of Quinte. The model was based on that described by Minns (1986), whereby a three-section model of the bay was applied to the upper, middle and lower Bay of Quinte. The model was implemented using STELLA modelling software with a daily time step for the period 1972–2001. Hydrology, stream concentrations, and sewage treatment plant (STP) flows and concentrations were reproduced. Future scenarios cover the period 2002–2031. Key parameter estimates can be changed to examine the effects of uncertainties on model predictions. Simulation output includes daily values for all compartments and major flows as well as annual and summer mean concentrations by years in the water column and surface sediment compartments. The model produced a high level of agreement with observations for the calibration period. The future scenario results indicated the following:

a) The recovery process is expected to continue after 2001 as long as 2001 STP flows continue at Certificate of Approval concentrations. Under these conditions, the water concentrations will be, by 2031, close to steady state, within 0.2 $\mu g\ L^{-1}$ of their final value.

b) With point source loading set at 2001 levels and zebra mussel effects at median levels, the model predicts that under the low river flow scenario (projected climate change effects), mean summer upper bay phosphorus concentrations will increase by 9 to 13 $\mu g\ L^{-1}$ above the baseline scenario, a level well above the Remedial Action Plan target phosphorus concentration for the upper bay.

c) These results suggest that currently approved final effluent concentrations will have to decrease at sewage treatment plants discharging to the Bay of Quinte before flows from these plants attain their rated capacities.

Recommendations for the Bay of Quinte

To manage phosphorus loading into the Bay of Quinte in the future, and thereby protect the restoration already achieved, several steps are necessary:

a) Point source loading directly into the Bay of Quinte needs to be managed on a watershed basis rather than at the level of the individual municipality. The loading into the upper bay (above the confluence with Hay Bay) requires the most attention.

b) The Ontario Ministry of Environment and the Bay of Quinte Restoration Council should establish a loading limit of 15 kg P day^{-1} for all the point sources in the upper Bay and then make allocations to specific communities from that limit on an equitable basis with all parties sharing in the costs and benefits of meeting the load limit. (As current loads are below capacity, some time [5 to 10 years] is available to develop and implement an acceptable approach.)

c) The Ministry of the Environment and the Bay of Quinte Restoration Council should keep the model up-to-date and use the model to assess the impact of any additional discharges from new potential point sources. (This action will require that monitoring of the necessary elements for water and nutrient budgets calculations be improved over current circumstances and maintained [cf Minns et al. 2004].)

d) There should be no consideration for using the middle and lower bay sections as recipients of future loading increases although they appear to be less sensitive as a result of back-flows from Lake Ontario. The middle and lower bay sections are vulnerable to hypolimnetic oxygen depletion (Minns and Johnson 1979).

e) Area load limits need to be considered in all jurisdictions around the Great Lakes because current management schemes based on concentration limits will not prevent the reoccurrence of eutrophication as populations grow and additional STPs are built.

Ecosystem Modelling

Both the Bay of Quinte (Lake Ontario) and Oneida Lake (New York) ecosystems have experience similar events and pressures over the past half century. In the 1950s and 1960s, phosphorus inputs increased greatly, increasing production and starting the process of eutrophication. With the implementation of phosphorus control in the 1970s, phosphorus concentrations declined, water clarity improved, macrophyte beds expanded, and the walleye (*Sander vitreus*) population increased. Then in the early 1990s, zebra mussels arrived. With high filtration rates and abundances, zebra mussels quickly increased water clarity. Macrophytes expanded rapidly and were able to establish and grow at greater depths. The number of double-crested cormorants (*Phalacrocorax auritus*) increased through the 1990s, and by the late 1990s, more cormorants were feeding in both ecosystems. In the late 1990s, the Bay of Quinte was invaded by two more exotic species, *Cercopagis pengoi*, a predatory zooplankter, and round gobies, *Neogobius melanostomus*, a small demersal fish. Finally, during the past decade, walleye abundance has declined. With all these changes, there are many hypotheses to explain this decline, and great uncertainty about how the ecosystem will continue to change. Even though the histories are similar between the two ecosystems, hypotheses concerning the decline of walleye differ. In the Bay of Quinte, it is hypothesized that declining walleye abundance is due to (1) a decrease in walleye habitat due to increased water clarity, (2) increased refuges for predators of juvenile walleye due to increased macrophyte cover, and (3) over-exploitation (both angling and aboriginal). In Oneida Lake, however, it is hypothesized that declining walleye abundance is due to (1) increased mortality of larval walleye during their pelagic phase due to lower abundance of buffering larval yellow perch (*Perca flavescens*) and (2) increased predation on sub-adults by cormorants. Decreased ecosystem productivity due to decreased nutrient loading may be a factor in both systems. To model these ecosystems, we chose to use Ecopath with Ecosim.

The Ecopath with Ecosim (EwE) modelling approach is a two-step process (Christensen and Walters 2004, Christensen et al. 2004). The first step (Ecopath) is the construction of a mass balance model of the ecosystem;the second step (Ecosim) uses the balanced model to run time dynamic simulations that can be used to explore the potential ecosystem impacts of changes and management strategies. Mass balance in Ecopath is achieved by solving the master equation (Christensen et al. 2004):

[Production] – [Predation] – [Fishery Catch] – [Biomass Accumulation] – [Net Migration] – [Other Mortality] = 0

This equation is solved simultaneously for each group (species or functional group) in the model. The diet composition, biomass accumulation, fishery catches and net migration must be specified for each group. In addition, three of the following four parameters must be specified: production to biomass ratio (P/B), consumption to biomass ratio (Q/B), biomass (B), and ecotrophic efficiency (EE). By only specifying three parameters, one parameter is free to be estimated by the EwE software to bring the model into mass balance. Usually, but not always, the EE parameter is left unspecified as it is often the most difficult to estimate. Since EE can only range between 0 and 1, it provides an easy check for mass balance. In most cases, initial inputs of parameter values will not result in a balanced model. Therefore, it is necessary to adjust parameter values to bring the model into mass balance. Having estimates of uncertainty about input values can ensure that adjustments are not unrealistic. A balanced model is one subset of many possible combinations of parameter values that can represent the ecosystem.

Building these Ecopath models brought together research specialists from both ecosystems on primary production, the microbial food web, zooplankton, benthic invertebrates, fish production and fisheries, cormorants and modelling. Research in both ecosystems has benefited from these interactions through the identification of a number of knowledge gaps, leading to additional research on the assessment of nearshore communities, primary production, fish community comparisons, winter mortality and methods for estimating population size. The process of building these ecosystem models has taught us that even though ecosystem models require large amounts of data, there is usually more data available than is initially apparent. The process of structuring the model and working up the data has taught us much about how we think the ecosystem functions, and has forced the group to think about the ecosystem in terms of the whole ecosystem, and not just the species of immediate interest. This is expected to provide additional benefits as we move into the exploration of alternative scenarios and management options.

Conclusions

Based on our experiences, we recommend that the modelling be started early in the planning process. This will provide a structural framework for the integration of monitoring data and science research for management. The process of building models will help to identify where the data are deficient to answer the pressing questions. The models should also be considered as works in progress. Recommendations and predictions can be produced, however, as new data and research results are collected, the models should be updated and refined to reflect and integrate these new findings. Finally, each model has its strengths and weaknesses. There is no need to be limited to a single model.

Bibliography

Christensen, V. and Walters, C.J. 2004. Ecopath with Ecosim: Methods, capabilities and limitations. Ecological Modelling 172: 109–139.

Christensen, V., Walters, C.J., and Pauly, D. 2004. Ecopath with Ecosim: A user’s guide. To be published as Fisheries Centre Research Reports, Volume 12(4), University of British Columbia, Vancouver. 154 p. (Available online at www.ecopath.org and www.fisheries.ubc.ca)

Minns, C.K. 1986. A simple whole-lake phosphorus model and a trial application in the Bay of Quinte. Pages 84–90 *in* Minns, C.K., Hurley, D.A. and Nicholls, K.H., eds. Project Quinte: Point-source phosphorus control and ecosystem response in the Bay of Quinte, Lake Ontario. Canadian Special Publication of Fisheries and Aquatic Sciences 86. 270 p.

Minns, C.K., Hurley, D.A., and Nicholls, K.H. 1986a. Project Quinte: Point-source phosphorus control and ecosystem response in the Bay of Quinte, Lake Ontario. Canadian Special Publication of Fisheries and Aquatic Sciences 86. 270 p.

Minns, C.K. and Johnson, M.G. 1979. Temporal variation in the nutrient export of rivers draining into the Bay of Quinte, Ontario, Canada. Water Resources Bulletin 15: 1061–1072.

Minns, C.K. and Moore, J.E. 2004. Modelling phosphorus management in the Bay of Quinte, Lake Ontario in the past, 1972 to 2001, and in the future. Canadian Manuscript Report of Fisheries and Aquatic Sciences 2695. 42 p.

Minns, C.K., Moore, J.E., and Seifried, K.E. 2004. Nutrient loads and budgets in the Bay of Quinte, Lake Ontario, 1972 to 2001. Canadian Manuscript Report of Fisheries and Aquatic Sciences 2694. 49 p.

Minns, C.K., Owen, G.E., and Johnson, M.G. 1986b. Nutrient loads and budgets in the Bay of Quinte, Lake Ontario, 1965–81. Pages 59–76 *in* Minns, C.K., Hurley, D.A., and Nicholls, K.H., eds. Project Quinte: Point-source phosphorus control and ecosystem response in the Bay of Quinte, Lake Ontario. Canadian Special Publication of Fisheries and Aquatic Sciences 86. 270 p.

APPENDIX VI: LAKE WINNIPEG SCIENCE WORKSHOP, NOV 29–30, 2004. DESCRIPTION OF IDEAS FOR NEW KNOWLEDGE FOR LAKE WINNIPEG

Index of Titles

Title

Water 1: Bacteria Levels At Recreational Beaches

Knowledge Continuum (Inventory, Monitoring, Desk Analysis, Applied Research, Experimental Research)

Inventory
- small amount of water column data
- correlate wind and wave activity with bacterial densities in Lake Winnipeg and other locations

Monitoring
- source tracking
- refine/expand current activities

Desk Analysis
- predictive and mechanistic modeling of weather and outbreaks

Research
- pathogens associated and different sources
- ecology of pathogens
- BMP and reduce exposure

Management Issue (Management issue as identified in the keynote presentations in Session 1 or as identified within the breakout group i.e. what is the rationale behind the idea?)

Control of notification of bacterial levels at recreational beaches

Description of Idea (to include the hypothesis(es) to be tested or question to be answered, methods to be used including data repositories/sharing and equipment/facilities required and timelines for completion of research)

- This proposal would develop a predictive model relating exposure/risk (source dependent) with wind/water and changing bacterial counts.
- It would necessitate identification of unknown sources of bacteria development of a DNA reference bank, understanding the ecology of pathogens in sand (replication/survival) through in lab culturing and field experiments to determine the size of the reservoir and whether or not it is expanding.
- The result would be best management practices and options for beach management.

Deliverables (identify the expected products or outputs of the research and how would it be used and include the timelines for completion)

Predictive model and best management practices

Facility And Infrastructure Support Requirements (to include the nature of facilities, analytical equipment and vessels needed, including estimate of time, place and season for the work)

- Provincial responsibility
- Existing laboratory

Possible Researchers (to include names of individuals or agencies that have the technical and intellectual capacity to carry out this research e.g. government agencies, universities, communities, fishermen, aboriginal groups, etc. Should also indicate what the individuals or group would bring to the research)

Manitoba Lead (Health and Water Stewardship)
Collaborators as required
- Health Canada
- Environment Canada
- Agriculture
- Universities
- Other jurisdictions

Session 3 Linkage to Other Ideas for New Knowledge (To be completed during Session 3. Identify Themes and Titles of other proposals and briefly describe synergies. Groups will have the descriptions the research ideas developed in Session 2 and will expand or add new descriptions as appropriate.)

This proposal should be linked to W6 (Physical model for Lake Winnipeg).

Title

Water 2: Carbon Cycling/Carbon Sequestering

Knowledge Continuum (Inventory, Monitoring, Desk Analysis, Applied Research, Experimental Research)

- Inventory and Monitoring – core samples and sedimentation rates in Lake Winnipeg
- Desk Analysis – review/analysis of historical data, analysis of satellite imaging to determine areas of intense blooms

Management Issue (Management issue as identified in the keynote presentations in Session 1 or as identified within the breakout group i.e. what is the rationale behind the idea?)

How will changing nutrient management relate to changes in carbon sequestration?

Description of Idea (to include the hypothesis(es) to be tested or question to be answered, methods to be used including data repositories/sharing and equipment/facilities required and timelines for completion of research)

This proposal would provide an estimate of the relationship between nutrient loading and carbon deposition and an economic evaluation of changes in carbon sequestration. The hypothesis to be addressed is whether decreased nutrient inputs will change carbon sequestration rates. Specific issues to be addressed would be: sedimentation rates; carbon fixation and respiration rates; the carbon budget for Lake Winnipeg; and deposition and suspension zones. The study would involve taking core samples and determining sedimentation rates in Lake Winnipeg. Desk analysis would involve a review/analysis of historical data, and analysis of satellite imaging to determine areas of intense blooms of phytoplankton.

Deliverables (identify the expected products or outputs of the research and how would it be used and include the timelines for completion)

- Estimate of the relationship between nutrient loading and carbon deposition.
- An economic evaluation of changes in carbon sequestration.

Facility And Infrastructure Support Requirements (to include the nature of facilities, analytical equipment and vessels needed, including estimate of time, place and season for the work)

- Include carbon with nutrient sampling.
- Carbon isotope analyses.
- Direct measure of sedimentation rates (2 to 3 years)
- Additional coring (1 year)
- Analyze existing cores and data (2 years)
- Review satellite imagery

Possible Researchers (to include names of individuals or agencies that have the technical and intellectual capacity to carry out this research e.g. government agencies, universities, communities, fishermen, aboriginal groups, etc. Should also indicate what the individuals or group would bring to the research)

- Universities
- Federal/provincial government agencies.

Session 3 Linkage to Other Ideas for New Knowledge (To be completed during Session 3. Identify Themes and Titles of other proposals and briefly describe synergies. Groups will have the descriptions the research ideas developed in Session 2 and will expand or add new descriptions as appropriate.)

Title

Water 3: Land Use: Lake Winnipeg Sustainability

Knowledge Continuum (Inventory, Monitoring, Desk Analysis, Applied Research, Experimental Research)

Desk Analysis, Applied Research

- model should use existing databases (APF linkages)
- Link to nutrient mass balance and hydrologic/hydraulic model
- Analyze future land use climate change scenarios

Management Issue (Management issue as identified in the keynote presentations in Session 1 or as identified within the breakout group i.e. what is the rationale behind the idea?)

- How does land use and landscapes impact on and impede loading to Lake Winnipeg?
- What land use activities require priority attention?
- How can land use be modified to reduce N and P loadings?

Description of Idea (to include the hypothesis(es) to be tested or question to be answered, methods to be used including data repositories/sharing and equipment/facilities required and timelines for completion of research)

This project would address the relationship between land use and soil type and their contributions to N and P enrichment of Lake Winnipeg. A model would be developed using existing databases (APF linkages). The model would be linked to nutrient mass balance models and hydrologic/hydraulic models. The model could also be used to analyze future land use and climate change scenarios.

Deliverables (identify the expected products or outputs of the research and how would it be used and include the timelines for completion)

- Identify land use of greatest relevance to N and P reductions
- Determine role of wetlands, riparian and other landscape uses
- Develop a land use inventory and decision support model
- Develop reach specific action plans

Facility And Infrastructure Support Requirements (to include the nature of facilities, analytical equipment and vessels needed, including estimate of time, place and season for the work)

- GIS mapping facilities
- Links to Red River flood mitigation
- Access to other databases

Possible Researchers (to include names of individuals or agencies that have the technical and intellectual capacity to carry out this research e.g. government agencies, universities, communities, fishermen, aboriginal groups, etc. Should also indicate what the individuals or group would bring to the research)

- DFO
- International partnerships

Session 3 Linkage to Other Ideas for New Knowledge (To be completed during Session 3. Identify Themes and Titles of other proposals and briefly describe synergies. Groups will have the descriptions the research ideas developed in Session 2 and will expand or add new descriptions as appropriate.)

This proposal should be linked to F2 (Partitioning sources of mortality other than the commercial harvest), F4 (Effects of exotic species on the Lake Winnipeg Ecosystem), H3 (Assessment of use of small and large tributaries and reefs by fish), H4 (Decline in wetland habitat), W4 (Watershed model – reach specific TMDLs, seasonal source loads), and W5 (Nutrient loading estimates for the Lake Winnipeg Basin).

Title

Water 4: Watershed Hydrology Model

Knowledge Continuum (Inventory, Monitoring, Desk Analysis, Applied Research, Experimental Research)

Inventory, Monitoring, Desk Analysis

Management Issue (Management issue as identified in the keynote presentations in Session 1 or as identified within the breakout group i.e. what is the rationale behind the idea?)

- Understanding flow delivery to the lake
- Flow variability and corresponding load
- Source allocation
- Targeting BMPs - most return on investment
- Transport/sediment resuspension/farmland erosion

Description of Idea (to include the hypothesis(es) to be tested or question to be answered, methods to be used including data repositories/sharing and equipment/facilities required and timelines for completion of research)

This proposal would develop a model for the understanding the quantity and timing of water flows into Lake Winnipeg. It would involve an understanding of basin-wide inputs and outputs including: seasonal variability and transport of flow; spring runoff/snow melt, groundwater inflow, withdrawals for irrigation; runoff characteristics/farm practices; travel time due to instream controls (e.g. Lockport, Winnipeg floodway, other controls on the Winnipeg River and Saskatchewan River).

The proposal would have to consider issues of scale, for example large basin-wide vs. reach specific accuracy, and the monitoring required for calibration of available model.

Deliverables (identify the expected products or outputs of the research and how would it be used and include the timelines for completion)

Hydrologic model for the watershed

Facility And Infrastructure Support Requirements (to include the nature of facilities, analytical equipment and vessels needed, including estimate of time, place and season for the work)

- Model selection and adaptation
- Computer and software

Possible Researchers (to include names of individuals or agencies that have the technical and intellectual capacity to carry out this research e.g. government agencies, universities, communities, fishermen, aboriginal groups, etc. Should also indicate what the individuals or group would bring to the research)

NWRI, USGS, Consultants, Manitoba Water Stewardship, DFO, MOE, PFRA, Universities, North Dakota

Session 3 Linkage to Other Ideas for New Knowledge (To be completed during Session 3. Identify Themes and Titles of other proposals and briefly describe synergies. Groups will have the descriptions the research ideas developed in Session 2 and will expand or add new descriptions as appropriate.)

This proposal should be linked with F3 (Subpopulation structure of commercial species of fish), H4 (Decline in wetland habitat), H6 (Define, describe critical habitat for SARA species), and Water Quality and Nutrients proposals W3, W5, W6, W7.

Title

Water 5: Nutrient Loading Estimates For The Lake Winnipeg Basin

Knowledge Continuum (Inventory, Monitoring, Desk Analysis, Applied Research, Experimental Research)

Inventory, Monitoring, Desk Analysis

- Desk analysis of existing data and identify gaps
- Monitoring to be determined through design of a monitoring program (frequency and spatial scale)

Management Issue (Management issue as identified in the keynote presentations in Session 1 or as identified within the breakout group i.e. what is the rationale behind the idea?)

The present levels of precision and accuracy of the nutrient budgets of Lake Winnipeg are insufficient to allow management decision making on control levels or methods.

Description of Idea (to include the hypothesis(es) to be tested or question to be answered, methods to be used including data repositories/sharing and equipment/facilities required and timelines for completion of research)

The objective of this idea would be to develop a nutrient budget with known precision and accuracy. Current understandings of nutrient loading are not considered precise enough to allow effective management. There should be an analysis of existing data and identification of gaps then the development of a more comprehensive monitoring of flow and water quality so that more precise annual averages with confidence limits can be determined.

Deliverables (identify the expected products or outputs of the research and how would it be used and include the timelines for completion)

- 10 year precise annual average with confidence limits
- Include monitoring design and interpretation of flow measurements and water-quality sampling
- Mass balance model for DSS

Facility And Infrastructure Support Requirements (to include the nature of facilities, analytical equipment and vessels needed, including estimate of time, place and season for the work)

- Flow and sampling network
- No seasonal limitations

Possible Researchers (to include names of individuals or agencies that have the technical and intellectual capacity to carry out this research e.g. government agencies, universities, communities, fishermen, aboriginal groups, etc. Should also indicate what the individuals or group would bring to the research)

State, provincial and federal agencies

Session 3 Linkage to Other Ideas for New Knowledge (To be completed during Session 3. Identify Themes and Titles of other proposals and briefly describe synergies. Groups will have the descriptions the research ideas developed in Session 2 and will expand or add new descriptions as appropriate.)

This project should be linked with H4 (Decline in wetland habitat), H5 (Correlation of land use and watershed nutrient databases), W3 (Land use: Lake Winnipeg sustainability), W4 (Watershed model – reach specific TMDLs, seasonal source of loads), and W7 (Relating nutrients and biological endpoints for setting ecological objectives for Lake Winnipeg).

Title

Water 6: Physical Model For Lake Winnipeg

Knowledge Continuum (Inventory, Monitoring, Desk Analysis, Applied Research, Experimental Research)

Inventory, Monitoring, Desk Analysis

Management Issue (Management issue as identified in the keynote presentations in Session 1 or as identified within the breakout group i.e. what is the rationale behind the idea?)

Require an appropriate physical model of Lake Winnipeg to model nutrients, algae, carbon, sediments – key to developing objectives.

Description of Idea (to include the hypothesis(es) to be tested or question to be answered, methods to be used including data repositories/sharing and equipment/facilities required and timelines for completion of research)

The basic question is to determine how water moves within the lake. It will be necessary to consider a wide range of components including wind velocity, temperature, bathymetry, currents, and water velocity. The project would depend on a buoy network, and make optimum use of existing resources (ferries, fishermen, freighters, Namao). The timeline of the project would be 3-5 years but some information would be available after the first year.

Deliverables (identify the expected products or outputs of the research and how would it be used and include the timelines for completion)

Physical model for Lake Winnipeg

Facility And Infrastructure Support Requirements (to include the nature of facilities, analytical equipment and vessels needed, including estimate of time, place and season for the work)

Not much (if any) local expertise in physical limnology including infrastructure
Will require collaboration–technical expertise elsewhere (U of Western Australia for example) but maintenance and support from local expertise.

Possible Researchers (to include names of individuals or agencies that have the technical and intellectual capacity to carry out this research e.g. government agencies, universities, communities, fishermen, aboriginal groups, etc. Should also indicate what the individuals or group would bring to the research)

State, provincial and federal agencies

Session 3 Linkage to Other Ideas for New Knowledge (To be completed during Session 3. Identify Themes and Titles of other proposals and briefly describe synergies. Groups will have the descriptions the research ideas developed in Session 2 and will expand or add new descriptions as appropriate.)

- Government, Universities
- Local Knowledge regarding how water moves in the lake (calibration of computer models)
- This proposal should be linked with F2 (Partitioning sources of mortality other than the commercial harvest, F5 (Traditional Ecological Knowledge), H2 (Fish habitat classification for South Basin), H4 (Decline in wetland habitat), and all of the water proposals.

Title

Water 7: Relating Nutrients And Biological Endpoints For Settling Ecological Objectives For Lake Winnipeg

Knowledge Continuum (Inventory, Monitoring, Desk Analysis, Applied Research, Experimental Research)

Desk Analysis

- identify potential biological endpoints
- examine relationships between biological endpoints and N and P
- power analysis

Research – bioassays for N and P

Monitoring – continue enhance frequency of selected sites

Management Issue (Management issue as identified in the keynote presentations in Session 1 or as identified within the breakout group i.e. what is the rationale behind the idea?)

Development of science-based ecological objectives for managing water quality in Lake Winnipeg.

Description of Idea (to include the hypothesis(es) to be tested or question to be answered, methods to be used including data repositories/sharing and equipment/facilities required and timelines for completion of research)

This idea requires desk analysis, research and monitoring to determine the relationships between critical biological endpoints of Lake Winnipeg viz., algae, benthic invertebrates, fish, etc. and N and P concentrations. The question is whether the biological endpoints are a predictable function of N and P concentration?

Deliverables (identify the expected products or outputs of the research and how would it be used and include the timelines for completion)

- Establish potential endpoints for objectives
- Determine relationship between nutrients and endpoints

Facility And Infrastructure Support Requirements (to include the nature of facilities, analytical equipment and vessels needed, including estimate of time, place and season for the work)

Continue present monitoring and expand where appropriate.

Possible Researchers (to include names of individuals or agencies that have the technical and intellectual capacity to carry out this research e.g. government agencies, universities, communities, fishermen, aboriginal groups, etc. Should also indicate what the individuals or group would bring to the research)

State, provincial and federal agencies, universities

Session 3 Linkage to Other Ideas for New Knowledge (To be completed during Session 3. Identify Themes and Titles of other proposals and briefly describe synergies. Groups will have the descriptions the research ideas developed in Session 2 and will expand or add new descriptions as appropriate.)

- Government, Universities
- Local Knowledge regarding how water moves in the lake (calibration of computer models)
- Project should be linked with F4 (Effects of exotic species on the Lake Winnipeg ecosystem), F5 (Traditional Ecological Knowledge), H7 (Develop a better understanding of relevant importance of nutrients, light, temperature to algal communities), H5 (correlation of land use and watershed nutrient databases), H9 (Invasion of exotics and consequences on the fish community), and W6 (Physical model for Lake Winnipeg).

Title

Fish 1: Fish Community Index Sampling Programs

Knowledge Continuum (Inventory, Monitoring, Desk Analysis, Applied Research, Experimental Research)

- Primarily Monitoring and Desk Analysis
- Annual reporting to management agencies
- Special projects: looking at relationships to other factors
- Initiation of a LONG TERM data series

Management Issue (Management issue as identified in the keynote presentations in Session 1 or as identified within the breakout group i.e. what is the rationale behind the idea?)

- Supports management decision-making
- Allows evaluation of implemented decisions

Description of Idea (to include the hypothesis(es) to be tested or question to be answered, methods to be used including data repositories/sharing and equipment/facilities required and timelines for completion of research)

- Relative abundance indices using standard bottom set multi-mesh gillnets to allow understanding of community structure and dynamics.
- The surveys need to be standardized, to include all species and should be extensive not intensive.
- These studies should be supplemented with trawls, and a small inshore program, e.g. electrofishing.
- There also should be spring and fall spawn stock surveys.

Deliverables (identify the expected products or outputs of the research and how would it be used and include the timelines for completion)

- Relative abundance indices
- Community structure
- Growth, maturity and mortality regimes
- Predator–prey interactions
- Contaminant samples

Facility And Infrastructure Support Requirements (to include the nature of facilities, analytical equipment and vessels needed, including estimate of time, place and season for the work)

- Three major sample areas including rivers
- 3 fisheries units: office, professional staff, tech. support, assessment, management and research integrated in each unit (south, channel, north)
- Equipment warehouse, safe vessels
- Needs involvement from universities, FFMC, etc.
- Preliminary survey to set up stations (3 years)

Possible Researchers (to include names of individuals or agencies that have the technical and intellectual capacity to carry out this research e.g. government agencies, universities, communities, fishermen, aboriginal groups, etc. Should also indicate what the individuals or group would bring to the research)

- Independent commission or consortium at arm's length away from government
- Tap into existing institutional knowledge

Session 3 Linkage to Other Ideas for New Knowledge (To be completed during Session 3. Identify Themes and Titles of other proposals and briefly describe synergies. Groups will have the descriptions the research ideas developed in Session 2 and will expand or add new descriptions as appropriate.)

Sampling – overlap with other projects will require training/protocol development and additional capacity funding in order to link with other projects as follows:

- Fish subpopulation sampling
- Water-quality sampling
- Fish habitat inventories

Project should be linked with H3 (Assessment of use of small and large tributaries and reefs by fish), H8 (Causes and consequences of declines in zoobenthos), F3 (Subpopulation structure of commercial species), and F7 (Contaminants and ecological tainting).

Title

Fish 2: Partitioning Sources Of Mortality, Other Than The Commercial Harvest.

Knowledge Continuum (Inventory, Monitoring, Desk Analysis, Applied Research, Experimental Research)

Inventory, Monitoring

Management Issue (Management issue as identified in the keynote presentations in Session 1 or as identified within the breakout group i.e. what is the rationale behind the idea?)

Lake Winnipeg Fish and Fisheries. We need to know the total harvest of fish, and we need to know what affects survival, e.g. harmful algal blooms (HABs), toxins, oxygen depletion, starvation, foodweb interactions.

Description of Idea (to include the hypothesis(es) to be tested or question to be answered, methods to be used including data repositories/sharing and equipment/facilities required and timelines for completion of research)

This project would address all sources of mortality including total harvest of fish and other sources of mortality including harmful algal blooms, toxins, oxygen depletion, starvation, foodweb interactions among others. A number of specific projects would be necessary. Specific issues would include: domestic fishery harvesting; unrecorded commercial harvest (special permits, bushing/discarding); impacts of cormorants on survival of commercial species; any effect of algal blooms on young-of-the-year or adult fishes; impact of water regulation on survival of fishes.

Methods would include

- One season dock-side monitoring program.
- Accounting of the number of special permits issued by the province. Survey individual fishermen to estimate the quantity of fish sold through the special permit system. Survey retailers for an independent estimate of the quantity of fish. Comparison of estimate acquired from surveys of fishermen and retailers.
- Survey the abundance of cormorants. Estimate diets from cormorant scats/regurgitate. Simple budgeting to get estimates.
- Use live satellite data to identify when and where algal blooms are occurring. Sample these locations for fishes, record number of dead or dying fish, water samples to identify algae, fish samples for toxicity analyses, HPLC, test tube kit for microcystins.
- Desk analysis to see if there is an influence of level of winter water draw down and recruitment strength.
- Water levels and recruitment data

Deliverables (identify the expected products or outputs of the research and how would it be used and include the timelines for completion)

Estimates of sources of mortality.

Facility And Infrastructure Support Requirements (to include the nature of facilities, analytical equipment and vessels needed, including estimate of time, place and season for the work)

Equipment/facilities required:

- Personnel.
- Personnel.
- Personnel, lab facilities.
- Satellite data, vessel, field sampling equipment, personnel, lab facilities or contract lab for processing toxicity analyses
- Computers, field sampling equipment, boats.
- Office and lab space.

Timeline:

All could be one-year projects.

Possible Researchers (to include names of individuals or agencies that have the technical and intellectual capacity to carry out this research e.g. government agencies, universities, communities, fishermen, aboriginal groups, etc. Should also indicate what the individuals or group would bring to the research)

- Walt Lysak
- Ken Mills
- Manitoba Natural Resources
- DFO
- Could be MSc projects

Session 3 Linkage to Other Ideas for New Knowledge (To be completed during Session 3. Identify Themes and Titles of other proposals and briefly describe synergies. Groups will have the descriptions the research ideas developed in Session 2 and will expand or add new descriptions as appropriate.)

No links – one-time survey with infrequent updates (5-10 yrs).

Title

Fish 3: Subpopulation Structure Of Commercial Species (Walleye, Sauger, Whitefish).

Knowledge Continuum (Inventory, Monitoring, Desk Analysis, Applied Research, Experimental Research)

Inventory

Management Issue (Management issue as identified in the keynote presentations in Session 1 or as identified within the breakout group i.e. what is the rationale behind the idea?)

We don't understand stock structure. This is problematic for effective management if we assume that there is a single stock of a species and in fact there are several stocks.

Description of Idea (to include the hypothesis(es) to be tested or question to be answered, methods to be used including data repositories/sharing and equipment/facilities required and timelines for completion of research)

The question to be addressed by this proposal is whether there separate stocks of commercial species and if the presumptive discrete stocks show fidelity of spawning. That is, do they return to spawn in the same area year after year? Mitochondrial DNA analyses would be used to determine whether different spawning areas are genetically different.

The plan would be to sample fish in late winter offshore Grand Rapids, Berens/Matheson Island, and Gimli (100 each of 3 quota species) and then repeat the sampling in the summer in the same areas to determine if there were changes in the genetic structure of the stocks. Spring spawning sampling for percids would be carried out in rivers around lake (large and small, and east and west shore, north and south).

Deliverables (identify the expected products or outputs of the research and how would it be used and include the timelines for completion)

- Best tools to manage the fishery
- Managing lake fish population in entirety rather than biological units
- Protection of spawning populations in relation to commercial (lake) and sport fishing (river)

Facility And Infrastructure Support Requirements (to include the nature of facilities, analytical equipment and vessels needed, including estimate of time, place and season for the work)

- Facility – Analytical lab – Mitochondrial DNA analyses
- Sampling by skiff, commercial fishers or could purchase from fishers (require contract to oversee collection)
- Collect fish in one year
- Complete project and analyses in 3 years

Possible Researchers (to include names of individuals or agencies that have the technical and intellectual capacity to carry out this research e.g. government agencies, universities, communities, fishermen, aboriginal groups, etc. Should also indicate what the individuals or group would bring to the research)

- Potential grad student project(s).
- Collaborative Federal/Provincial project potential
- Contract analyses to Lab
- Cost – fish analyses $30K

Session 3 Linkage to Other Ideas for New Knowledge (To be completed during Session 3. Identify Themes and Titles of other proposals and briefly describe synergies. Groups will have the descriptions the research ideas developed in Session 2 and will expand or add new descriptions as appropriate.)

- There are clear synergies with other fish sampling proposals F1 (Community index sampling programs), F4 (Effects of exotic species on the Lake Winnipeg ecosystem), and F5 (Traditional and local knowledge).
- There are also logistical overlaps and efficiencies with key fish habitat and water-quality sampling programs namely H3 (Assessment of use of small and large tributaries and reefs by fish), H9 (Invasion of exotics and consequences on the fish community), and W6 (Physical model for Lake

Winnipeg).

Title

Fish 4: Effects Of Exotic Species On The Lake Winnipeg Ecosystem Including The Commercial Fishery.

Knowledge Continuum (Inventory, Monitoring, Desk Analysis, Applied Research, Experimental Research)

- Surveys – to assess current and emerging exotics species
- Monitoring – to assess establishment, growth of ES
- Desk Analysis – to evaluate existing database to develop historical perspective on ES and establish share of community structure (linked to broad scale sampling would be able to evaluate changes in biodiversity and future changes in ecosystem structure and function)

Management Issue (Management issue as identified in the keynote presentations in Session 1 or as identified within the breakout group i.e. what is the rationale behind the idea?)

Based on experience from Great Lakes, exotic species are affecting ecosystem structure and function and their impacts on the Lake Winnipeg ecosystem need to be defined. Proactive approach.

Description of Idea (to include the hypothesis(es) to be tested or question to be answered, methods to be used including data repositories/sharing and equipment/facilities required and timelines for completion of research)

This proposal would address a number of critical questions regarding exotic species (fish, invertebrates, plants, viruses, etc.) that have or could potentially invade Lake Winnipeg. Specific issues include the following: routes and modes of transfer; the effects of exotic species on the Lake Winnipeg biological community structure and function (nutrient cycling , food web structure); the impacts of exotic species on contaminant/toxin transfer through the food chain; the effect of exotic species on quality taste and texture, disease and condition of fish flesh among others.

Deliverables (identify the expected products or outputs of the research and how would it be used and include the timelines for completion)

- A management tool to reduce risk of further invasive species, e.g. a risk assessment model
- Improved understanding and ability to predict productive capacity
- Maintaining quality of fisheries products and commercial fishery yields
- Timeline – 3-5 years

Facility And Infrastructure Support Requirements (to include the nature of facilities, analytical equipment and vessels needed, including estimate of time, place and season for the work)

- Lake wide surveys requiring vessel with capacity to simultaneously sample several environmental variables
- Open water seasons, sampling station network as used in previous surveys with intermittent winter sampling
- CCFAM to identify sources of invasives

Possible Researchers (to include names of individuals or agencies that have the technical and intellectual capacity to carry out this research e.g. government agencies, universities, communities, fishermen, aboriginal groups, etc. Should also indicate what the individuals or group would bring to the research)

- U of Man – grad students
- DFO – technical expertise
- DOE – technical expertise
- Health Canada – technical expertise
- Provincial Government – field assistance
- Commercial fishers/TEK
- CCFAM Aquatic invasive species task force

Session 3 Linkage to Other Ideas for New Knowledge (To be completed during Session 3. Identify Themes and Titles of other proposals and briefly describe synergies. Groups will have the descriptions the research ideas developed in Session 2 and will expand or add new descriptions as appropriate.)

This project would be linked to a number of other proposals. It is directly related to a similar proposal H9

(Invasion of exotics and consequences on the fish community). The following are some specific linkages with other proposals:

- W2 (Carbon cycling) – Exotic species (e.g. zebra mussels) would have significant impact on C cycling in Lake Winnipeg.
- W5 (Nutrient loading estimates of Lake Winnipeg Basin) – Exotic species would have significant impact on nutrient budget in Lake Winnipeg.
- W7 (Endpoints for ecological objectives) – Zebra mussels impact N and P targets
- H6 (Define, describe critical habitat for SARA species) – SAR programs need to consider impacts of exotic species on critical habitat (zebra mussels – physa snail).
- H7 (Develop a better understanding of relevant importance of nutrients, light, temperature to algal communities) – Exotic species will also impact on algal communities.
- H1 (Aerial inventory of North Basin and channel areas) – Inventories should consider exotic species and impacts.
- H2 (Fish habitat classification for South Basin)
- H4 (Decline in wetland habitat) – Exotic species such as carp, affect wetlands.
- H8 (Causes and consequences of decline in zoobenthos) – The impact of exotics should also be considered in this proposal.

Title

Fish 5: Traditional And Local Knowledge.

Knowledge Continuum (Inventory, Monitoring, Desk Analysis, Applied Research, Experimental Research)

- Inventory – collection of stories.
- Applied Research – use to focus scientific research

Management Issue (Management issue as identified in the keynote presentations in Session 1 or as identified within the breakout group i.e. what is the rationale behind the idea?)

To fully understand fish communities and the lake ecosystem, it is necessary to collect traditional and local knowledge both to identify additional management issues and potential cause of problems and their ultimate solutions. Current scientific studies do not make use of traditional knowledge and are too narrowly focused.

Description of Idea (to include the hypothesis(es) to be tested or question to be answered, methods to be used including data repositories/sharing and equipment/facilities required and timelines for completion of research)

TEK is the first step to a better understanding of the ecosystem. This proposal is to collect local and traditional ecological knowledge from fishers and local elders on what is known about the fisheries and the ecosystem of Lake Winnipeg. It would be carried out through non-structured visits and interviews. It is important that the information be collected in the field in a non-academic/scientific setting in order for there to be full participation by the interviewees.

This project could also be designed to contribute significant local information to several of the other water, habitat and fish assessment and classification studies.

Deliverables (identify the expected products or outputs of the research and how would it be used and include the timelines for completion)

- Holistic understanding that can be used to identify areas to carry out scientific research (understanding of social issues re: fishing pressure/activity?)
- Local knowledge to contribute to other fisheries and habitat studies

Facility And Infrastructure Support Requirements (to include the nature of facilities, analytical equipment and vessels needed, including estimate of time, place and season for the work)

- Equipment: Transportation to remote sites (vehicles and boats), recording equipment
- A translator might be required in some areas.
- Timeline – flexible, ideally ongoing
- Place – fishing, First Nation communities
- Season – summer (out of fishing season)

Possible Researchers (to include names of individuals or agencies that have the technical and intellectual capacity to carry out this research e.g. government agencies, universities, communities, fishermen, aboriginal groups, etc. Should also indicate what the individuals or group would bring to the research)

- Government agencies (bring $$)
- Universities (provide researchers, dissemination)
- Communities (provide coordination – who to talk to)
- Fishermen and Aboriginal groups – hold knowledge

Session 3 Linkage to Other Ideas for New Knowledge (To be completed during Session 3. Identify Themes and Titles of other proposals and briefly describe synergies. Groups will have the descriptions the research ideas developed in Session 2 and will expand or add new descriptions as appropriate.)

TEK is the first step to a better understanding of the ecosystem.
Tapping into this knowledge can fill gaps in our understanding of

- fish spawning behaviour/habitat preferences,
- ecological factors contributing to changes/declines in some communities,

- consequences of the presence of exotics and fish quality/community structure,
- habitat for SAR,
- environmental changes such declines in wetlands
- observations re: lesions (fish) contaminants, morphology,
- water currents in Lake Winnipeg, and
- climate change.

Specific linkages to other research ideas includeH4, H5, H6, H9, W3, W6, W7 plus F1, F2, F3, F4, F6.

Title

Fish 6: Effect Of Climate And Climate Change On The Aquatic Ecosystem: Monitoring And Analysis

Knowledge Continuum (Inventory, Monitoring, Desk Analysis, Applied Research, Experimental Research)

Monitoring, Inventory

Management Issue (Management issue as identified in the keynote presentations in Session 1 or as identified within the breakout group i.e. what is the rationale behind the idea?)

- What are the effects of climate and climate change on the biota, productivity and fish populations of Lake Winnipeg?
- What are the potential climate change effects on runoff and nutrient and sediment supply from the watershed?

Description of Idea (to include the hypothesis(es) to be tested or question to be answered, methods to be used including data repositories/sharing and equipment/facilities required and timelines for completion of research)

Understanding the thermal regime is essential to understanding of population abundance and community dynamics and structure at all trophic levels and critical to understanding problems related to Species at Risk and aquatic invasive species.

This idea would involve integrating historic data sets [water buoys Gimli Pier, Grand Rapids Reservoir, cruise survey (data includes profiles)] and air temperatures in the lake and basin. Temperature profiles would be measured at multiple stations in three seasons.

Equipment needed would include the establishment of standardized long-term stations for surface and water column temperature monitoring (utilizing at least three buoys) or continuous flow pump on shore.

Remote sensing would be used to calibrate AVHRR surface temperatures locally and develop historical SST maps for the whole lake.

Deliverables (identify the expected products or outputs of the research and how would it be used and include the timelines for completion)

Description of the thermal habitat of Lake Winnipeg (ongoing) and understanding of effects of altered thermal regime on Lake Winnipeg biota, including fish, and on overall lake productivity.

Facility And Infrastructure Support Requirements (to include the nature of facilities, analytical equipment and vessels needed, including estimate of time, place and season for the work)

- Ship and vessel time for three seasons per year, buoys, data loggers, CTD profiler (high temperature resolution). Still need to capture years of extreme (high and low temperature).
- Need to develop a good data repository and data management system.
- This has application to many other projects. This is a linkage – need a GIS-based database capable of integrating numerous datasets.

Possible Researchers (to include names of individuals or agencies that have the technical and intellectual capacity to carry out this research e.g. government agencies, universities, communities, fishermen, aboriginal groups, etc. Should also indicate what the individuals or group would bring to the research)

- EC
- DFO
- U of Manitoba, Geography and Environment Departments
- Manitoba Water Stewardship Consortium

Session 3 Linkage to Other Ideas for New Knowledge (To be completed during Session 3. Identify Themes and Titles of other proposals and briefly describe synergies. Groups will have the descriptions the research ideas developed in Session 2 and will expand or add new descriptions as appropriate.)

This idea would be linked to W6 (Physical model for Lake Winnipeg), water quality, habitat classification projects (H3, H4, W5) as well as F4 (Effects of exotic species on the Lake Winnipeg ecosystem), H9 (Invasion of exotics and consequences on the fish community), H6 (Define, describe critical habitat for SARA species), and F5 (Traditional and local knowledge).

Title

Fish 7: Contaminant Levels In Lake Winnipeg Biota

Knowledge Continuum (Inventory, Monitoring, Desk Analysis, Applied Research, Experimental Research)

- Inventory: emerging issues, monitoring changes in basin, use patterns
- Monitoring: fish, sediment (suspended and bottom), and water.

Management Issue (Management issue as identified in the keynote presentations in Session 1 or as identified within the breakout group i.e. what is the rationale behind the idea?)

- Prevent impacts on resource user (proactively).
- Ensure ecosystem protection from contaminants (early warning system).

Description of Idea (to include the hypothesis(es) to be tested or question to be answered, methods to be used including data repositories/sharing and equipment/facilities required and timelines for completion of research)

It is proposed that a routine reporting structure be established to track changes in contaminant levels in fish, water and sediments as an early warning system for potential problems. This reporting structure would depend on ongoing programs such as those operated for the commercial fishery by the Canadian Food Inspection Agency, other ongoing and periodic monitoring by other Canadian and US agencies and by additional contaminants surveys and monitoring in Lake Winnipeg as required.

Deliverables (identify the expected products or outputs of the research and how would it be used and include the timelines for completion)

- Inventory of use patterns
- Concentrations of targeted materials in fish, water, sediment, etc.

Facility And Infrastructure Support Requirements (to include the nature of facilities, analytical equipment and vessels needed, including estimate of time, place and season for the work)

Routine conventional sampling of water, fish, sediment.

Possible Researchers (to include names of individuals or agencies that have the technical and intellectual capacity to carry out this research e.g. government agencies, universities, communities, fishermen, aboriginal groups, etc. Should also indicate what the individuals or group would bring to the research)

- Agencies responsible for monitoring in the basin.
- Will require cooperation and coordination, exchange between jurisdictions in the basin.

Session 3 Linkage to Other Ideas for New Knowledge (To be completed during Session 3. Identify Themes and Titles of other proposals and briefly describe synergies. Groups will have the descriptions the research ideas developed in Session 2 and will expand or add new descriptions as appropriate.)

This proposal would have broad linkages to modeling initiatives on the lake.

Title

Fish 8: An Ecosystem Model To Understand The Impact Of Changes In Food Web Structure On Fisheries Productivity.

Knowledge Continuum (Inventory, Monitoring, Desk Analysis, Applied Research, Experimental Research)

Desk Analysis – identify known sources of data, determine data gaps

Management Issue (Management issue as identified in the keynote presentations in Session 1 or as identified within the breakout group i.e. what is the rationale behind the idea?)

Current discussions on Lake Winnipeg involve potential management of nutrients, fish harvest, and exotic species. The combined and separate effects of various management strategies can be assessed using an ecosystem model. This model can also be used to identify knowledge gaps and guide future research on the lake.

Description of Idea (to include the hypothesis(es) to be tested or question to be answered, methods to be used including data repositories/sharing and equipment/facilities required and timelines for completion of research)

Current discussions on Lake Winnipeg involve potential management of nutrients, fish harvest, and exotic species. The combined and separate effects of various management strategies can be assessed using an ecosystem model. It is proposed to accumulate the necessary data and develop and ecosystem model (e.g. ECOPATH) of the Lake Winnipeg food web.

Relevant questions that would be addressed by the use of the model include the following: How will changes in nutrient loading affect fisheries productivity? How will changes in food web structure caused by exotic species affect fisheries productivity? Which management strategies will be most effective for minimizing detrimental effects on the fisheries?

This model would also be used to identify knowledge gaps and guide future research on the lake.

Deliverables (identify the expected products or outputs of the research and how would it be used and include the timelines for completion)

- An ecosystem model that managers could use to explore various scenarios
- Identify data and knowledge gaps to guide future research
- Help synthesize data collected from different projects.

Facility And Infrastructure Support Requirements (to include the nature of facilities, analytical equipment and vessels needed, including estimate of time, place and season for the work)

Data, a computer, time and ingenuity

Possible Researchers (to include names of individuals or agencies that have the technical and intellectual capacity to carry out this research e.g. government agencies, universities, communities, fishermen, aboriginal groups, etc. Should also indicate what the individuals or group would bring to the research)

Links to researchers at the DFO GLLFAS lab in Burlington, who have experience with similar models.

Session 3 Linkage to Other Ideas for New Knowledge (To be completed during Session 3. Identify Themes and Titles of other proposals and briefly describe synergies. Groups will have the descriptions the research ideas developed in Session 2 and will expand or add new descriptions as appropriate.)

This proposal would have links to many other projects including W5 (Nutrient loading estimates for the Lake Winnipeg Basin), W7 (Relating nutrients and biological endpoints for setting ecological objectives for Lake Winnipeg), H7 (Develop a better understanding of relevant importance of nutrients, light, temperature to algal community), H8 (Causes and consequences of declines in zoobenthos), F1 (Community index sampling programs), and F2 (Partitioning sources of mortality other than the commercial harvest), among others

Title

Habitat 1: Aerial Inventory Of North Basin And Channel Areas Of Lake Winnipeg

Knowledge Continuum (Inventory, Monitoring, Desk Analysis, Applied Research, Experimental Research)

- Inventory and Desk Analysis
- Current and historical inventory, old air photos and satellite imagery

Management Issue (Management issue as identified in the keynote presentations in Session 1 or as identified within the breakout group i.e. what is the rationale behind the idea?)

Lack of physical inventory (Lack of historical habitat inventory against which to assess change, both anthropogenic and natural)

Description of Idea (to include the hypothesis(es) to be tested or question to be answered, methods to be used including data repositories/sharing and equipment/facilities required and timelines for completion of research)

This proposal would involve a current and historical (satellite imagery and air photos) of the North Basin and the channel areas. It would provide physical descriptions of various habitat types and classification and measurements of same. It would also provide baseline indication of habitat status for critical areas (spawning, rearing, food supply).
It would involve fixed wing collection of digital GPS photos at optimal altitude, seasons and water levels based on stratified sampling regime as determined from suitable sources (e.g. orthos, satellite imagery).

Deliverables (identify the expected products or outputs of the research and how would it be used and include the timelines for completion)

- Collection of historical archival data.
- A geo-referenced digital photographic habitat inventory which will be used to reference and plan additional research activities and to access existing and future habitat impacts.

Facility And Infrastructure Support Requirements (to include the nature of facilities, analytical equipment and vessels needed, including estimate of timele, place and season for the work)

- Funding for support costs, aircraft, pilot, photographer. GIS integrated software and database and contractual salary for data integration with other research databases plus contractual salary for archival researcher.
- Need fixed wing with door off or helicopter with door open.

Possible Researchers (to include names of individuals or agencies that have the technical and intellectual capacity to carry out this research e.g. government agencies, universities, communities, fishermen, aboriginal groups, etc. Should also indicate what the individuals or group would bring to the research)

- This study would make use of an aerial survey carried out in 1994 by Forbes and shoreline photography by Phil Menagre.
- Provincial government - orthophotos, Manitoba archives, old Canadian Land Use Inventory, geological maps – Karen Scott.
- Consultation with aboriginal groups and elders and main stakeholders.

Session 3 Linkage to Other Ideas for New Knowledge (To be completed during Session 3. Identify Themes and Titles of other proposals and briefly describe synergies. Groups will have the descriptions the research ideas developed in Session 2 and will expand or add new descriptions as appropriate.)

In plenary it was noted that this proposal should be linked with H3 (Assessment of use of small and large tributaries and reefs by fish), and H4 (Decline in wetland habitat).

Title

Habitat 2: Fish Habitat Classification For The South Basin Of Lake Winnipeg

Knowledge Continuum (Inventory, Monitoring, Desk Analysis, Applied Research, Experimental Research)

Inventory, Desk Analysis and Applied Research

Management Issue (Management issue as identified in the keynote presentations in Session 1 or as identified within the breakout group i.e. what is the rationale behind the idea?)

Lack of understanding of watershed impacts and of shoreline developments

Description of Idea (to include the hypothesis(es) to be tested or question to be answered, methods to be used including data repositories/sharing and equipment/facilities required and timelines for completion of research)

This proposal would collect the necessary data to apply existing fish habitat models developed for the Great Lakes (Randall, Minns et. al.). Data required will include the following: bathymetry (will require support from Hydrographic services using ROXANN to determine substrate types); fetch (from GIS-based maps); and cover (from aerial photos, sonar, and stratified field surveys). The proposal would also involve the development of a good fish habitat suitability database. A database that is based on the current literature and includes: depth preferences by life stage of critical species; thermal preferences; and habitat structures, among others.
The timeline for this project would two years.

Deliverables (identify the expected products or outputs of the research and how would it be used and include the timelines for completion)

- Fish habitat management plan for South Basin
- Map of habitat classifications and shoreline areas
- Documentation of the data base and method

Facility And Infrastructure Support Requirements (to include the nature of facilities, analytical equipment and vessels needed, including estimate of timele, place and season for the work)

- Hydrographic service
- Namao and yawls
- Aerial survey
- GIS based maps
- ROXANN
- Contracts for developing habitat suitability database
- Strong link with fish habitat management
- Timeline 2 years, ice free season

Possible Researchers (to include names of individuals or agencies that have the technical and intellectual capacity to carry out this research e.g. government agencies, universities, communities, fishermen, aboriginal groups, etc. Should also indicate what the individuals or group would bring to the research)

- Expertise from fish habitat science in Great Lakes Region
- Bill Franzin?
- Link with Universities, Fish Habitat Management, Hydrographic services

Session 3 Linkage to Other Ideas for New Knowledge (To be completed during Session 3. Identify Themes and Titles of other proposals and briefly describe synergies. Groups will have the descriptions the research ideas developed in Session 2 and will expand or add new descriptions as appropriate.)

This proposal should be linked with H2 (Fish habitat classification for the South Basin), H1 (Aerial inventory of North Basin and channel areas), H3 (Assessment of use of small and large tributaries and reefs by fish), and H4 (Decline in wetland habitat). It would also be linked with F3 (Subpopulation structure of commercial species), and W6 (Physical model for Lake Winnipeg).

Title

Habitat 3: Assessment Of Use Of Tributaries And Reefs By Lake Winnipeg Fishes

Knowledge Continuum (Inventory, Monitoring, Desk Analysis, Applied Research, Experimental Research)

Inventory

Management Issue (Management issue as identified in the keynote presentations in Session 1 or as identified within the breakout group i.e. what is the rationale behind the idea?)

Lack of physical inventory, in particular 1 b.

Description of Idea (to include the hypothesis(es) to be tested or question to be answered, methods to be used including data repositories/sharing and equipment/facilities required and timelines for completion of research)

- This proposal would determine which tributaries and reefs are important habitats for Lake Winnipeg fishes, especially species at risk. It would involve extensive surveys by boat using boat and hand electrofishers, mark and recapture techniques, egg sampling devices and larval fish emergent traps.
- Data collected could rest with Manitoba Water Stewardship, Fisheries and Oceans or the University of Manitoba. This would be a long-term study but it should be completed by 2010.

Deliverables (identify the expected products or outputs of the research and how would it be used and include the timelines for completion)

- Product – Habitat Use Inventory
- Use – Water and Land Management Tool for Protecting Tributary and Reef Fish Habitat in Lake Winnipeg

Facility And Infrastructure Support Requirements (to include the nature of facilities, analytical equipment and vessels needed, including estimate of timeline place and season for the work)

- Facilities – DFO, Manitoba Fisheries
- Vessels – small boats, NAMAO, electrofishing boats, diving equipment
- Location – all tributaries and reefs
- Season – spring, summer and fall

Possible Researchers (to include names of individuals or agencies that have the technical and intellectual capacity to carry out this research e.g. government agencies, universities, communities, fishermen, aboriginal groups, etc. Should also indicate what the individuals or group would bring to the research)

- DFO
- Manitoba Fisheries
- SARA – DFO
- Commercial fishermen
- Aboriginal groups

Session 3 Linkage to Other Ideas for New Knowledge (To be completed during Session 3. Identify Themes and Titles of other proposals and briefly describe synergies. Groups will have the descriptions the research ideas developed in Session 2 and will expand or add new descriptions as appropriate.)

F1 – Community Index Sampling Programs
F5 – Traditional and Local Knowledge

Title

Habitat 4: Decline Of Wetland Habitat In Lake Winnipeg.

Knowledge Continuum (Inventory, Monitoring, Desk Analysis, Applied Research, Experimental Research)

- Inventory of Lake Winnipeg wetlands – look for correlations with potential causative agents
- Monitoring – factors implicated in wetland health – water quality, nutrients and turbidity, water level, invasive species
- Desk Analysis – correlate wetland diversity and distribution with water level, nutrients, invasive species and timing of water level fluctuations and cycles
- Applied Research – review results of coastal wetlands of Manitoba Great Lakes (ongoing U of M and Ducks Unlimited)

Management Issue (Management issue as identified in the keynote presentations in Session 1 or as identified within the breakout group i.e. what is the rationale behind the idea?)

Hydro facility – possible effects of water level regulation and impacts on fish passage.

Description of Idea (to include the hypothesis(es) to be tested or question to be answered, methods to be used including data repositories/sharing and equipment/facilites required and timelines for completion of research)

This proposal is to determine whether wetland decline is related to water regulation, nutrients and turbidity or invading species. The provinces and DFO would participate in monitoring and support ongoing research by the University of Manitoba and Ducks Unlimited to address the above hypothesis. The proposal would conduct research in existing marshes in Lake Winnipeg to identify potential adverse effects such as turbidity, carp biomass, and water level regulation (timing, magnitude, duration, frequency, annual cycles).

The proposal would also determine whether fish passage past Hydro facilities is a major factor affecting the fish community of Lake Winnipeg. It would involve sampling below Hydro facilities to identify potential fish movement.

Deliverables (identify the expected products or outputs of the research and how would it be used and include the timelines for completion)

- Identify most important factors responsible for wetland loss
- Identify potential mitigation options to recover wetlands (carp exclusion, artificial water level manipulation-cell modified flow regime)

Facility And Infrastructure Support Requirements (to include the nature of facilities, analytical equipment and vessels needed, including estimate of timeline place and season for the work)

Unknown

Possible Researchers (to include names of individuals or agencies that have the technical and intellectual capacity to carry out this research e.g. government agencies, universities, communities, fishermen, aboriginal groups, etc. Should also indicate what the individuals or group would bring to the research)

- Ducks Unlimited
- Manitoba Hydro
- University of Manitoba
- DFO
- Province of Manitoba
- University of Winnipeg

Session 3 Linkage to Other Ideas for New Knowledge (To be completed during Session 3. Identify Themes and Titles of other proposals and briefly describe synergies. Groups will have the descriptions the research ideas developed in Session 2 and will expand or add new descriptions as appropriate.)

This project would be integrated with the other Habitat inventory projects (H1, H2, H3) into a single habitat project. It should be expanded to include other factors including dredging; lack of dredging;

wetlands connectivity to tributary drains and; native and indigenous biodiversity.

It also has links to F4 (Effects of exotic species on Lake Winnipeg ecosystem) and H9 (Invasion of exotics and consequences on the fish community).

Title

Habitat 5: Correlation Of Land Use And Watershed Nutrient Database

Knowledge Continuum (Inventory, Monitoring, Desk Analysis, Applied Research, Experimental Research)

Desk Analysis

Management Issue (Management issue as identified in the keynote presentations in Session 1 or as identified within the breakout group i.e. what is the rationale behind the idea?)

Determine habitat impacts of watershed land use on water quality of runoff for management planning. Land use definitions are clear cut, agricultural (crop, pasture), forested.

Description of Idea (to include the hypothesis(es) to be tested or question to be answered, methods to be used including data repositories/sharing and equipment/facilities required and timelines for completion of research)

This proposal would assemble existing land use information and river nutrient concentrations and load information into an integrated GIS database. The proposal would test for correlation between land use and nutrient concentrations, loads in downstream runoff. In this context, land use refers to all aspects of land cover, physiography, soils geology, etc.

Deliverables (identify the expected products or outputs of the research and how would it be used and include the timelines for completion)

- Land use, cover, etc. maps of watershed in GIS form.
- Relative yields (nutrients) of significant land use types.

Facility And Infrastructure Support Requirements (to include the nature of facilities, analytical equipment and vessels needed, including estimate of timeline place and season for the work)

Access to a GIS lab and access to land use databases and water-quality databases. These are government databases. Equivalent to a Master's thesis.

Possible Researchers (to include names of individuals or agencies that have the technical and intellectual capacity to carry out this research e.g. government agencies, universities, communities, fishermen, aboriginal groups, etc. Should also indicate what the individuals or group would bring to the research)

University of Manitoba – Department of Geography and Environment

Session 3 Linkage to Other Ideas for New Knowledge (To be completed during Session 3. Identify Themes and Titles of other proposals and briefly describe synergies. Groups will have the descriptions the research ideas developed in Session 2 and will expand or add new descriptions as appropriate.)

This proposal will also contribute to habitat inventory studies. It should be linked to W4 (Watershed model – reach specific TMDLs, seasonal source loads), W3 (Land use: Lake Winnipeg sustainability), and H4 (Decline in wetland habitat).

Title

Habitat 6: Define And Describe Critical Habitats For Species At Risk

Knowledge Continuum (Inventory, Monitoring, Desk Analysis, Applied Research, Experimental Research)

Desk Analysis, Applied Research

Management Issue (Management issue as identified in the keynote presentations in Session 1 or as identified within the breakout group i.e. what is the rationale behind the idea?)

Critical habitat for species at risk, as defined under SARA or associated policy development, cannot be destroyed

Description of Idea (to include the hypothesis(es) to be tested or question to be answered, methods to be used including data repositories/sharing and equipment/facilities required and timelines for completion of research)

- This proposal would provide the support necessary for experts to peer review known information regarding critical habitat descriptions as developed under National or Zonal Action Plans and develop a schedule and timetable of studies required to identify basic habitat requirements.
- Critical habitat for SARA species would be described and located.

Deliverables (identify the expected products or outputs of the research and how would it be used and include the timelines for completion)

- Descriptions of critical habitat for SARA species
- Critical habitat areas identified
- SARA species protected
- New areas of critical habitat restored or created

Facility And Infrastructure Support Requirements (to include the nature of facilities, analytical equipment and vessels needed, including estimate of timeline place and season for the work)

- Aerial surveys, geo-referenced digital aerial photos
- Vessel surveys – sampling of near shore/off shore sites

Possible Researchers (to include names of individuals or agencies that have the technical and intellectual capacity to carry out this research e.g. government agencies, universities, communities, fishermen, aboriginal groups, etc. Should also indicate what the individuals or group would bring to the research)

- Lake Winnipeg Research Consortium
- University of Winnipeg
- University of Manitoba
- First Nations
- DFO
- Manitoba Government

Session 3 Linkage to Other Ideas for New Knowledge (To be completed during Session 3. Identify Themes and Titles of other proposals and briefly describe synergies. Groups will have the descriptions the research ideas developed in Session 2 and will expand or add new descriptions as appropriate.)

This proposal should be linked with F1 (Community index sampling program) and other habitat inventory efforts.

Title

Habitat 7: Develop A Better Understanding Of The Relative Importance Of Nutrients (N And P), Light (Sediment Load), And Temperature To The Algal Community In Lake Winnipeg

Knowledge Continuum (Inventory, Monitoring, Desk Analysis, Applied Research, Experimental Research)

Desk Analysis

Management Issue (Management issue as identified in the keynote presentations in Session 1 or as identified within the breakout group i.e. what is the rationale behind the idea?)

Better tools to assess the effects of land management decisions (e.g. nutrient reduction exercises) on algal communities, especially blue green development.

Description of Idea (to include the hypothesis(es) to be tested or question to be answered, methods to be used including data repositories/sharing and equipment/facilities required and timelines for completion of research)

This proposal would provide a description of the current state of knowledge of nutrients, sediment load, and temperature to the algal community of the Lake Winnipeg ecosystem. It is a desk analysis to complete the analysis of existing data on Lake Winnipeg sufficiently that practitioners can bring their own understanding of the lake ecosystem up to date in terms of data already collected. The analyses would be enhanced by adding a modeler to the team to develop models of algal productivity and use models to test sensitivity of algal community to significant factors.

Deliverables (identify the expected products or outputs of the research and how would it be used and include the timelines for completion)

Description of current state of knowledge of Lake Winnipeg ecosystem.

Facility And Infrastructure Support Requirements (to include the nature of facilities, analytical equipment and vessels needed, including estimate of timeline place and season for the work)

Just a desk exercise

Possible Researchers (to include names of individuals or agencies that have the technical and intellectual capacity to carry out this research e.g. government agencies, universities, communities, fishermen, aboriginal groups, etc. Should also indicate what the individuals or group would bring to the research)

Researchers with current data on Lake Winnipeg ecosystem not yet analysed and published.

Session 3 Linkage to Other Ideas for New Knowledge (To be completed during Session 3. Identify Themes and Titles of other proposals and briefly describe synergies. Groups will have the descriptions the research ideas developed in Session 2 and will expand or add new descriptions as appropriate.)

This proposal should be linked to W7 (Relating nutrients and biological endpoints for setting ecological objectives for Lake Winnipeg). Breakout group members noted a gap in the proposals, specifically the effect of toxins in sediment runoff as a result of drain construction or maintenance on successful reproduction, is not fully addressed. It is partially reflected in H2 (Fish habitat classification for the South Basin) and in this proposal.

It is critical to ensure that TEK is incorporated across the board. In particular, the following proposals should consider TEK: W4 (Watershed model), H4 (Decline in wetland habitat), W3 (Land use: Lake Winnipeg sustainability), H5 (Correlation of land use and watershed nutrient databases), W6 (Physical model for Lake Winnipeg), and F3 (Subpopulation structure of commercial species).

It is important to compile all data that is available on the lake itself (catalogue what is available and where), including management data (database manager and method to collect it) and ability to collect and analyze the huge inventory of samples that exist. Quality control caveats need to be established.

The science of habitat restoration/enhancement needs and BMPs needs to be addressed (has there been a Net Gain in productive capacity?).

Title

Habitat 8: Causes And Consequences Of The Decline In Zoobenthos Communities In Lake Winnipeg

Knowledge Continuum (Inventory, Monitoring, Desk Analysis, Applied Research, Experimental Research)

Monitoring, Desk Analysis, Applied Research, Experimental Research

Management Issue (Management issue as identified in the keynote presentations in Session 1 or as identified within the breakout group i.e. what is the rationale behind the idea?)

Zoobenthos are a critical component of the food web supporting fish production in Lake Winnipeg. Zoobenthic abundance and production are declining but it is unclear what the causes or consequences of these declines are for fish productivity.

Description of Idea (to include the hypothesis(es) to be tested or question to be answered, methods to be used including data repositories/sharing and equipment/facilities required and timelines for completion of research)

The hypotheses for this proposal are that potential causes of zoobenthic decline are 1) hypoxia in the North Basin related to changes in thermal stratification and eutrophication, 2) sedimentation, and 3) nutrients and contaminants.

The approach will be to 1) examine relationship between spatial and temporal distribution of zoobenthic taxa relative to oxygen and water quality and sediment conditions, 2) collect sediment cores to reconstruct short and long-term changes in benthic community structure and geo chemical indicators of anoxia and sedimentation rates, 3) assess gut contents, utilize stable isotopes of fish, and 4) expand sampling of zoobenthos to shallow waters.

The results should demonstrate the extent to which fish in Lake Winnipeg rely on zoobenthos as a food resource.

Deliverables (identify the expected products or outputs of the research and how would it be used and include the timelines for completion)

Scientific publications relating zoobenthic community structure and environmental conditions in Lake Winnipeg. Predictive model relating zoobenthos to changes in environmental conditions in Lake Winnipeg.

Facility And Infrastructure Support Requirements (to include the nature of facilities, analytical equipment and vessels needed, including estimate of timeline place and season for the work)

- Namao
- Universities and grad students
- Stable isotope analysis
- Fish collections and ID

Possible Researchers (to include names of individuals or agencies that have the technical and intellectual capacity to carry out this research e.g. government agencies, universities, communities, fishermen, aboriginal groups, etc. Should also indicate what the individuals or group would bring to the research)

Session 3 Linkage to Other Ideas for New Knowledge (To be completed during Session 3. Identify Themes and Titles of other proposals and briefly describe synergies. Groups will have the descriptions the research ideas developed in Session 2 and will expand or add new descriptions as appropriate.)

In session 3 it was noted that there may be a need expand the study to more of an ecosystem approach and include species like mayflies. This study should be linked with W7 (Relating nutrients and biological endpoints for setting ecological objectives for Lake Winnipeg). It should also be linked to F4 (Effects of exotic species on Lake Winnipeg ecosystem), and H9 (Invasion of exotics and consequences on the fish community). There may also be linkages with other research ideas with respect to the relationships of zooplankton to nutrient loading.

Title

Habitat 9: Invasion Of Exotics Into Lake Winnipeg And Consequences On Fish Community

Knowledge Continuum (Inventory, Monitoring, Desk Analysis, Applied Research, Experimental Research)

Monitoring, Desk Analysis

Management Issue (Management issue as identified in the keynote presentations in Session 1 or as identified within the breakout group i.e. what is the rationale behind the idea?)

Management targets prevent preventative measures to constrain the invasion of exotics. Invasive species can have unanticipated impacts on food webs and valuable commercial fisheries, wetlands potential for proactive approach to invasion of exotics.

Description of Idea (to include the hypothesis(es) to be tested or question to be answered, methods to be used including data repositories/sharing and equipment/facilities required and timelines for completion of research)

This proposal would be directed towards predicting the role potential invasive species would have on the Lake Winnipeg ecosystem (the null hypothesis is that invading species will not have an effect on the food web). This would be a risk assessment of potential invading species. Ecological requirements of potential invaders (fish, invertebrates, plants or viruses) would be matched with existing conditions in Lake Winnipeg.

Deliverables (identify the expected products or outputs of the research and how would it be used and include the timelines for completion)

Risk assessment model for invasive species.

Facility And Infrastructure Support Requirements (to include the nature of facilities, analytical equipment and vessels needed, including estimate of timeline place and season for the work)

CCFAM (Canadian Council of Fisheries and Aquaculture Ministers) to identify sources of invasives.

Possible Researchers (to include names of individuals or agencies that have the technical and intellectual capacity to carry out this research e.g. government agencies, universities, communities, fishermen, aboriginal groups, etc. Should also indicate what the individuals or group would bring to the research)

Aquatic invasive species task force (US)

Session 3 Linkage to Other Ideas for New Knowledge (To be completed during Session 3. Identify Themes and Titles of other proposals and briefly describe synergies. Groups will have the descriptions the research ideas developed in Session 2 and will expand or add new descriptions as appropriate.)

F4 (Effects of exotic species on the Lake Winnipeg ecosystem), F1 (Community index sampling programs), W7 (Relating nutrients and biological endpoints for settling ecological objectives for Lake Winnipeg).

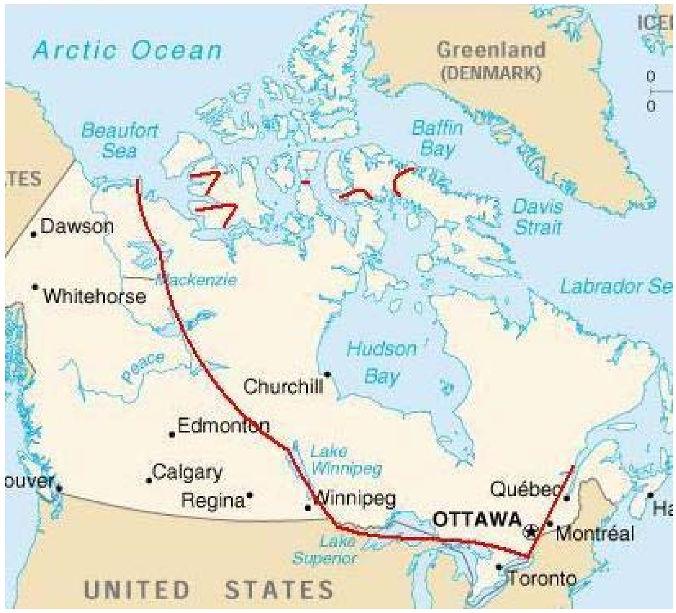
APPENDIX VII and VIII.
Documents found on the CDROM attached to this report.

File name	Title
LWSW.pdf	Lake Winnipeg Science Workshop (this report)
	Appendix VII Keynote Presentations
LWSW Ayles Overview.pdf	An overview of Lake Winnipeg – Burton Ayles
LWSW Williamson Water 1.pdf	Lake Winnipeg Water Quality: History, Current and Future State, and Management Needs - Dwight Williamson
LWSW Charlton Water 2.pdf	Lake Erie and the Lake Winnipeg Situation – Murray Charlton
LWSW Lysack Fisheries 1.pdf	Lake Winnipeg's Fish and Fisheries – Walt Lysack
LWSW Casselman Fisheries 2.pdf	Fish and Fisheries of Lake Ontario: A case history – John Casselman
LWSW Kristofferson Habitat 1.pdf	Lake Winnipeg Habitat Impacts, Past, Present and Future – Keith Kristofferson
LWSW Randall Habitat 2.pdf	Lessons learned from the Great Lakes: Habitat Science experience – Bob Randall
LWSW Millard Integration 1.pdf	Models as tools for data integration and management - Scott Millard
LWSW Koops Integration 2.pdf	Models as tools for data integration and management - Marten A. Koops
	Appendix VIII Breakout Presentations
Appendix VIII Breakout presentations.pdf	Breakout sessions 2 & 3 for Water Quality and Nutrients, Fish Communities and Fish Habitat

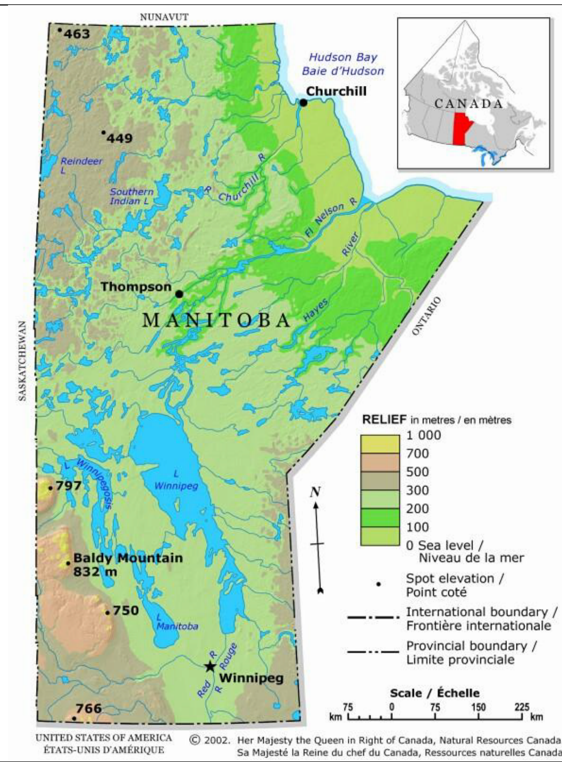
An Overview of Lake Winnipeg

Prepared for:
The Lake Winnipeg Science Workshop
Winnipeg, MB, Nov. 29-30, 2004
Prepared by:
G. Burton Ayles

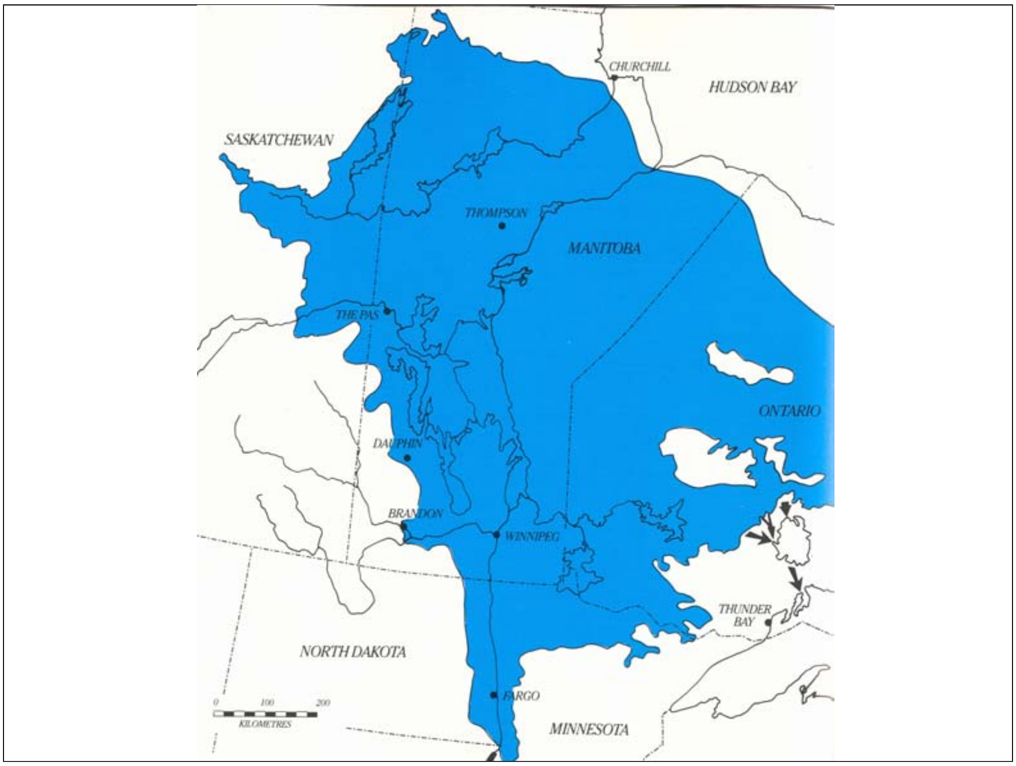
The purpose of this presentation is to provide the context for the more detailed presentations on water quality and nutrients, fish communities and fish habitat that will follow, and the subsequent discussions. It provides a brief physical description of Lake Winnipeg and its watersheds, an outline of major organizations that are involved with the management and protection of the aquatic resources of the Lake and overviews some of the issues that are currently at the forefront of people's concerns for the health of the Lake Winnipeg ecosystem.



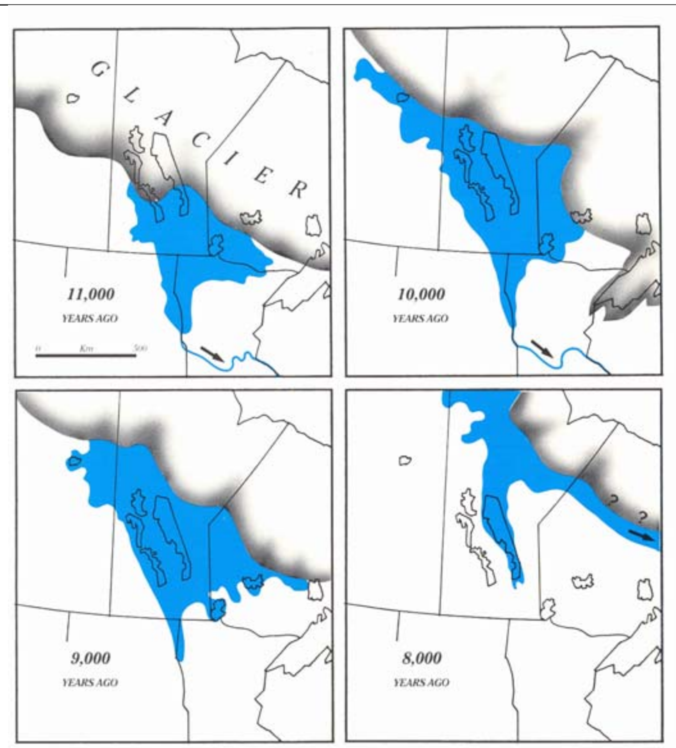
Lake Winnipeg, like the Laurentian Great Lakes and the other great lakes of North America, Great Bear, Great Slave and Athabasca, is an ice-scour lake on the border of the Canadian Shield. It is a result of repeated glaciation and the scraping away of relatively soft Paleozoic sediments along the margin of the Canadian Shield.



Lake Winnipeg is flanked by Precambrian (Superior Province from the Kenoran Orogeny >2.5Ga) rocks on its eastern and northern shores and Paleozoic carbonate rocks (primarily Ordovician, Silurian and Devonian dolomite, limestone and sandstones) of the Williston Basin to the west and south. The axis of the lake follows the contact between the Precambrian and Paleozoic rocks. Lake Winnipeg and the other large Manitoba lakes to the west, Manitoba, Dauphin, Winnipegosis and Cedar, are the remnants of glacial Lake Agassiz.



Lake Agassiz was the largest of all the glacial lakes in North America extending over a total area of almost 950,000 km^2 in Saskatchewan, Manitoba and Ontario, and south into North Dakota and Minnesota, though not all at any one time.



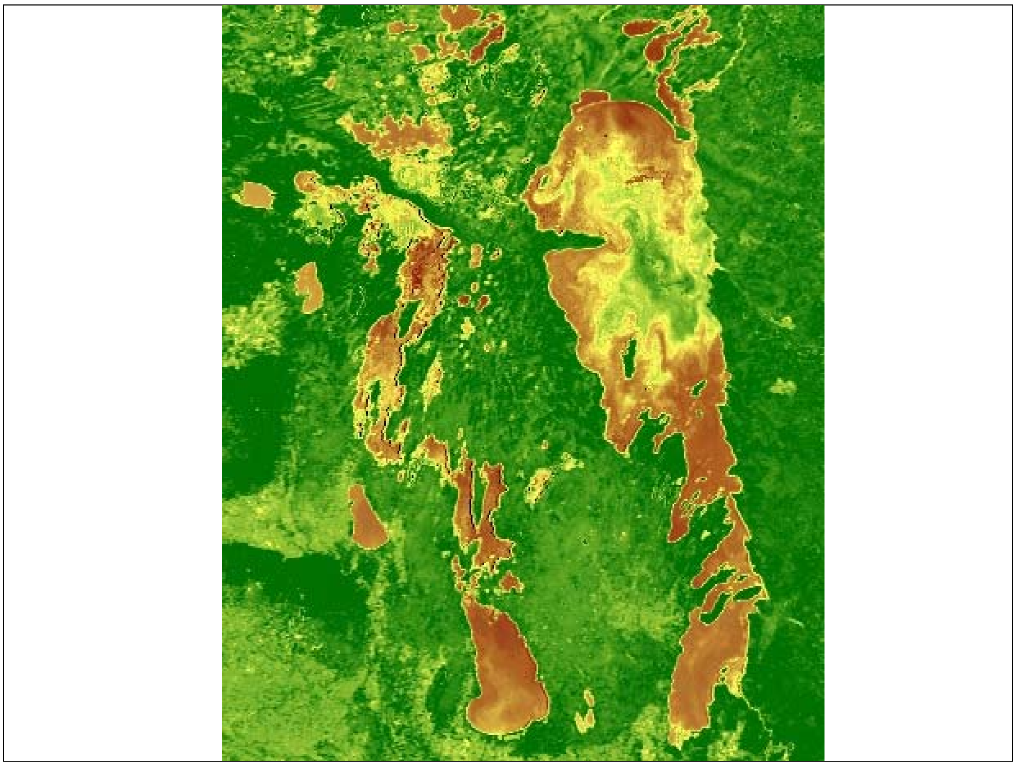
Lake Agassiz began forming about 11,000 to 12,000 BP because the northward-draining rivers of the Prairies were dammed by the Laurentide ice sheet. As the glaciers melted, the areas adjacent to the ice filled with water until they overflowed first to the south into the Mississippi, then north-west, then east into Lake Nipigon and Superior and then finally to the north and into Hudson Bay about 7000 to 8,000 years ago. The water was more than 50 m deep over much of Lake Agassiz and, at Winnipeg, it reached a maximum depth of more than 200 m.

Trenhalle, A.S. 1990. The Geomorphology of Canada. Oxford University Press, Don Mill, Ontario. 240p.

Teller J.T. 1984. ed Natural heritage of Manitoba: Legacy of the Ice Age. Manitoba Museum of Man and Nature. Winnipeg, MB. 208p.

Glaciers moved over the area in a general south west direction and have generated thick layers of drift in some areas. The Precambrian rocks are overlain with thin, sandy glacial sediments (overburden is generally less than 10 m and in many areas bedrock is at the surface) while to the east and south sediments are thicker, glacial, glaciolacustrine and lacustrine sediments of Lake Agassiz (about 20 m thick in the Red River Valley and up to 45 m in some areas) (Nielsen and Thorleifson).

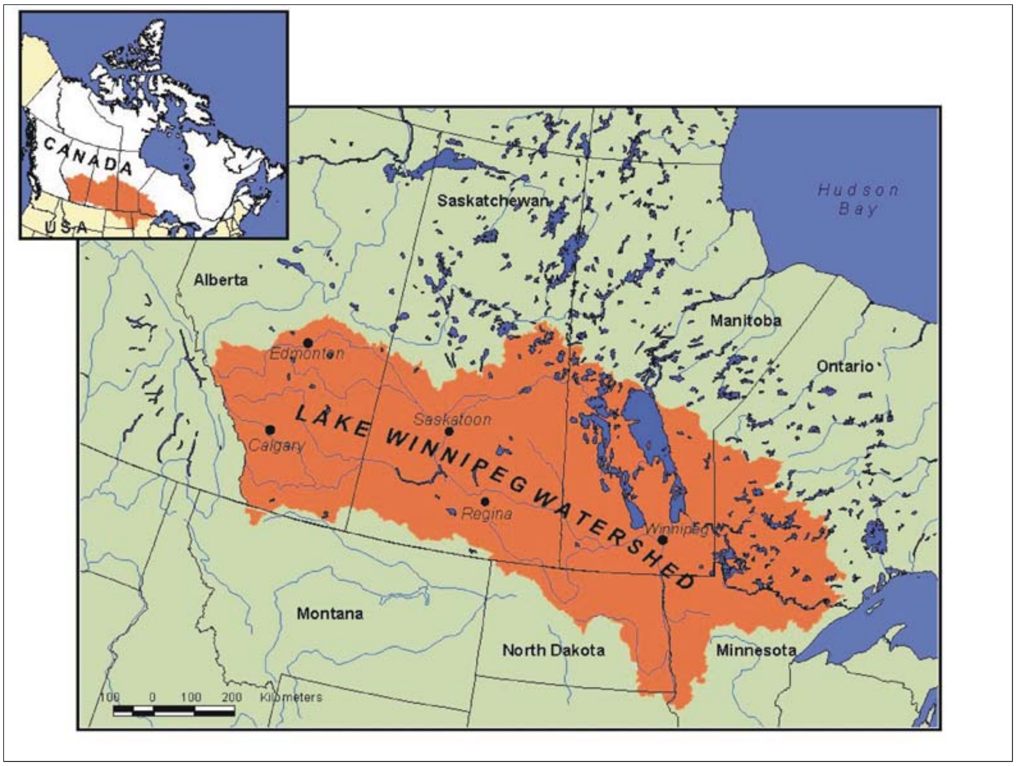
Nielsen, E., and Thorleifson, L.H. 1996. Quaternary geology of the Lake Winnipeg area. Pg. 141-158. In



At 24,400 km^2 Lake Winnipeg is 25% larger than Lake Ontario and just slightly smaller than Lake Erie. However, the total volume of Lake Winnipeg is considerably less, some 127 km^3 compared with 1,710 km^3 and 545 km^3 for the two Laurentian lakes. Lake Winnipeg is divided into the South and North Basins separated by The Narrows, an area of islands and narrow passages only a few kilometres wide, a region of islands and constricted passages. The Lake is 430 km long while the North Basin is up to 100 km wide and the South Basin reaches 40 kmin width. The Lake is very shallow, the mean depths of the North Basin, The Narrows and the South Basin are 13.3 m, 7.2 m and 9.7 m respectively. (Brunskill et. al. 1980). Its outlet is through the Nelson River in the north east and this is a controlled outflow. Major inflows are from the Winnipeg River to the south east (mean monthly flow 771 m^3s^{-1}), the Saskatchewan River from southern Alberta and central Saskatchewan (667 m^3s^{-1}), the Red River from southern Manitoba and nearby United States (159 m^3s^{-1}), Dauphin River from the interlake area (57 m^3s^{-1}) and other smaller streams (Lewis and Todd 1996). The Lake has evolved over time and continues to evolve with changes in water flow and regional tilting of the Earth's crust from glacial rebounding. Lake Winnipeg initially formed as a much smaller body of water in the north. It then enlarged towards the south as the outlet at the head of the Nelson River rose. About 8,000 years ago the southern and northern basins were two separate lakes and it was not until about 2,500 years ago that the north, south and central basins coalesced into a single lake. Models predict that in 2,000 years time water levels at the current southern shore of the South Basin will be 6.5 m higher than at present. (Lewis and Todd).

Korzun, V.I. 1974. (ed) World water balance and water resources f the earth. Translated from Russian by UNESCO 1978 Paris, France 664 pp.

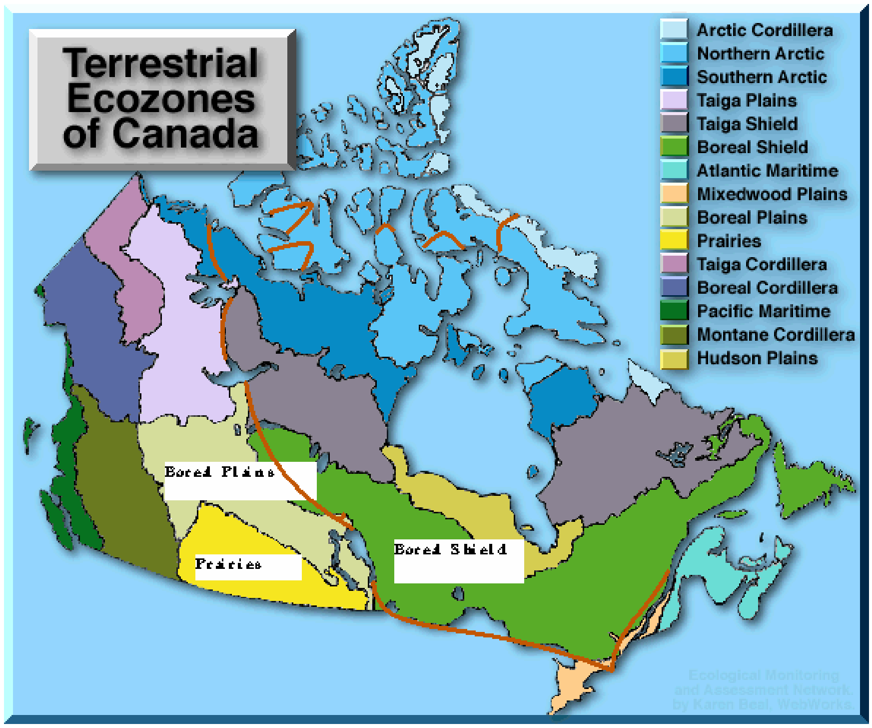
Lewis, C.F. and Todd, B.J. 1996. Lithology and seismostratigraphy of long cores, and a reconstruction of Lake Winnipeg water history. Pp 161-201. In Todd., B.J., Lewis, C.F.M., Thorleifson, L.H., Nielsen, E. 1996. (eds) Lake Winnipeg Project: Cruise report and scientific results. Geological Survey of Canada Open File 3113. 655 pp.



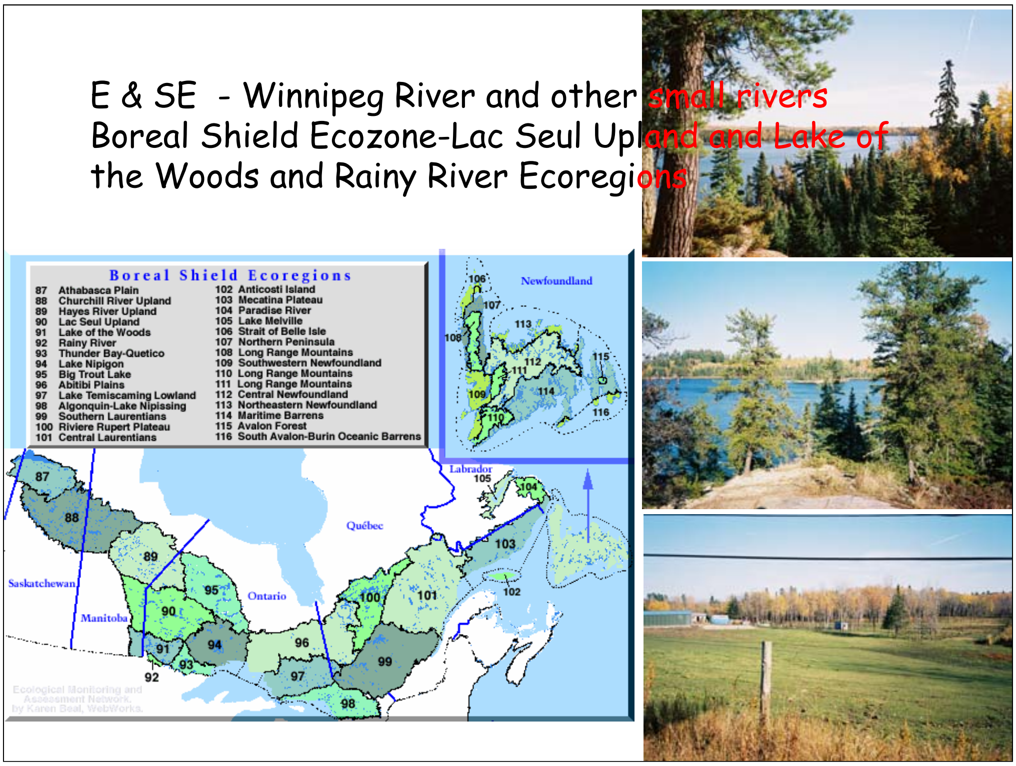
The Lake Winnipeg watershed covers approximately 950,000 km^2, about 10% of Canada's surface area. It is the second largest watershed in Canada

The eastern watersheds of Lake Winnipeg are overlain with variable thicknesses of glacial Lake Agassiz-derived soils, muskegs, and boreal forests. The southern, western and north-western watersheds are overlain with considerable thickness of glacial Lake Agassiz sediments, well-developed chernozemic soils, originally prairie grasses in the south, and mixed deciduous and coniferous forests to the west and north-west. The prairie watersheds now support agricultural activities and a number of cities, whereas the Precambrian Shield supports mining and forest industries, little agriculture, and few large communities. There are approximately 5.5 million people in the watershed and 20 milion livestock

The rivers draining these markedly different watersheds have different chemical and biological characteristics, and they have very different effects upon the limnology of Lake Winnipeg.



The eastern and south-eastern watersheds of Lake Winnipeg are part of the Boreal Shield Ecozone and the Winnipeg River is the major source of input. The Red River is the major drainage system to the south and south-west of Lake Winnipeg and its watershed extends well into North Dakota and Minnesota. The watersheds to the west and north-west of Lake Winnipeg are part of the Boreal Plains Ecozone and the Prairies Ecozone and the Saskatchewan River is the major source of input.

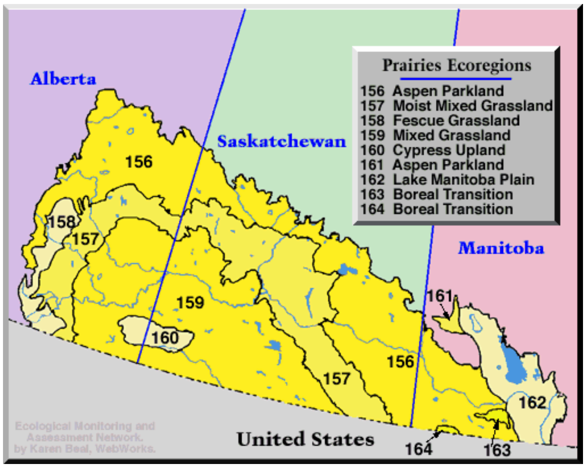


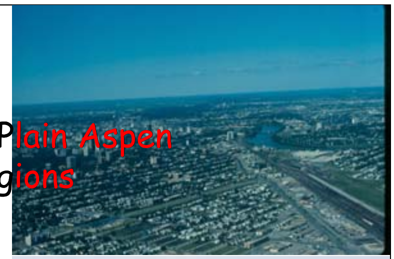
The eastern and south-eastern watersheds of Lake Winnipeg are part of the Boreal Shield Ecozone and the Winnipeg River is the major source of input. The Lac Seul Upland ecoregion extends along much of the east shore, while the Lake of the Woods and Rainy River ecoregions extend from Lake Winnipeg to the east end of Rainy Lake in Ontario.

There are several small rivers flowing into the Lake from the Lac Seul Upland including the, Poplar, Berens, Bloodvein, Manigotogan and others, while the more southern ecoregions are drained by the Winnipeg River. The dominant land cover of the Lac Seul Upland is primarily coniferous forest, white and black spruce and balsam fir, with some aspen and poplar. Wetlands, covering over 25% of the ecoregion, and hummocky bedrock outcrops covered with discontinuous acidic, sandy, granitic tills and glaciolacustrine deposits dominate the landscape. The mean annual temperature is approximately 0.5°C. The mean summer temperature is 14°C and the mean winter temperature is -14.5°C. The population of the ecoregion is extremely low and industrial activity and agriculture are minimal.

The Lake of the Woods and Rainy River ecoregions are slightly warmer and moister than the region further north and a more mixed forest region predominates with trembling aspen, paper birch, jack pine, white spruce, black spruce, and balsam fir and red and eastern white pine in warmer areas. The ecoregion is underlain by Canadian Shield bedrock and bare rock outcrops are common. In lowlands there are significant areas of Lake Agassiz clay deposits and fluvioglacial outwash deposits. Forestry, water-based recreation, and hunting are the major land uses in this region with some agriculture close to the US border in the Rainey River ecoregion. Southern parts of the ecoregion correspond with the Northern Minnesota Wetlands ecoregion in the United States. The Canadian population in the watershed remains low, less than 75,000. The Winnipeg River provides as much as 40% of the inflow to Lake Winnipegbut less than 27% of the phosphorous input.

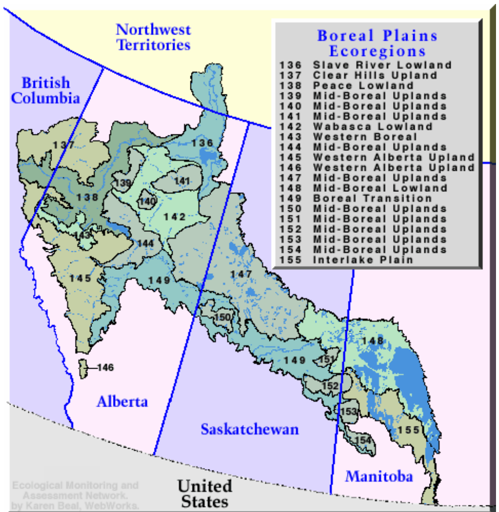
S & SW Red River
Prairies Ecozone - Lake Manitoba Plain Aspen Parkland, Mixed Grasslands Ecoregions





The Red River is the major drainage system to the south and south-west of Lake Winnipeg and its watershed extends well into North Dakota and Minnesota (138,600 km^2 in Canada vs. 148,900 km^2 in the USA). The Lake Manitoba Plain ecoregion, of the Prairies Ecozone, lies closest to the Lake and it is one of the warmest and most humid regions in the Canadian prairies. The mean annual temperature ranges from 2°C in the north to over 3°C in the south. Corn, spring wheat, oilseeds, hay, and livestock production are common depending on local conditions. Hog farming, in particular, has been increasing in the region. Hunting and water-oriented recreation are additional significant uses of land. The ecoregion includes Winnipeg and several other small centres with considerable industrial activity and a population of close to 800,000 in Canada. Major US centres include Grand Forks and Fargo-Moorehead. The Red also drains parts of the Aspen Parkland and Moist Mixed Grassland ecoregions to the west via the Assiniboine .and Souris Rivers. Although it provides less than 10% of the inflow to the lake it contributes almost 60% of the phospohorous input.

W & NW Saskatchewan River
Boreal Plains Ecozone - Mid-Boreal Lowlands & Interlake Plains and Prairies Ecozone



The watersheds to the west and north-west of Lake Winnipeg are part of the Boreal Plains Ecozone and the Prairies Ecozone and the Saskatchewan River the major source of input. The Mid-Boreal Lowlands ecoregion lies along much of the western shore of Lake Winnipeg while the western and southern shores of the South Basin are part of the Interlake Plains ecoregion. The climate of these regions is marked by short, warm summers and cold winters with an annual temperature of approximately -1°C in the north and 1°C to the south. The north is a relatively flat, low-lying region with extensive wetlands. The cold and poorly drained fens and bogs are covered with tamarack and black spruce while the mixed deciduous and coniferous forest is characterized by medium to tall, closed stands of trembling aspen and balsam poplar with white and black spruce, and balsam fir. Permafrost occurs in isolated patches. Forest industries, sport fishing, and wildlife trapping and hunting are the dominant uses of land in this region, although seed grains, within some small pockets of agriculture. The warmer southern Interlake Plains is a transition zone of farmland and forest, marking the southern limit of closed boreal forest and northern extent of arable agriculture. The population of these ecoregions are just over 100,000. Lake Winnipegosis and Lake Manitoba drain into Lake Winnipeg via the Dauphin River but the total inflow is less than 3% of the total and the phosphorous input is even less.

The Saskatchewan River flows into Lake Winnipeg through Boreal Plain Ecozone but it also drains the northern and western parts of the Prairies Ecozone and the east slopes of the Rockies. The Boreal Plains Ecozone is predominately deciduous boreal forest that extends from south-eastern Manitoba to the Peace River in north-central Alberta across the northern prairies and its population in the Lake Winnipeg watershed is low. It has fewer bedrock outcrops and considerably fewer lakes that the Boreal Shield. The Prairies ecozone has its base on the Canada-United States border and arcs from the western edge of Alberta to the eastern edge of Manitoba. This zone comprises the northern extension of open grasslands in the Great Plains of North America. There is relatively little topographic relief with grasslands and limited forests predominating. The climate is subhumid to semiarid and mean annual temperatures range from 1.5°C to 3.5°C. It is the most human-altered region in Canada. Agriculture is the dominant land use and the ecozone contains over 60% of Canada's cropland and 80% of its rangeland and pasture. Major economic activities include mining (coal, potash, mineral and aggregates and oil and gas production. The total population in the watershed is over 3.0 million. The Saskatchewan contributes over 20% of the flow but just over 10% of the phosphorous input. A water deficit situation is a characteristic of the Prairies ecozone

Lake Winnipeg in History

Pre-European contact, the lake was important for fisheries and as a transportation route for the people in the area. It would have been particularly important for the groups living in the Boreal Forest: the ancestors of the Cree. Fishing was critical to the Laurel people (200 B.C. – 1000 A.D.) and they consumed pike, sturgeon, sucker, walleye and bass. The Blackduck culture at the grassland forest edge and the Selkirk culture further north moved into the Region in about 800 AD and they showed an increasing reliance on fish.

Lake Winnipeg was the centre of the fur trade in the 17^{th} and 18^{th} centuries. It formed the cross roads between the east and the west and the link from the south to the north.

The first permanent European community on the lake was Icelandic colonists in 1875 who settled in the area of Gimli, and that was the start of commercial fisheries on the Lake.

Lake Winnipeg at Present

Despite ups and downs, (e.g. at the beginning here was a valuable sturgeon fishery, which soon disappeared due to overfishing), the commercial fisheries have generally been amongst the most successful in inland waters of Canada. They are second only to Lake Erie in freshwater fisheries in Canada with a value aproaching $25 million annually. Domestic and recreational fisheries are of considerable, but unestimated, value as well.

Recreational use of the Lake began in the first two decades of the last century as the railways extended lines up the west and the east shores of the south basin. Grand Beach and Winnipeg Beach were weekend destination sites until the 1950s but with the extension of highways cottage use has expanded and predominates. Manitoba Tourism estimates recreational expenditures exceed $100 million annually.

Beginning in the late 1960's the Lake has been increasingly important for hydro-electric production. Lake Winnipeg is now a reservoir (third largest in the world) and 60% of the inflow is regulated. Downstream, the Nelson River has a series of dams that generate electricity as the water from over 10% of the country spills off of the Shield, and across the Hudson Bay Lowlands into the ocean. $350 - $580 million per year in export power sales.

Manitoba Water Stewardship

Manitoba Dept of Water Stewardship established Nov. 2004

First jurisdiction in Canada to create a stand alone department dedicated to water management.

- **Ecological Services Division** is responsible for: Planning and Coordination, Transboundary Issues, Water Science and Management, Fisheries, and Drinking Water.
- **Infrastructure and Operations Division** is responsible for: Water Licensing, Water Control Infrastructure, and Regional Operations.

Since the Department's formation, the **Water Protection Act** was tabled in the legislature. This important legislation will govern water in Manitoba into the future, allowing for: stricter water quality standards, regulation of water quality management zones for nutrients, control of invasive species through regulation and will provide a comprehensive framework for integrated management.

Lake Winnipeg Stewardship Board

- Announced in February 2003 as part of Lake Winnipeg Action Plan
  - establish Board and identify actions to reduce N and P levels to pre-1970 levels
  - new measures to protect Red and Assiniboine from erosion and reduce nutrient run off
  - expand soil testing
  - new sewage and septic regs
  - shoreline protection plan in partnership with Manitoba Hydro
  - cross-border nutrient management discussions
- Membership - Fishermen, biologists, government, farm industry, Hydro, Municipalities, First Nations, NGO's

Announced in February 2003 as part of the six point Lake Winnipeg Action Plan to help protect Lake Winnipeg

establish Board and identify actions to reduce N and P levels to pre-1970 levels in the lake by 13%, subject of further findings of the Nutrient Management Strategy

•introduce new measures to help protect Red and Assiniboine from erosion and reduce nutrient run off

•expand soil testing to ensure appropriate fertilizer application in rural and urban settings

•new sewage and septic regs

•shoreline protection plan in partnership with Manitoba Hydro to address erosion concerns

•cross-border nutrient management discussions

Membership - Fishermen, biologists, government, farm industry, Hydro, Municipalities, First Nations, NGO's

Department of Fisheries and Oceans (DFO)

- DFO mandated responsibilities for Lake Winnipeg are:
  - Maintenance of fishing harbours, production of navigational charts and deploying aids to navigation
  - Protection of fish habitat
  - Protection of endangered or threatened species under the Species at Risk Act (SARA)
- Other activities (dependent on resources and priorities)
  - Specific scientific activities including habitat degradation, invasive species, climate change and species at risk

DFO Central & Arctic Region (C&A) includes Ontario, Prairie Provinces, Nunavut, NWT, and the north slope of Yukon.

• DFO Manages Fisheries in the Arctic areas of C&A Region, however this responsibility has been delegated to the Provinces in Ontario and the Prairie Provinces.

•DFO has responsibility to maintain Safe Harbours, Waters and Waterways and for the production of reliable Navigation Charts. DFO also maintains a network of Navigational Aids and Marine Communication.

•DFO administers the Habitat provisions of the Fisheries Act specifically aimed at preventing the harmful alteration, disruption or destruction of Fish Habitat.

•Under the Species at Risk Act (SARA), DFO must produce Recovery Strategies and Action Plans for Endangered or Threatened species. SARA protects Critical Habitat for these species.

DFO mandated responsibilities for Lake Winnipeg are limited to:

•Maintaining fishing harbours (24 in total on Lake Winnipeg), producing and maintaining 13 navigational charts, deploying approximately 35 aids to navigation and maintaining marine communication.

•Protecting fish habitat.

•Protecting endangered or threatened aquatic species and their critical habitat. At the present time DFO is producing Recovery Strategies for the Shortjaw cisco (Threatened) and the Physa snail (Endangered) in Lake Winnipeg.

Under the terms of a science Memorandum of Understanding (MOU) signed with the Prairie Provinces (aimed at developing science initiatives of mutual interest) and as a partner in the Lake Winnipeg Research Consortium, DFO has already been involved in some science activities on Lake Winnipeg aboard the CGS Namao, specifically investigating habitat degradation, aquatic invasive species, species at risk and climate change issues.

Department of the Environment (DOE)

- DOE mandated responsibilities for Lake Winnipeg are limited:
  - Water quality monitoring programs in a number of major tributaries thru such as the International Joint Commission (IJC), the Prairie Provinces Water Board (PPWB) and the Canada-Manitoba Agreement
  - SARA responsibilities shared with DFO.
  - Under the Canadian Environmental Protection Act (CEPA) the Minister "shall" undertake pollutant monitoring to ensure no adverse impacts from pollutants in the environment
- Other activities (dependent on resources and priorities)
  - National Water Resources Institute (NWRI) involved in a remote sensing study on algal blooms in the North Basin.
  - "Large Ecosystem Initiatives" of national concern (e.g., climate change impacts, Great Lakes Action Plan). Could be model for DOE to get involved.

The DOE has limited mandated responsibilities for aquatic research and monitoring in Lake Winnipeg. The Department has few activities in the Lake itself but has ongoing water quality monitoring programs in a number of major tributaries to the Lake. In addition, there are mechanisms by which the Department could become involved in lake studies should the program justify it and resources allow it.

Under agreements such as the International Joint Commission (IJC), the Prairie Provinces Water Board (PPWB)and the Canada-Manitoba Agreement on water DOE monitors water quality in several of the major tributaries to Lake Winnipeg although not in the Lake itself.

As a result of the Species at Risk Act (SARA) the Department shares responsibility with DFO for endangered species but at this point all SARA issues with respect to Lake Winnipeg relate more to DFO than DOE.

Under the Canadian Environmental Protection Act (CEPA) the Minister of the Environment "shall" undertake monitoring to ensure no adverse impacts from pollutants in the environment. There is no monitoring in Lake Winnipeg under CEPA at the moment.

DOE/NWRI has recently been involved in a remote sensing study to assess the frequency (spatial and temporal) and extent of algal blooms in the North Basin. This is a one-off study and not part of a larger DOE initiative.

Environment Canada is involved in a number of "Large Ecosystem Initiatives" (e.g., Great Lakes Action Plan) and other research initiatives to address issues of national concern (e.g., climate change impacts). None involve Lake Winnipeg at the moment but this could represent a mechanism to get involved.

International Joint Commission (IJC) International Red River Board (IRRB) Ecosystem Subcommittee

- IJC established in 1909 to deal with transboundary water issues. Four Boards have jurisdiction related to Lake Winnipeg.
  - Winnipeg River: Rainy Lake Board of Control, Rainy River Water Pollution Board and Lake of the Woods Control Board and Red River:International Red River Board (IRRB)
  - IRRB established in 2000 to assist the IJC on the Red River through best available science and knowledge of the aquatic ecosystem of the basin and the needs, expectations and capabilities of residents
    - Aquatic Ecosystem Health Committee has established 5 water quality objectives (chloride, sulphate, TDS, DO and fecal coliforms)
    - Considering nutrient objectives

The (IJC) was established by the Canada-USA Boundary Waters Treaty of 1909 to deal with the apportionment, conservation and development of water resources along the international boundary. It has a wide range of investigative, quasi-judicial, administrative and arbitral functions. The IJC has established a number of Boards to deal with specific issues and 4 of those Boards have responsibilities that can potentially affect Lake Winnipeg. Three of the Boards have responsibilities in the Winnipeg River watershed. The Rainy Lake Board of Control, established in 1941, is empowered to adopt such measures of control that it might deem proper with respect to dams at Kettle Falls and at International Falls-Fort Frances to maintain lake levels in Rainy Lake. The Rainy River Water Pollution Board was established in 1966 to address water quality issues in the Rainey River. The Lake of the Woods Control Board was established by the 1925 Lake of the Woods Convention and Protocol. As a result of this treaty, IJC was given responsibilities for establishing elevation and discharge requirements for regulating Lake of the Woods.

The (IRRB) was established in 2000, by the consolidation of the International Red River Pollution Bard and the Souris-Red Rivers Engineering Board, to ensure a more ecosystemic approach to transboundary water issues and to achieve operational efficiencies in the conduct of IJC responsibilities. The mandate of the IRRB is to assist the Commission in preventing and resolving transboundary disputes regarding the waters and aquatic ecosystem of the Red River and its tributaries and aquifers. This is to be accomplished through the application of best available science and knowledge of the aquatic ecosystem of the basin and an awareness of the needs, expectations and capabilities of residents of the Red River watershed. The geographical scope of the Board's mandate is the Red River watershed, excluding the Assiniboine and Souris Rivers. The Board's activities focus on those factors that affect the Red River's water quality, water quantity, levels and aquatic ecological integrity.

- Recommending on water quality, water quantity and aquatic ecosystem health objectives
- Continuous surveillance of water quantity and quality at the international boundary
- Maintaining an awareness of basin activities that affect the above
- Provide a forum for identification and resolution of transboundary issues

Lake Winnipeg Research Consortium (LWRC)

- Founded in 1998 and incorporated in 2001.
- Membership includes commercial and recreational fishers organizations, the universities of Manitoba and Winnipeg, aboriginal groups, Manitoba Hydro, many different NGOs, and federal and provincial agencies amongst others.
- Objectives: facilitate multi-disciplinary scientific research and educational opportunities on Lake Winnipeg; expedite information exchange and foster co-operation among all stakeholders; protect and sustain the lake ecosystem; and provide a dedicated and capable platform for research on the lake.
- Examples of research of members: lake carbon budgets and cycles; calibration of satellite imagery for estimation of chlorophyll and turbidity; nitrogen fixation rates and algal physiology; nutrient loading amongst others.

The Lake Winnipeg Research Consortium was founded in 1998 and incorporated in 2001. Its membership is extremely diverse and includes, commercial and recreational fishers organizations, the universities of Manitoba and Winnipeg, aboriginal groups, Manitoba Hydro, many different NGOs, and federal and provincial agencies amongst others. Its objectives are to: facilitate multi-disciplinary scientific research and educational opportunities on Lake Winnipeg; expedite information exchange and foster co-operation among all stakeholders; protect and sustain the lake ecosystem; and provide a dedicated and capable platform for research on the lake. Examples of ongoing Lake Winnipeg Research in which members of the LWRC are involved includes: lake carbon budgets and cycles; calibration of satellite imagery for estimation of chlorophyll and turbidity; nitrogen fixation rates and algal physiology; nutrient loading amongst others.

Lake Winnipeg Issues

Q&A | DAVID SCHINDLER

WHAT AILS LAKE WINNIPEG

An ecologist fears there isn't enough political will to save it from death

David Schindler, Killam Memorial Professor of Ecology at the University of Alberta in Edmonton, has been keeping an eye on Lake Winnipeg for the past 33 years, and considers it Canada's sickest large body of water. U.S.-born Schindler, who moved to Canada in 1966, is an expert on the effects of pollutants and climate change on woodland ecosystems. In 1968 he founded the Experimental Lakes Project of the Canadian Department of Fisheries and Oceans, directing the interdisciplinary team, based near Kenora, Ont., until 1989. His work has influenced policy-making in Canada, the U.S. and Europe. He discusses the growing threat to Lake Winnipeg, the 10th-largest freshwater lake in the world, with Toronto-based **Robert W. Ferguson**, *author of* The Devil and the Disappearing Sea: Or, How I Tried to Stop the World's Worst Ecological Catastrophe.

How bad is Lake Winnipeg right now?
It's in a very similar state to that of Lake Erie 30 years ago, when journalists were calling it dead. Large blooms of blue-green algae invade the lake every summer and last for months, producing algal toxins far in excess of World Health Organization guidelines. As these decay they consume oxygen, causing fish kills. These conditions appeared in Erie until control of the nutrient phosphorus, particularly in sewage effluent and household detergents, reversed the situation. We can do the same for Lake Winnipeg, if we have the will.

What's causing the problem?
Increased use of fertilizer, and manure in livestock culture. A single adult hog produces about 10 times more phosphorus than a single human. Yet while we carefully control human sources, hog manure is typically sprayed over the watersheds of streams and lakes. If manure is oversupplied, or a huge rainfall follows spreading, there is potential for these wastes to get into water. Cattle are also a potentially large source. Some more forward-looking producers are now composting hog and cattle waste, sterilizing it and distributing it to larger areas.

What about the estimated 10,000 cottages on the lake?
There are hundreds of studies that show the damage cottages do. Typically, many septic tanks are poorly installed and maintained, allowing leakage of nutrients and pathogens. Conversion of shoreline trees and brush to lawns and gardens, fertilizer use, pet excrement, drainage patterns changed by roads and driveways, reduction of fish habitat by removing weed beds and regulation of water levels are the most common symptoms.

Schindler's list includes fertilizer, manure, cottagers and global warming

Does global warming also have an impact?
Warmer conditions and longer open water seasons cause more evaporation, both from the lake and its tributaries. The net result is less dilution of nutrients and longer periods of warm water when algae blooms thrive. Even if we were to stop producing greenhouse gases now, we would have a few more degrees of warming because carbon dioxide has a long residence time in the atmosphere. However, we could lessen the worst effects of warming by acting now.

So, what's the solution?
Large cities in the watershed, livestock operations, slaughterhouses and fertilizer factories should use tertiary treatment to remove phosphorus. However, water is a more difficult problem. The western prairies are experiencing some of the driest conditions since we started keeping records a century ago. We're locked into climate warming for at least a couple of hundred years, and increasing industry and population have people demanding more water.

In the 1970s the U.S. and Canadian governments worked together to restrict nutrient intake, and Lake Erie was saved. Why is there so little concern today about Lake Winnipeg's fate?
I think that in the 1970s we still had a few vertebrates among politicians and bureaucrats. And in those days, there was none of the stupid "sustainable development" rhetoric that obfuscates environmental issues today and always ends up with environment second to economics.

How optimistic are you that Lake Winnipeg will be saved?
Not optimistic. Environment has slipped from the political agenda both federally and provincially in Canada. We're in another federal election with very little of substance being debated. We'll probably need major episodes of waterborne disease to smarten up politicians and bureaucrats before there's any action. Then it will be very expensive with lots of wasted money.

MACLEAN'S | JUNE 14, 2004

The pages of the Winnipeg newspapers illustrate the growing concern about the state of the Lake Winnipeg environment but they present a confusing narrative of rational and irrational concerns and fears. They range from statements that the Lake is dying or contaminated to claims that the problems are overstated and that the fishery has rarely been better.

Winnipeg Free Press

Who recorded worst song ever?

This list of 50 all-time clunkers may surprise you D1

Great Vegemite challenge

Weird Aussie spread can add zing to recipes — really D1

SPORTS: Canadian curlers hot at worlds C2 *plus*... Bombers re-sign star receiver C5

It's time to fix the lake

'We should have acted 20 years ago,' scientist warns province

Over-fertilizing of fields is common in livestock-abundant areas.

MICHAEL MOORE / ASSOCIATED PRESS ARCHIVE

Over-fertilizing polluting province's water bodies

By Helen Fallding

FARMERS in livestock-intensive ...

said farmers applying manure to their fields from livestock barns are also applying some chemical fertilizer.

Toxic algae fouls beaches

Wpg Free Press Friday Aug 8, 2003

Nature eroded shoreline, study finds

Lake Winnipeg review vindicates Manitoba Hydro

By Bill Redekop

NATURE, not Manitoba Hydro, is responsible for shoreline erosion on Lake Winnipeg, says an independent review team appointed by the province two years ago.

"In most instances, erosion, flooding and dynamic beach changes at the shoreline are the result of naturally occurring processes," the study concludes.

The study is by the Lake Winnipeg Shoreline Erosion Advisory Group, comprised of three engineers, mayors and reeves from the lake's south basin, property owners, and First Nations representatives.

Local groups in the lake's south basin have long blamed Manitoba Hydro's control of water levels for southern shoreline erosion. The lake feeds the Nelson River where hydro stations supply 75 per cent of the province's electricity.

"Even though studying Manitoba Hydro's role was not part of our mandate, it kept coming up at public meetings. People said the lake level is a lot higher since Manitoba Hydro began regulating water levels," said chairman Dave Farlinger, engineering consultant for Energy Consultants International.

But the study found the lake level has not increased since Manitoba Hydro began regulating water levels in 1976.

Neither has the rate of erosion. The study found erosion rates remain between zero-to-two metres per year, depending on location.

However, some areas have suffered more severe erosion because three of the 10 worst windstorms have occurred during the past decade, Farlinger said. The worst windstorms always occur in the fall when northerly winds replace summer's more prevalent south winds, he said.

The Lake Winnipeg Property Owners Association could not be reached for comment. The association claims Hydro has raised the lake level two feet above normal.

One the study's main recommendations is for greater regulation of shoreline structures. Farlinger said many structures designed to protect the shoreline only worsen erosion.

For example, a groyne — a man-made line of rock extending perpendicular from the shore — may trap sand and prevent erosion for that particular property owner. But it creates a sand deficit for neighbours up to a kilometre around it.

A Shoreline Protection Handbook is being developed for different shoreline types and will be available at public meetings.

The report also recommends:

• An advisory committee to review and consider lake management issues related to erosion and environmental concerns.

• A commitment from governments to provide technical services helping property owners with shoreline protection.

The schedule for public meetings, where the panel will explain the report, is: Nov. 6, Gimli Recreation Centre; Nov. 7, Brokenhead Community Hall; Nov. 8, Canad Inn in Winnipeg; Nov. 9, Victoria Beach Seniors Centre.

HISTORY OF LAKE WINNIPEG B1

Winnipeg Free Press, Thursday, July 27, 2000

A6 Local

Cause of fish kill hotly debated

By Aldo Santin

DECOMPOSING organic material has been blamed for a massive fish kill in Sturgeon Creek, but environmentalists and government officials disagree on the culprit.

Poor agricultural practices are to blame for conditions that killed thousands of fish between the Assiniboine River and Warren, says the president of the Sturgeon Creek Association.

Duncan Wain Jr. said his group believes that the high levels were caused by farm manure runoff into the stream.

"I can't substantiate that," said Wendy Ralley, a water quality specialist with Manitoba Conservation.

Other factors like street runoff, combined water and sewer pipe overflow, and animal feces could have contributed to conditions that led to the massive fish kill and E. coli levels five times the allowable provincial limit, she said.

Ralley said the fish kill follows the July 6 rainstorm, which flushed material into the creek. As weeds and plants decomposed, they consumed dissolved oxygen which fish species need to survive.

Ralley said similar fish kills have occurred in the past three years, adding they are a fact of life on the Prairies.

"I don't know of any way to control the rain," Ralley said. "It's a natural occurrence on the Prairies."

But Wain said conditions in Winnipeg don't explain how fish died beyond the Perimeter Highway all the way to Warren.

"If this were happening to a salmon stream in B.C., there'd be an uproar over it," Wain said.

Wain said the fish kills happened all the way up Sturgeon Creek, in an area that's essentially farmland.

"We're not interested in stamping out agriculture but we want things done differently and we want (Conservation) to keep tabs on what is going on out there," said Wain, a fisheries biologist.

In addition to the fish kills, extremely high E. coli levels were recorded at Grant's Mill on July 11, a site where Sturgeon Creek crosses Portage Avenue.

Ralley said the high E. coli counts could also be explained by dog feces and sewer overflow. She said later testing for E. coli at Grant's Mill and several other sites showed that the levels had dropped below the province's maximum allowable limits.

winnipegfreepress.com

Winnipeg Free Press

Garbage Day

Monday, March 27, 2000

Lake Winnipeg fragile: report

'97 flood dumped nutrients, toxins

By Tracy Tjaden
Staff Reporter

HUGE AMOUNTS of nutrients and toxins flushed into Lake Winnipeg during the 1997 Red River flood are threatening the health of the lake, a study has found.

Elevated levels of toxaphene, a toxin that affects the nervous systems of

And a huge jump in the amount of algae in the lake is clogging fish nets and could threaten the health of fish, said Alex Salki, a biologist with the Freshwater Institute, a research branch of the federal Department of Fisheries and Oceans.

sioned to work on the report, slated for release by the International Joint Commission April 17.

Refusing to provide exact numbers until the study is released, Salki said if the lake's algae levels rise much higher, swimming, fishing and using the lake

Some forms of algae at high lev[els] produce a toxin called microcyst[is] which can affect the neurosystems [of] fish, livestock and humans.

"If we don't address the nutrient l[ev]els in the (Lake Winnipeg) basin, [we] could have major problems with [the] fishery," said Salki.

Continued
Please see FLOOD/A2

Wpg Free Press
Tuesday Aug 12/03

Lake will be saved: province

Recovery well under way in three years: water boss

By Mia Rabson

WITHIN two or three years, Lake Winnipeg should be well on its way to recovery, Manitoba's top water quality official vowed yesterday.

Efforts are already under way to reduce the levels of phosphorus and nitrogen in the lake, said Dwight Williamson, manager of the Water Quality Management Section for Manitoba Conservation.

"We have a pretty good idea now where the major sources are," Williamson said.

Cleanup efforts include educating farmers about the dangers of excess fertiliza- that contribute about one-third of the nutrients in the lake.

But those initiatives aren't enough, warned Liberal Leader Jon Gerrard, noting several Lake Winnipeg beaches were recently posted as dangerous.

"We need some action here," he said. "The NDP for four years have done nothing except put together a committee. The NDP could have started this in their first year in office."

Conservation Minister Steve Ashton announced last February a strategy to cut phosphorus and nitrogen in the lake to the levels of 30 years ago. Ashton was on vacation yesterday and

A4 LOCAL WINNIPEG FREE PRESS, SUNDAY, MARCH 2, 2003

Big hog barns are the least of Manitoba's water pollution worries, according to Don Flaten, acting head of soil science at the U of M.

Water worries are unclear

Predicting pollution spots tough; still huge information gaps

By Helen Fallding

BIG hog barns are the least of Manitoba's water pollution worries, according to a scientist who believes activists intent on shutting down the industry are manipulating the debate.

"We've got to restore a sense of bal-

entists know so far about real contamination — although everyone acknowledges there are still huge information gaps.

It's known there's too much algae-promoting phosphorus flowing into Lake Winnipeg from the flat Red River basin, but according to the model, phosphorus should only be a problem in the hilly regions of western Manitoba.

Analysis

and what will it take to stop it?

Watch for some of these solutions in Conservation Minister Steve Ashton's water strategy, due out next month.

■ Soil testing: Runoff of chemical farm and lawn fertilizer is a pollution source that doesn't get neighbours up in arms like stinky hog barns. Since soil testing was privatized a decade ago, the provincial government has not had access to the results, making it hard to know where nutrients are

FOCUS

A15 WINNIPEG FREE PRESS, THURSDAY, JANUARY 29, 2004

Canada's sixth Great Lake' faces a multiplicity of problems. They include severe nutrient loading, low water, climate change and the invasion of exotic species.

Lake Winnipeg faces many threats

Cruise like sailing across sea of thick, green paint

SATURDAY, JANUARY 18, 2003

EDITORIALS

Freedom of Trade
Liberty of Religion
Equality of Civil Rights

FP 18/1/03

Lake Winnipeg dying?

Scientists warn levels of damaging micro-organisms are soaring

By Carol Sanders

LAKE Winnipeg is starting to look more like Lake Erie of 30 years ago, which was then considered the slop pail of North America, scientists warn.

"Everybody is contributing to the problem," Al Kristofferson, co-ordinator of the Lake Winnipeg Research Consortium, told the Red River Basin Summit yesterday.

"Things have happened in the lake during the last 50 years that we have to pay attention to," said Kristofferson, who leads the University of Manitoba-based consortium, which is made up of 23 agencies. It spent 81 days on Lake Winnipeg last year checking the health of the so-called Prairie ocean.

Algae blooms in the north basin of the lake are clogging commercial fisher's nets with "dirt" in the summer and in the south basin during the winter, he said. "Seeing is believing."

Lake Erie gained notoriety as a "dead lake," killed by pollution, before controls were put in place with the U.S. Clean Water Act in 1972. A vast, deep section of Lake Erie was oxygen-starved in the summer because rotting algae on the bottom used up the oxygen.

Continued
Please see DYING A2

Lake Winnipeg faces many threats

Cruise like sailing across sea of thick, green paint

LAKE Winnipeg had an 8,000-square-kilometre algal bloom in its vast north basin in the relatively windless summer of 1999. Members of the scientific consortium studying the lake recall that their cruise from Grand Rapids to George Island on board the Canadian Coast Guard ship Namao was like sailing across a sea of thick, green paint.

Last year, a windier year, satellite photos revealed a 6,000-square-kilometre bloom of the deadly blue-green toxin in the north basin — the same toxin that closed beaches in the south basin.

One of Canada's pre-eminent scientists issued a dramatic plea to save Lake Winnipeg at a meeting of senior Canadian and U.S. government officials last month. Addressing the American and Canadian co-chairs of the International Joint Commission sharing the platform with him, Dr. David Schindler, Killam Memorial Professor of Ecology at the University of Alberta, fellow of the Royal Society and winner of the prestigious NSERC Award of Excellence said: "My message to the IJC is please give Lake Winnipeg some attention. We've got to get started."

Dr. Schindler, a former senior federal scientist at Winnipeg's Freshwater Institute and the leader of the Experimental Lakes Program of the Department of Fisheries and Oceans, told a meeting of the Summit Institute Society on Managing U.S.-Canada Relations in Ottawa Dec. 5 that "Canada's sixth Great Lake" faces a multiplicity of threats. They include severe nutrient loading, low water, climate change and the invasion of exotic species.

"Yet no one seems to know or care," he declared to the roomful of top continental decision-makers.

The scientific consortium who sailed on the sea of green paint in 1999 today faces another vividly coloured sea — $200,000 of red ink. Its funds were supposed to come from Manitoba, Ottawa and Manitoba Hydro. So far, only Hydro has contributed its share. Many of the scientists have resorted to using their own money to fund this vital research.

Lake Winnipeg is an orphan. Located within one province, its watershed encompasses three provinces and part of a fourth plus two American states. The majority of the phosphorus and nitrogen polluting the lake comes from the Red River and the majority of the Red River's nutrients come from the U.S. Thus, the lake's plight is clearly a national if not international responsibility. But Ottawa's current line-by-line spending review examines all existing and new programs to see if they can be eliminated, downloaded or privatized. In addition, Ottawa is terrified of treading on any provincial toes, especially in the West, and desperate to mend fences with the U.S. Manitoba is finally taking action, but the lake's problems are far beyond its ability to solve alone.

The impacts on Lake Winnipeg are now known to be cumulative, self-reinforcing and rising. The Saskatchewan River, once the source of 60 per cent of Lake Winnipeg's water, has seen its flows drop 80 per cent since 1910, thanks to enormous draws in Alberta and Saskatchewan for agriculture, municipal use and oil extraction. Then there is the exponential increase in nutrients from farm fertilizers, concentrated livestock operations, human sewage and humanity's destruction of the wetlands and riparian areas that act as "kidneys" filtering out the land's poisons.

"Since the mid-1960s when I participated in the first survey of (Lake Winnipeg), we've had explosions in nutrients, nitrogen and phosphorus and algae expressed as chlorophyll well up to the hypertrophic range," Dr. Schindler said. "The lake right now is as eutrophic as Lake Erie was in the early 1970s when journalists were calling it dead. We've moved Lake Erie back with our restrictions on nutrient input, but meanwhile Lake Winnipeg has taken off."

The 2003 algal bloom produced toxins of several thousand micrograms per litre. The world drinking water standard is one microgram. "Why isn't anyone excited about this?" Dr. Schindler demanded.

Manitoba is finally taking action, but the lake's problems are far beyond its ability to solve alone.

The scientist was blunt about a huge part of the problem — concentrated livestock operations. Alberta has a population of three million humans plus eight million hogs and cattle, each of whom is equivalent to 10 or 11 people.

"So we have a human equivalent population of 87 million. We control the (phosphorus output) of the three million actual humans with municipal sewage systems. We take out the phosphorus and we treat it for pathogens. The other 84 million virtual humans we say, 'Well, just go crap on the land or in a pit somewhere and then spray it around and that's OK.' This is why we have Walkertons."

Climate change is set to make the prairies much hotter. Since the mid-20th century, Edmonton's temperature has increased by 2.5 degrees Celsius. By the mid-21st century, it will rise at least another one to three degrees Celsius.

"If you look at predictions for 25 years from now, evaporation is around 20 to 25 per cent," Dr. Schindler said. "So it outstrips any projected increase in precipitation. Translated, it's not only going to be much warmer, it will be much drier."

In an interview, Dr. Schindler was asked what fate awaits Manitoba's Great Lake. Could it become a small, stinky — and toxic — green slough?

He won't go that far but he predicts there will be more frequent, intense and lasting algal blooms and the lake will likely shrink. He warns that after a certain level of phosphorus and nitrogen from animal, human and agricultural run-off embeds in the lake's soil, the algal blooms become self-generating, increasing on their own.

There is one possible bright note. The Red and Winnipeg river systems are forecast to flush more water into the lake. That will not be enough to offset entirely the Saskatchewan River loss or to stop eutrophication. But it might be enough to achieve a stable, if deteriorated, new state.

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Knowledge & Attitude

Concern for Lake Winnipeg

Lessons learned, solutions shared

Fisheries minister appreciates 'warnings'

Lake Winnipeg woes set out for Regan

By Carol Sanders

THE federal Fisheries and Oceans minister paid his first visit to land-locked Winnipeg yesterday and got an earful from fishers, municipal politicians and scientists about the challenges facing the province's largest freshwater lake.

"Within 15 years, Lake Winnipeg will be destroyed," said Sam Murdock, president of Fisher River MacBeth Fisheries.

Murdock issued the dire warning to Fisheries and Oceans Minister Geoff Regan that nutrients draining into the lake from sewage and farming are clogging it with algae blooms that are harming the fishery.

"The lake used to cleanse itself in 10 months, now it takes four years," Murdock told Regan at a Liberal lunch yesterday at the Laurier Club of Manitoba. Close to 1,000 people depend on Lake Winnipeg for their source of income, said Murdock, a member of the Lake Winnipeg Stewardship Board.

"If word gets out, it will have a devastating effect on the commercial fishery," said Murdock. "I hope our federal government will come on board with the province. There's got to be a solution," he said.

"If the lake is dead, it will be devastating to the entire province," said Bruce Benson, a fourth-generation commercial fisher from Gimli who's seeking the federal Liberal nomination in Selkirk-Interlake.

The minister from the Maritimes said he visited Winnipeg's Freshwater Institute yesterday on his tour that began earlier on the West Coast. Regan said he was shown a satellite image of a huge algae bloom in the northern part of Lake Winnipeg that is a cause for concern for everyone. Regan said fresh water is like a canary in a coal mine and the canary, in Lake Winnipeg's case, appears to be choking.

"I appreciate the warnings," said Regan.

The new minister heard that his department needs to clear up its image as well.

"From a municipality's point of view, three years ago the DFO arrived with guns," said St. Andrews Reeve Don Forfar. He said the officers were overzealous and understaffed. Any farming, land use or drainage projects that might have an impact on streams and fish habitat were halted and getting approvals took too long.

"It was not a good working relationship. Farmers have got to make a living too... I would encourage them to be more pragmatic."

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Regan: fresh water like a canary

Warning labels for tinned tuna?

WPG F. PRESS Nov 5/2004

Scientists say feasting on fish is becoming even more risky

By Helen Fallding

GIMLI — Mercury scientists say eating fish may be more risky than most consumers — or even the government — realizes.

Health Canada warns against eating too much fresh tuna, shark, swordfish and other gourmet fish most Canadians only encounter in restaurants or at the sushi bar.

But Montre…

…the Canadian ambassador to Ukraine

Mergler's research suggests some kinds of canned tuna are also a significant source of mercury.

At the annual meeting of Canada's Collaborative Mercury Research Network yesterday, she called for labelling of toxic foods, similar to the colour scheme she designed for people in the Amazon who eat fish daily.

Pale tuna could have a green dot and white tuna, which has 10 times as much mercury, could have a red dot, she suggested to her peers.

Continued
Please see FISH A4

Neptune's Michelle Vandal holds a tray of whitefish, one of the species low in mercury.

Devils Lake outlet gets Powell's approval

bill.redekop@freepress.mb.ca

BISMARCK, N.D. — U.S. Secretary of State Colin Powell said a federally funded outlet to drain Devils Lake floodwaters would not violate a water quality treaty with Canada.

North Dakota officials applauded his decision but said the U.S. government plan still is too costly.

Expert warns of hog farm 'disaster'

FREE PRESS Oct 6/2004

Booming industry 'lacks regulation'

By Leah Janzen

MANITOBA must tighten regulations on its burgeoning hog industry or face serious water problems, a conference heard yesterday.

Hans Schreier, a professor at the University of British Columbia Institute for Resources and Environment, addressed a conference yesterday on Living with Livestock being held this week at the Canad Inns Polo Park.

He warned that a massive increase in worldwide demand for meat and water, coupled with a spike in the number of large-scale hog barns in Manitoba is a recipe for disaster.

"Everyone tells us efficiency gets higher as you get more intensive," he said. "But eventually it comes to the point where I don't think we can manage it."

Pig production in Manitoba has…

Lake Winnipeg not dead yet

WE are writing this in response to your editorial of Aug. 24 entitled, "Fishy Algae Blooms".

As Lake Winnipeg commercial fishermen, we found your article very reassuring; a voice in the wilderness. Someone has had the temerity to question the increasingly alarmist reports being generated by the Lake Winnipeg Research Consortium.

We have known for some time now that there has been too much nitrogen and phosphorous entering the Lake Winnipeg watershed. Years ago the Province of Manitoba had made that information available through the…

…algae, and all things for that matter, with a healthy skepticism. After all, isn't that the scientific way?

Our fishery has been thriving in recent years. Catches have been excellent and stocks of all species healthy. Scientists from the Consortium have advised that our good fortune is really the portent of a looming disaster. They tell us that nutrient loading is responsible for increased production. They…

We spend an enormous amount of time on Lake Winnipeg in all kinds of weather... risking our lives to extract a living from this unforgiving inland sea


N.D. landfill could pollute Red: group
Citizens' coalition in opposition to $6-million Grand Forks dump
GF landfill
EARLY WARNING
Snail an indicator of the health of Lake Winnipeg, but it needs some help
Lake Winnipeg dying?
Mistehay Sakahegan
The Great Lake
by Frances Russell
The Beauty and the Treachery of Lake Winnipeg
MARGARET McWILLIAMS AWARD WINNER
Manitoba Historical Society
STATE OF THE LAKE
Algae a growing threat to Manitoba's largest body of water
BY TINA PORTMAN
HARDCOVER
TRADE PAPER
FOR YOUNG PEOPLE
AUTHOR EVENT
FROM ANNE

Lake Winnipeg Issues

- Climate Change
- Biological Contamination
- Chemical Contamination
- Endangered Species
- Eutrophication
- Exotic Species
- Floods
- Interbasin Transfers
- Overfishing
- Sedimentation
- Water Control

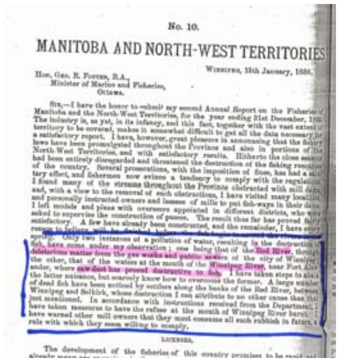
•**Climate change:** There is a concern that the impacts of eutrophication on Lake Winnipeg may be compounded by an increasing potential for climate warming that could stress foodweb structure and function through changes in watershed hydrology. Climate warming will directly impact stenothermal species such as lake whitefish (*Coregonus clupeaformis*) and will further increase the likelihood of other invasive species penetrating the Nelson River/Lake Winnipeg watershed via natural or anthropogenic mechanisms. Alteration of regional hydrology by climate change may increase the risk of inter-basin biota transfer if water diversion schemes are developed.

•**Biological contaminants**: There are concerns that recreational beaches of Lake Winnipeg have experienced increasing numbers of closures arising from elevated fecal coliform levels.

•**Chemical Contaminants**: There are concerns that contaminants such as PCBs, organo-chlorine pesticides, and hormones may rise as an outcome of increased cattle and hog production and increased wastes in the watershed.

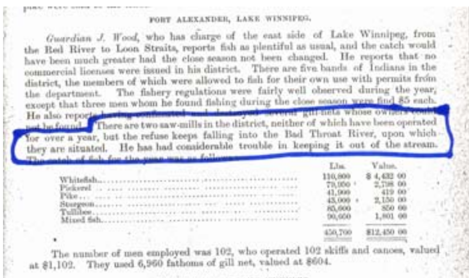
•**Endangered species** There are concerns about the survival of components of the aquatic ecosystem. *Physa winnipegensis*, an endangered snail has been proposed for COSEWIC listing, a remnant population of shortjaw cisco (*Coregonus zenithicus*) is threatened, and other fish species (bigmouth buffalo, chestnut lamprey, silver chub and lake sturgeon) are also under stress.

•**Eutrophication:** There are concerns that the levels of eutrophication in Lake Winnipeg are reaching dangerous levels. Input of N and P from rivers is increasing. Levels of N and P in the lake are increasing. The incidence and severity of algal bloom formation seem to be increasing. Algal populations in lake are shifted to nitrogen-fixing blue greens. Increasing populations and lack of tertiary sewage treatment, intensive cropping and increased use of fertilizers, increased cattle and hog production and increased wastes in the watershed have all been identified as potential causative factors



No. 10.

MANITOBA AND NORTH-WEST TERRITORIES



FORT ALEXANDER, LAKE WINNIPEG.

Guardian J. Wood, who has charge of the east side of Lake Winnipeg, from the Red River to Loon Straits, reports fish as plentiful as usual, and the catch would have been much greater had the close season not been changed. He reports that no commercial licenses were issued in his district. There are five bands of Indians in the district, the members of which were allowed to fish for their own use with permits from the department. The fishery regulations were fairly well observed during the year, except that three men whom he found fishing during the close season were find $5 each. He also reports having confiscated and destroyed several gill-nets whose owners could not be found. There are two saw-mills in the district, neither of which have been operated for over a year, but the refuse keeps falling into the Bad Throat River, upon which they are situated. He has had considerable trouble in keeping it out of the stream. The catch of fish for the year was as follows:—

	Lbs.	Value.
Whitefish	110,800	$ 4,432 00
Pickerel	79,950	2,798 00
Pike	41,900	419 00
Sturgeon	43,000	2,150 00
Tullibee	85,000	850 00
Mixed fish	90,050	1,801 00
	450,700	$12,450 00

The number of men employed was 102, who operated 102 skiffs and canoes, valued at $1,102. They used 6,960 fathoms of gill net, valued at $604.

GIMLI DISTRICT, LAKE WINNIPEG.

- Department of Marine and Fisheries Annual Report 1886
  - *"Two instances of pollution of water... Red River at Winnipeg through deleterious matter from the gas works and public sewers and Fort Alexander where saw-dust has proved destructive to fish*
- Department of Marine and Fisheries Annual Report 1892 - Fort Alexander
  - *"There are two saw-mills in the district … the refuse keeps falling into the Bad Throat River upon which they are situated*"

Unfortunately many of these issues have been identified for many years. And, in many cases the actions necessary are well known. three reports from before the turn of the last century illustrate this.

•The Department of Marine and Fisheries Annual Report 1886. "Two instances of pollution of water... the Red River at Winnipeg through deleterious matter from the gas works and public sewers and Fort Alexander where saw-dust has proved destructive to fish".

•Department of Marine and Fisheries Annual Report 1892 - Fort Alexander. "There are two saw-mills in the district … the refuse keeps falling into the Bad Throat River upon which they are situated"

•Department of Marine and Fisheries Annual Report 1890. Appendix 3 Special Report of Mr. S. Wilmot to the Minister of Fisheries the Honourable Charles H. Tupper, Relative to the Preservation of the Whitefish Fisheries of Lake Winnipeg. "Regarding the alleged depletion of whitefish, and to investigate other matters connected therewith;"

Lake Winnipeg Knowledge Gap

Lake	ASFA	ESPM
• Michigan	1816	3085
• Ontario	1764	2590
• Erie	1712	2578
• Superior	1050	1543
• Huron	622	907
• Victoria	756	343
• Malawi	398	159
• Great Slave	79	57
• Winnipeg	71	73
• Great Bear	22	22

Citation search

ASFA Aquatic Science and Fisheries Abstracts (1978-2002)

Environmental Sciences and Pollution Management (1981 to present)

From the perspective of scientific knowledge and understanding what is perhaps most telling is the lack of research on the Lake Winnipeg aquatic ecosystem in comparison to the other great lakes of Canada and the world

Acknowledgements for Pictures and Figures in Presentation

- Lake Winnipeg Research Consortium
- Manitoba Archives
- Glenbow Museum, Canadian Archives
- Manitoba Museum of Man and Nature
- Natural Resources Canada
- Staff of the Department of Fisheries and Oceans
- Environment Canada
- Greg McCullough
- Bell and Associates
- Al Kristofferson

Lake Winnipeg Water Quality:

History, Current and Future State, and Management Needs

Dwight Williamson, A/Director
Water Science and Management Branch
Manitoba Water Stewardship

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Principal Lake Winnipeg Water Quality Issues

Issue 1: Nuisance, harmful, and toxic blooms of algae

Issue 2: Periodic elevated densities of *Escherichia coli* at bathing beaches

Issue 3: Miscellaneous issues such as transportation of toxaphene in flood waters, introduction of exotic species, climate change, reductions in stream flow, etc.

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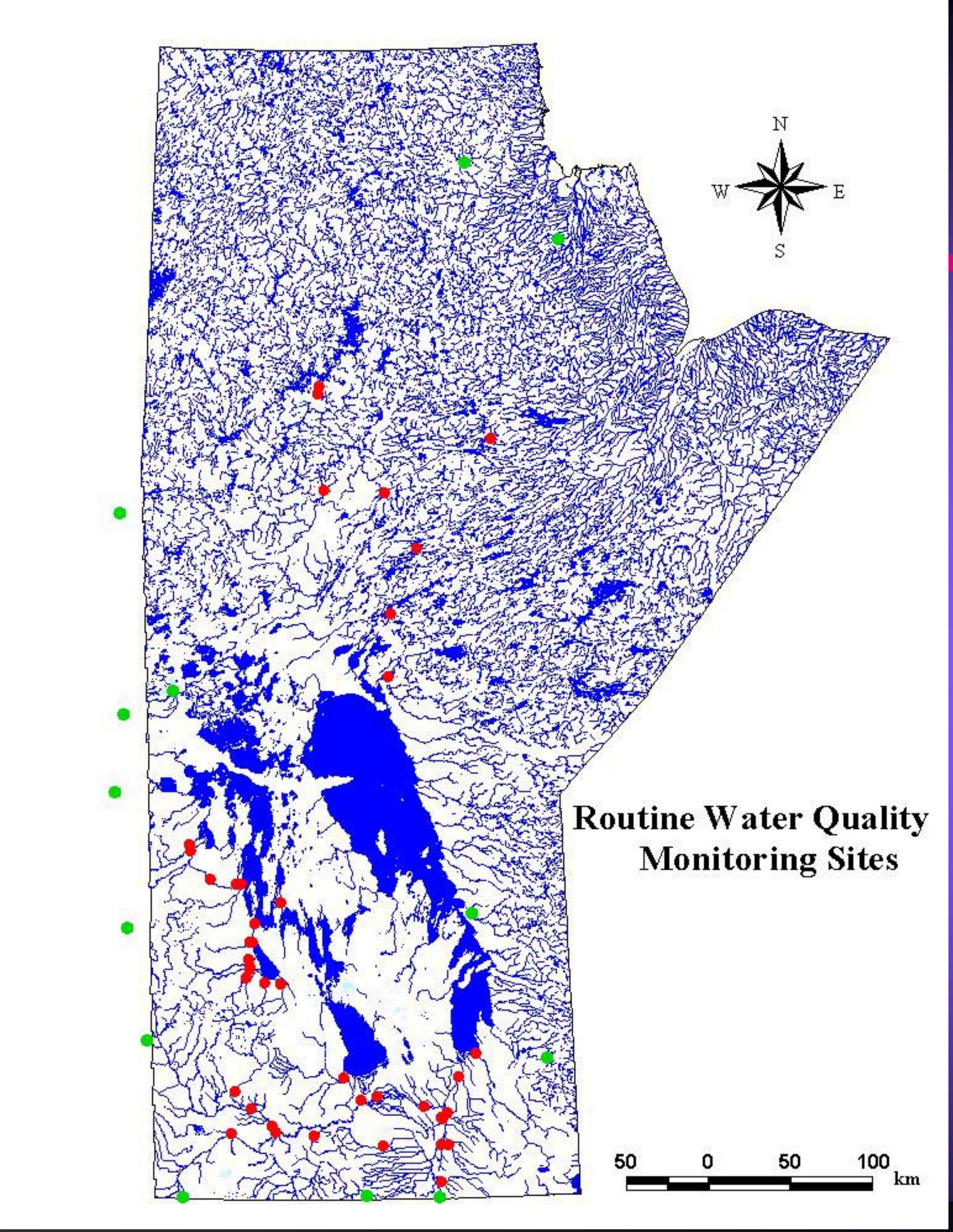
Issue 1: Nuisance, Harmful, and Toxic Blooms of Algae

- Fouling of commercial fishers' nets, thus increasing fishing effort or diminishing income
- Fouling of beaches, thus creating unpleasant conditions for cottagers and bathers
- Reduction of dissolved oxygen upon decomposition
- Alteration of food web and species interactions
- Production of toxins that may result in fish die-off and bathing advisories

Stream Water Quality Monitoring



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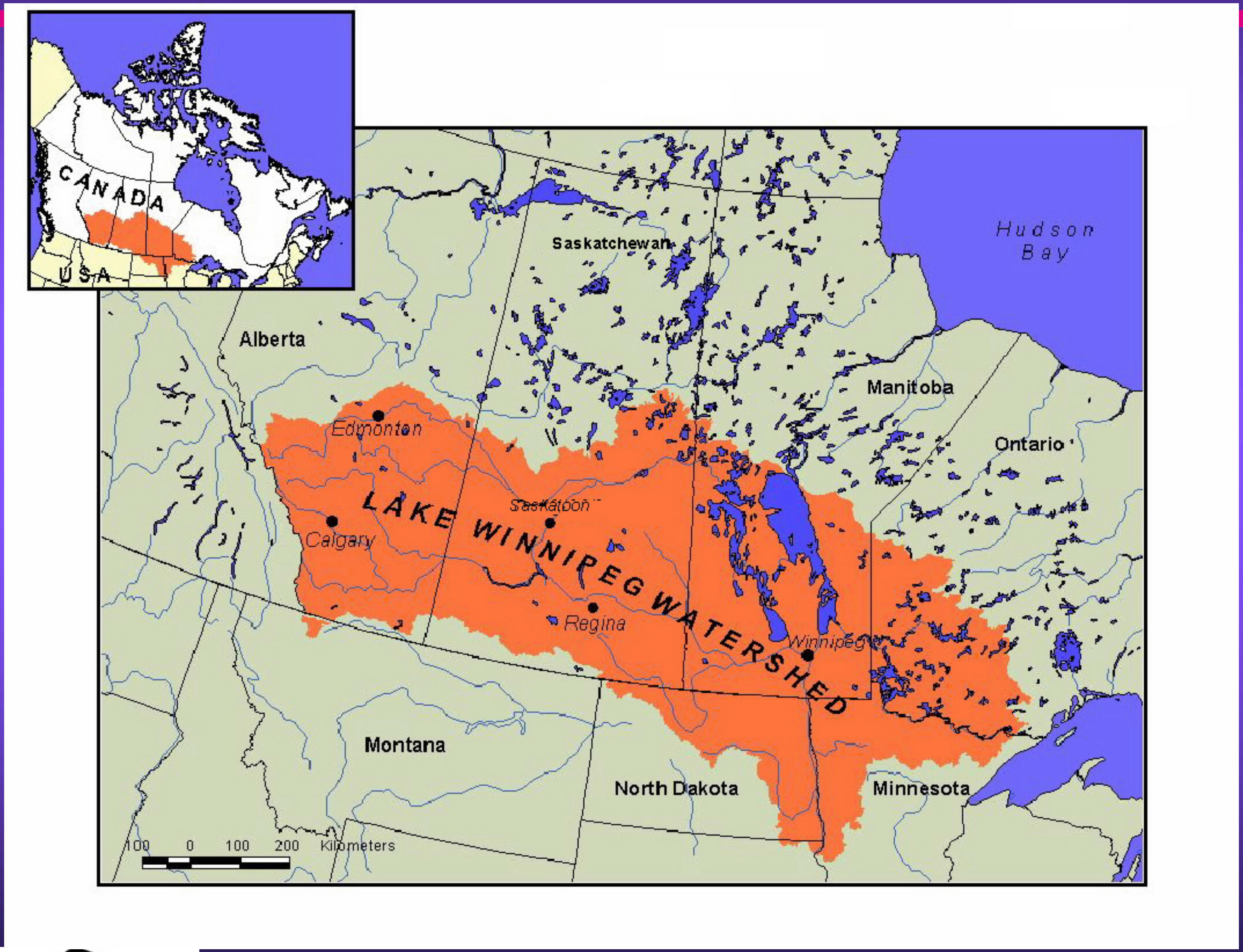
Lake Winnipeg Drainage Basin



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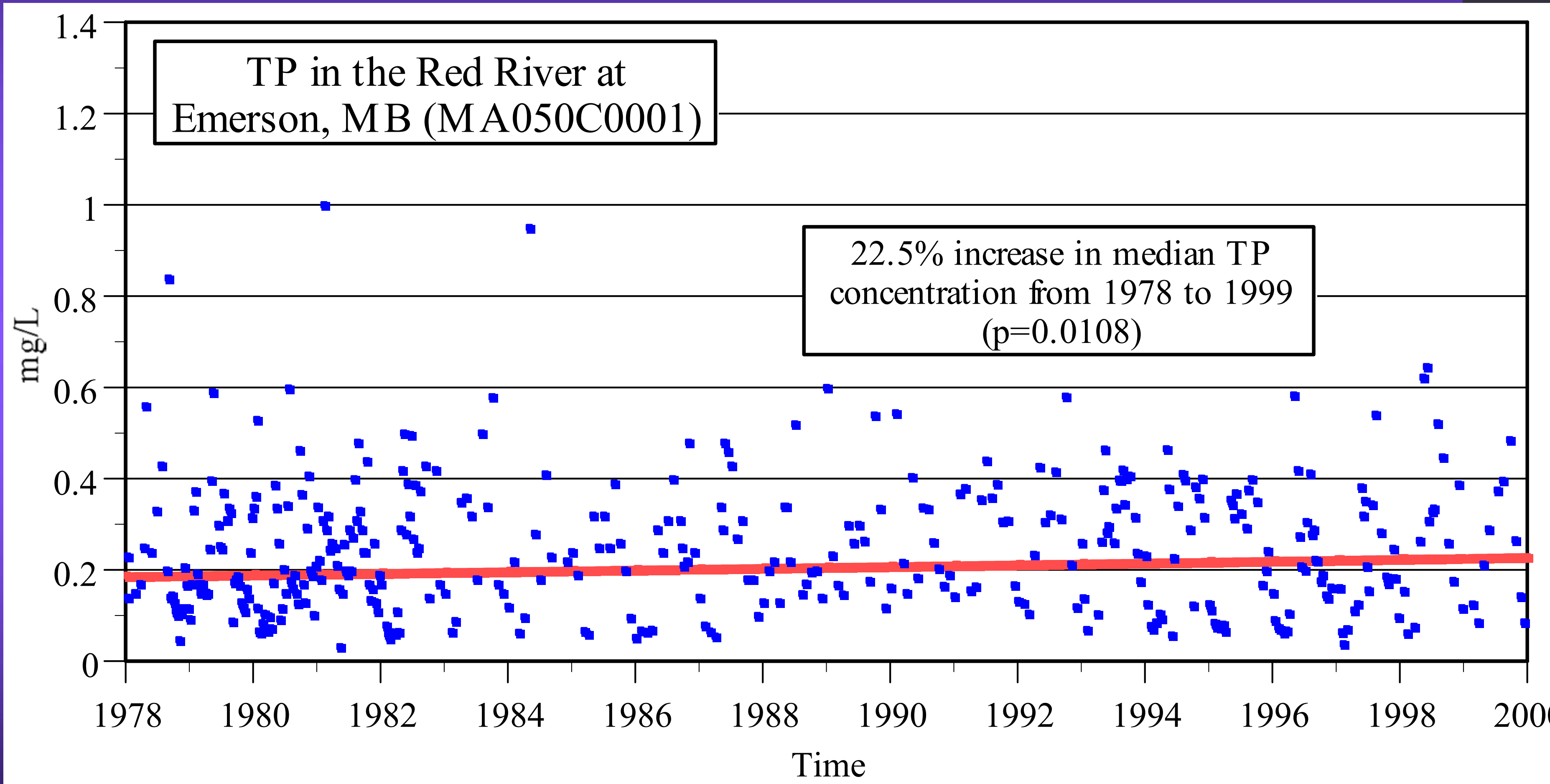
Phosphorus in Red River at Emerson



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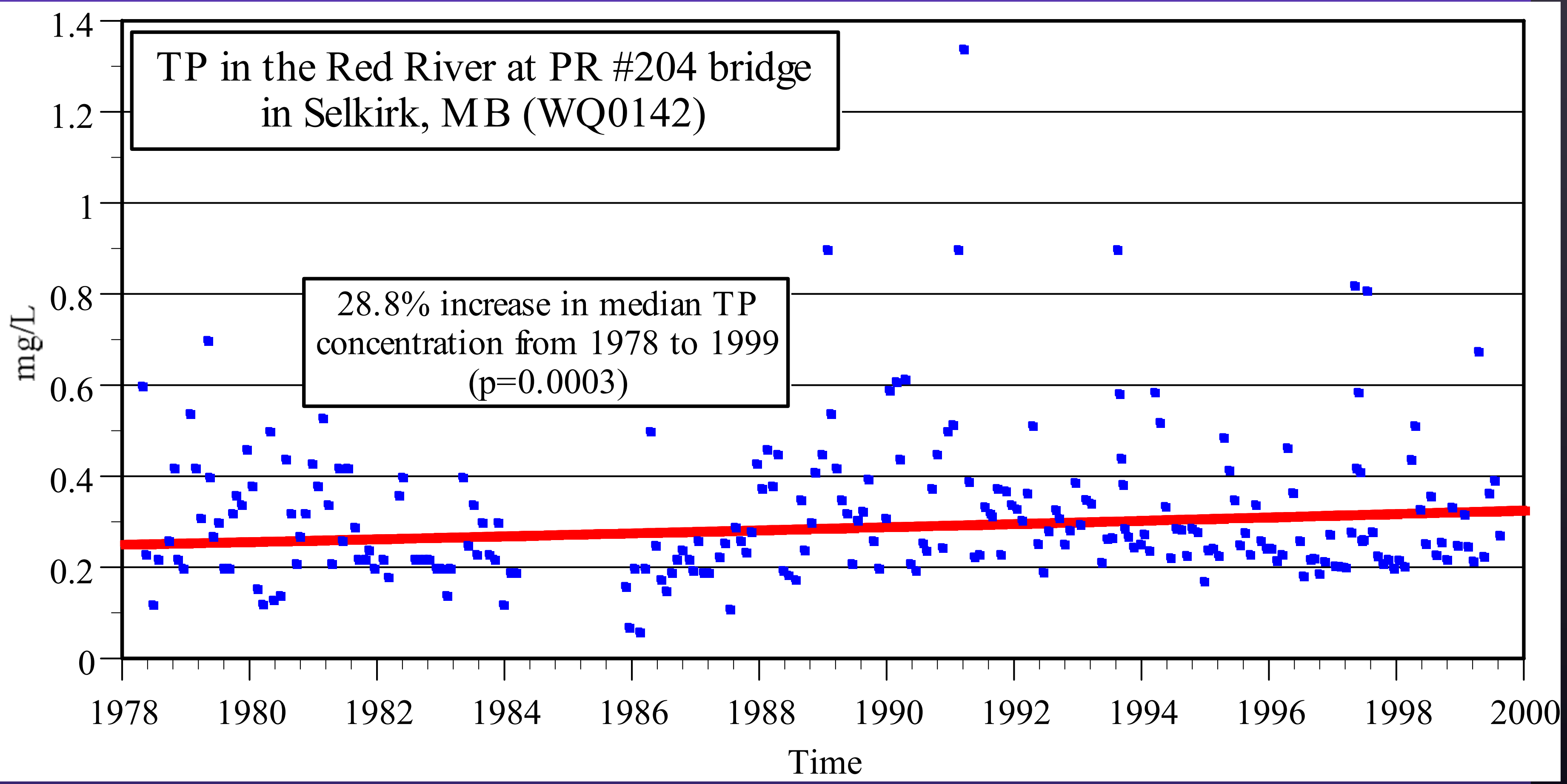
Phosphorus in Red River at Selkirk



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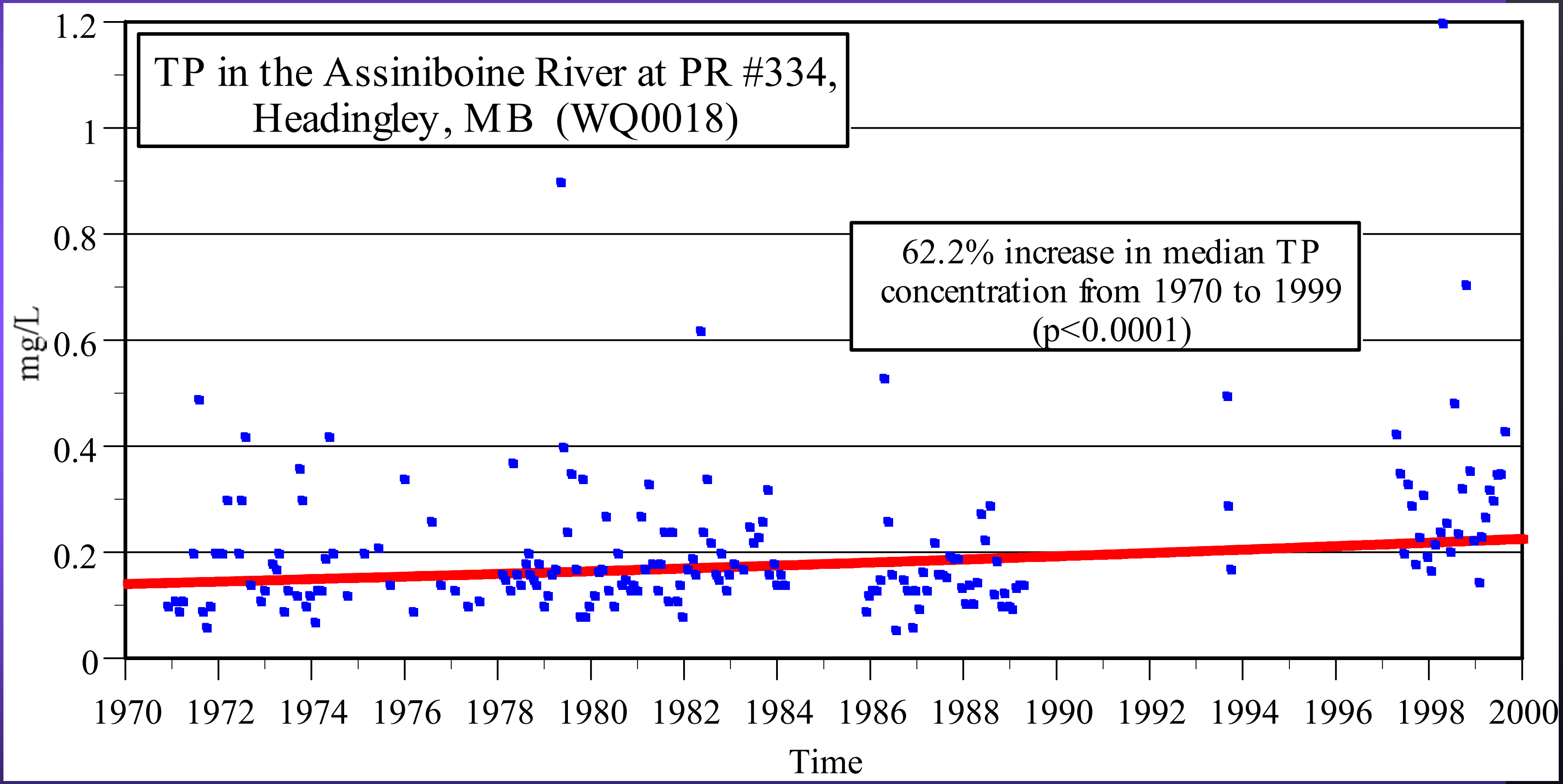
Phosphorus in Assiniboine River at Headingley



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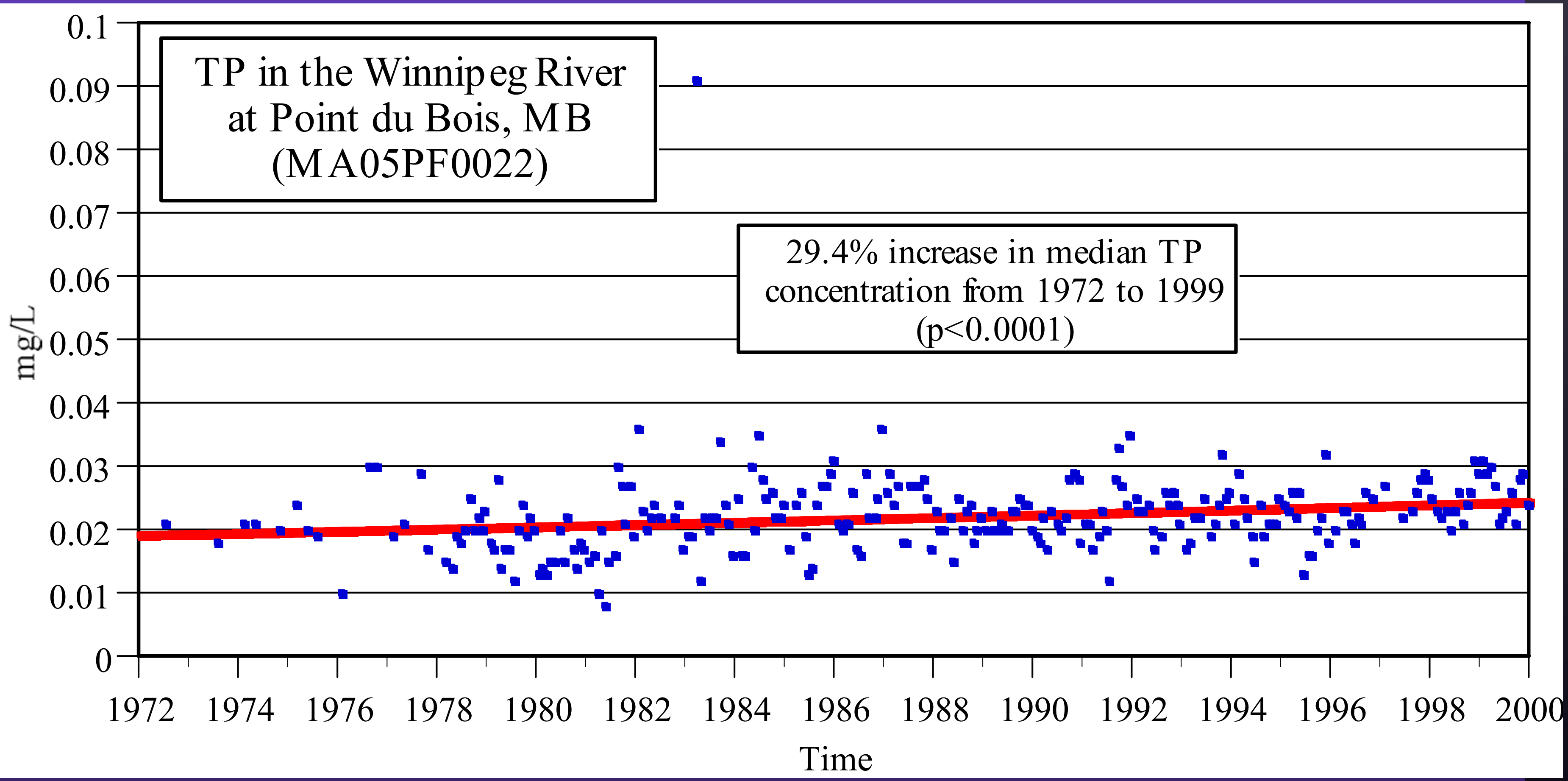
Phosphorus in Winnipeg River at Pointe du Bois



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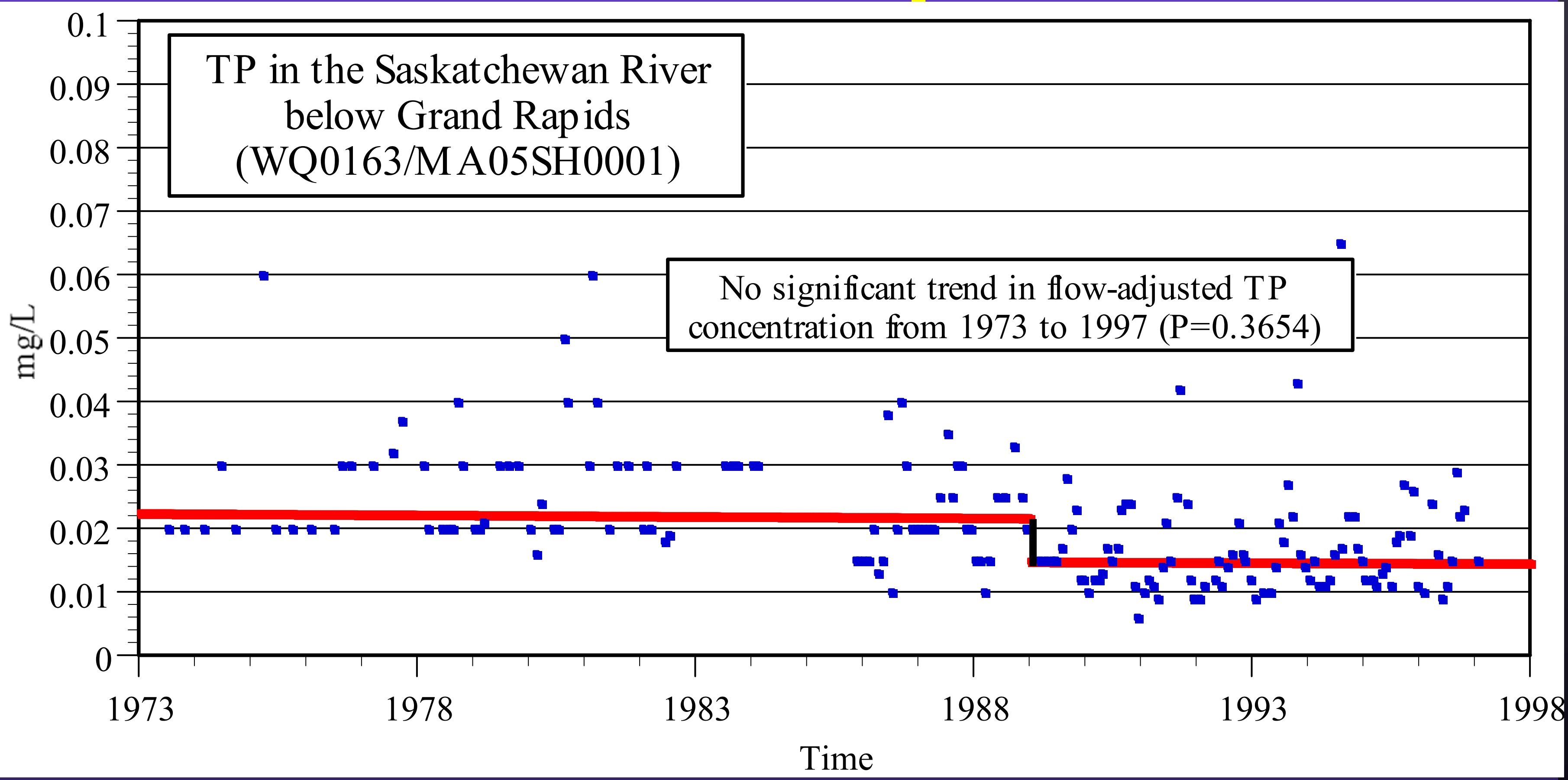
Phosphorus in Saskatchewan River below Grand Rapids



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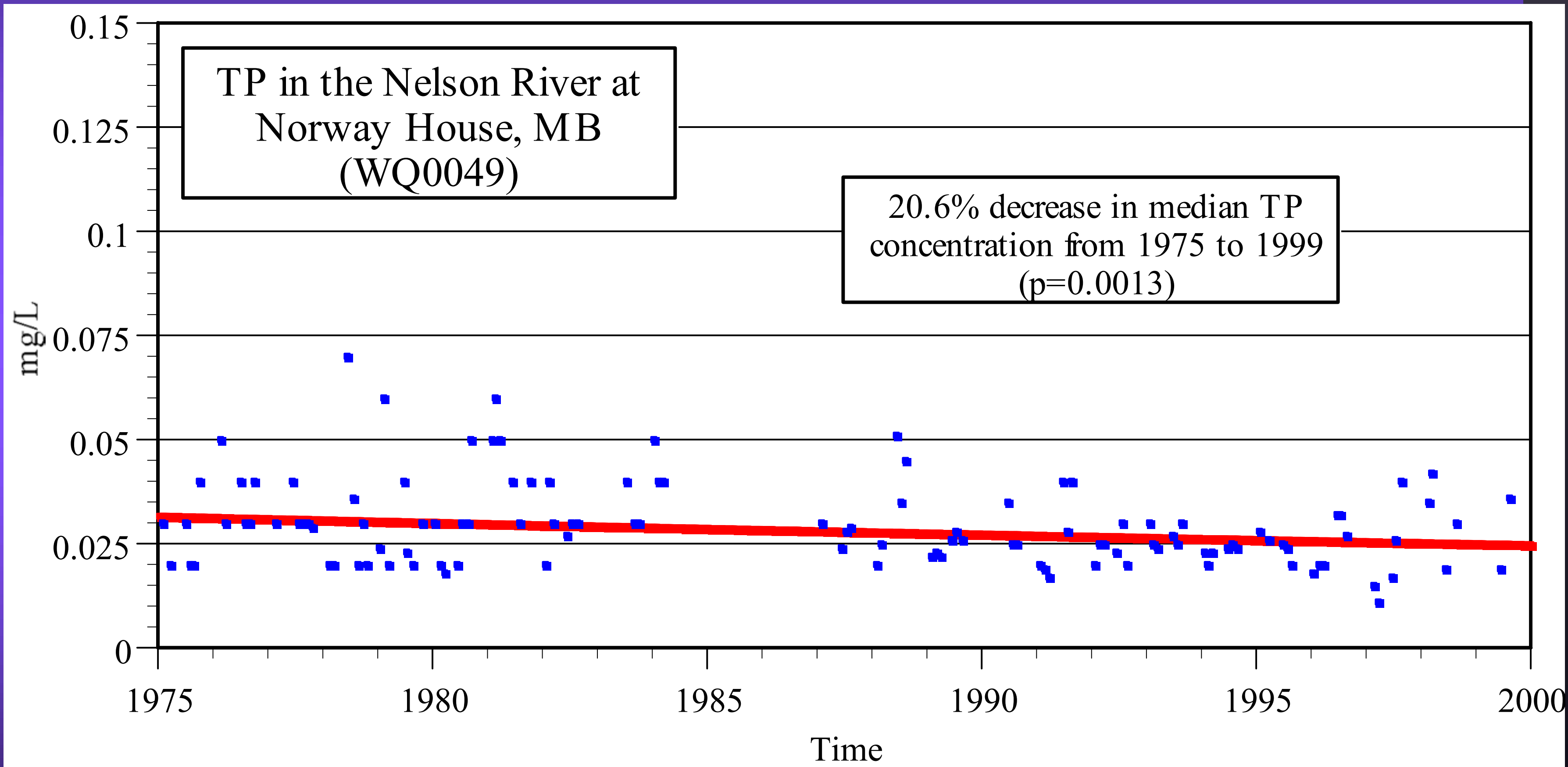
Phosphorus in Nelson River



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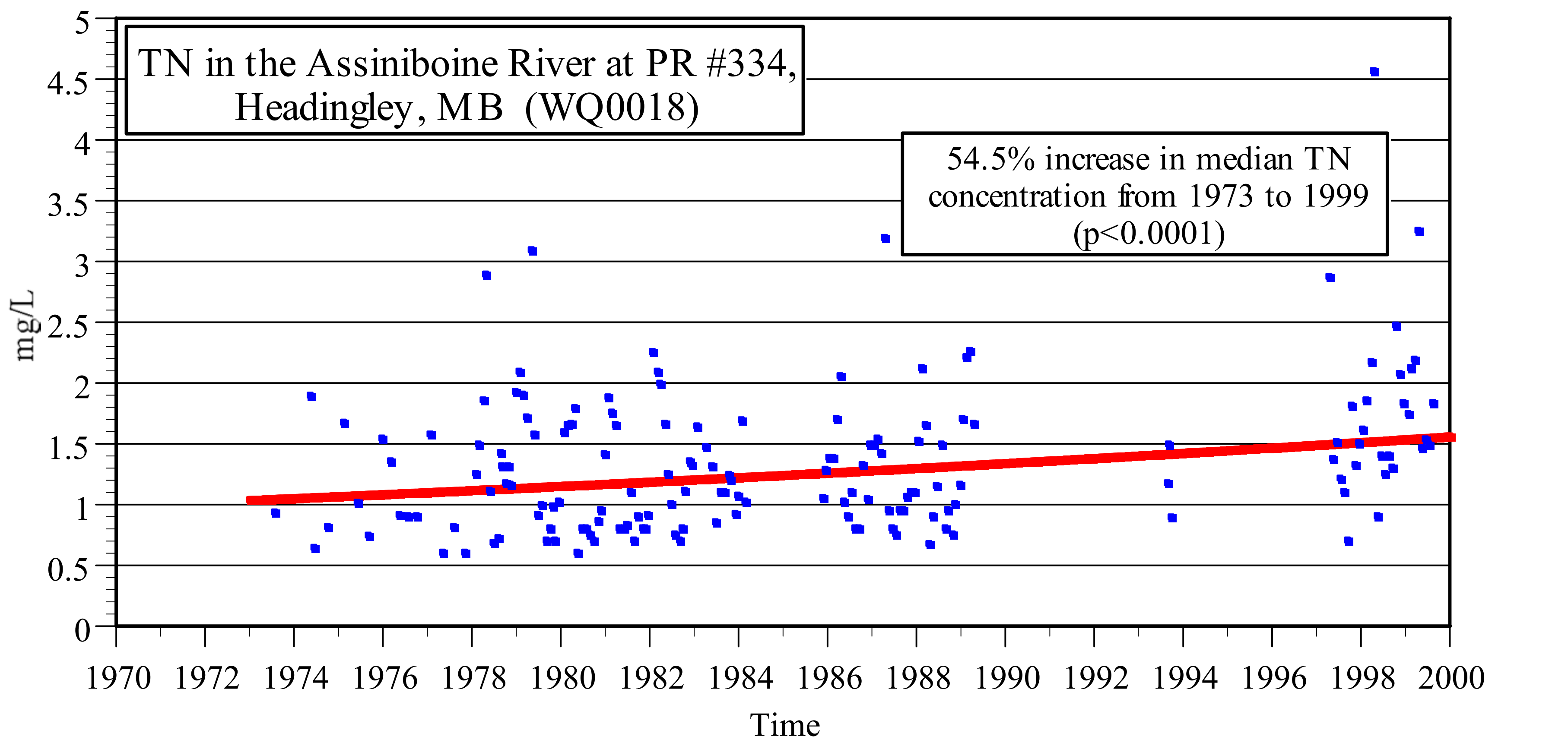
Nitrogen in Assiniboine River at Headingley



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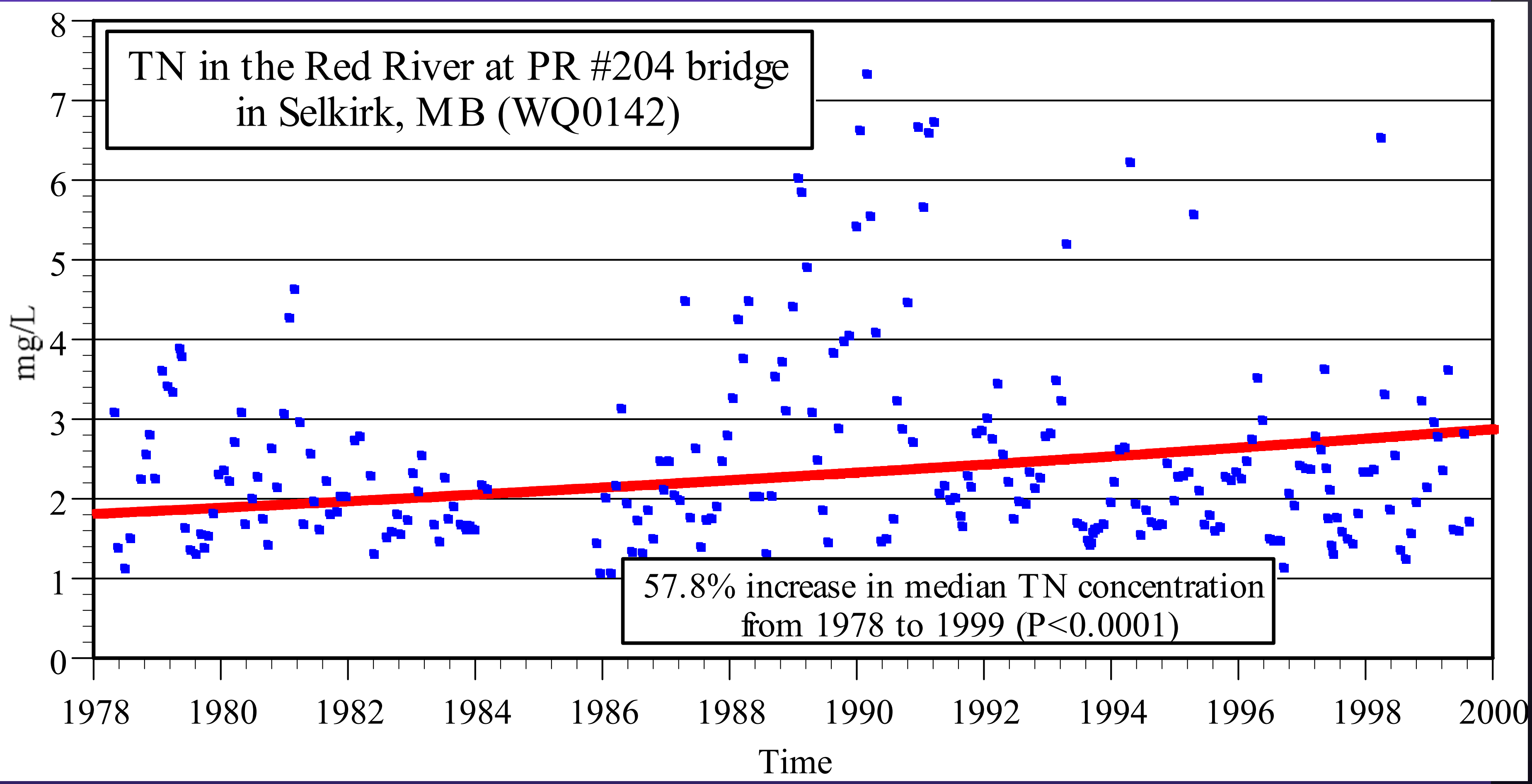
Nitrogen in Red River at Selkirk



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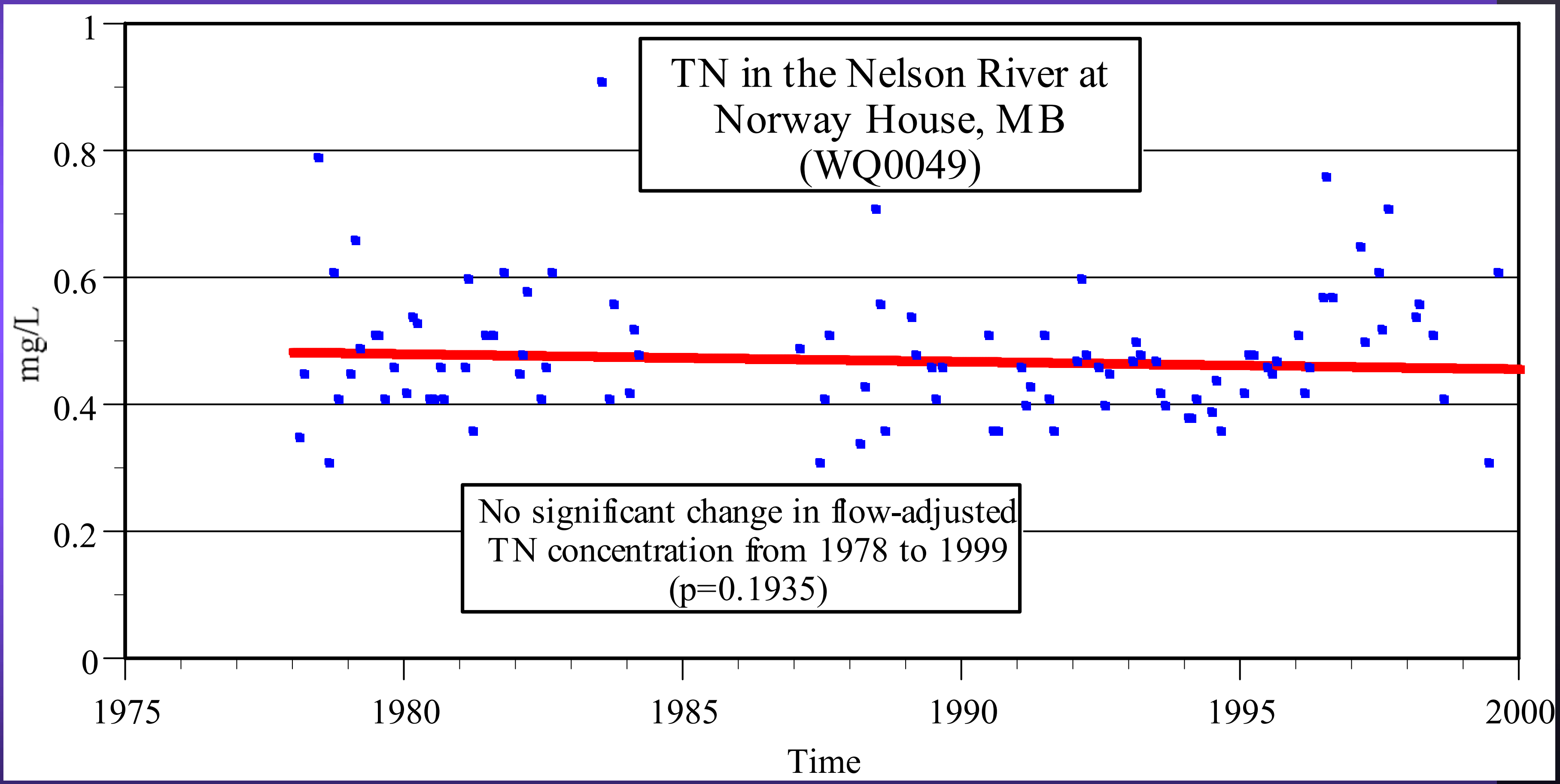
TN in Nelson River



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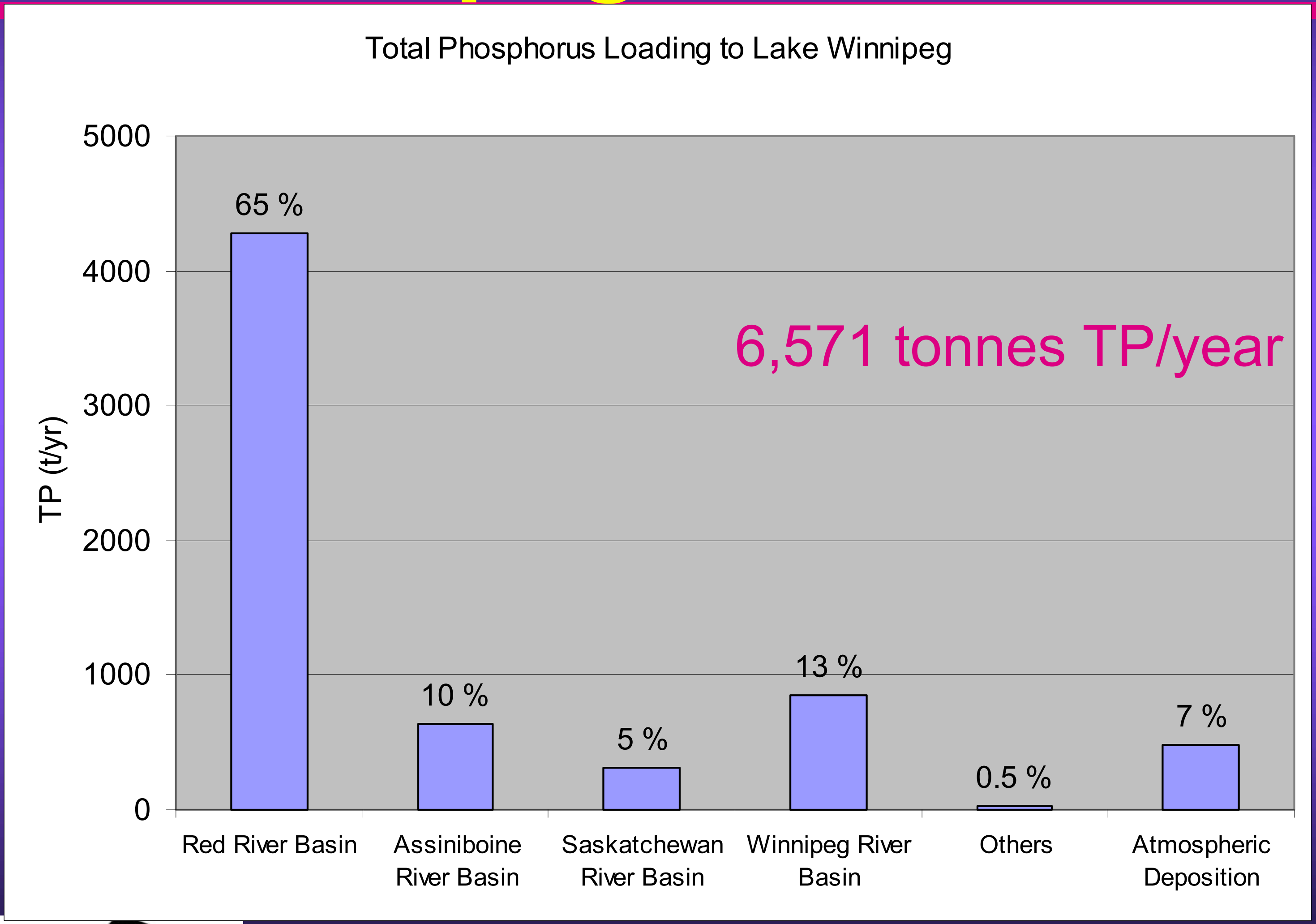
Phosphorus Loading to Lake Winnipeg



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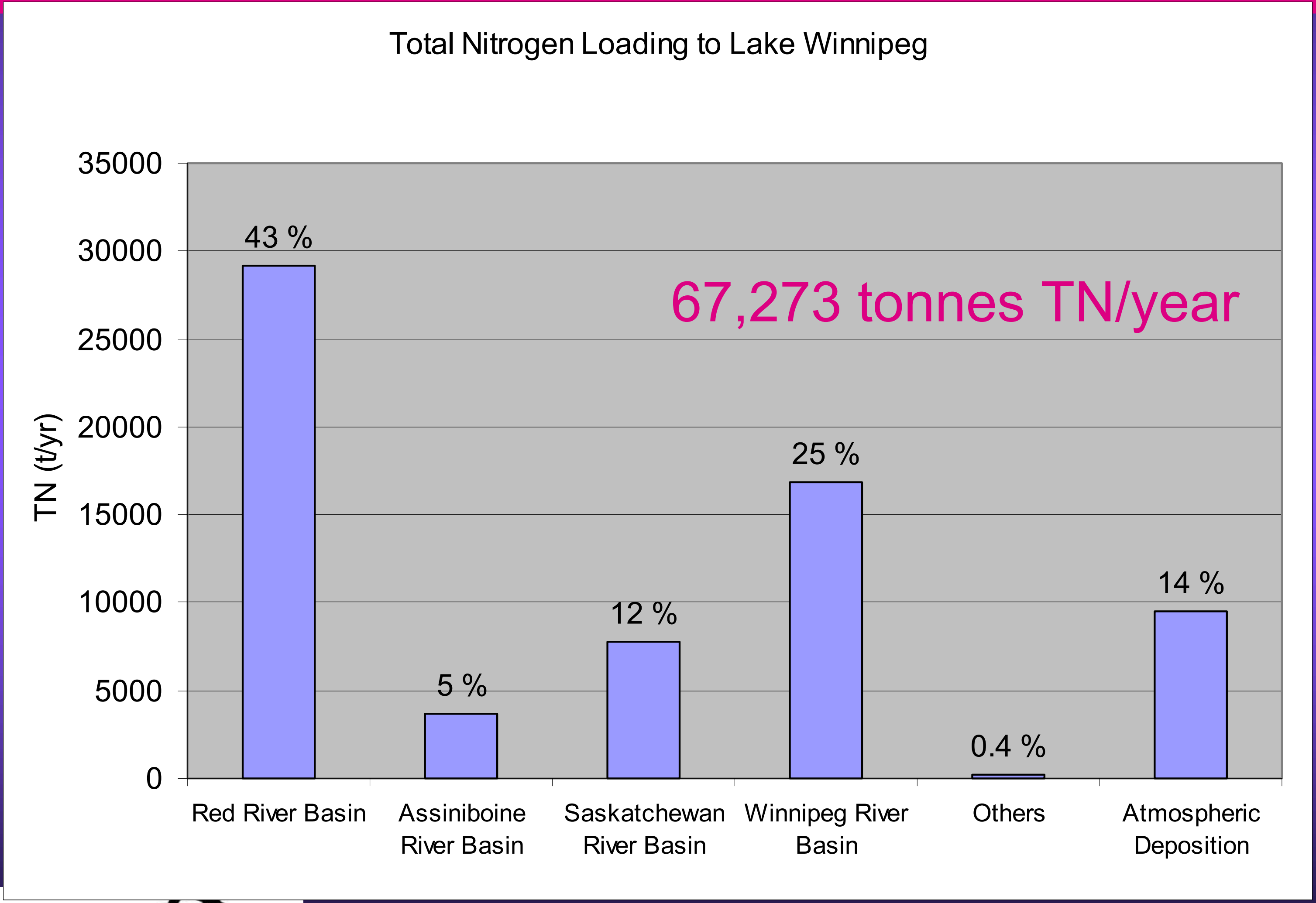
Nitrogen Loading to Lake Winnipeg



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Nitrogen and Phosphorus Loading to Lake Winnipeg

Category	%TN	% TP
Overall annual nutrient load to Lake Winnipeg	100	100
Upstream jurisdictions	67	59
United States (Red River)	28	39
United States (Souris River)	2	3
Saskatchewan and Alberta (Assiniboine and Saskatchewan rivers)	12	5
Ontario (Winnipeg River)	25	12
Manitoba Sources	33	41
Manitoba Point Sources	7	10
City of Winnipeg	5	6
All others	2	4
Manitoba Watershed Processes	11	24
Estimated natural background	8	9
Present day agriculture	3	14
Atmospheric Deposition	14	7

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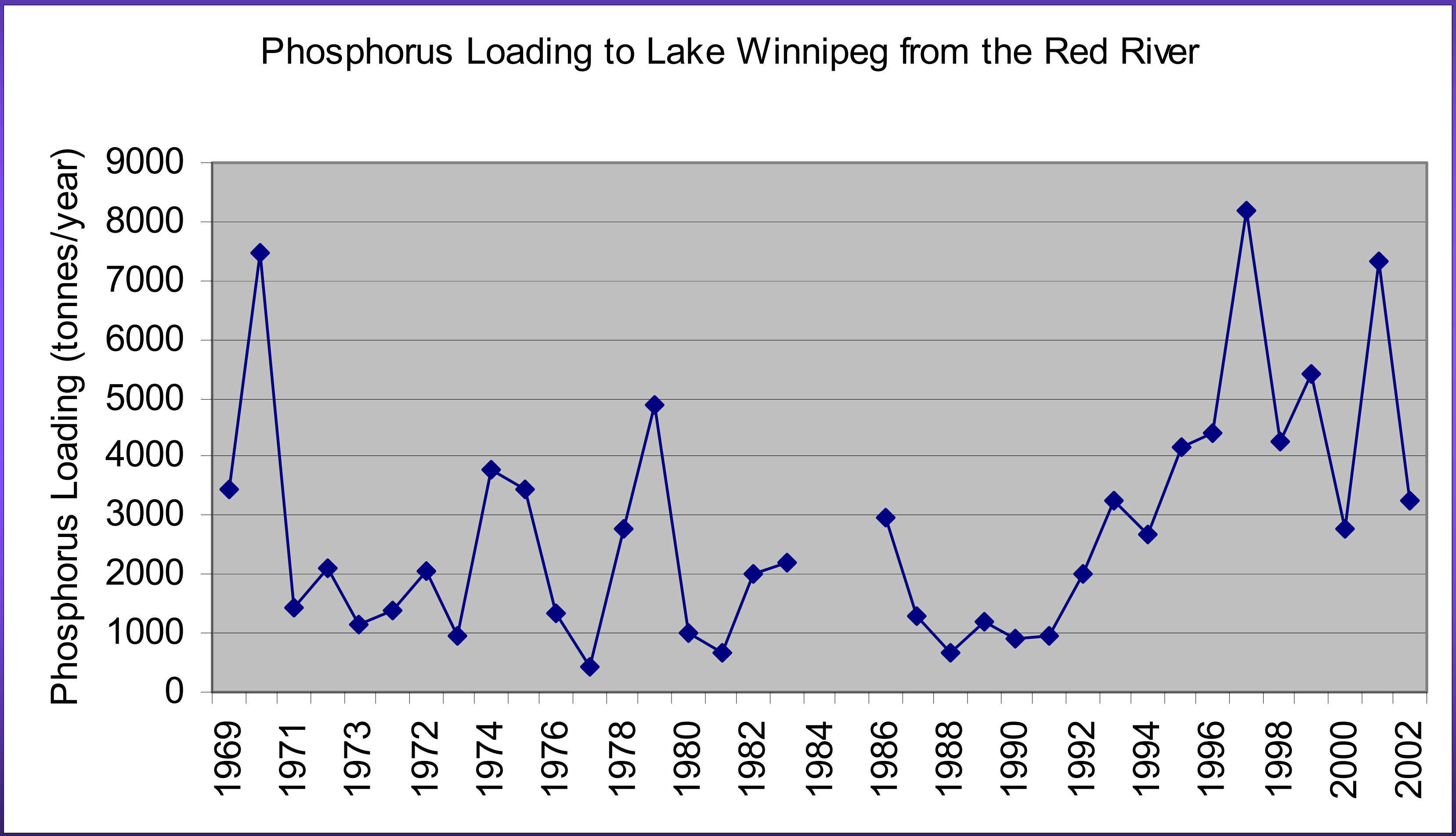
Phosphorus Loading to Lake Winnipeg from the Red River



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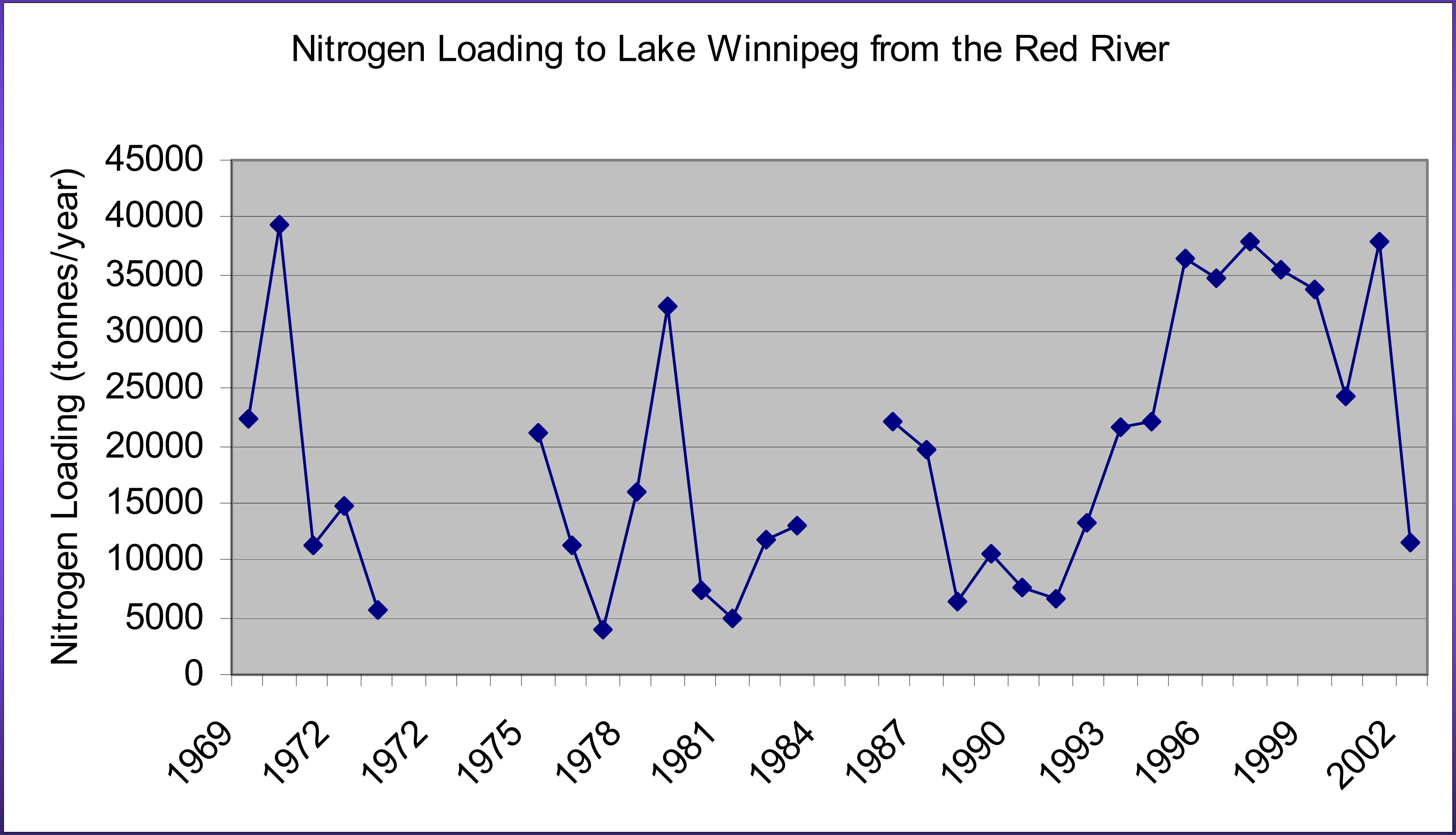
Nitrogen Loading to Lake Winnipeg from the Red River



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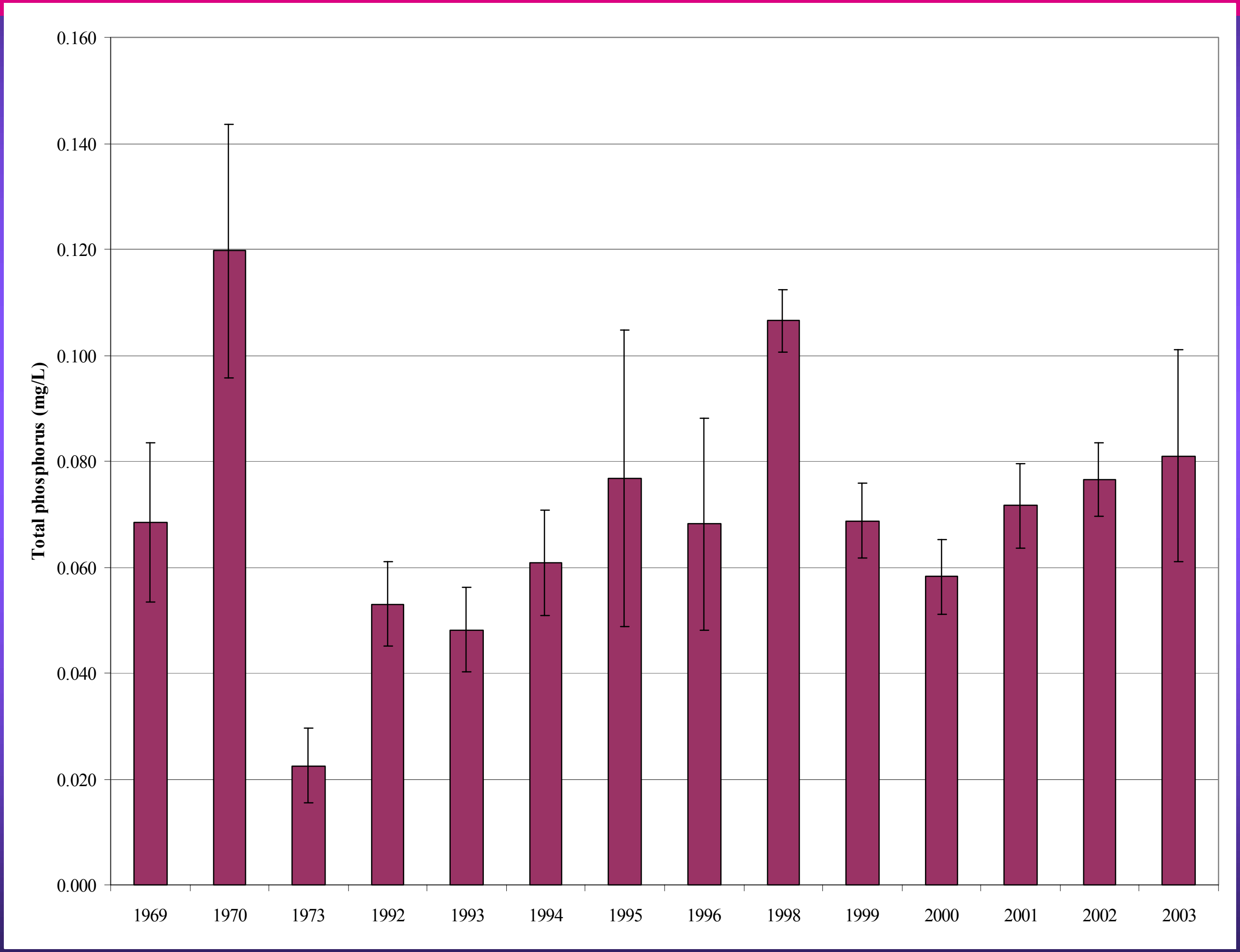
Phosphorus - Lake Winnipeg



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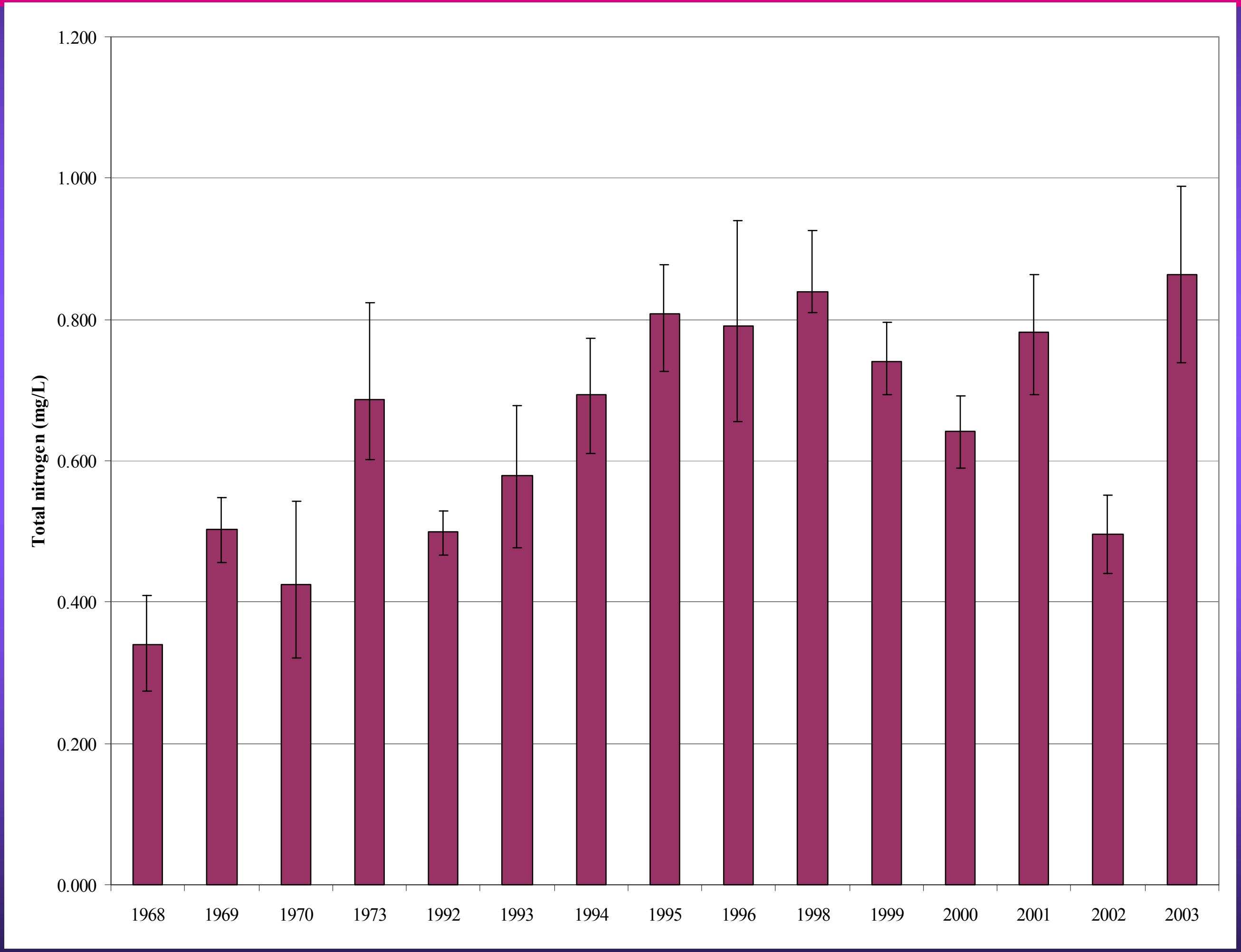
Nitrogen - Lake Winnipeg



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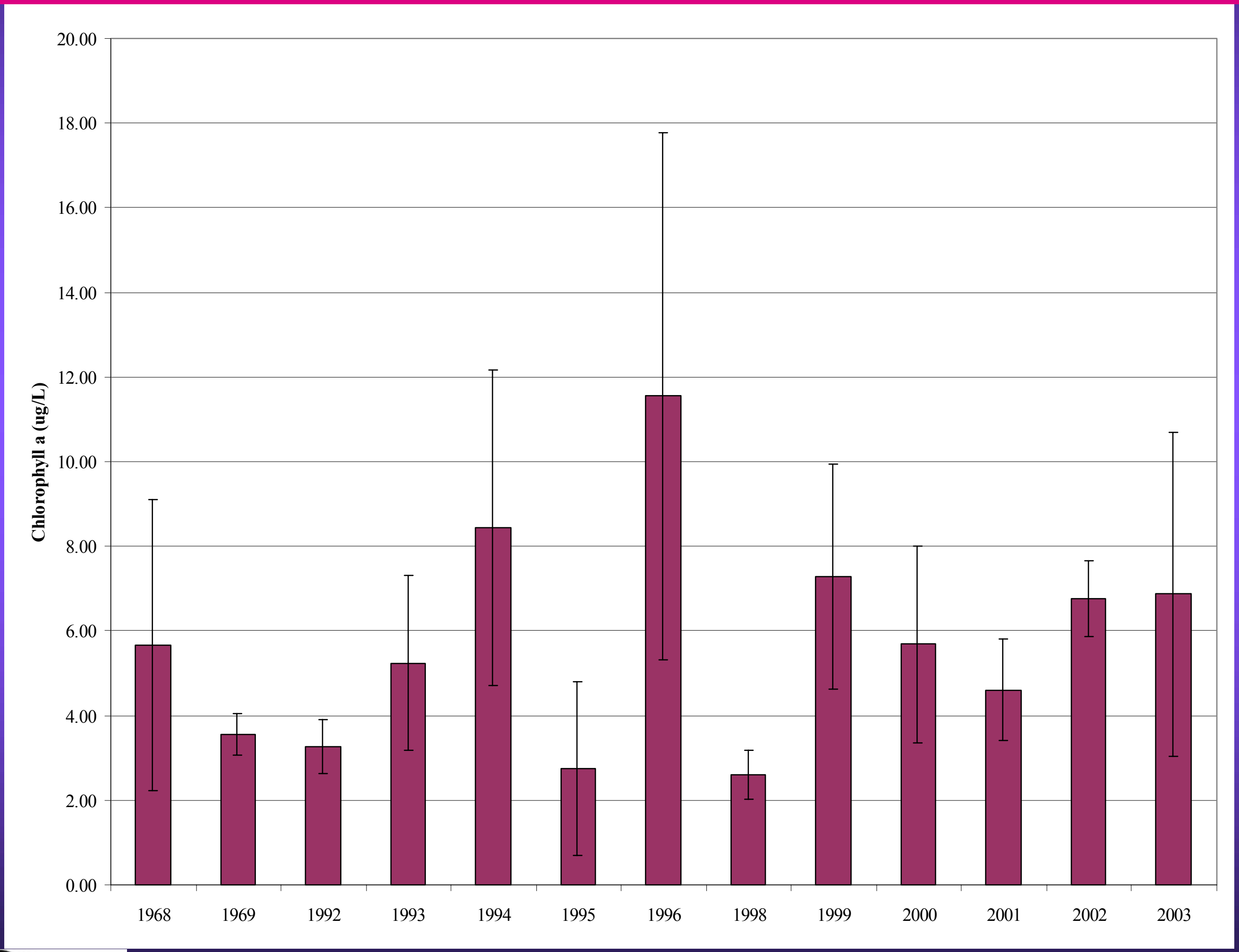
Chlorophyll a - Lake Winnipeg



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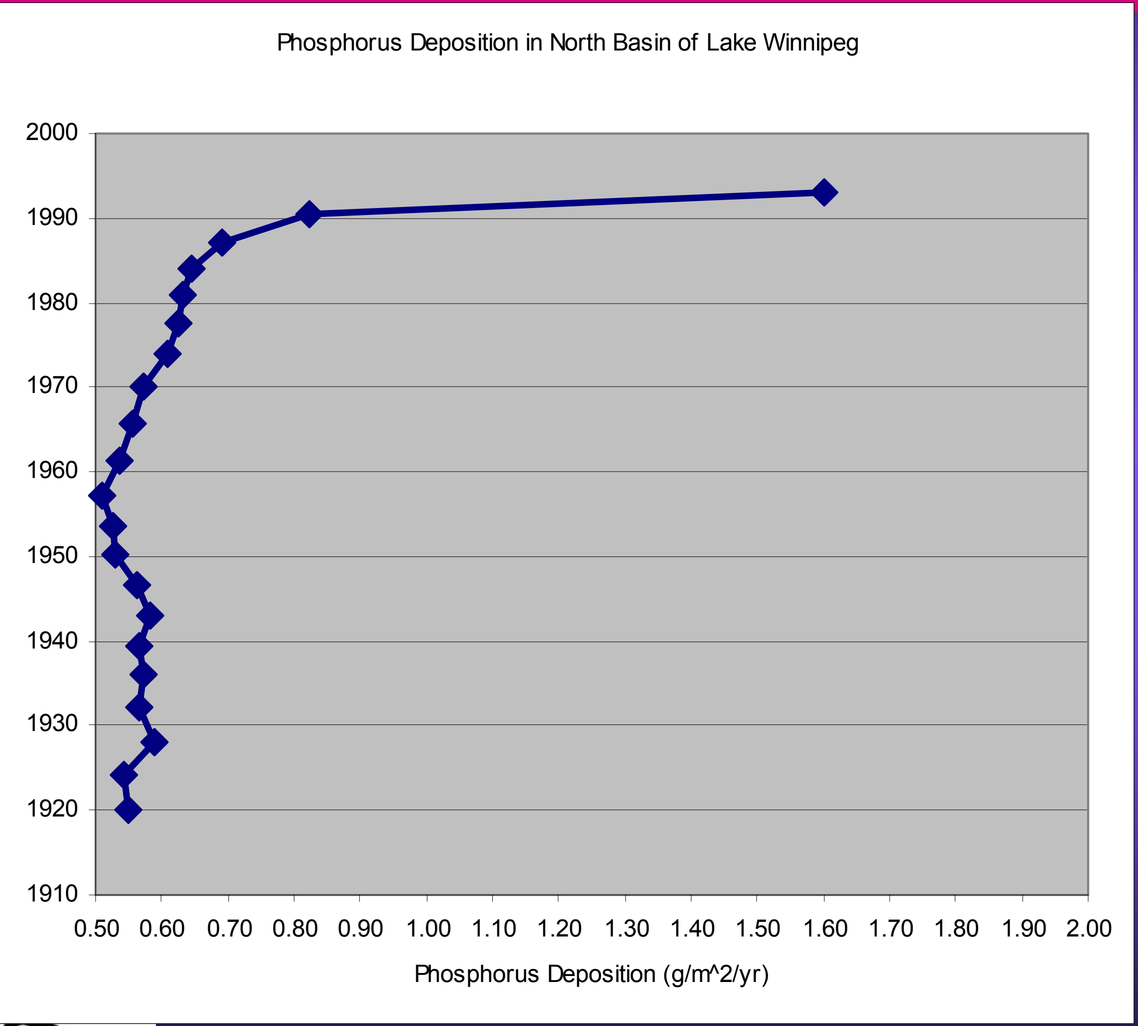
Phosphorus in North Basin Sediment Core



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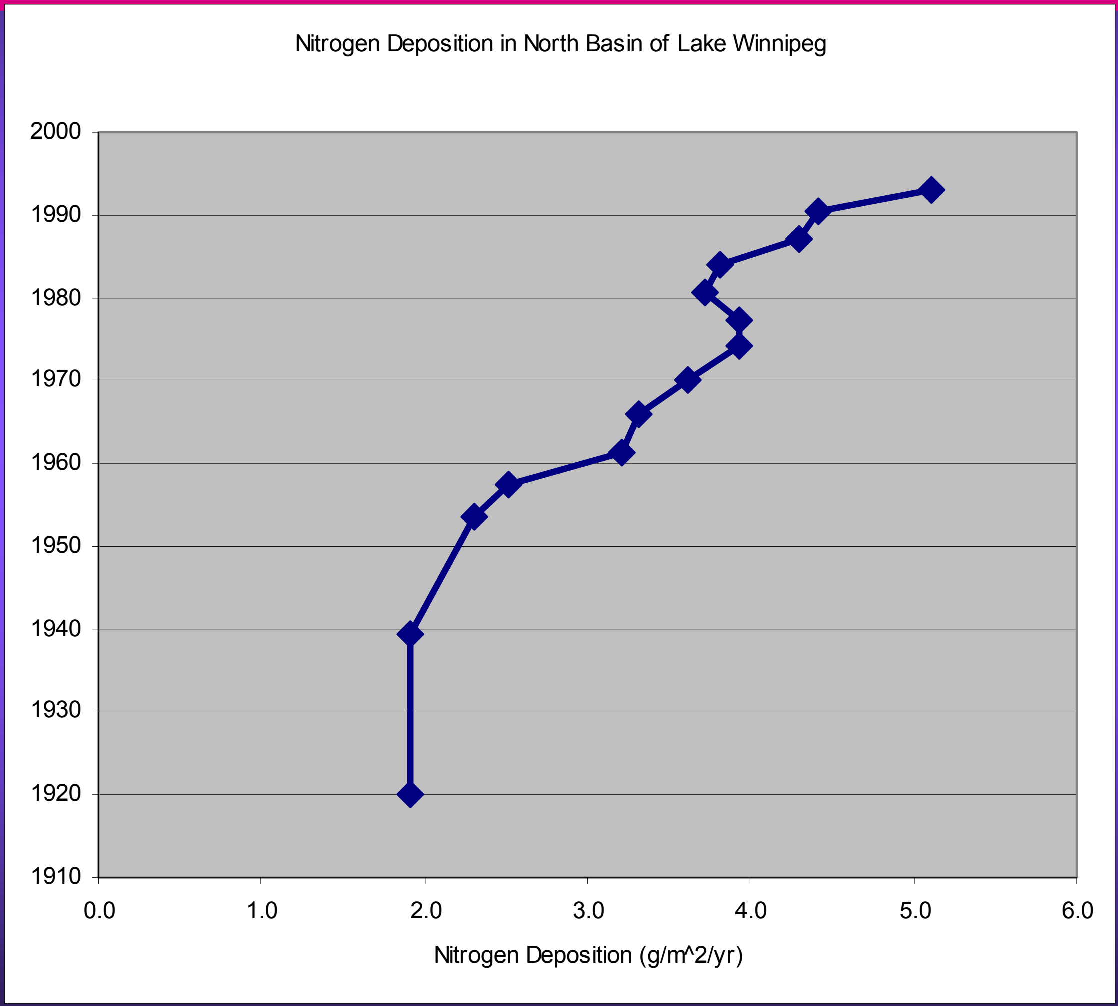
Nitrogen in North Basin Sediment Core



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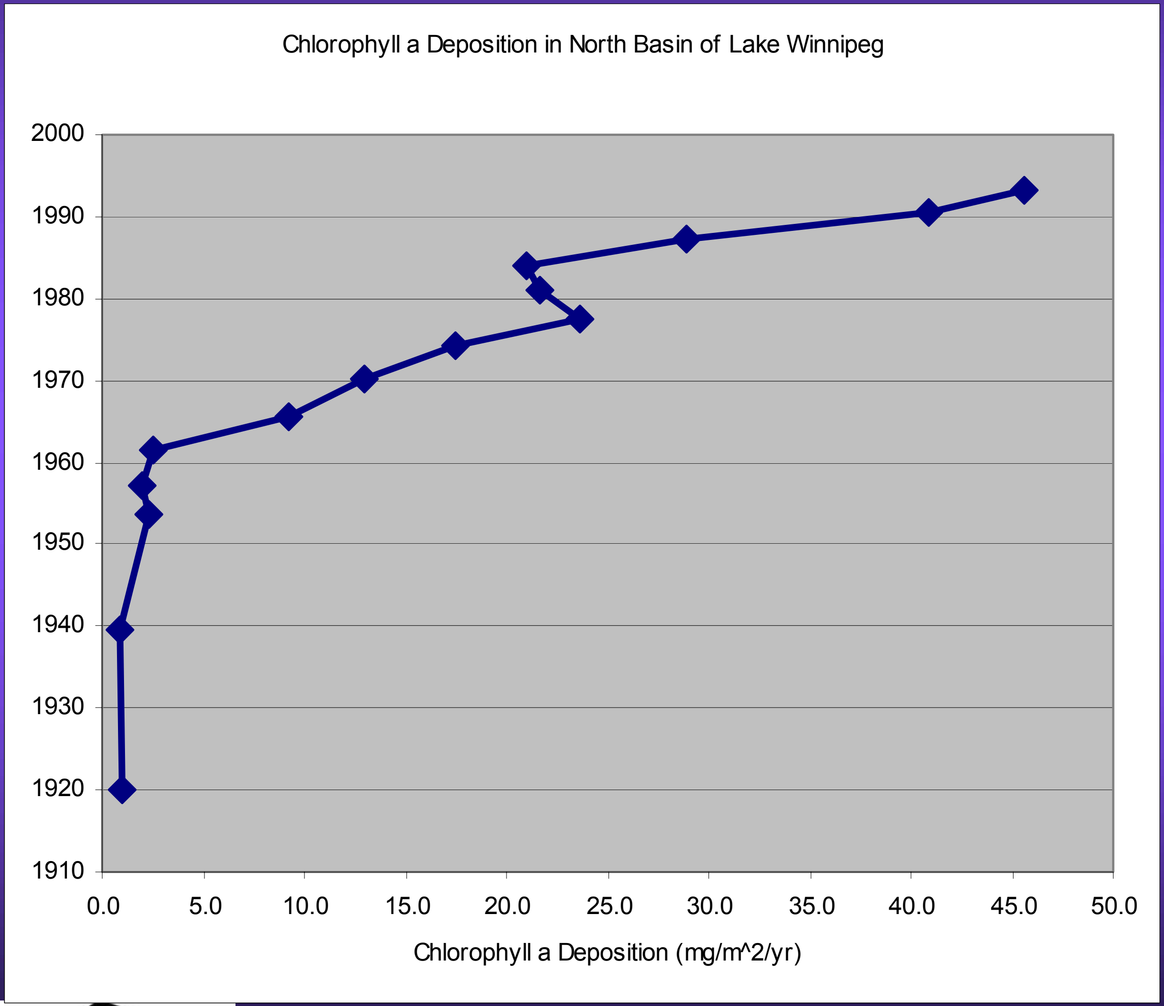
Chlorophyll *a* in North Basin Sediment Core



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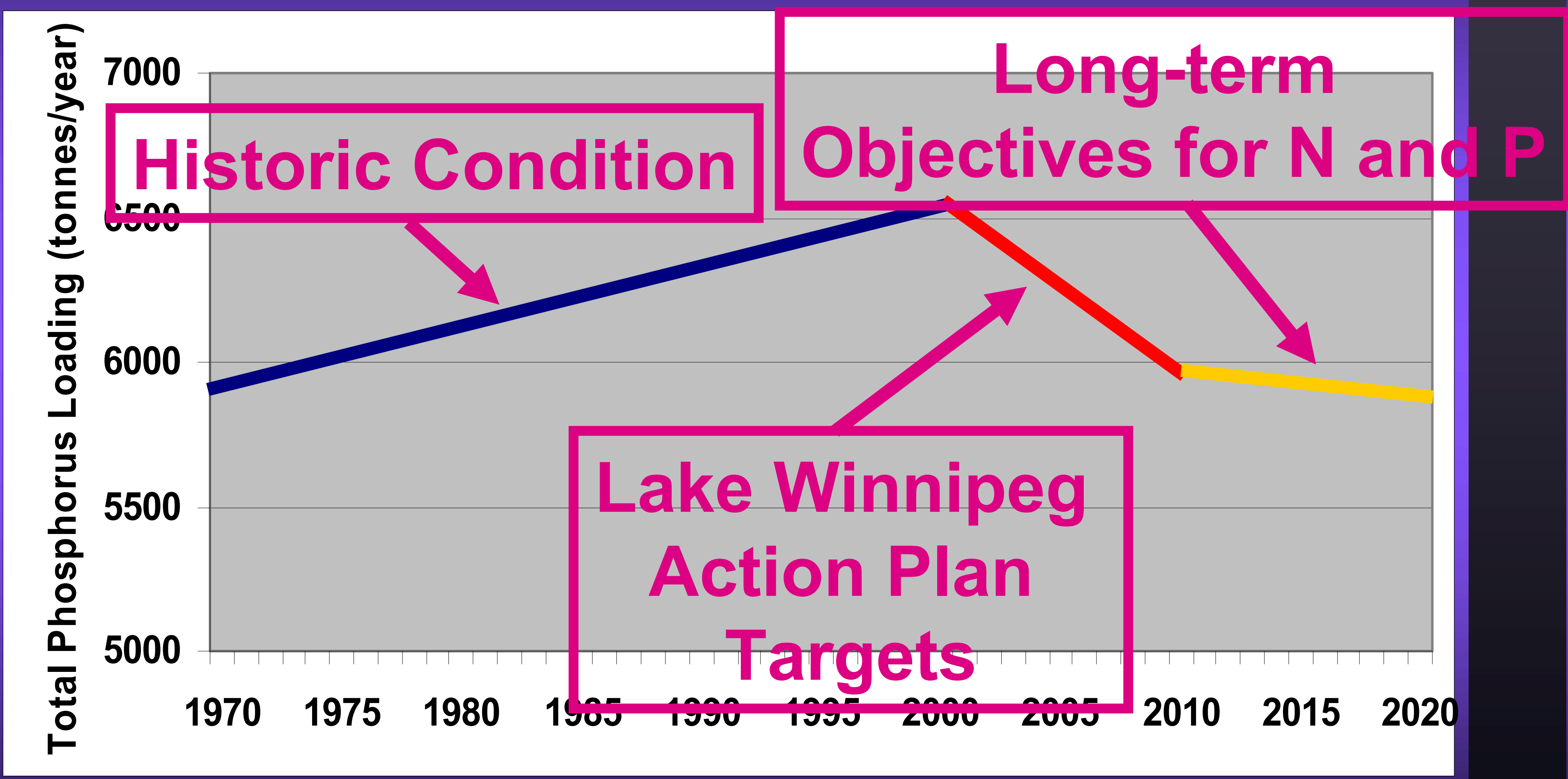
Future Condition: Lake Winnipeg Action Plan Targets



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Issue 2: Periodic Elevated Densities of *E. coli* at Bathing Beaches

- Human health implications
- Diminishes recreational enjoyment potential
- May reduce economic benefits to shoreline communities and to region

Principal Finding of Lake Winnipeg Studies in 2003 and 2004

- **Main reservoir of *E. coli* available for transfer to bathing water is located in the wet sand underlying foreshore beaches**

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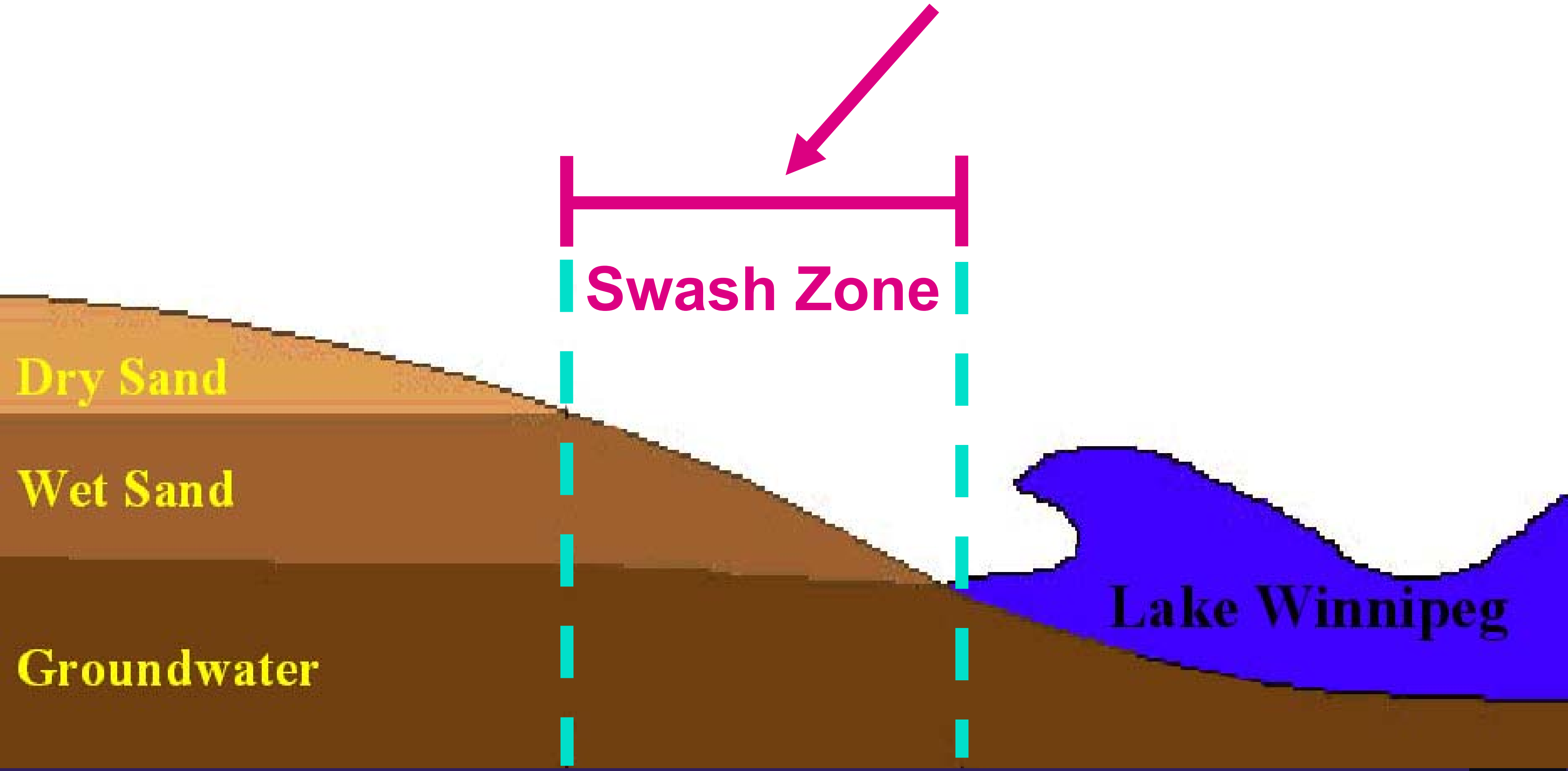
Typical Lake Winnipeg Beach Profile



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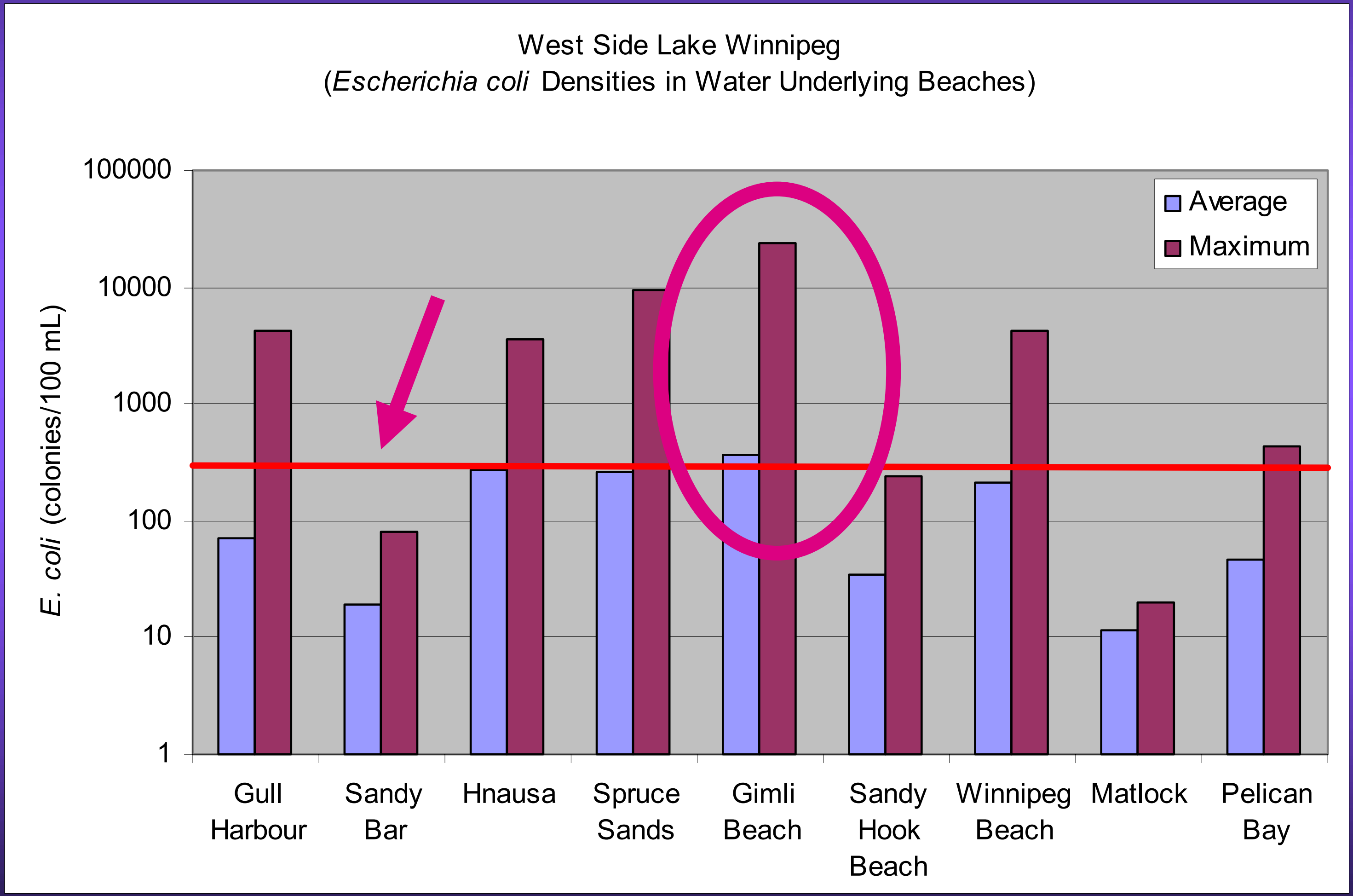
E. coli Underlying West Side Beaches



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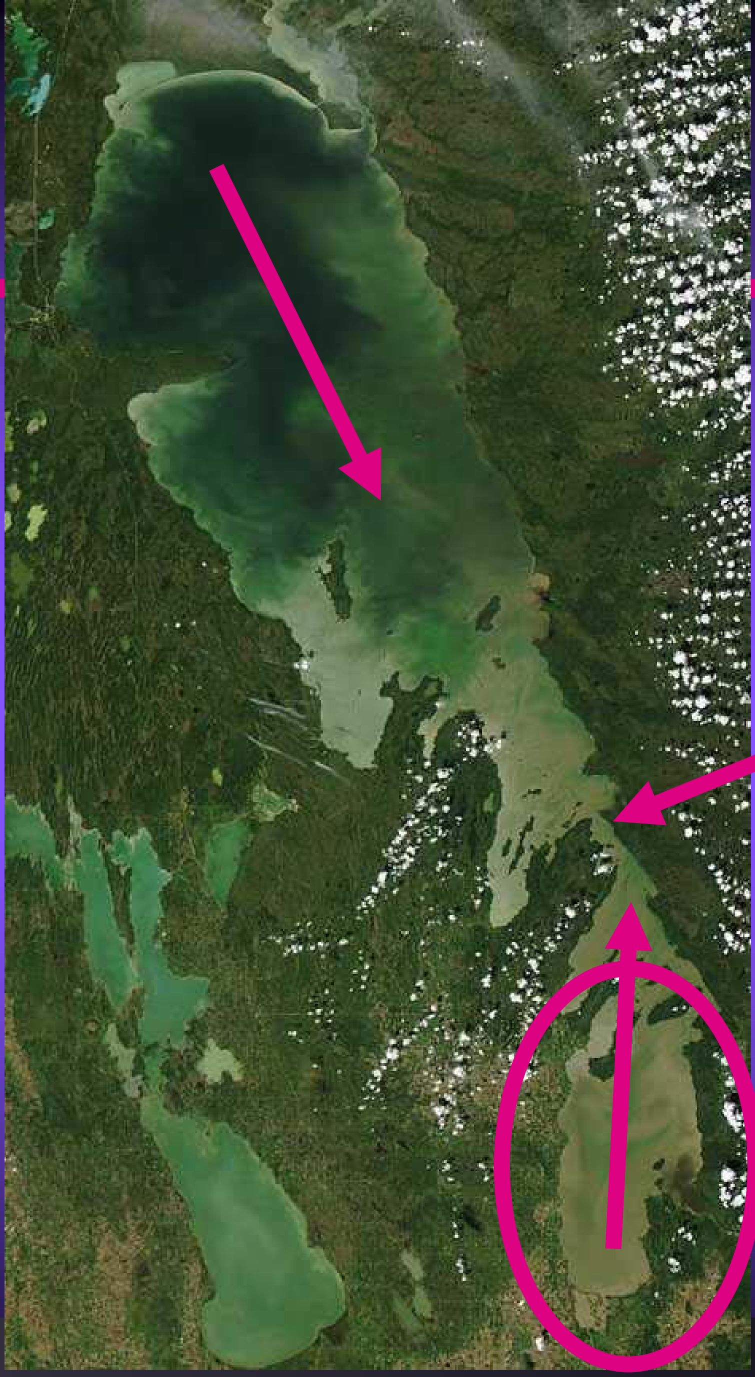
Satellite Image of Lake Winnipeg



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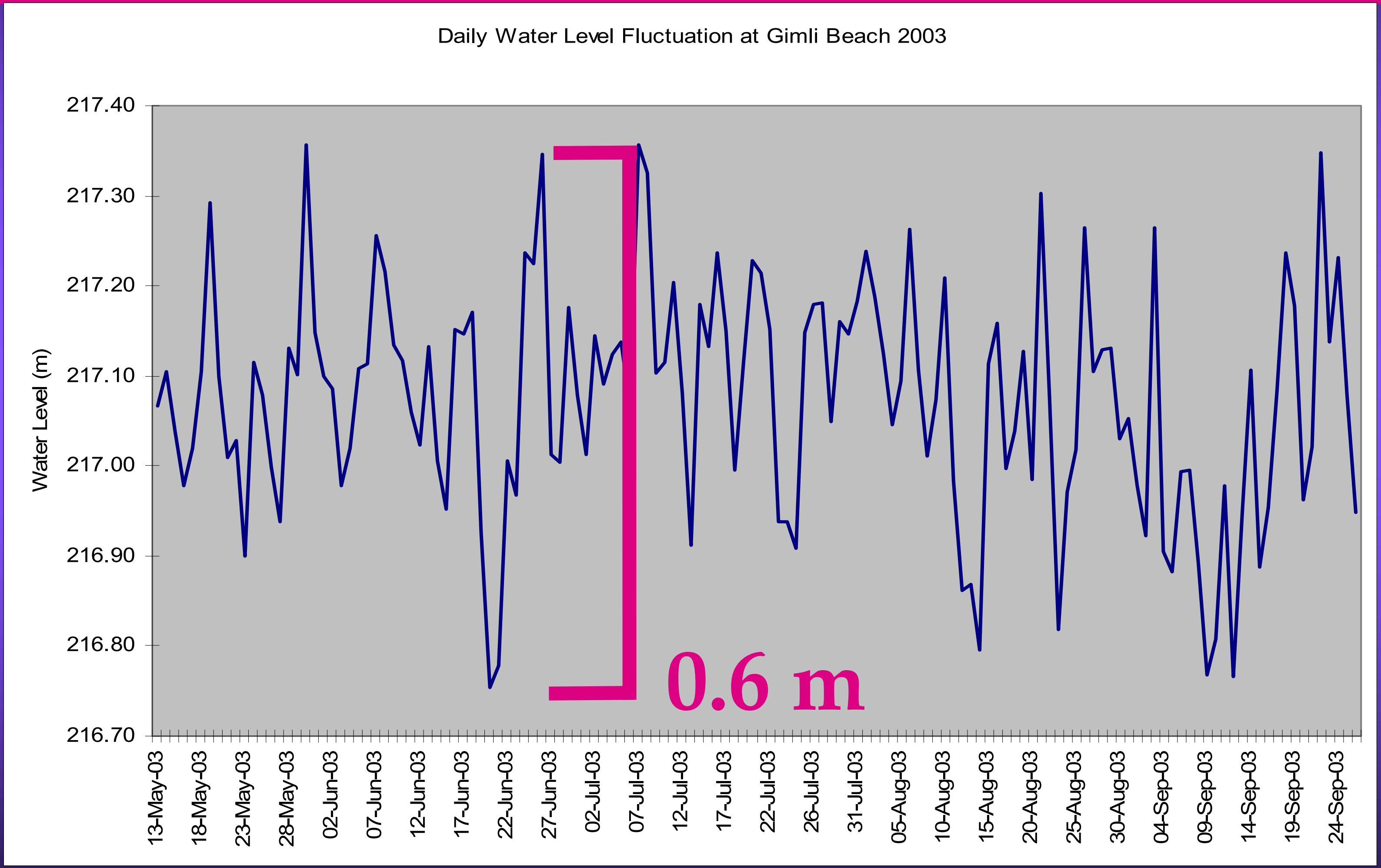
Daily Water Level Changes at Gimli



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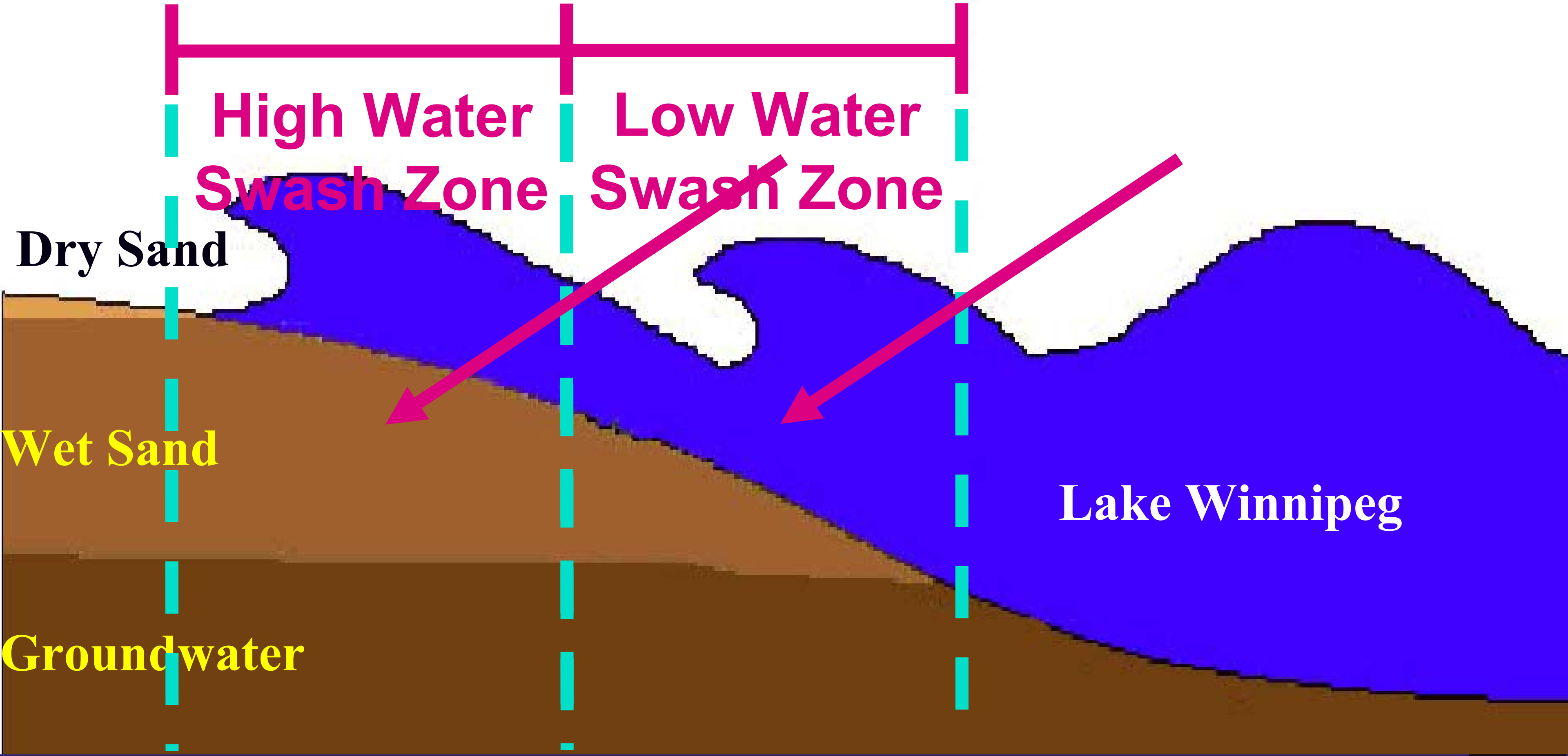
High and Low Water Swash Zones



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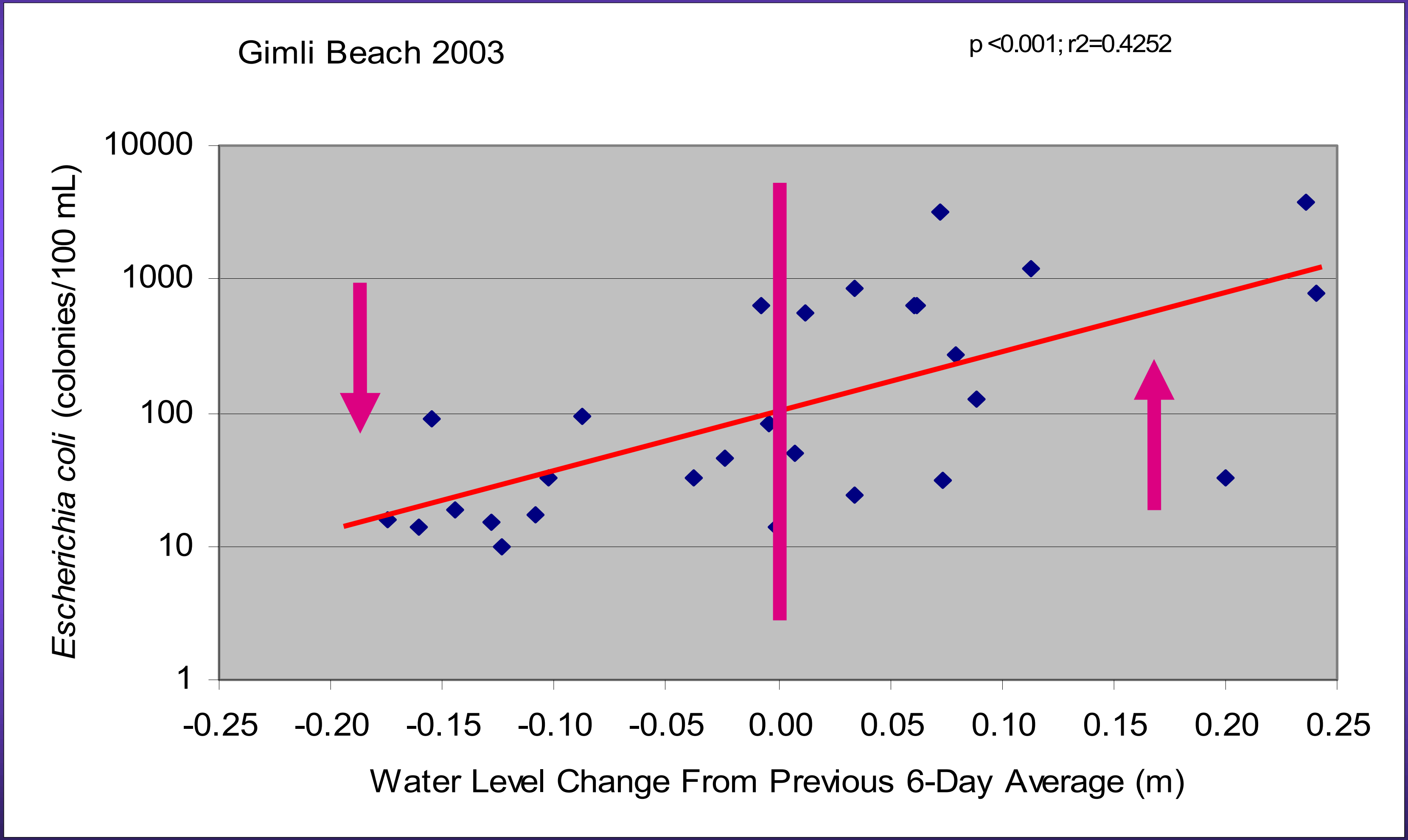
Relationship between *E. coli* and Lake Level Changes at Gimli



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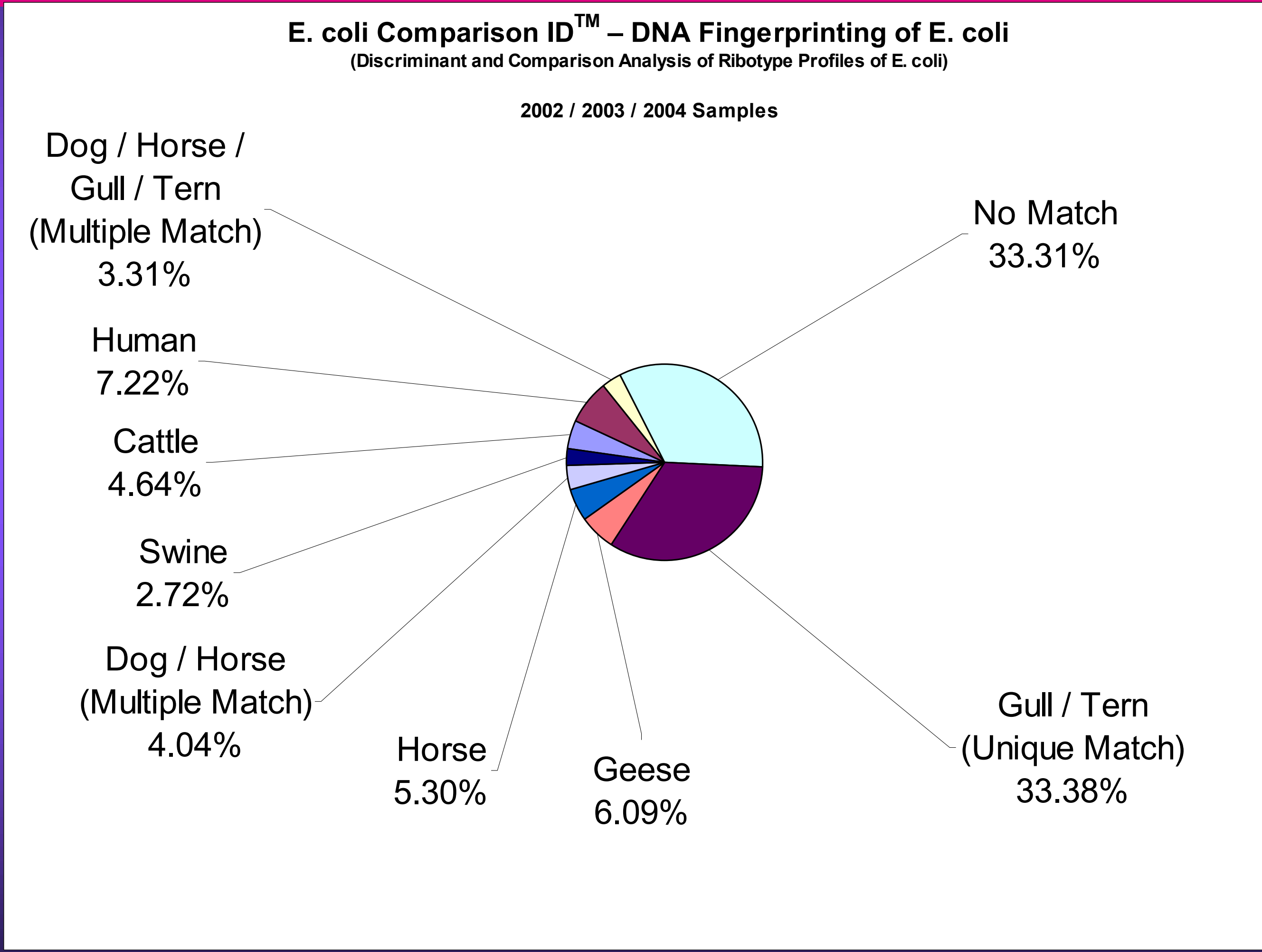
Sources of *E. coli* (2002, 2003, 2004)



Issue 3: Toxaphene, Exotic Species, Climate Change, Stream Flow Reductions, Etc.

- Human health implications
- Unpredictable change in community structure and function
- Related impacts on water quality from changes in quality of inflowing streams and changes in lake residence times
- Etc.

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Management Needs

Issue 1

- Nuisance, harmful, and toxic blooms of algae

Cause 1

- Nutrient enrichment

Remedy 1

- Reduce nutrient contributions

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Management Needs (continued)

Management Needs 1

- Development of long-term water quality objectives for nitrogen and phosphorus based upon ecologically-sensitive end-points
  - resolution of controversy surrounding N and P targets identified in the Lake Winnipeg Action Plan
- Water quality model to assist in implementing water quality objectives
- Better understanding of interactions within the watershed at interface between soil – water

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Management Needs (continued)

Issue 2

- Periodic elevated densities of *Escherichia coli* at bathing beaches

Cause 2

- Contributions of bacteria to foreshore sand by birds, animals, and humans

Remedy 2

- Beach management, predictive model, relevant epidemiological studies

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Management Needs (continued)

Management Needs 2

- Development of predictive model to link meteorological factors with water level increases
- Determination of whether *E. coli* are replicating in foreshore sand
- Relevant epidemiological information - do health risks to bathers differ depending upon human versus animal sources of *E. coli?*

Management Needs (continued)

Issue 3

- Miscellaneous issues such as transportation of toxaphene in flood waters, introduction of exotic species, climate change, reductions in stream flow, etc.

Cause 3

- Various

Remedy 3

- Proactive prevention strategies
- Improved understanding

Management Needs (continued)

Management Needs 3

- Various

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Closing Observations

- Most important issue facing Lake Winnipeg is nutrient enrichment
- Nutrient enrichment virtually unrelated to the issue of *E. coli* at beaches
- Management actions implemented to reduce nutrient contributions will increase the resilience of Lake Winnipeg and its watershed to better withstand and to minimize impacts from future threats such as invasive species, climate change, water flow reductions, etc.

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Thank You

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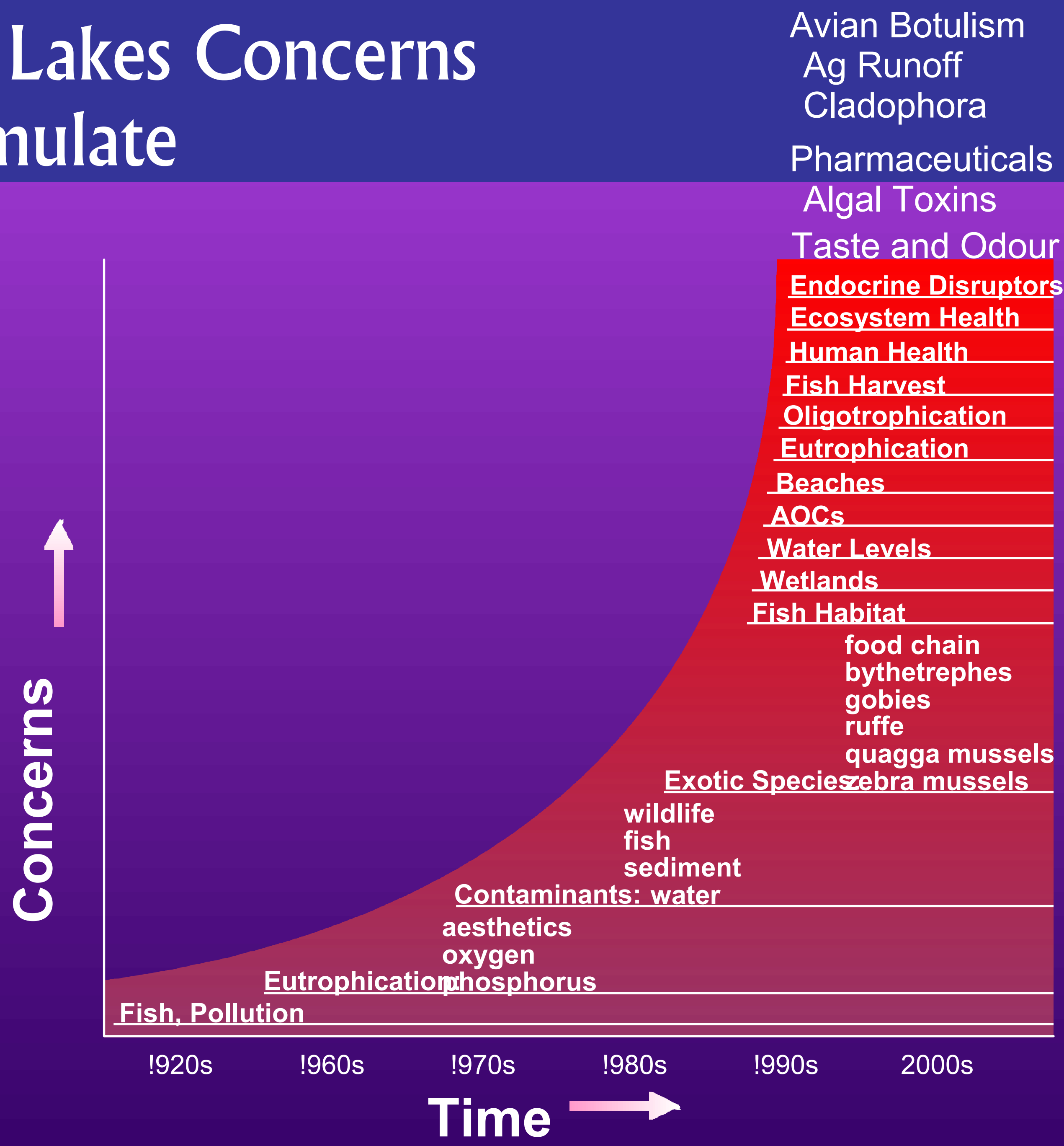
Lake Erie Management and the Lake Winnipeg Situation

Murray Charlton
National Water Research Institute
Environment Canada
Burlington, Ontario
Nov 29, 2004

Great Lakes Concerns Accumulate



Lake Erie Problems

- Fishing,
- Eutrophication, too much phosphorus, Lake Erie is dead!
  - Water Quality, Green water, Dissolved Oxygen, Shoreline Algae
  - Beach closures
- Toxic Chemicals

Lake Erie Problems

- Alien Species,
- EDCs
- Fishing, not enough phosphorus ? 1995
- Shoreline algae,
- Toxic Algae, 1994 Microcystis bloom
- Botulism - fish and bird kills
- Phosphorus increasing?

Why Phosphorus?

- Phosphorus is in short supply in many soils.
- Adding phosphorus usually increases algal growth.
- Some plants and algae can fix nitrogen from the atmosphere.
- Phosphorus seems easier to control

Canada/U.S. Great Lakes Water Quality Agreement 1972

- Decrease phosphorus loads by about %50
- Decrease algal problems
- Year - round aerobic conditions in Central Basin Hypolimnion
- Later versions called for Remedial Action Plans and restoration of "Ecosystem Integrity"

GLWQA Decisions

- Few studies on hand
- Burgeoning public concern
  - Detergent foam, Silent Spring
- Pivotal binational study of 1970
- International literature pointed to phosphorus.
- Demonstration at ELA of lake fertilization

Phosphorus Control Tactics

- 25% of load to the lake was from detergents – ban phosphorus from detergents
- Large portion of load was Municipal sewage:
- Control sewage to 1 mgP/L for all the largest sewage plants – technological based target would reduce load by half.
- Control non-point sources

GLWQA Success

- Phosphorus load reduced by 50% in Lake Erie and Lake Ontario.
- Phosphorus concentrations decreased by 50% in west Erie and Lake Ontario.
- The majority of the improvement was caused by better sewage treatment.
- Non-point sources hardly changed

Phosphorus Concentration matters

There is a lot of phosphorus in the ocean in terms of number of tonnes

- BUT
- The phosphorus is at a low concentration – hardly anything can live in abundance
- Plants and algae need a minimum concentration to be abundant.

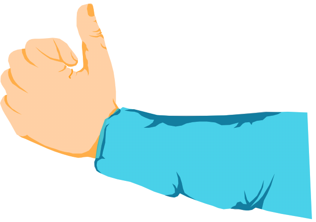
Phosphorus Concentrations Matter

- Rivers may have, say 0.02 milligram per litre. So, no matter how much flow there is, the lake will not be higher than 0.02.
- Sewage can have 1.0 milligram per litre.
- Sewage phosphorus is mostly available to grow algae whereas river phosphorus may be largely attached to eroded soils.
- Shallow lakes recycle phosphorus better.

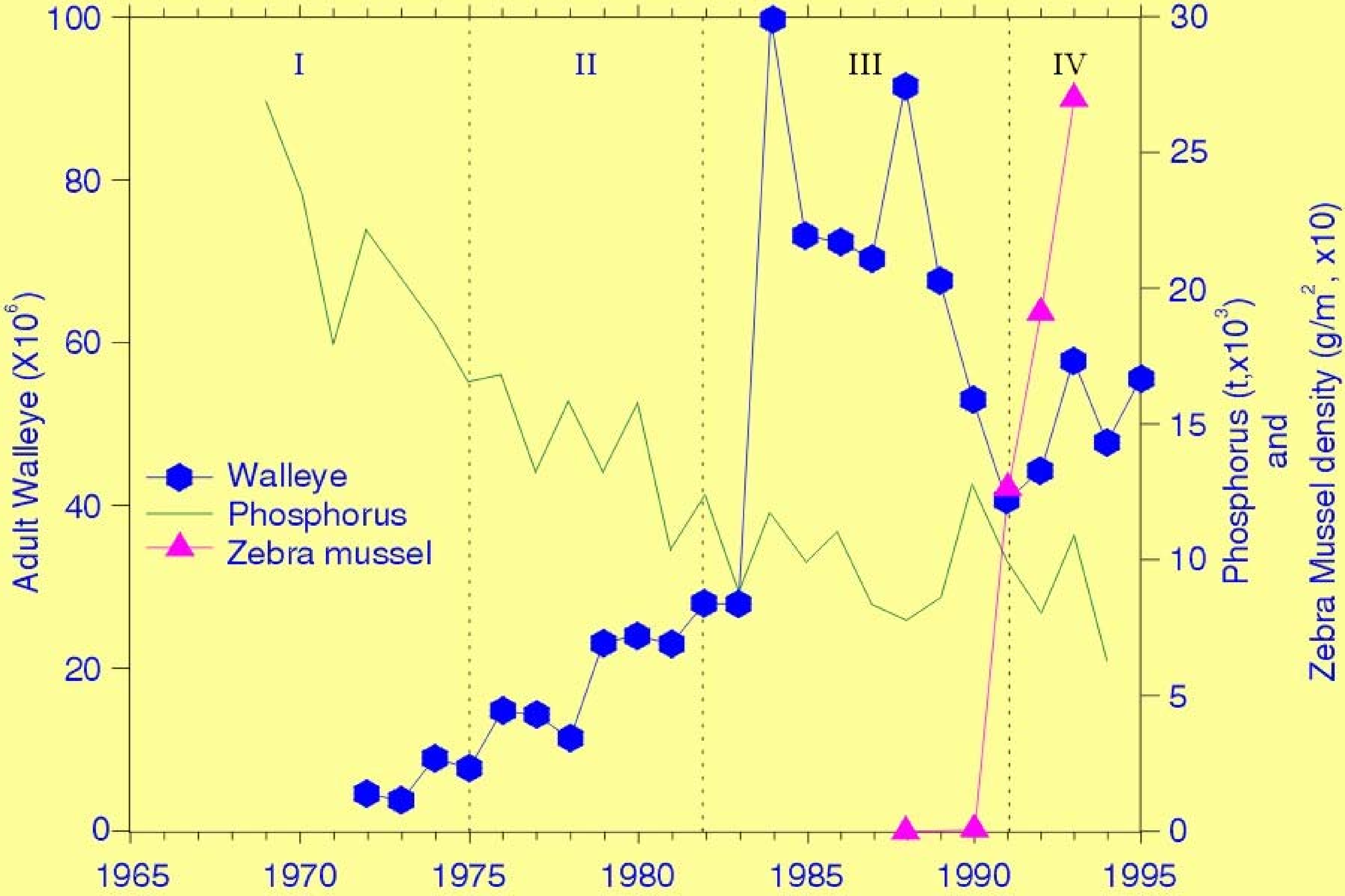
Non-Point Sources

- Soils contain phosphorus – some may be an unavailable mineral – rivers erode soil so there is a load that may grow little algae. Previously this was a large part of non-point.
- Agricultural fertilizers and feedlot waste will grow algae well.

Summary: GLWQA

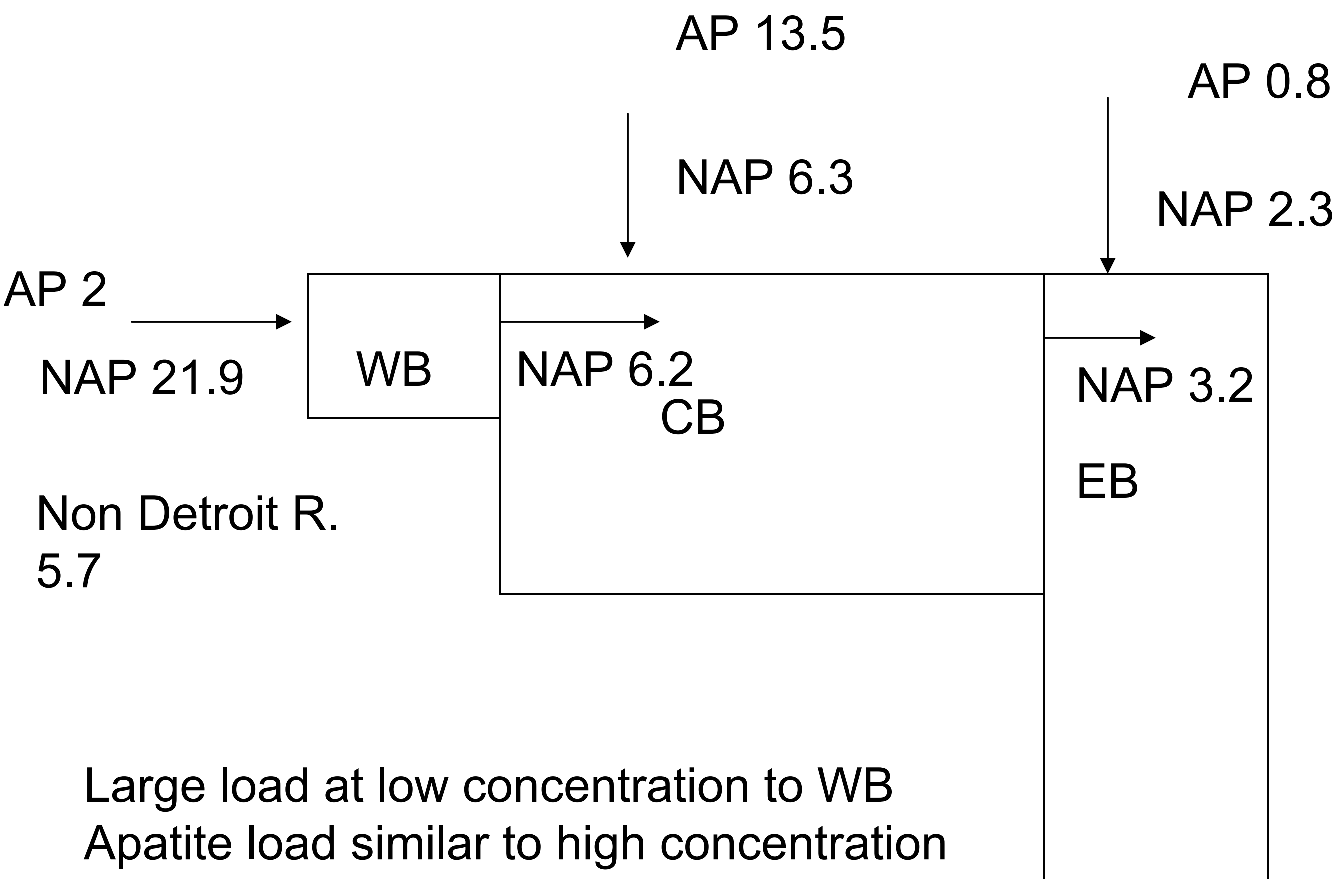


- Phosphorus controls worked as expected on P concentrations and algae - big effect in west basin and less effect elsewhere - as forecast by Noel Burns.
- Oxygen responding slowly if at all - low concentrations still occurring.



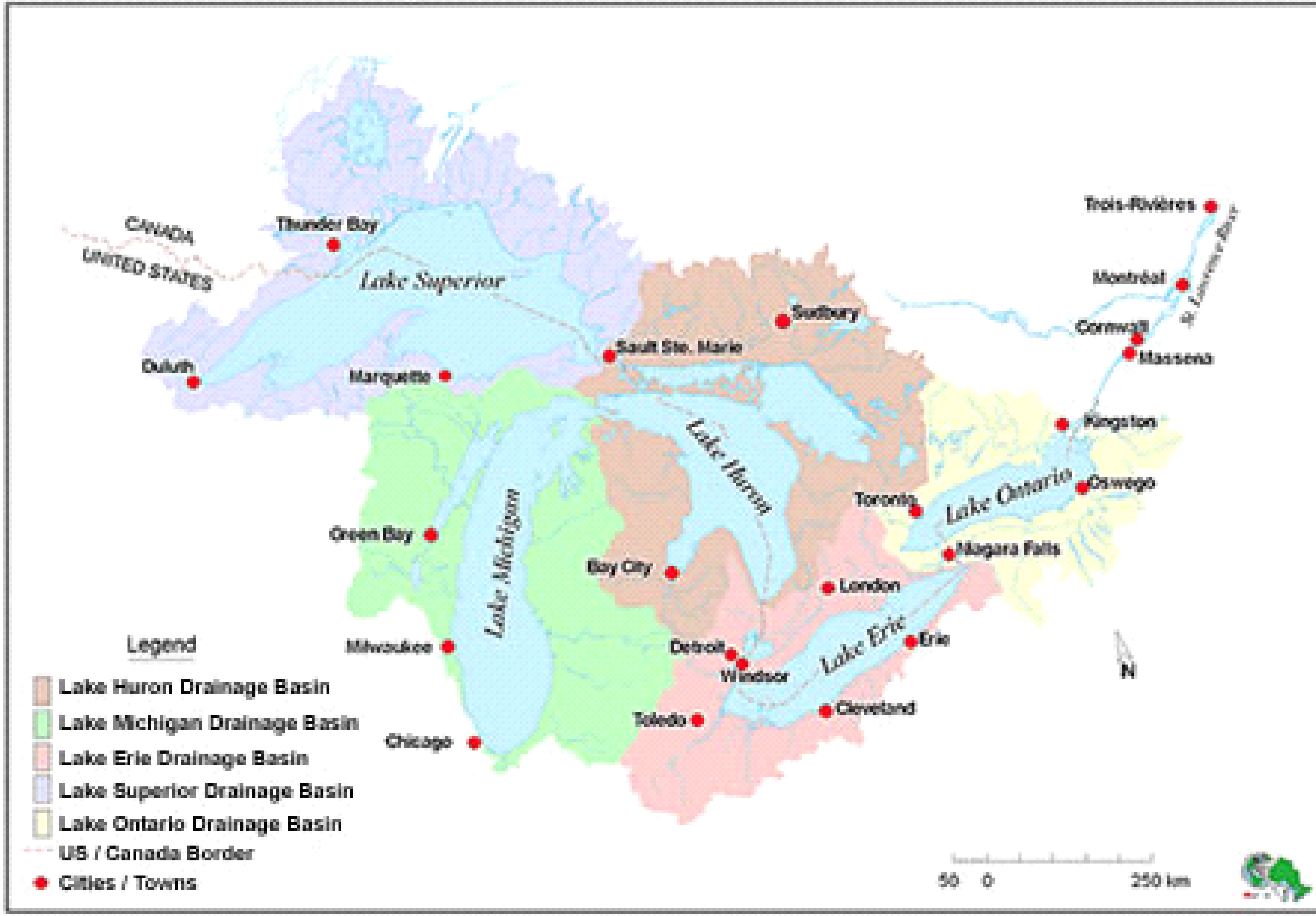
Can. J. Fish. Aquat. Sci. *55*: *Gopalan et. Al.*

Lake Erie Apatite and Non-Apatite loads in 1970

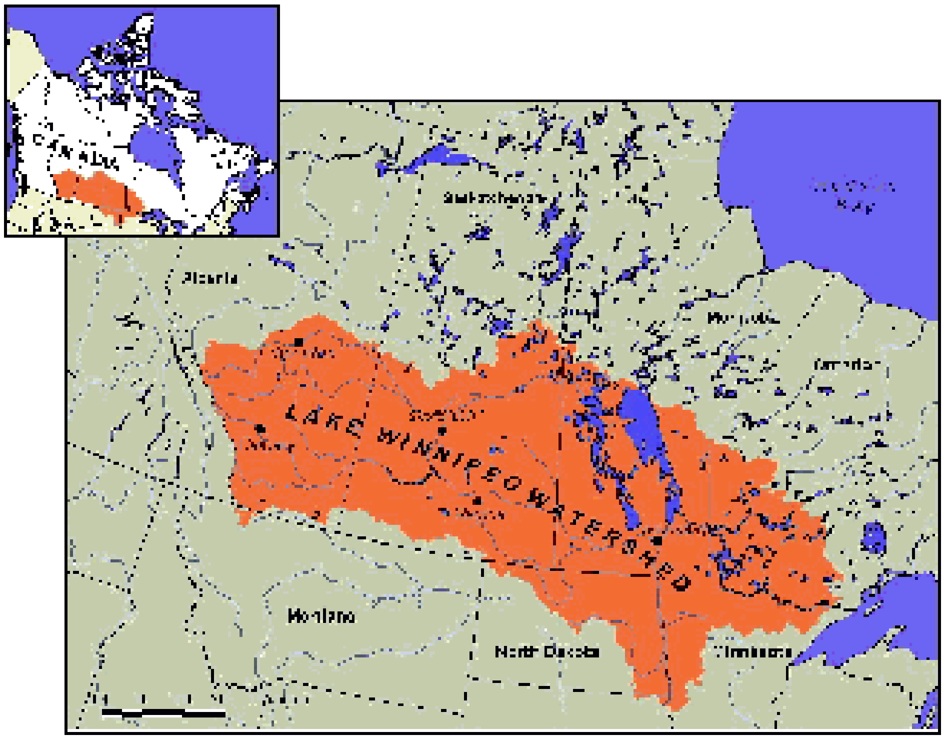


Large load at low concentration to WB
Apatite load similar to high concentration NAP loads.

Great Lakes Drainage Basin - St. Lawrence River



Lake Winnipeg Drainage Basin



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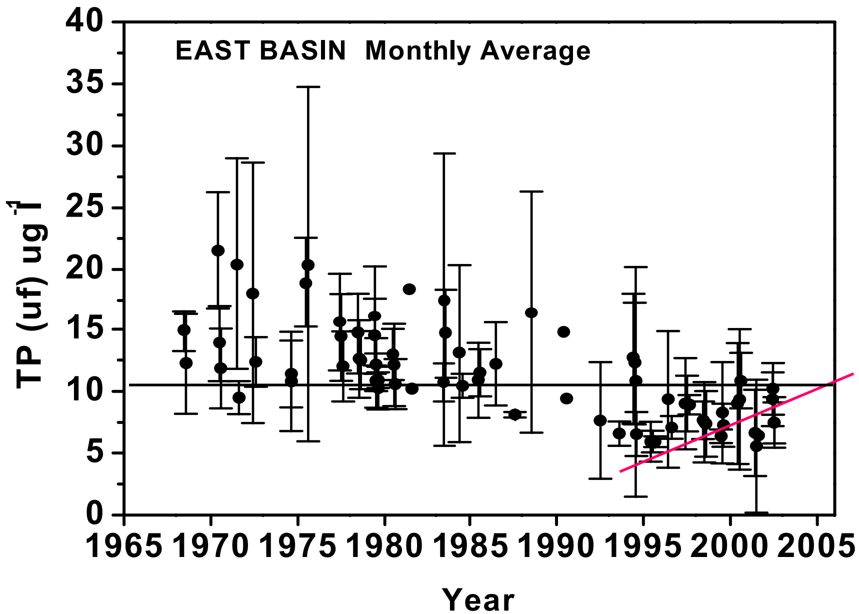
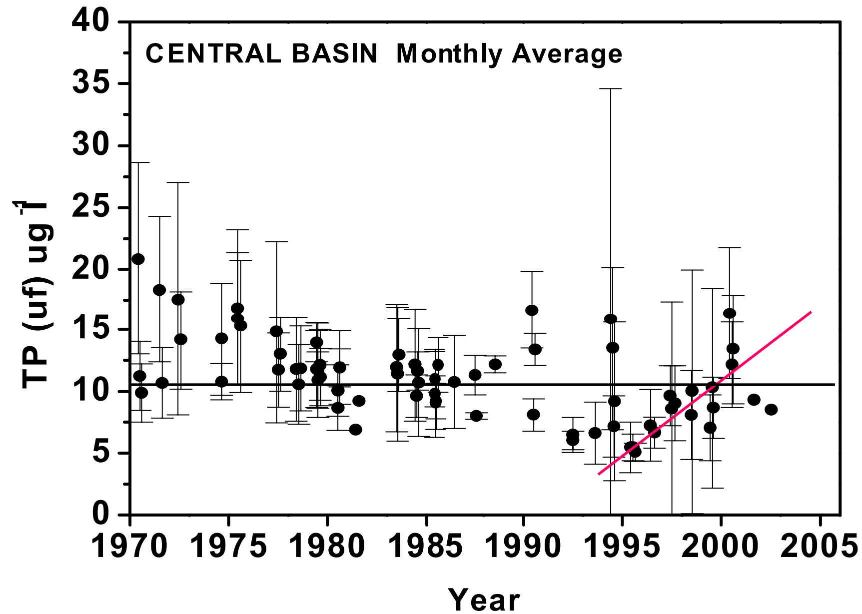
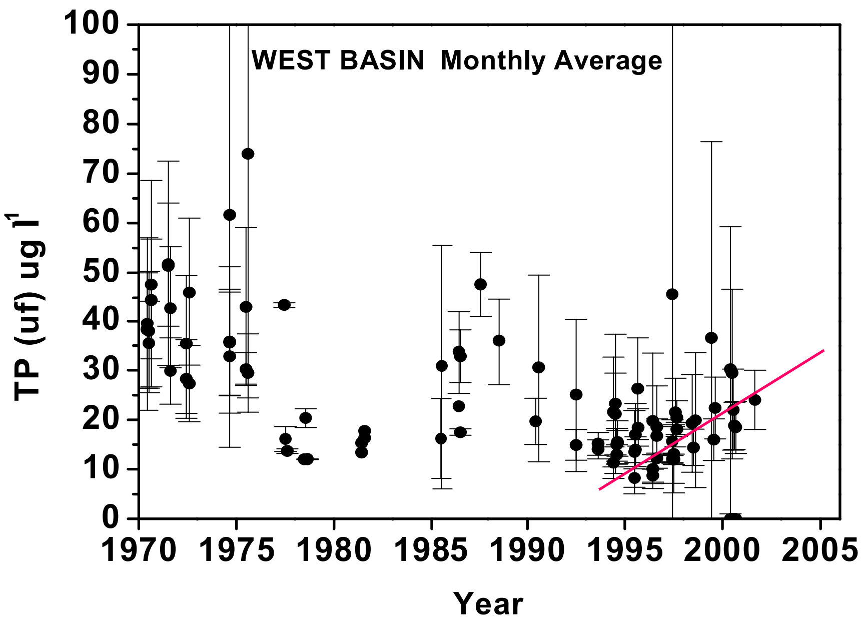
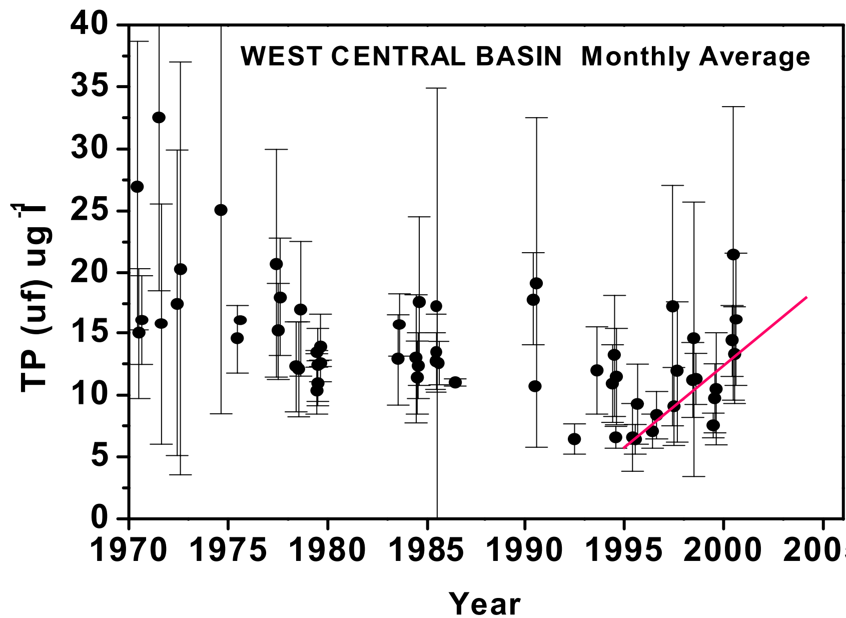


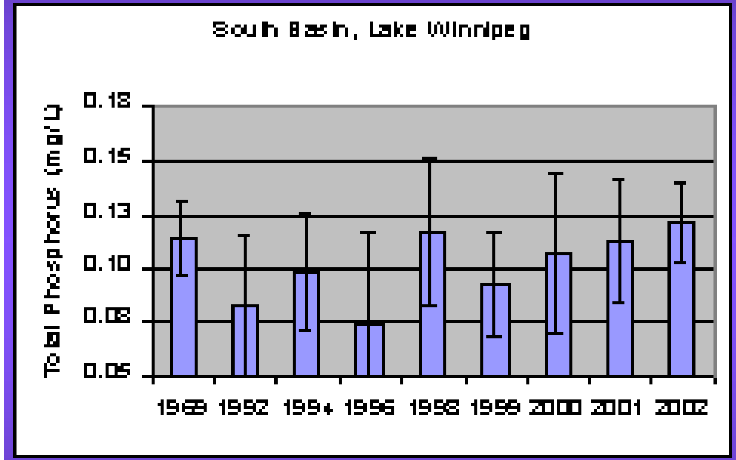


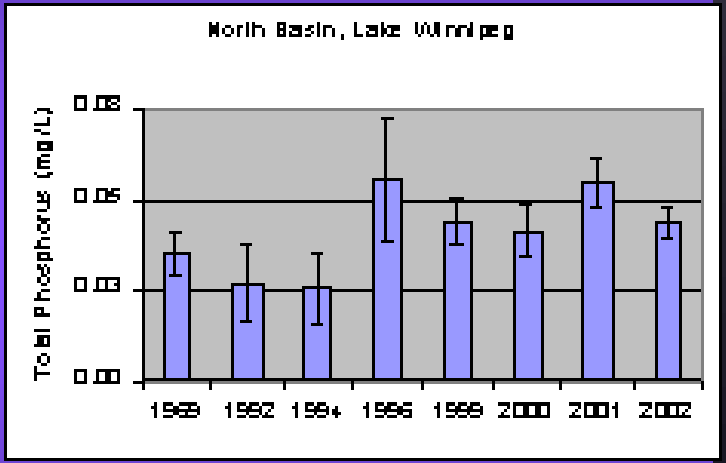
Total Phosphorus





Phosphorus - Lake Winnipeg





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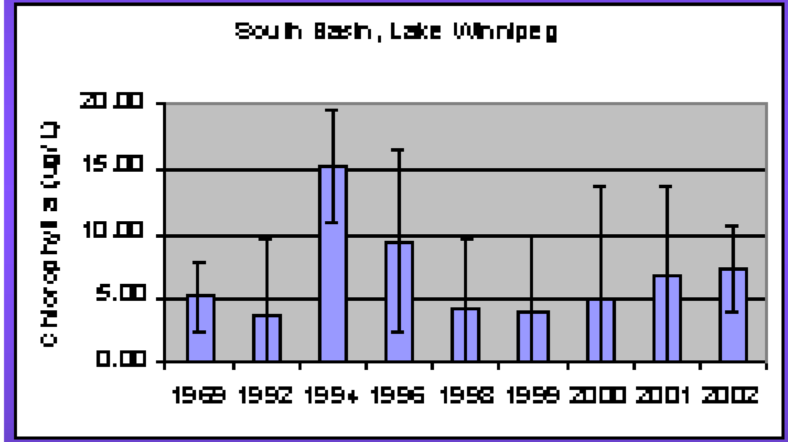
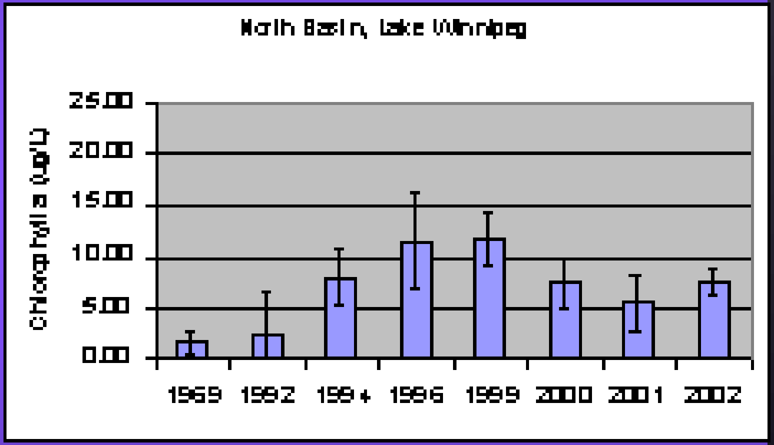
Chlorophyll a - Lake Winnipeg





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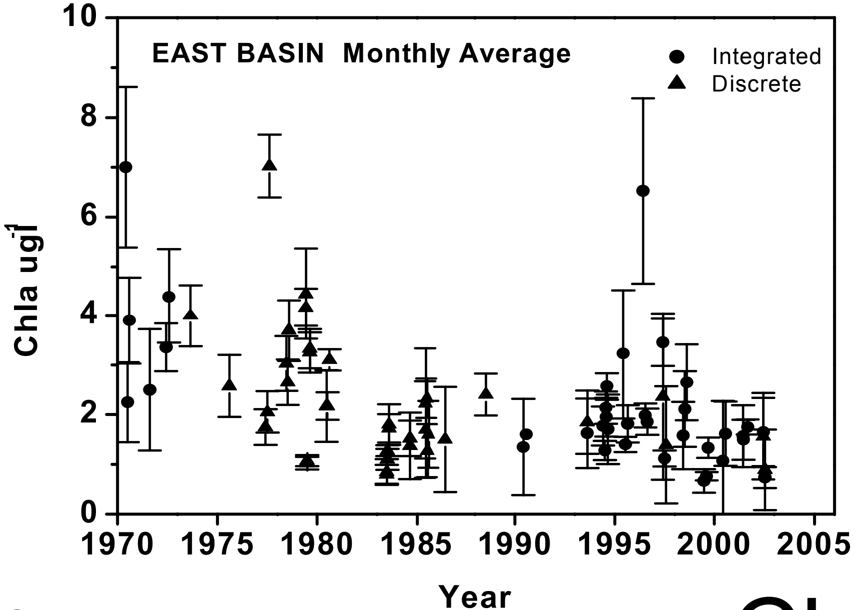
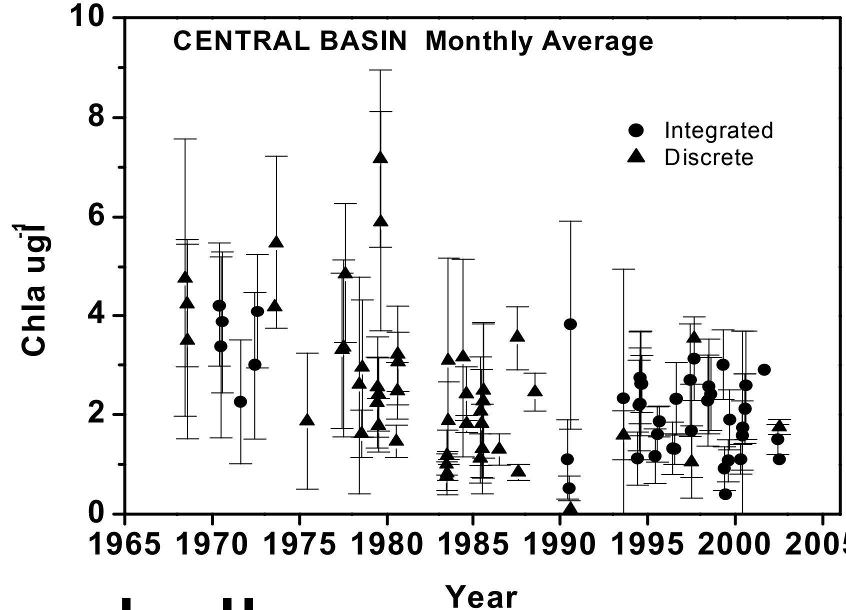
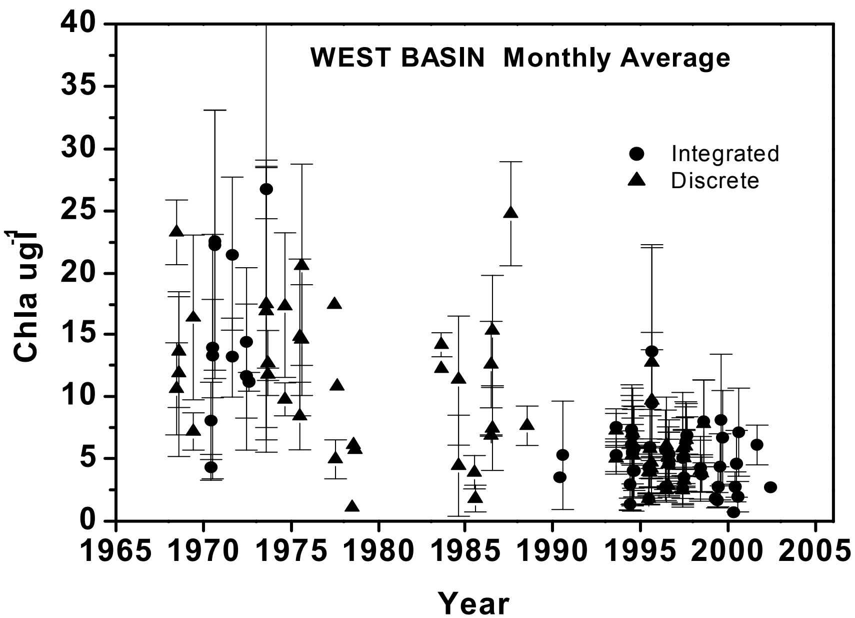
Chlorophyll

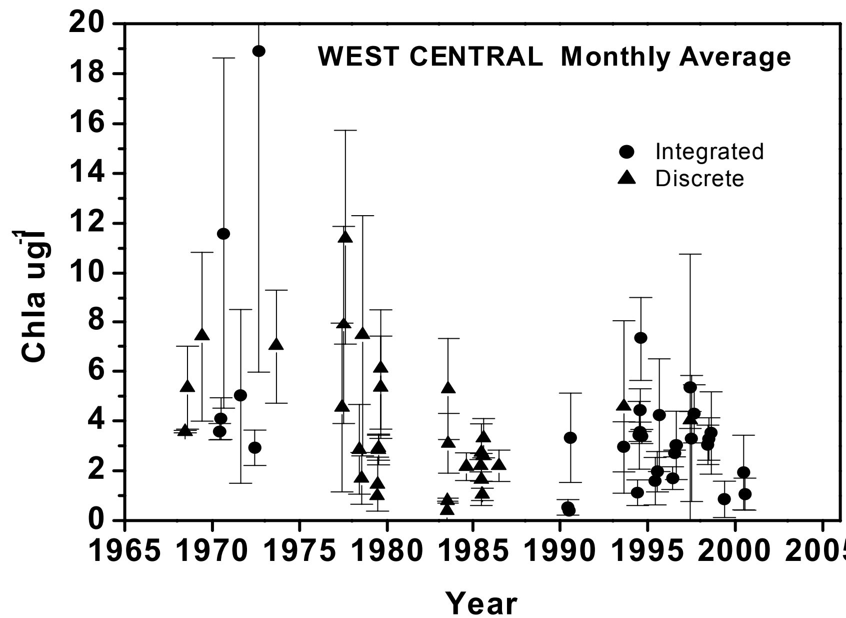




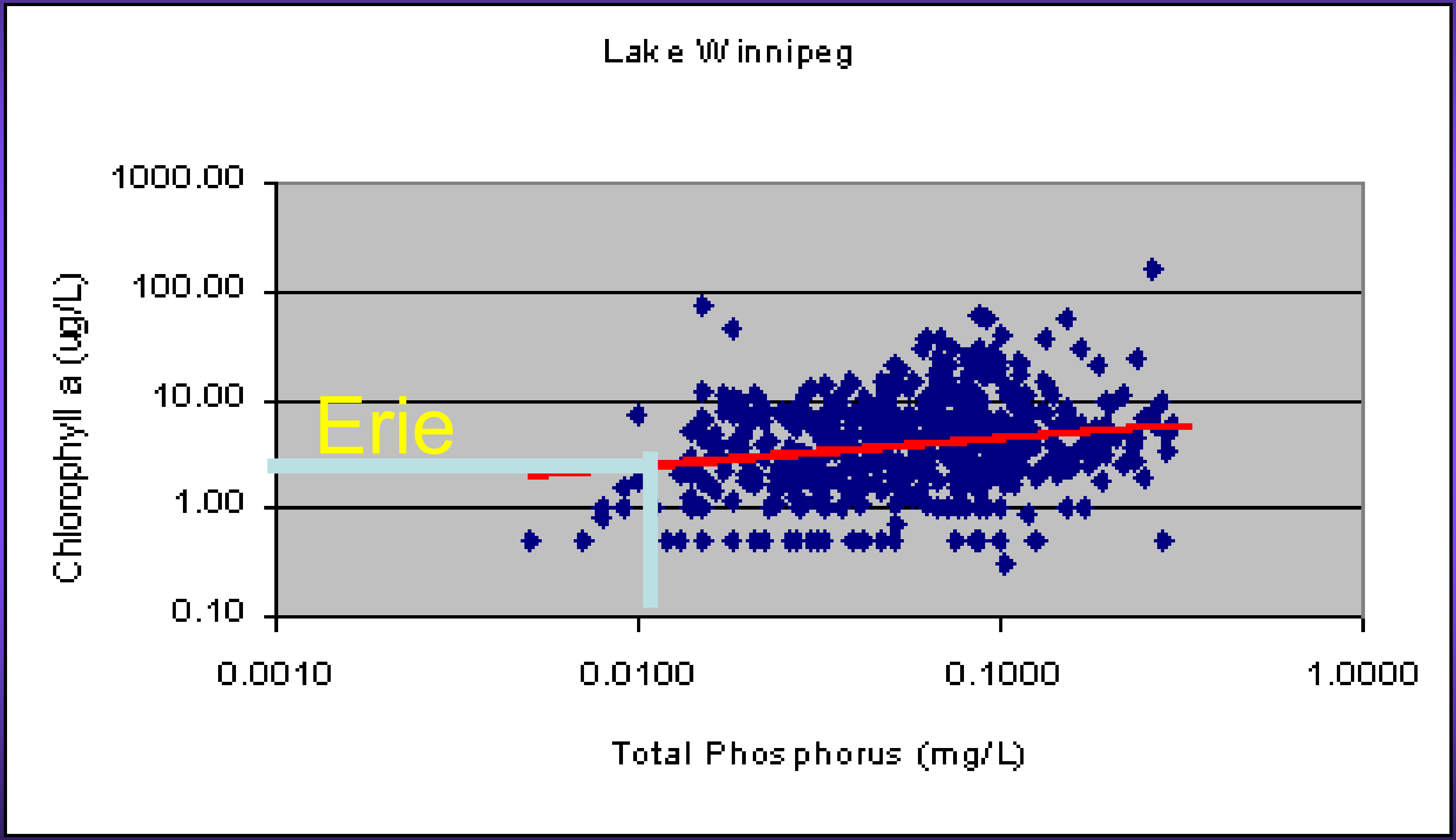
Chlorophyll probably lower in west basin after mussels

Chlorophyll recent levels seen before mussels





Preliminary Phosphorus - Algae Relationships



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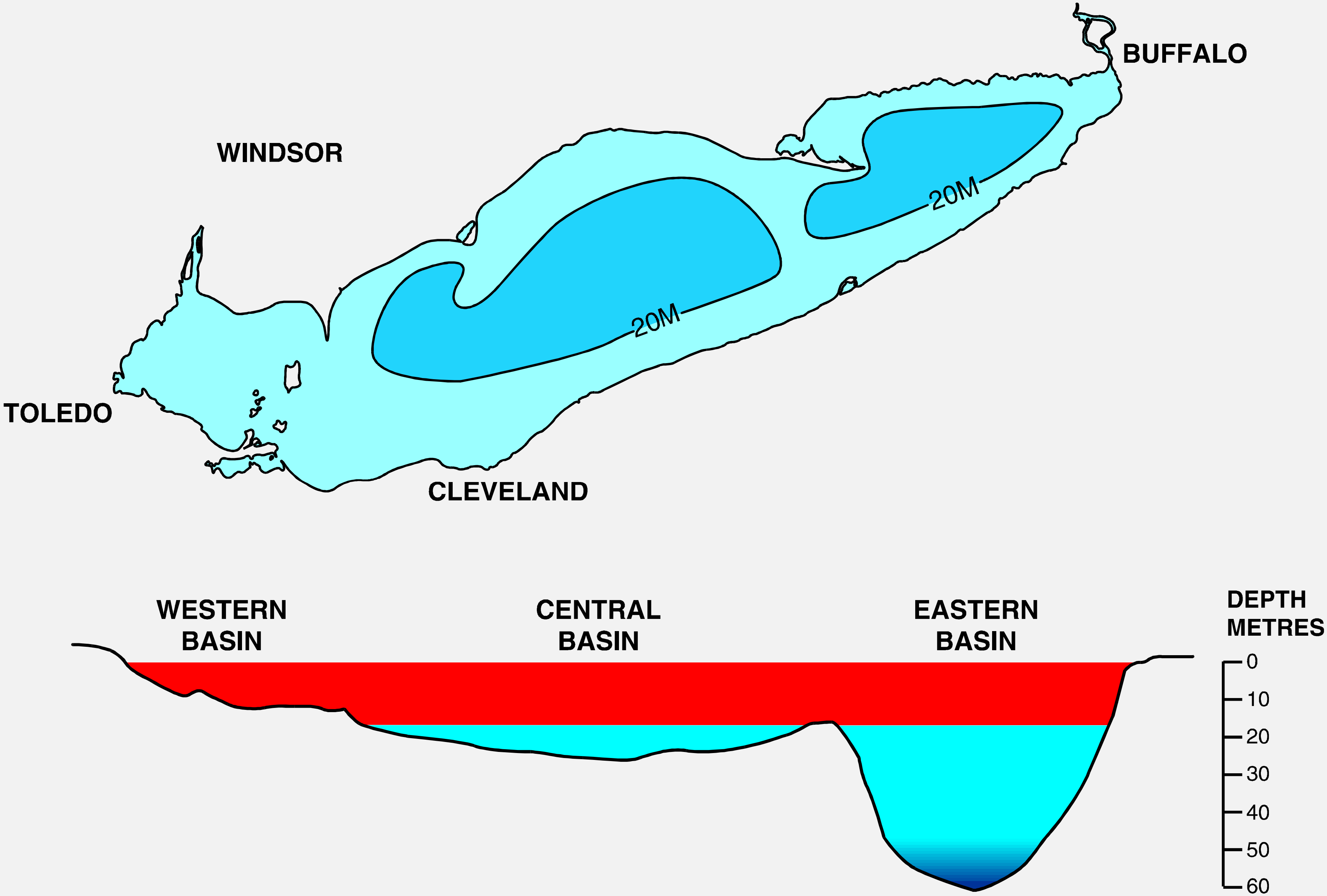


LAKE ERIE LONGITUDINAL CROSS SECTION

Minimum Hypolimnion Oxygen vs. Mean Depth

Data of Thiennemann 1928, plotted by Charlton 1980

Because Erie's size makes the stratification depth deeper, Erie is like a lake 10M deep

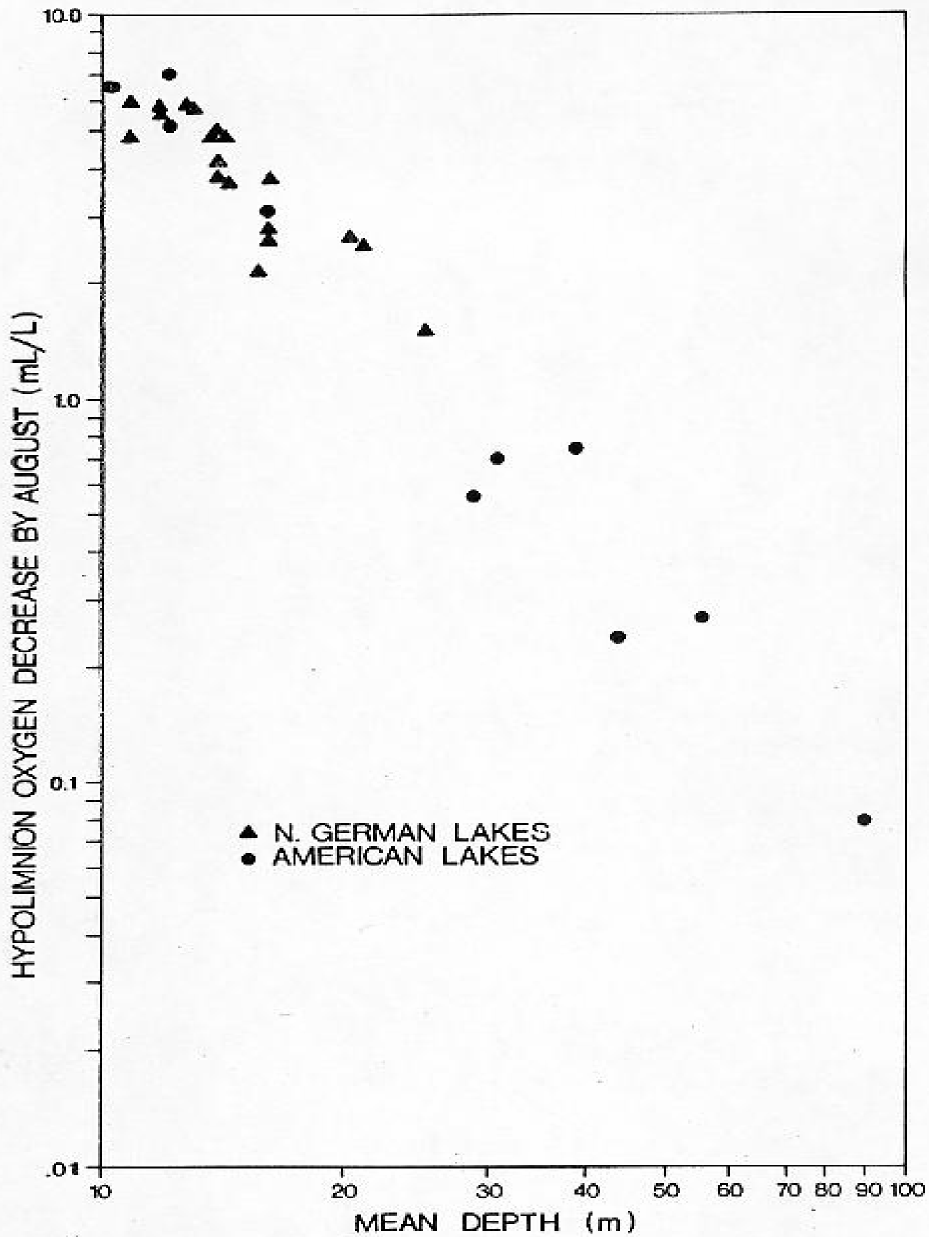


FIG. 1. Relationship between oxygen depletion and mean depth in lakes studied by Thienemann (1928).

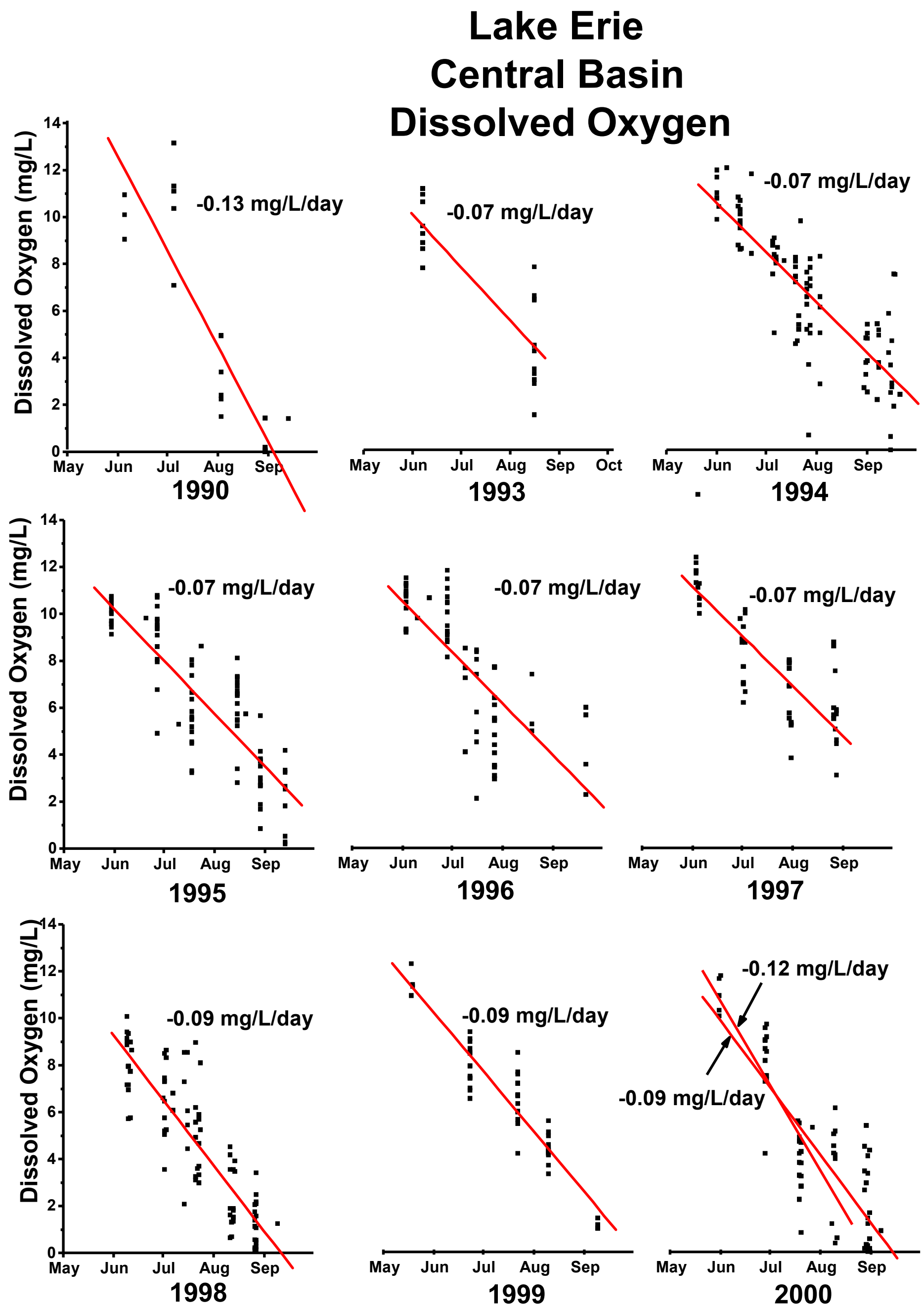
The effect of lake depth on hypolimnion oxygen was apparent 75 years ago.

Less depth tends to cause less oxygen after the same period of stratification.

Erie is very prone to low oxygen

1970
1990
2000
years
of
high
depletion
rates

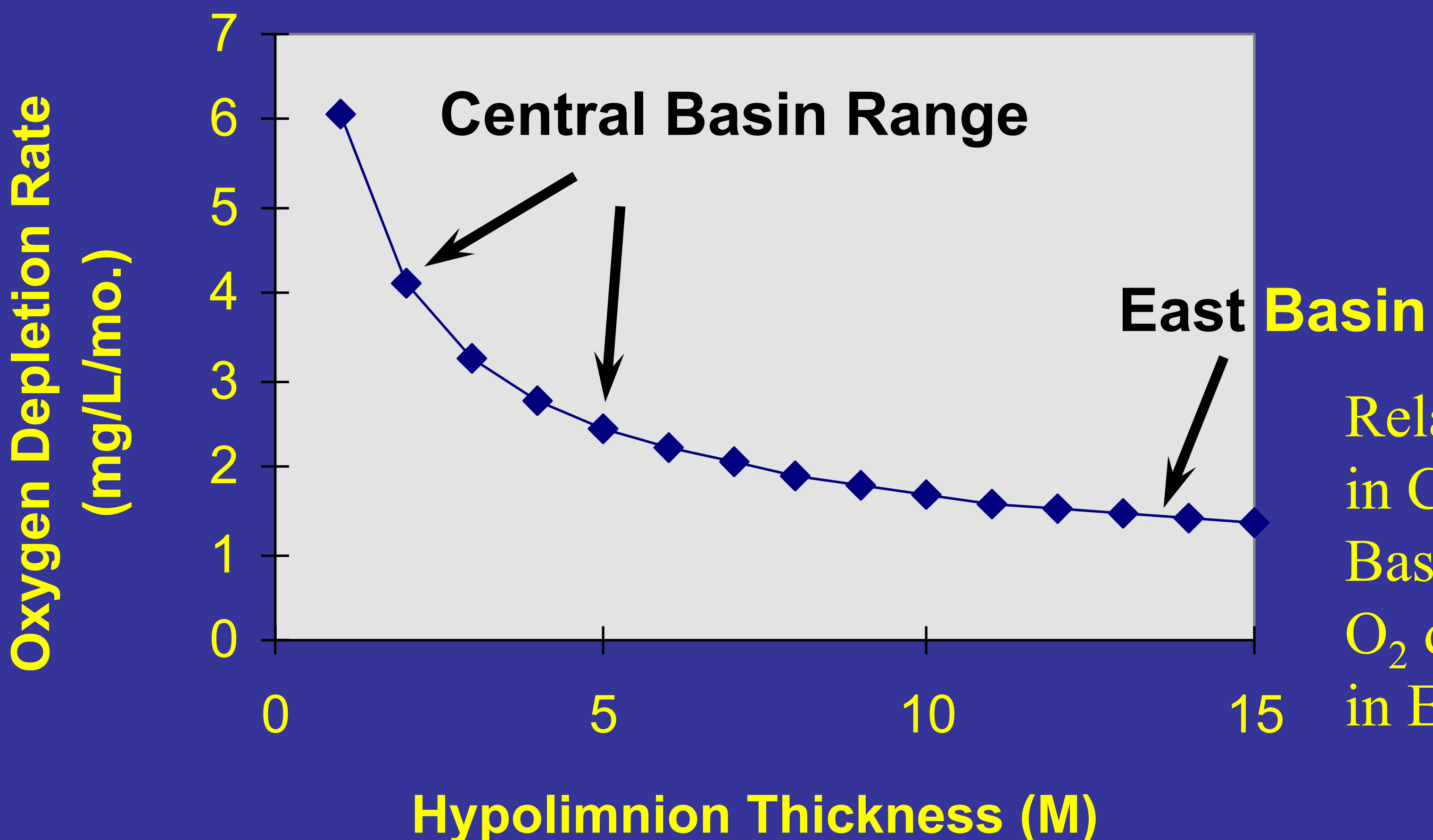
Duration of stratification is also a factor in severity of oxygen depletion



1975
1993
1997
years
of
low
depletion
rates

If oxygen depletion is an indicator of productivity how can it change so much between years?

Relationship Between Oxygen Depletion Rate and Hypolimnion Thickness in Lake Erie



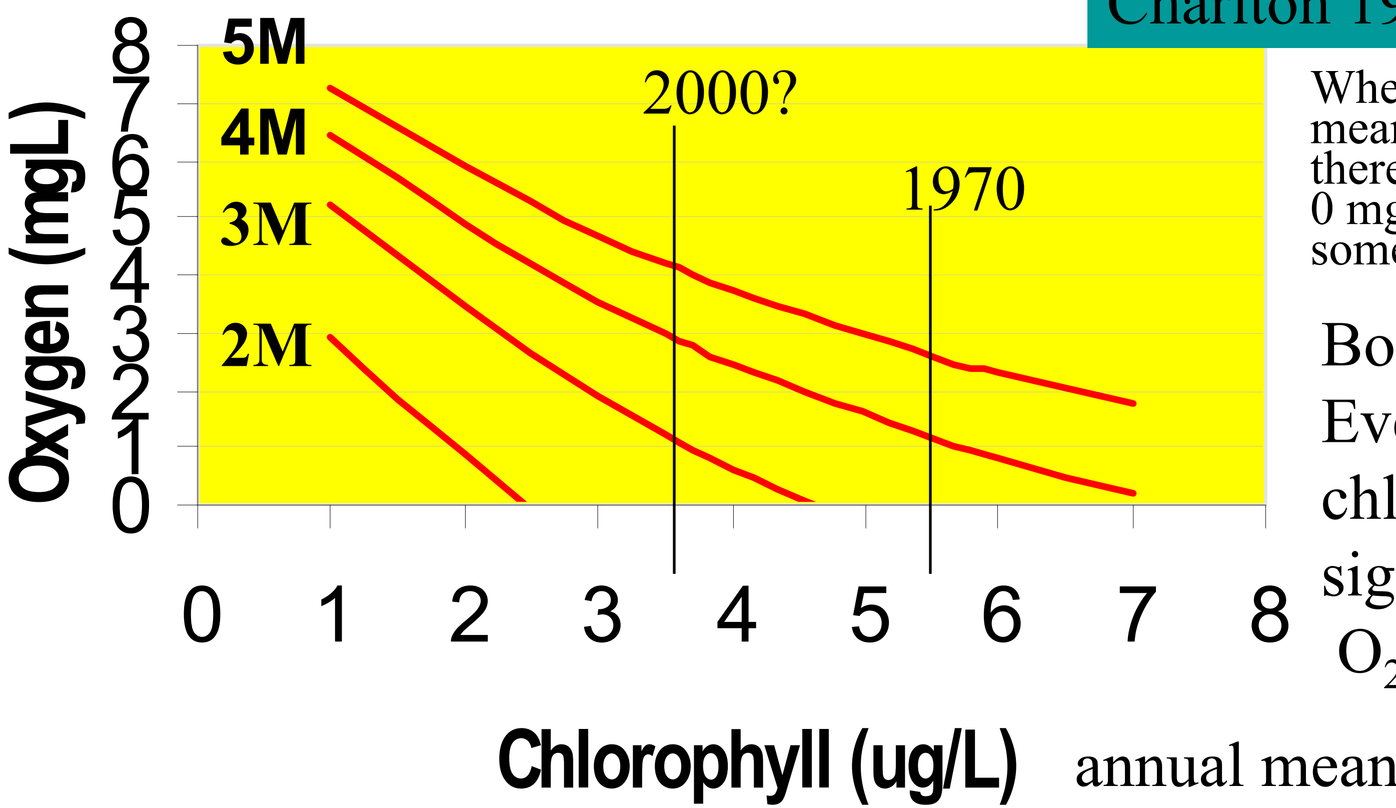
Relationship in Central Basin predicts O_2 depletion in East Basin

$Y = 6.07X^{-.56}$ Charlton 1979 CB data ($p<1\%$)

Dissolved Oxygen Remaining after 105 days Central Erie

From multiple regression Great Lakes and small lake data R=0.95 n=25 Charlton 1980b

← hypolimnion thickness range

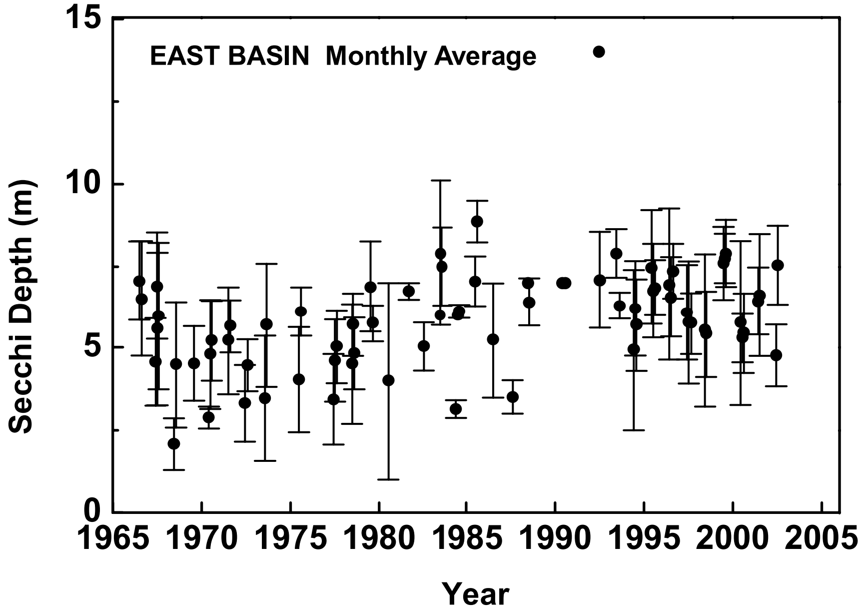


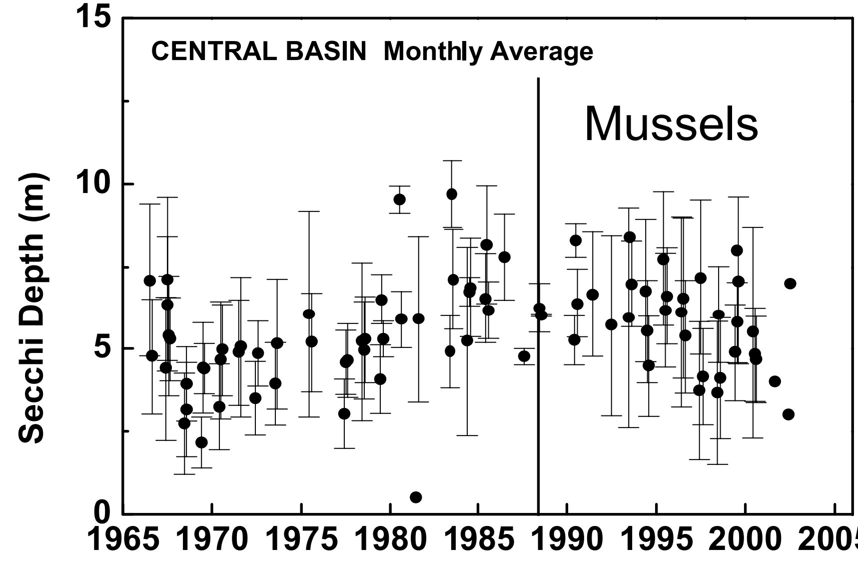
When the mean is 4mg/L there is likely 0 mg/L somewhere.

Bottom Line: Even at very low chlorophyll significantly low O_2 is expected

Oxygen Summary

- Shallow lakes tend to have worse oxygen depletion.
- Shallowness tends to be associated with weather driven between year variabilty.
- Variability makes it difficult to know whether there is a change or simply a difference between years.
- Do not want oxygen to get worse.

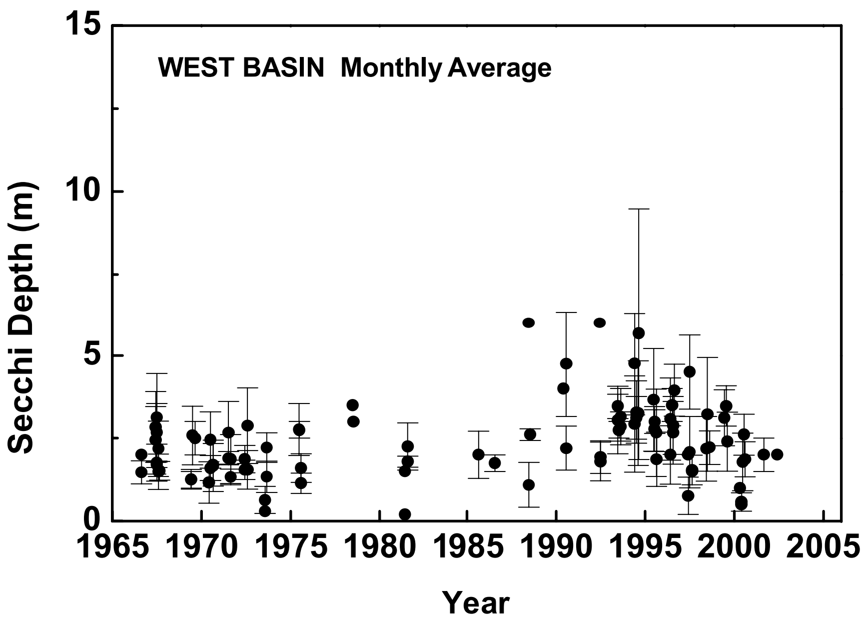


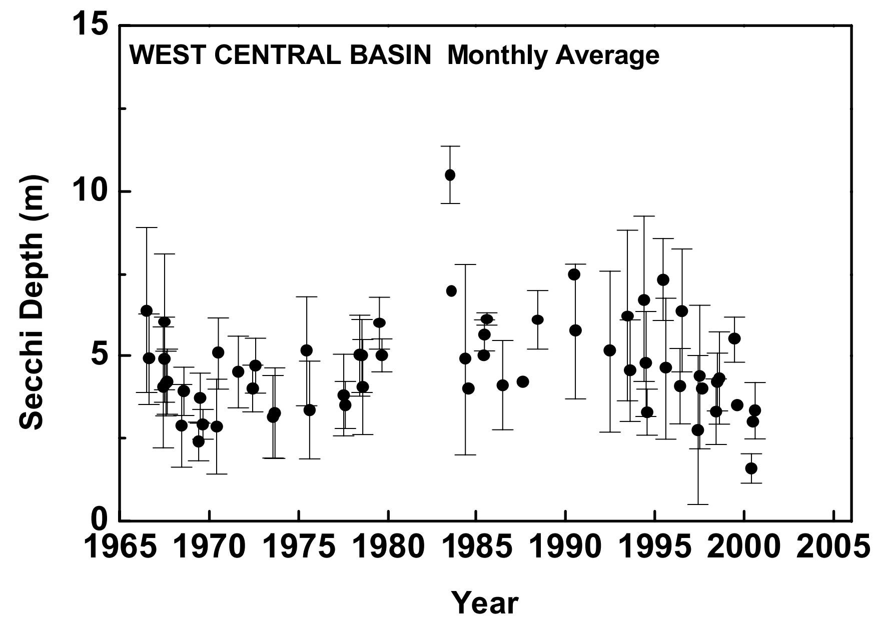


Little support for notion mussels cleaned up whole lake

Better in wb since mussels

Secchi Depth Clarity





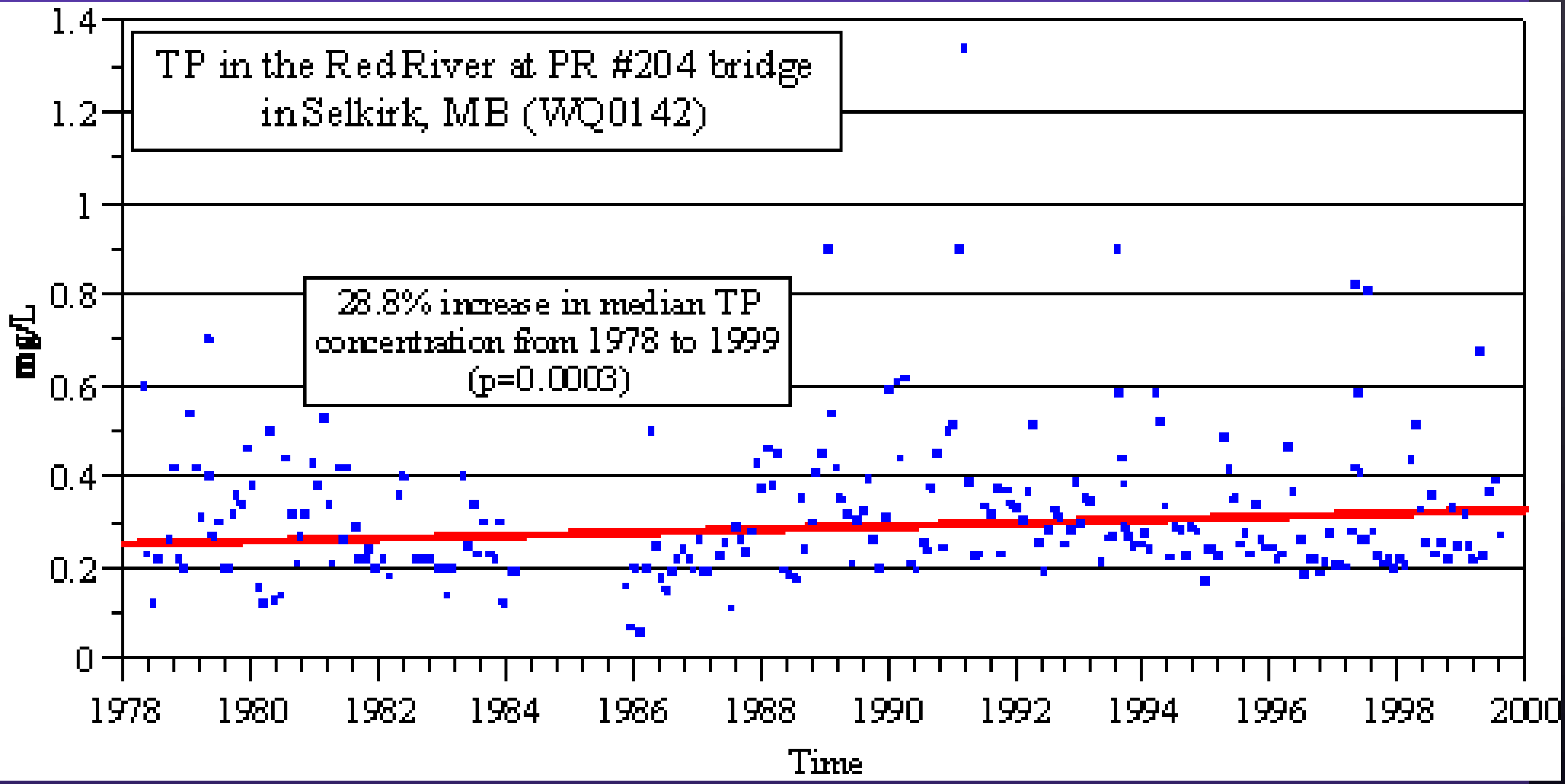
Some Sewage Plant Considerations

- Early effluent limit in Great lakes was 1mgP/L
- With optimization this can be brought down to 0.3 mgP/L using the same phosphorus precipitation chemistry.
- Other technologies can be even lower.
- Self monitoring can be an issue.

Halton regional Municipality “Skyway” Sewage Plant Final Effluent 2004 Monthly values

FINAL EFFLUENT							
BOD (mg/l)	2.10	2.70	2.30	1.20	1.20	1.00	<1
SS (mg/l)	2.60	3.00	2.70	2.50	1.80	3.10	2.90
NH_3 (mg/l)	1.59	4.18	0.59	0.34	0.30	1.10	0.19
TKN (mg/l)	3.10	6.10	1.80	1.50	1.60	2.50	1.30
Total P (mg/l)	**0.11**	**0.10**	**0.08**	**0.07**	**0.05**	**0.06**	**0.06**
E Coli (CFU/100ml)	7.00	4.00	36.00	15.00	14.00	50.00	27.00

TP in Red River at Selkirk



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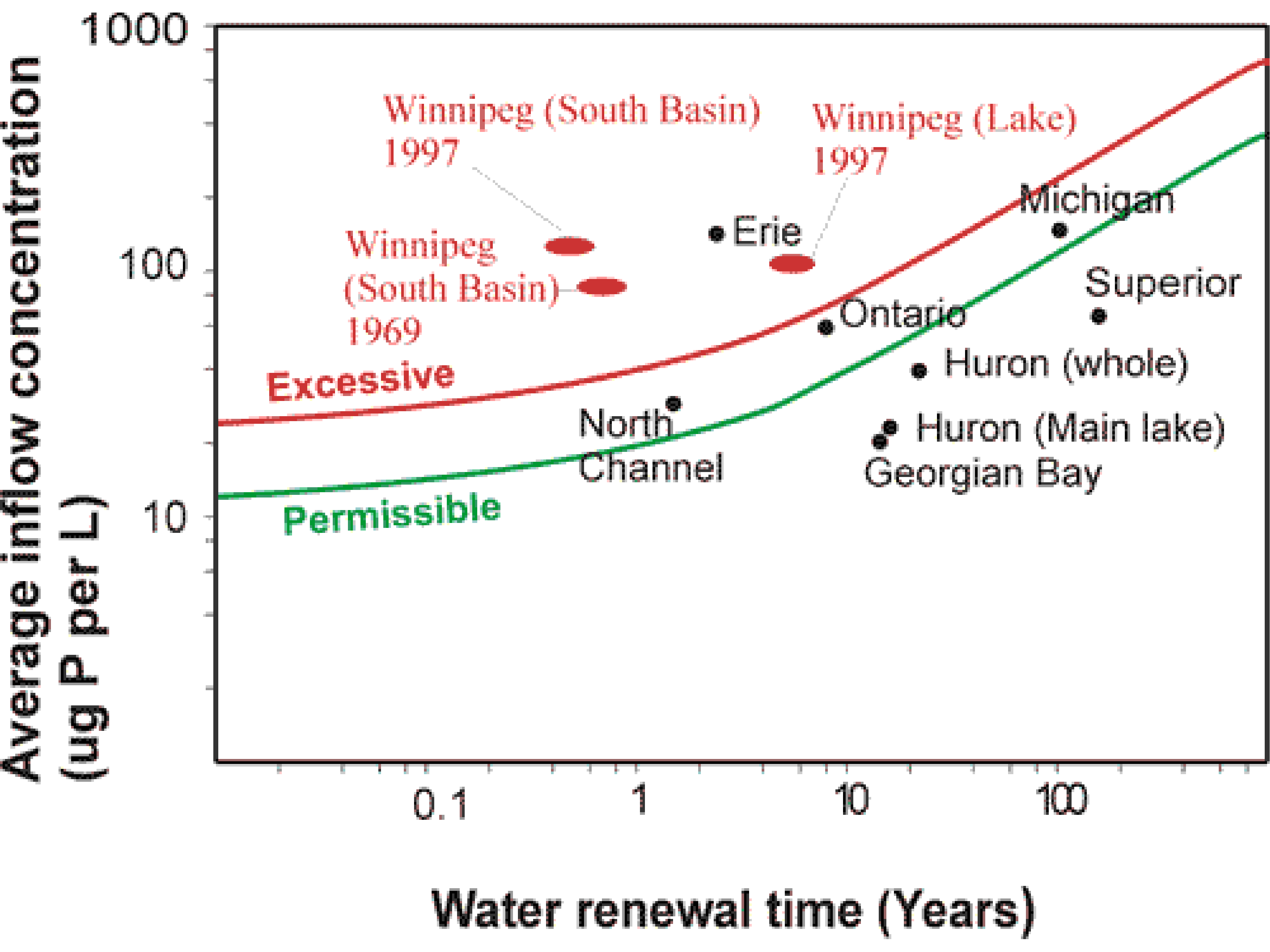
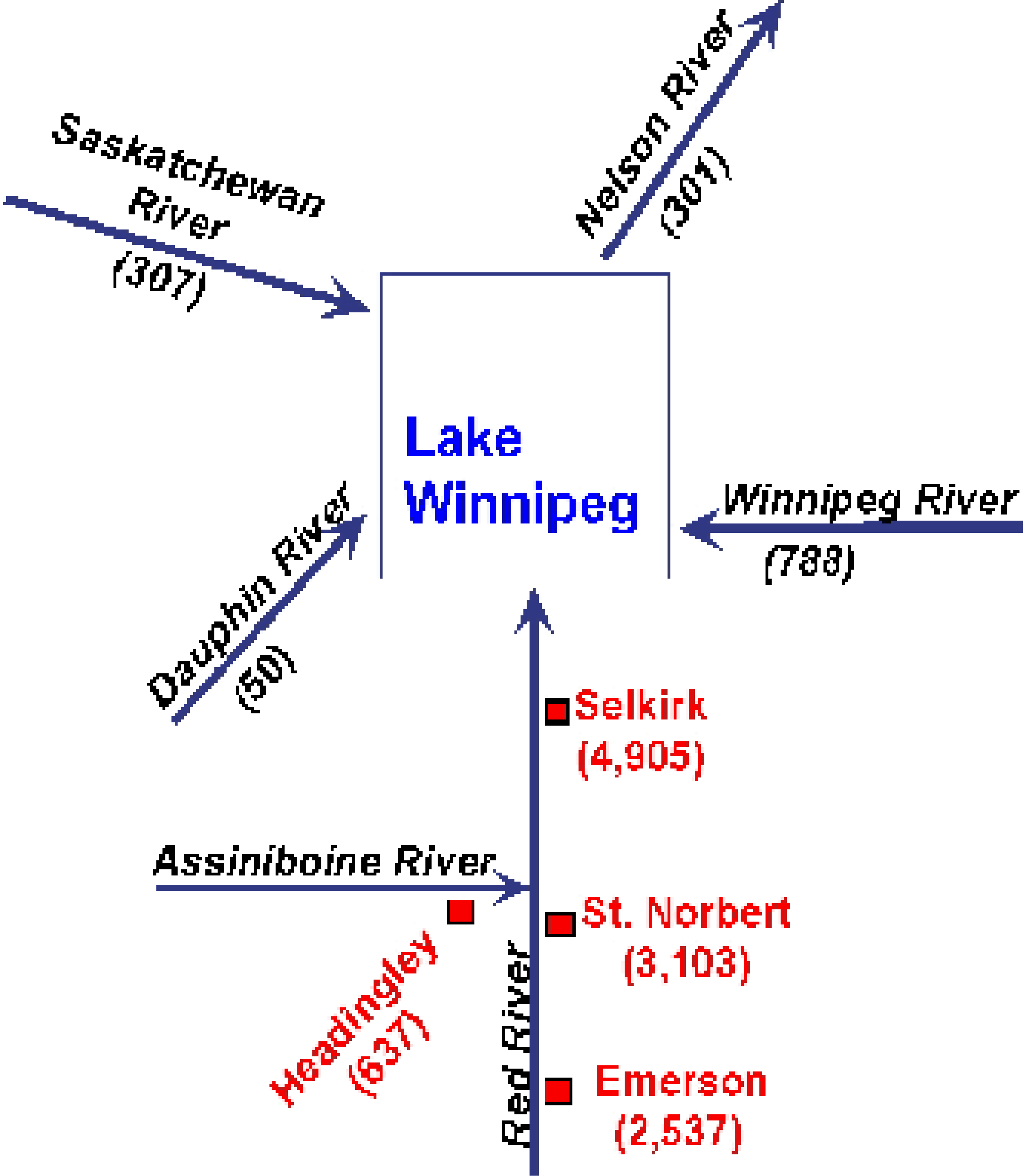


Average inflow concentration (ug P per L)
1000
100
10
0.1
1
10
100
Water renewal time (Years)
Winnipeg (South Basin) 1997
Winnipeg (Lake) 1997
Winnipeg (South Basin) 1969
Erie
Michigan
Superior
Ontario
Huron (whole)
Huron (Main lake)
Georgian Bay
North Channel
Excessive
Permissible

TP Loading to Lake Winnipeg



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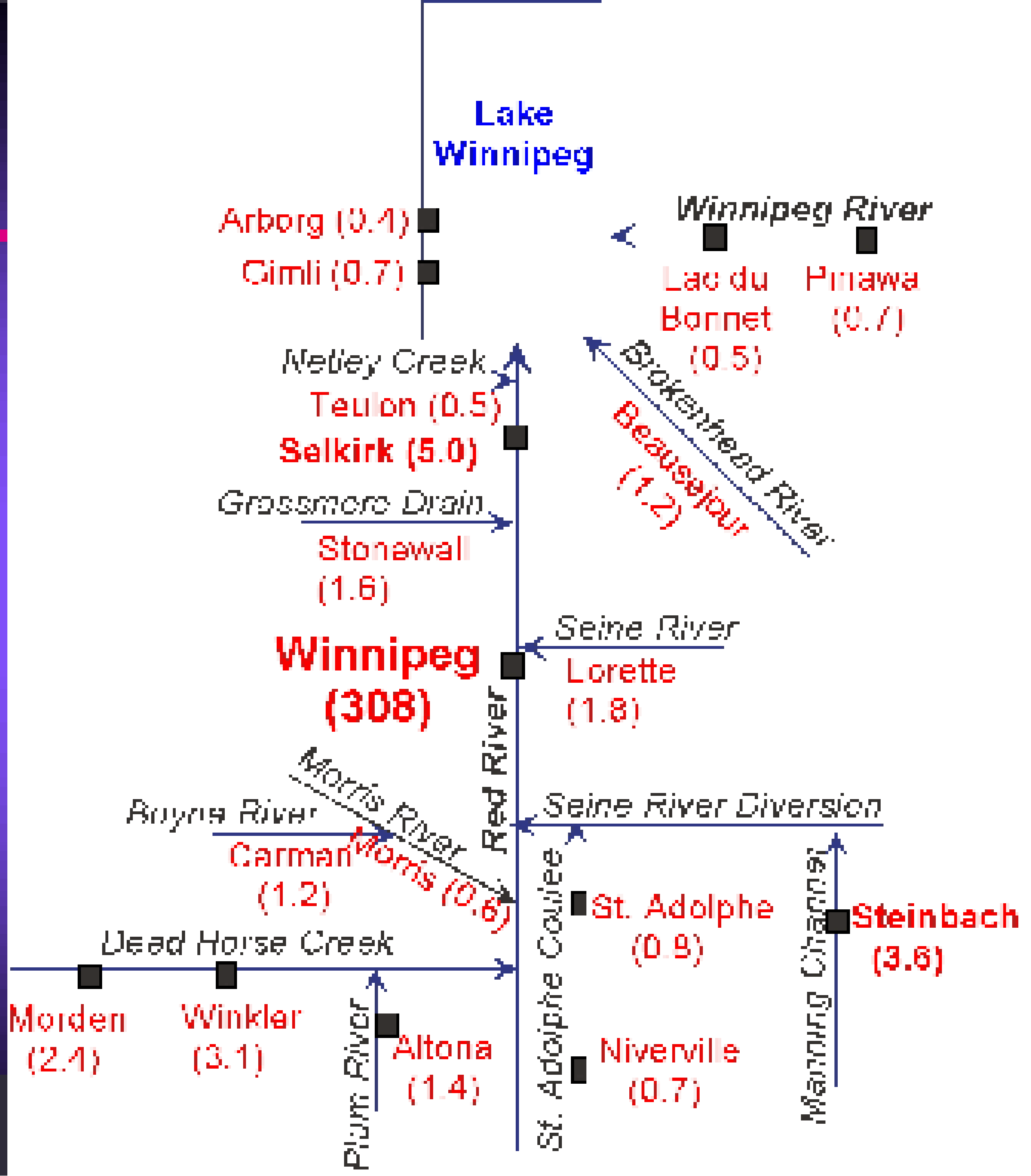
TP Loading from WWTF



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Questions

- Why are nutrient levels in the lake so variable?
- What is the cause of the increase in TP concentration in the Red River?
- How often does the lake stratify and have a low oxygen in the bottom water?
- What sources of nutrients can be controlled easily?

Questions:

- What is the bioavailability of the sources?
- What is the seasonal variation of source bioavailability?
- What is the seasonal variation in source concentration?
- How much do loads in low flow periods affect lake algae?

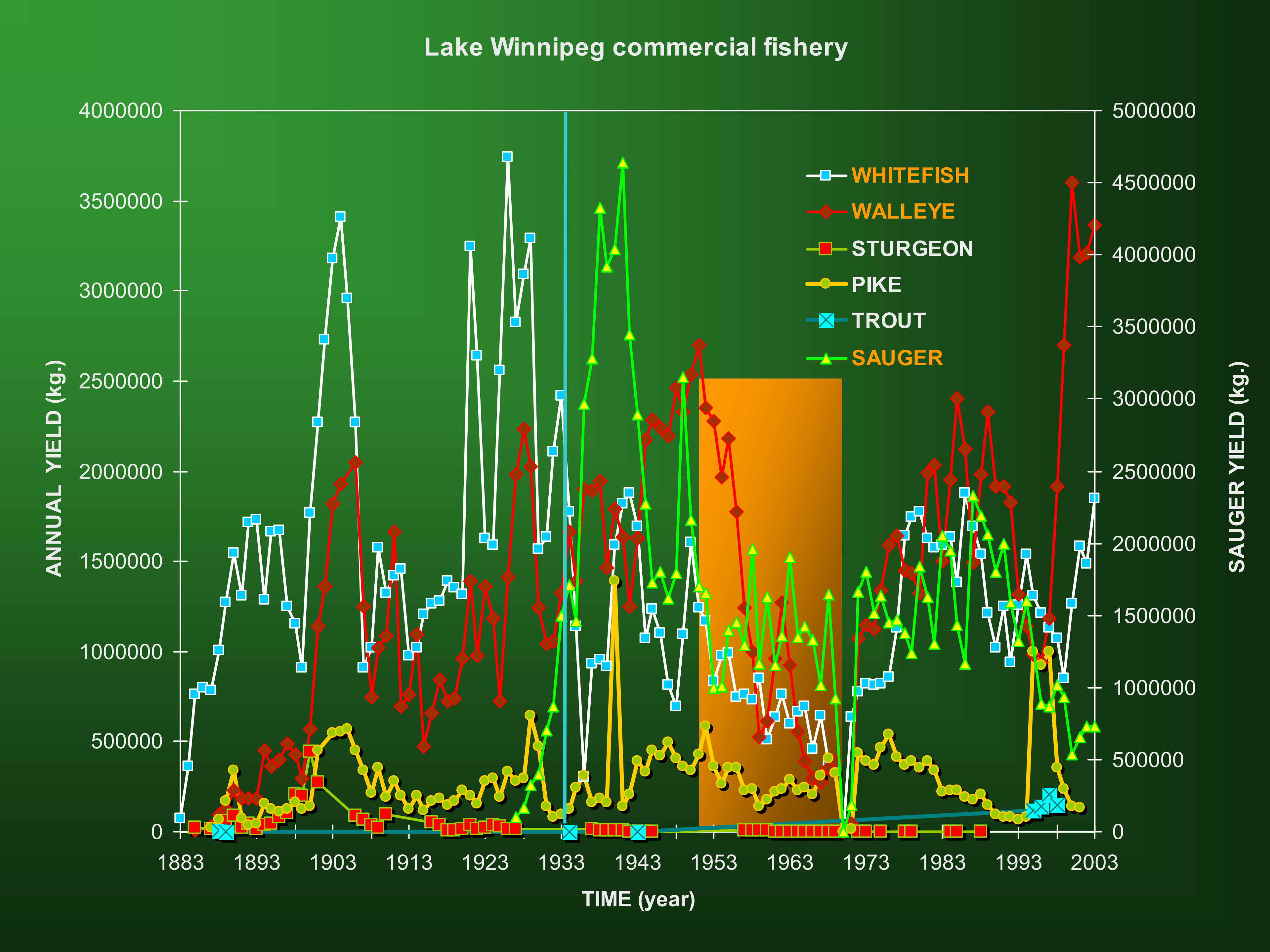
Management Levers

- Municipal Wastewater
- Agricultural Practices
  - Fertilizers
  - Manures
  - Land disruption, water retention
- Fish More, Fish Less, Stock fish
- Habitat Regeneration ?
- Level Manipulation

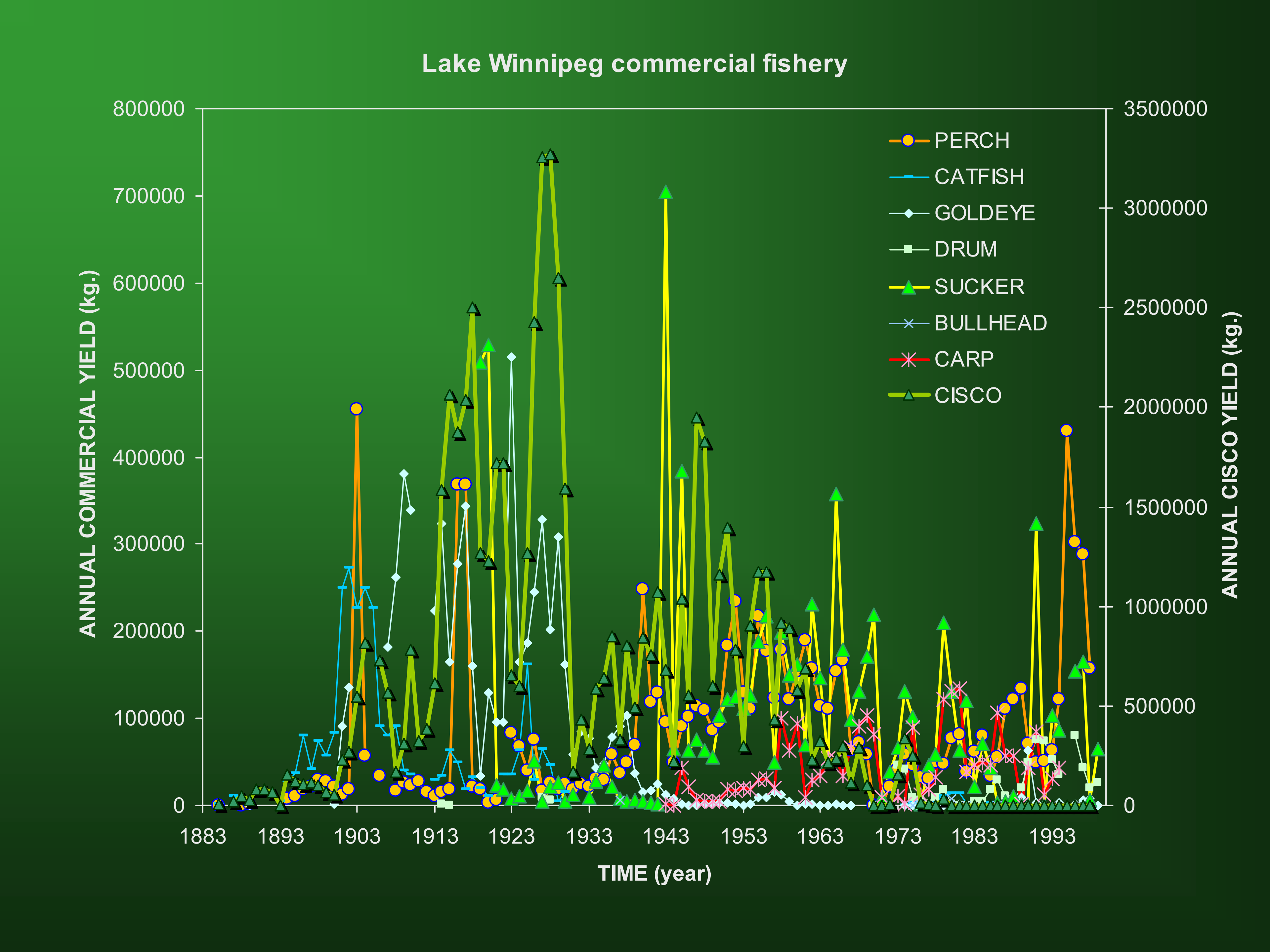
Research Priorities

- Management Levers point the way to priority research
- “My specialty is crucial to the understanding of phosphorus dynamics in the lake”
- “OK, but is that level of understanding crucial to a decision making process or not?”

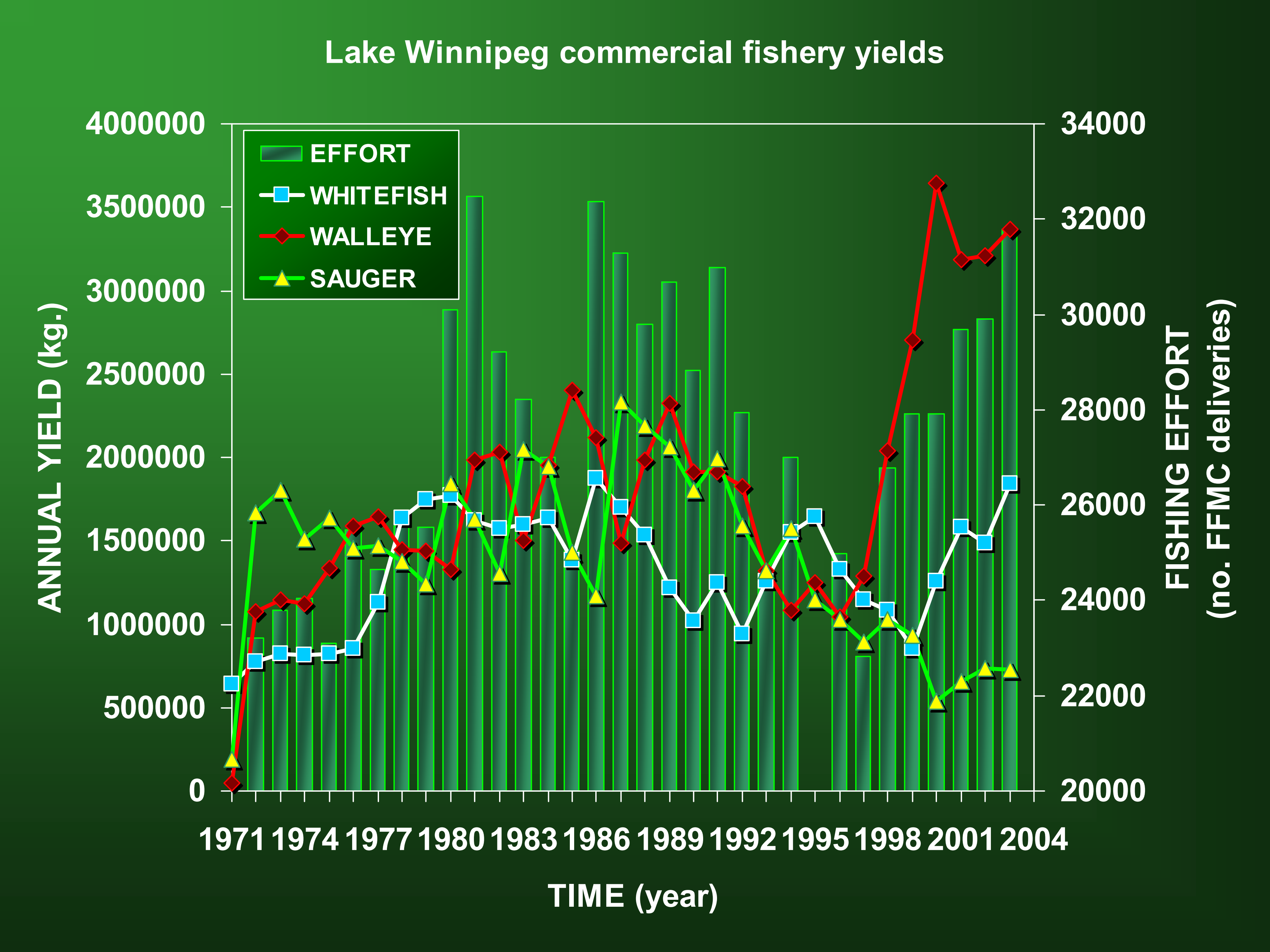
Lake Winnipeg's fish and fisheries



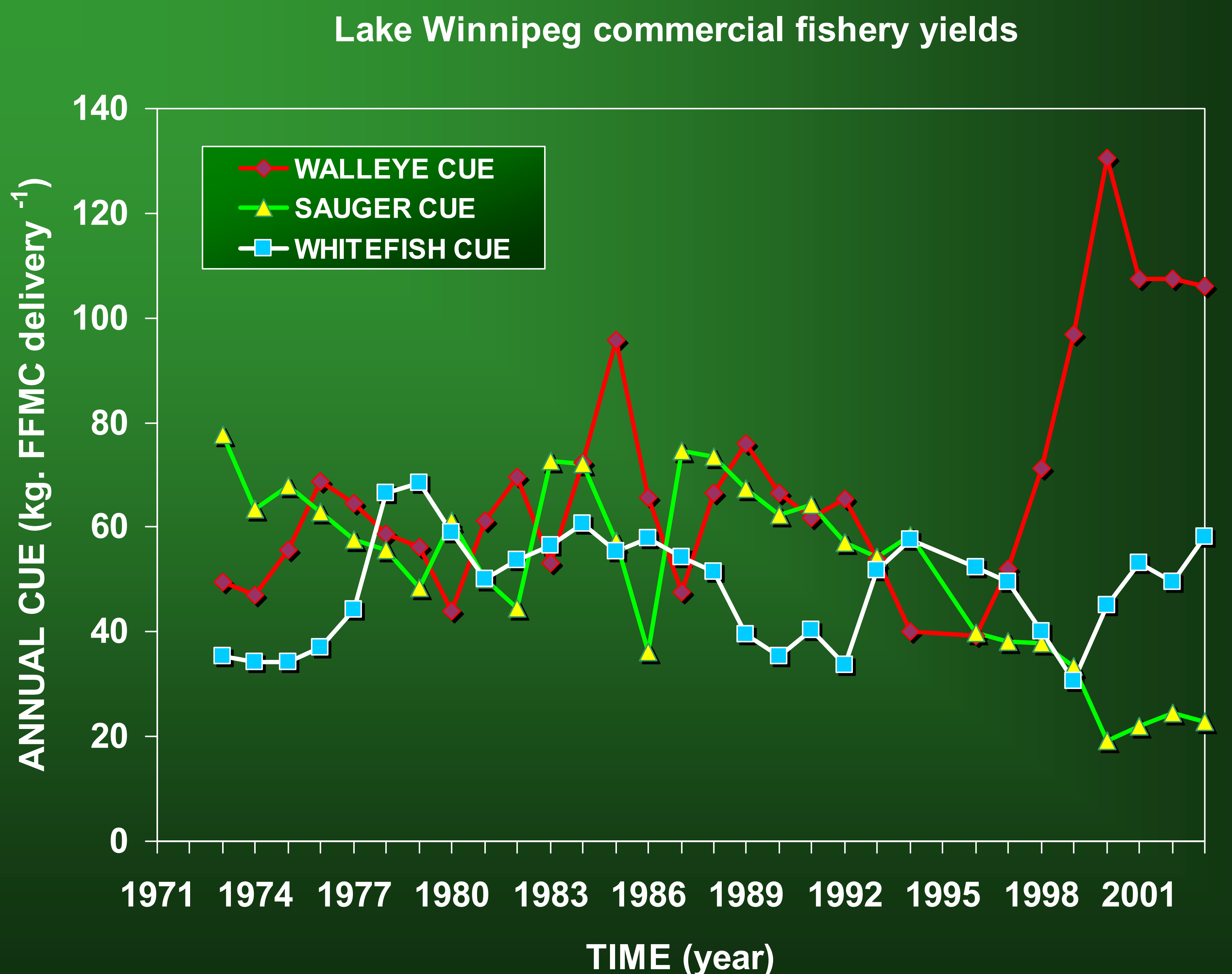
Lake Winnipeg commercial fishery
ANNUAL YIELD (kg.)
SAUGER YIELD (kg.)
TIME (year)
WHITEFISH
WALLEYE
STURGEON
PIKE
TROUT
SAUGER
0
500000
1000000
1500000
2000000
2500000
3000000
3500000
4000000
4500000
5000000
1883
1893
1903
1913
1923
1933
1943
1953
1963
1973
1983
1993
2003

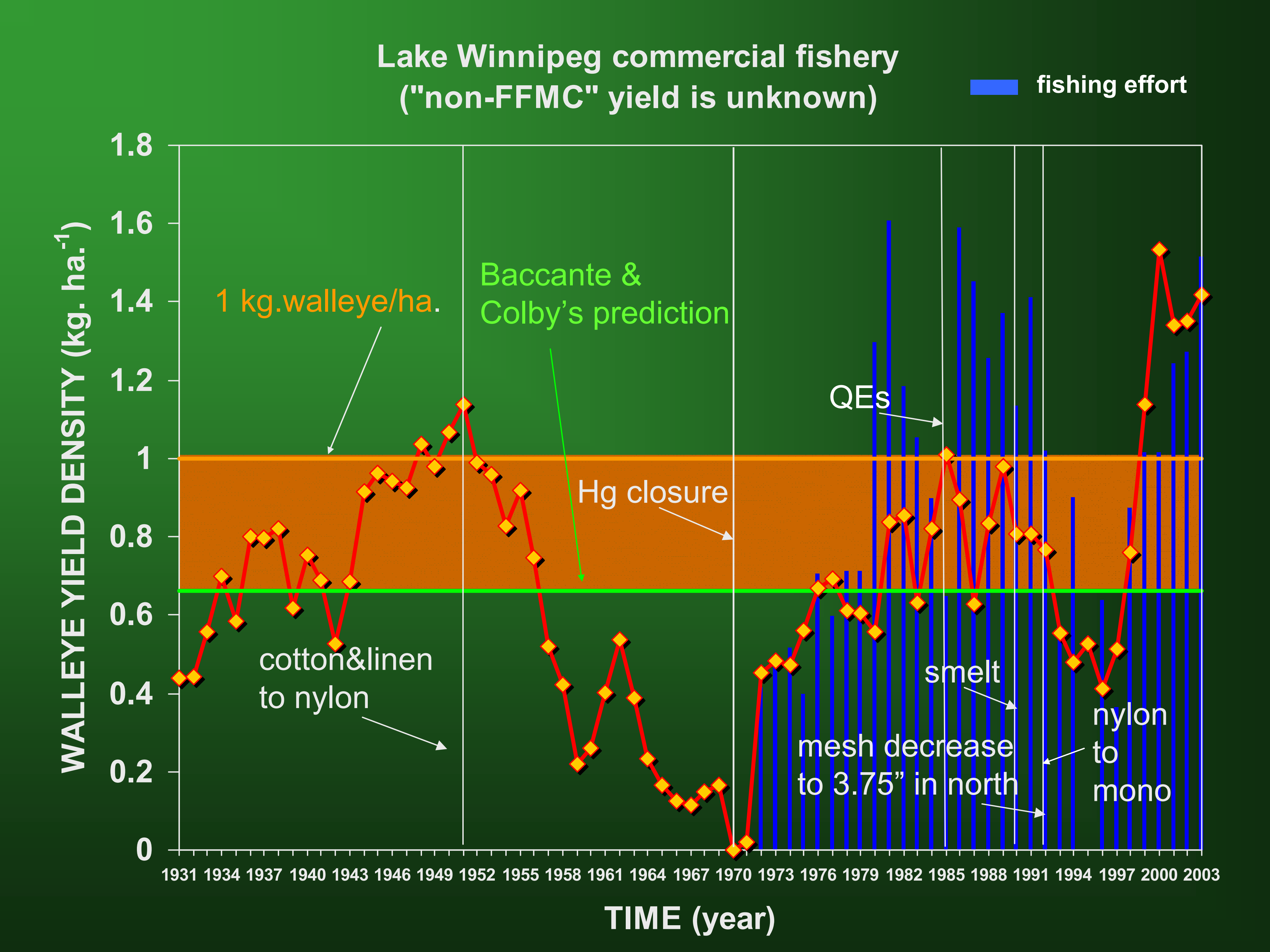


Lake Winnipeg commercial fishery
ANNUAL COMMERCIAL YIELD (kg.)
ANNUAL CISCO YIELD (kg.)
TIME (year)
800000
700000
600000
500000
400000
300000
200000
100000
0
3500000
3000000
2500000
2000000
1500000
1000000
500000
0
1883
1893
1903
1913
1923
1933
1943
1953
1963
1973
1983
1993
PERCH
CATFISH
GOLDEYE
DRUM
SUCKER
BULLHEAD
CARP
CISCO

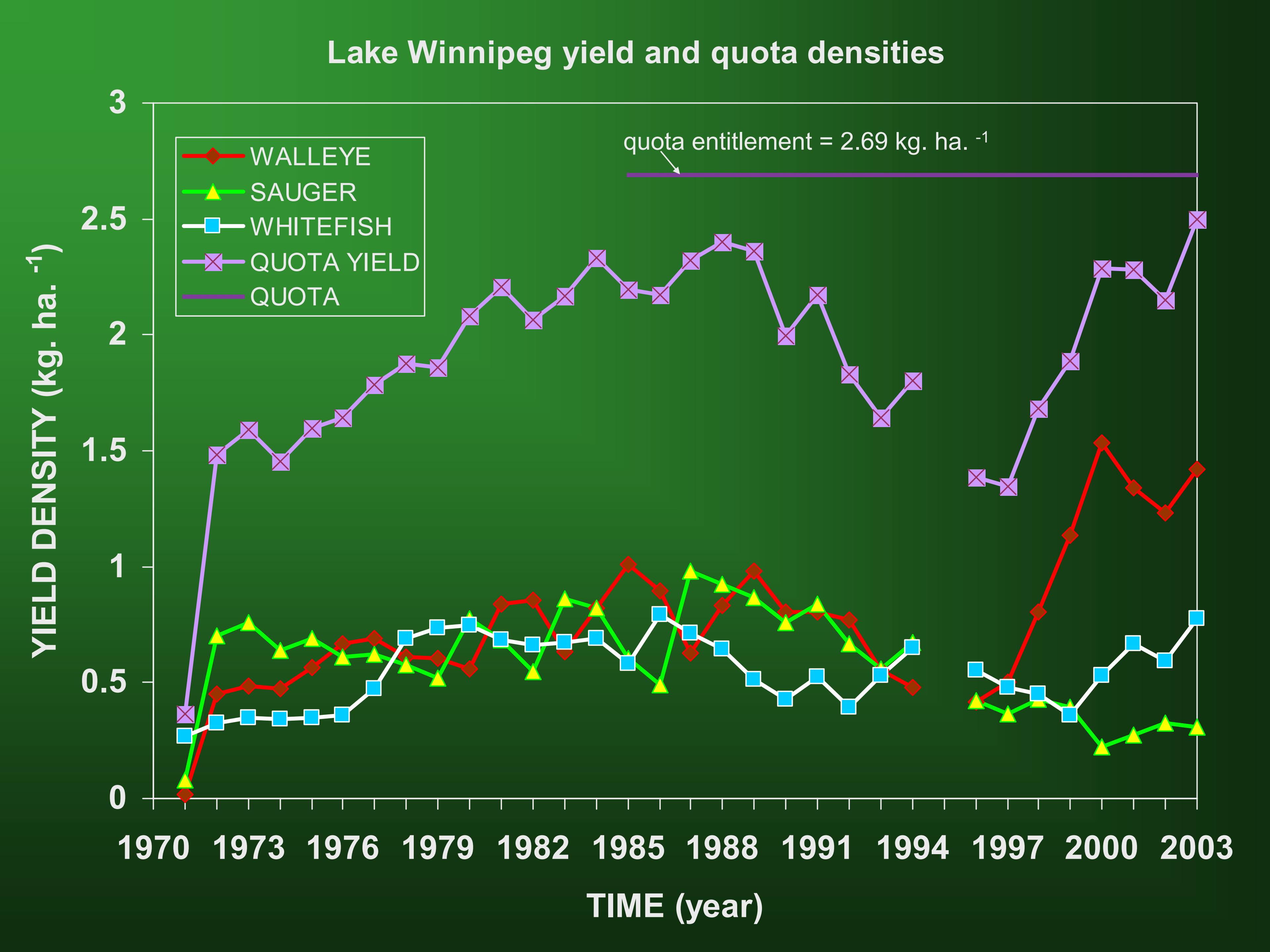


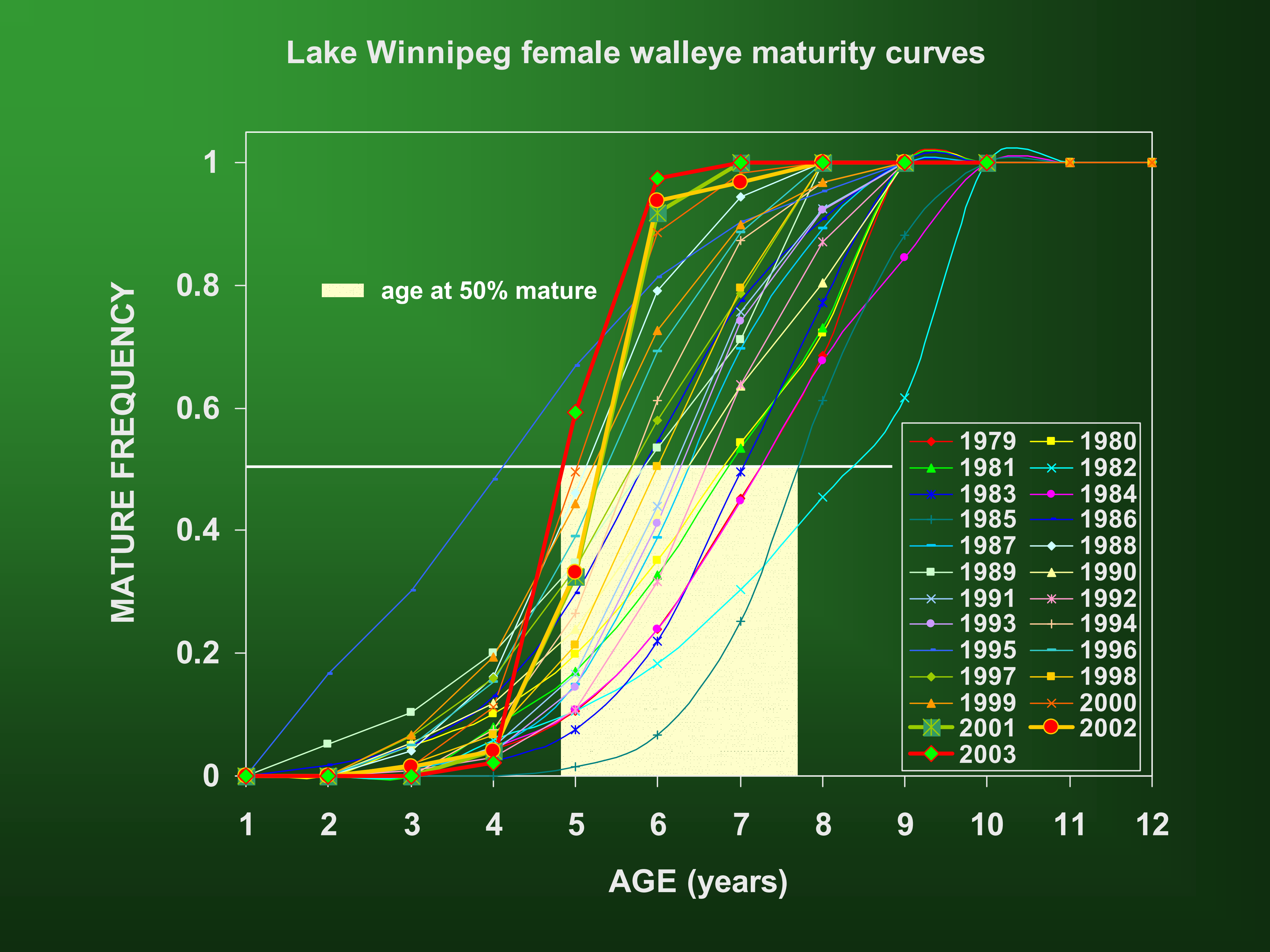
Lake Winnipeg commercial fishery yields
EFFORT
WHITEFISH
WALLEYE
SAUGER
ANNUAL YIELD (kg.)
4000000
3500000
3000000
2500000
2000000
1500000
1000000
500000
0
FISHING EFFORT
(no. FFMC deliveries)
34000
32000
30000
28000
26000
24000
22000
20000
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001
2004
TIME (year)


Lake Winnipeg commercial fishery yields
WALLEYE CUE
SAUGER CUE
WHITEFISH CUE
ANNUAL CUE (kg. FFMC delivery -1)
0
20
40
60
80
100
120
140
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001
TIME (year)

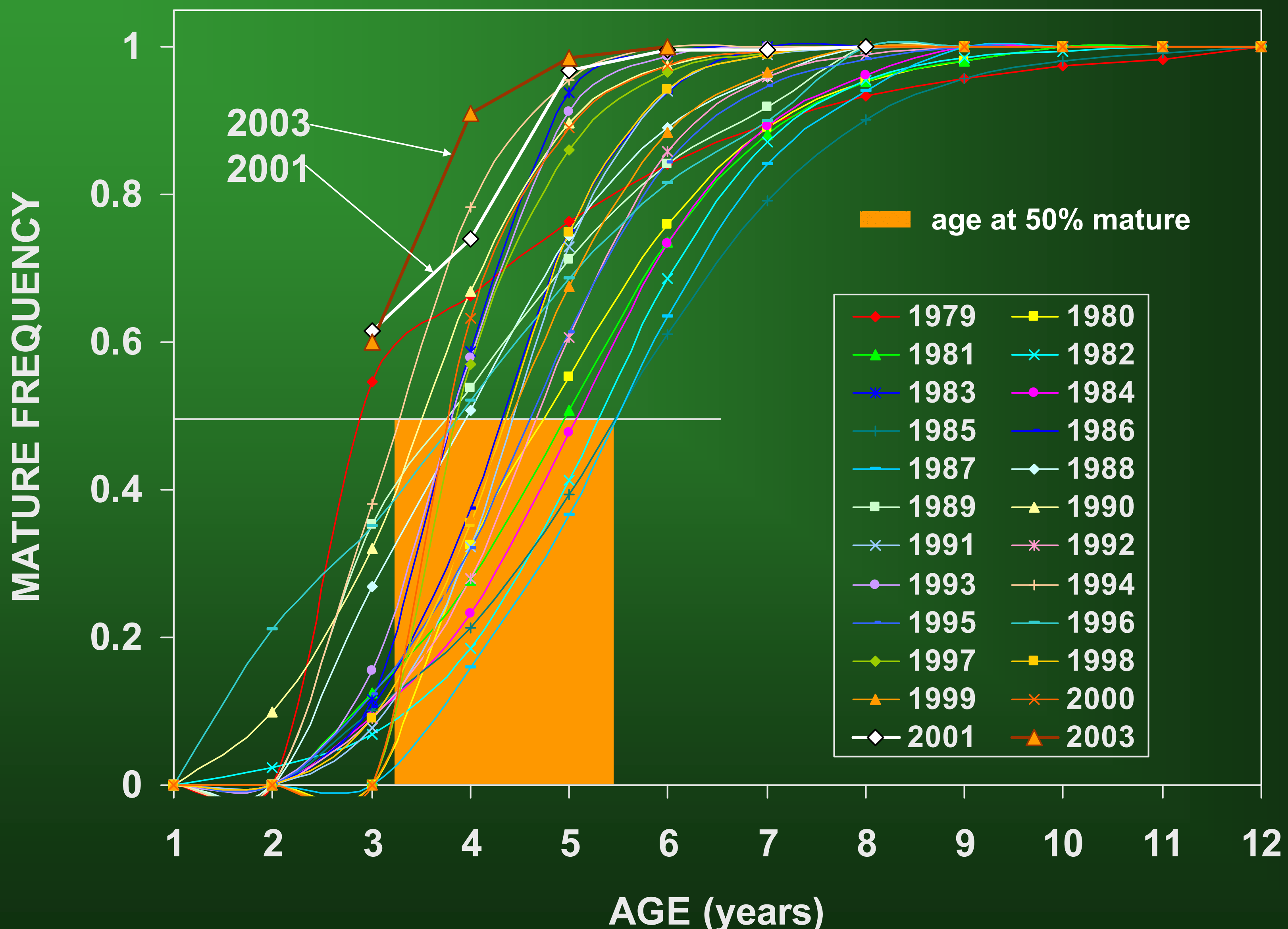


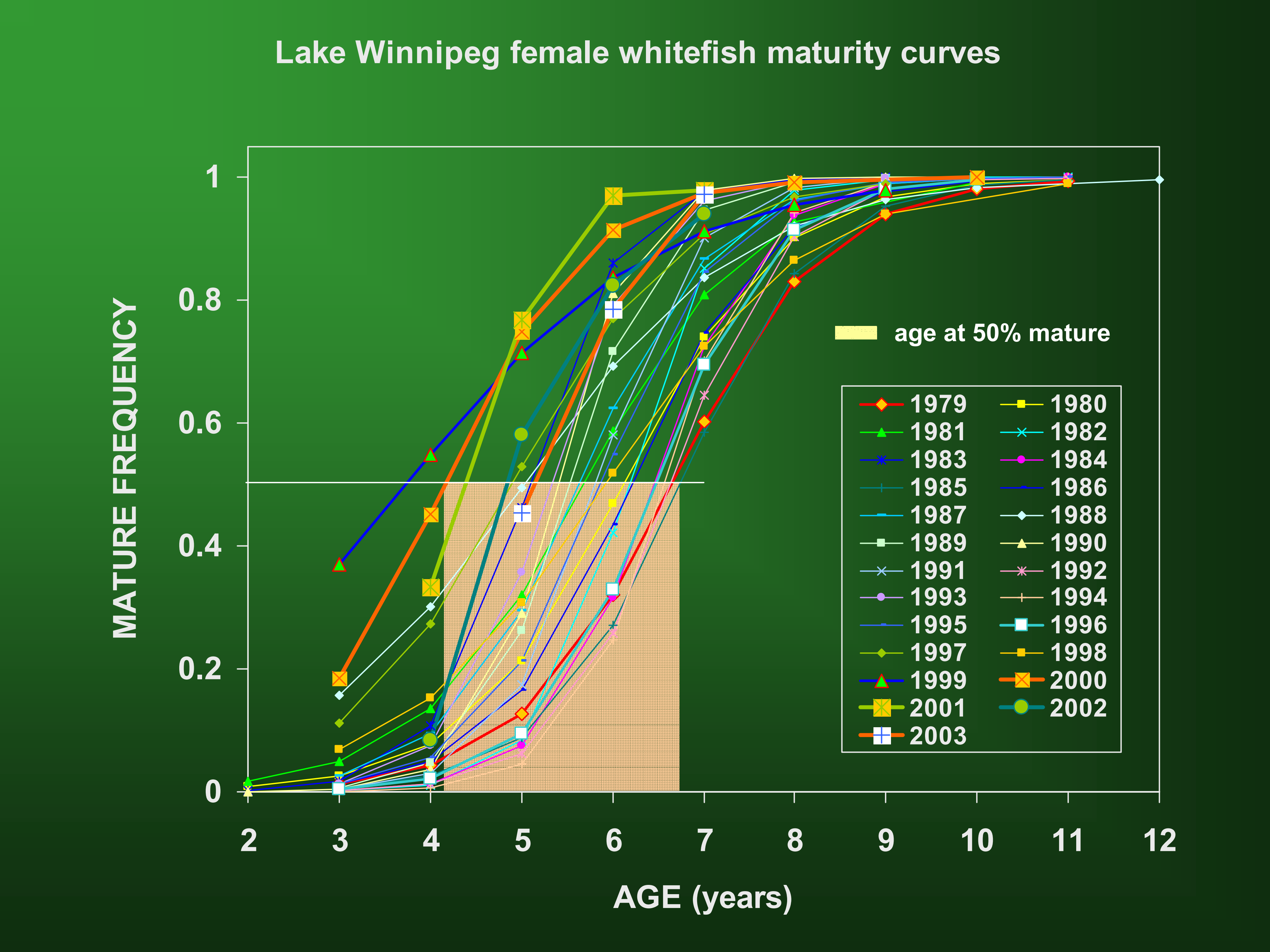
Lake Winnipeg commercial fishery
("non-FFMC" yield is unknown)
fishing effort
WALLEYE YIELD DENSITY (kg. ha.-1)
TIME (year)
1 kg.walleye/ha.
Baccante & Colby's prediction
Hg closure
QEs
cotton&linen to nylon
smelt
mesh decrease to 3.75" in north
nylon to mono
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
1931 1934 1937 1940 1943 1946 1949 1952 1955 1958 1961 1964 1967 1970 1973 1976 1979 1982 1985 1988 1991 1994 1997 2000 2003

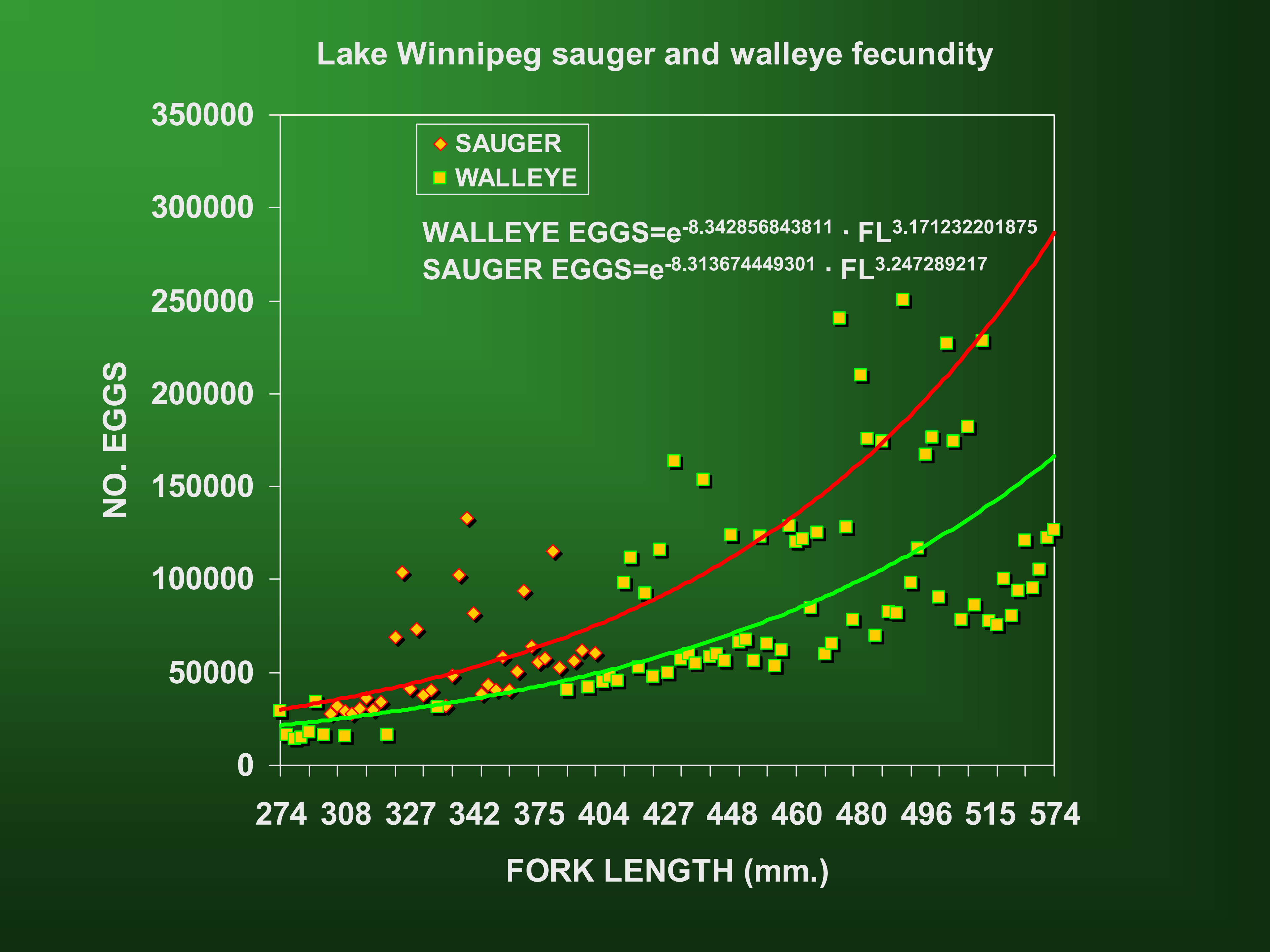

Lake Winnipeg yield and quota densities
3
2.5
2
1.5
1
0.5
0
YIELD DENSITY (kg. ha. -1)
quota entitlement = 2.69 kg. ha. -1
WALLEYE
SAUGER
WHITEFISH
QUOTA YIELD
QUOTA
1970
1973
1976
1979
1982
1985
1988
1991
1994
1997
2000
2003
TIME (year)

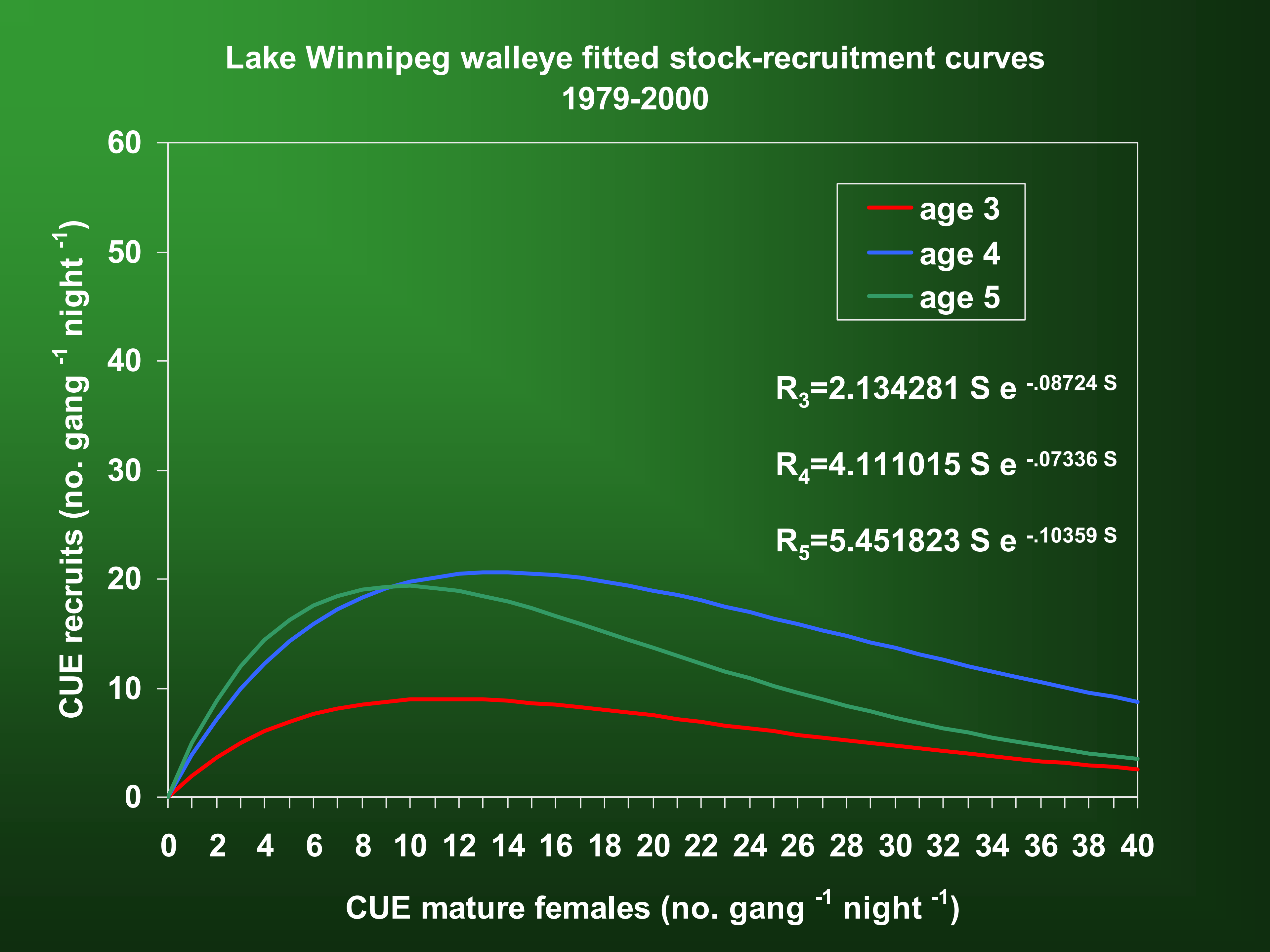

Lake Winnipeg female walleye maturity curves
age at 50% mature
MATURE FREQUENCY
AGE (years)
0
0.2
0.4
0.6
0.8
1
1
2
3
4
5
6
7
8
9
10
11
12
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003

Lake Winnipeg female sauger maturity curves

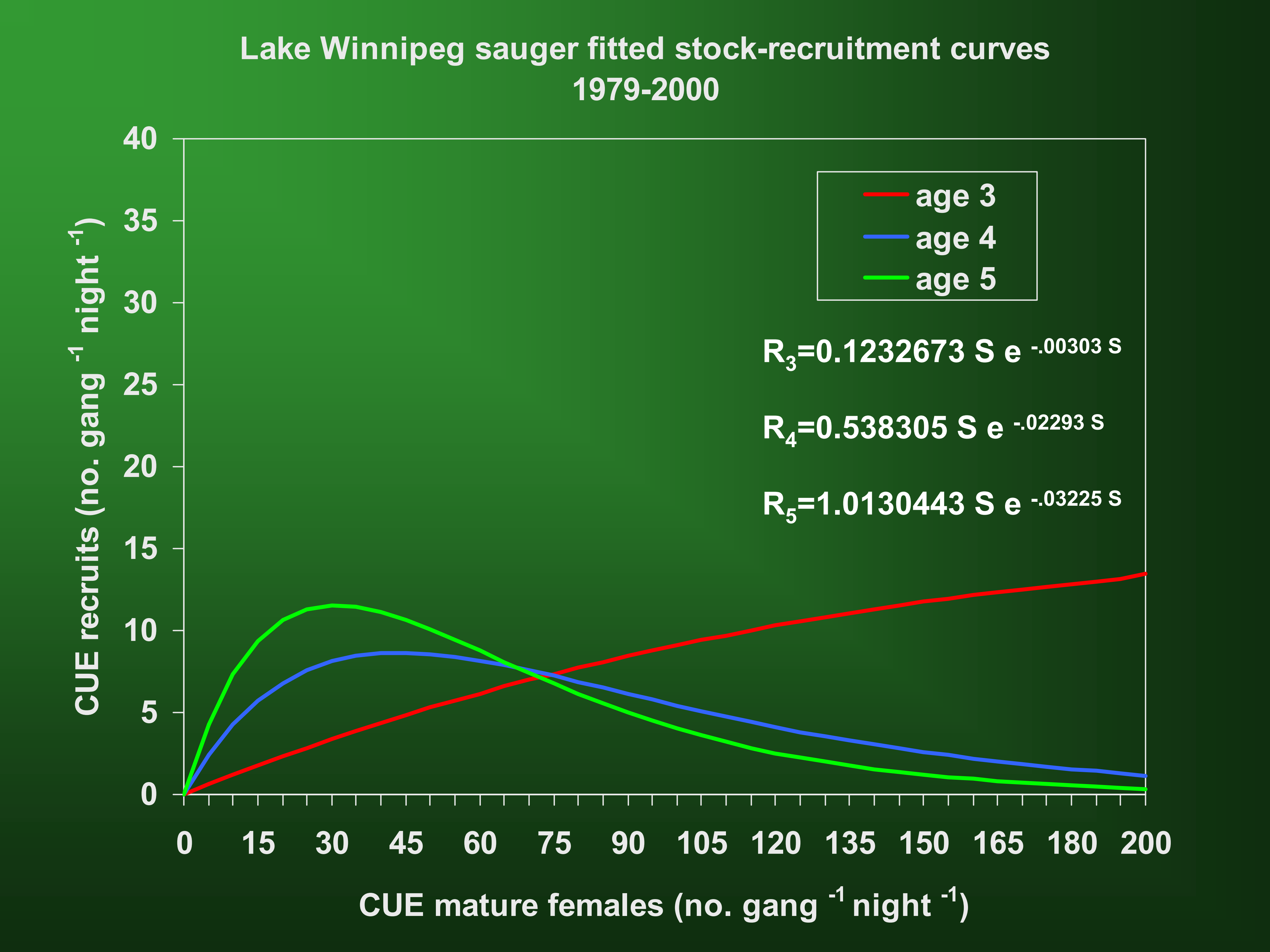



Lake Winnipeg female whitefish maturity curves
MATURE FREQUENCY
0
0.2
0.4
0.6
0.8
1
2
3
4
5
6
7
8
9
10
11
12
AGE (years)
age at 50% mature
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003

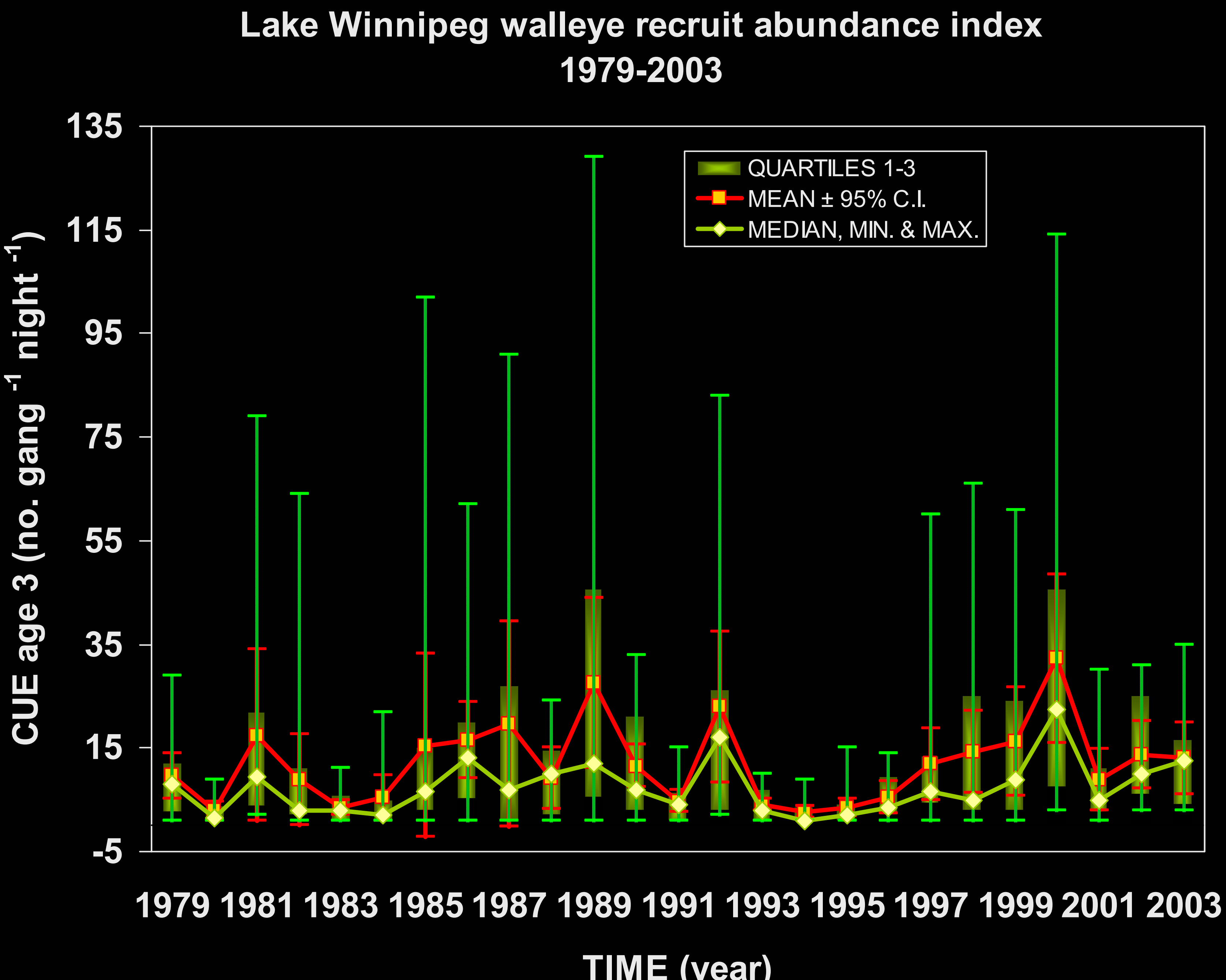

Lake Winnipeg sauger and walleye fecundity
SAUGER
WALLEYE
WALLEYE EGGS=e-8.342856843811 . FL3.171232201875
SAUGER EGGS=e-8.313674449301 . FL3.247289217
NO. EGGS
350000
300000
250000
200000
150000
100000
50000
0
274 308 327 342 375 404 427 448 460 480 496 515 574
FORK LENGTH (mm.)

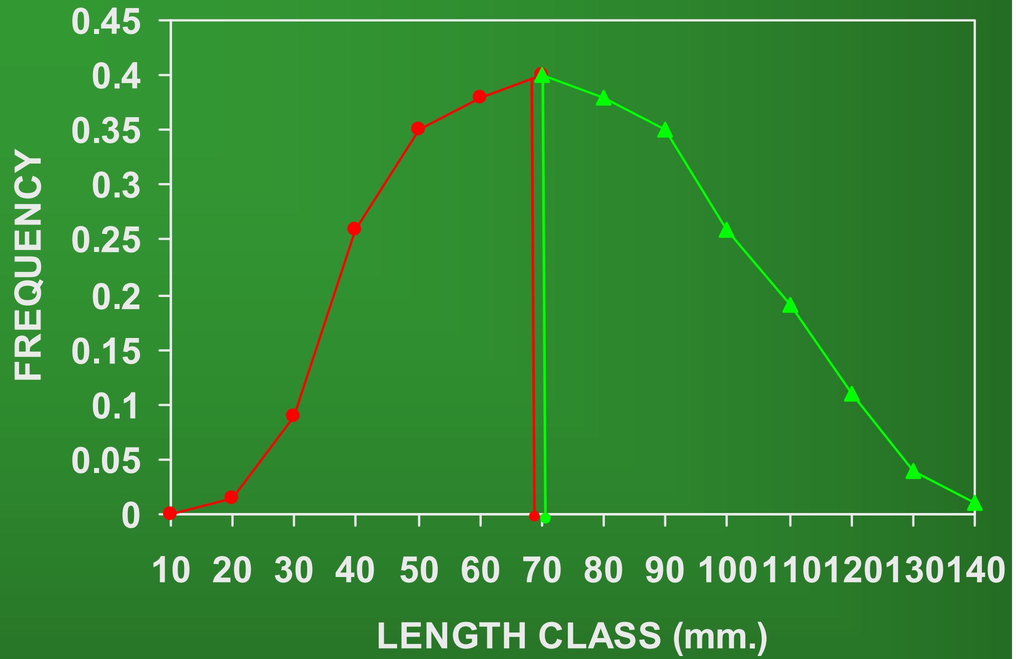


Lake Winnipeg walleye fitted stock-recruitment curves
1979-2000
CUE recruits (no. gang -1 night -1)
CUE mature females (no. gang -1 night -1)
0
10
20
30
40
50
60
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
age 3
age 4
age 5
R_3=2.134281 S e $^{-.08724\ S}$
R_4=4.111015 S e $^{-.07336\ S}$
R_5=5.451823 S e $^{-.10359\ S}$

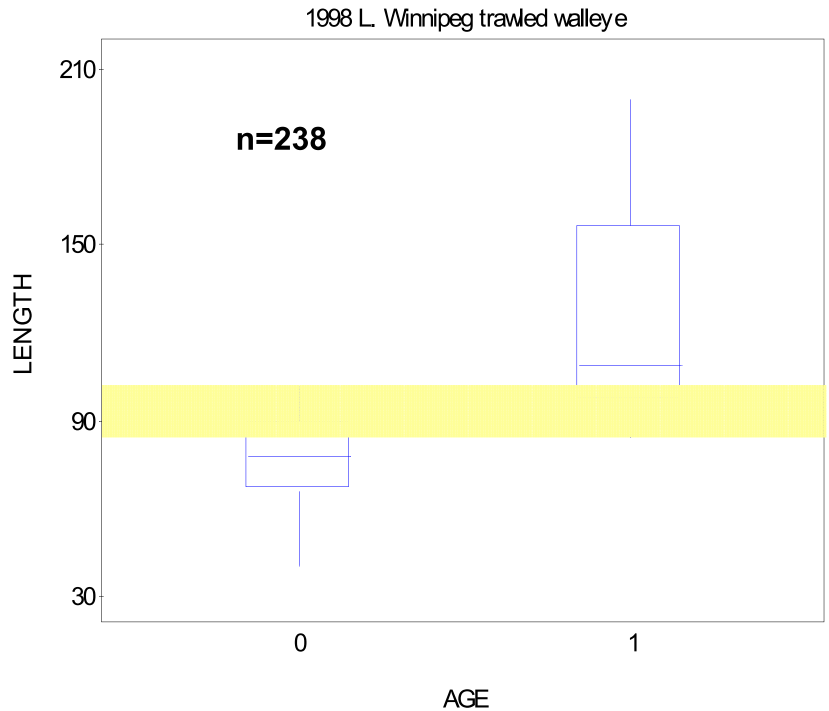


Lake Winnipeg sauger fitted stock-recruitment curves
1979-2000
CUE recruits (no. gang -1 night -1)
CUE mature females (no. gang -1 night -1)
age 3
age 4
age 5
R3=0.1232673 S e -.00303 S
R4=0.538305 S e -.02293 S
R5=1.0130443 S e -.03225 S
0
5
10
15
20
25
30
35
40
0
15
30
45
60
75
90
105
120
135
150
165
180
200

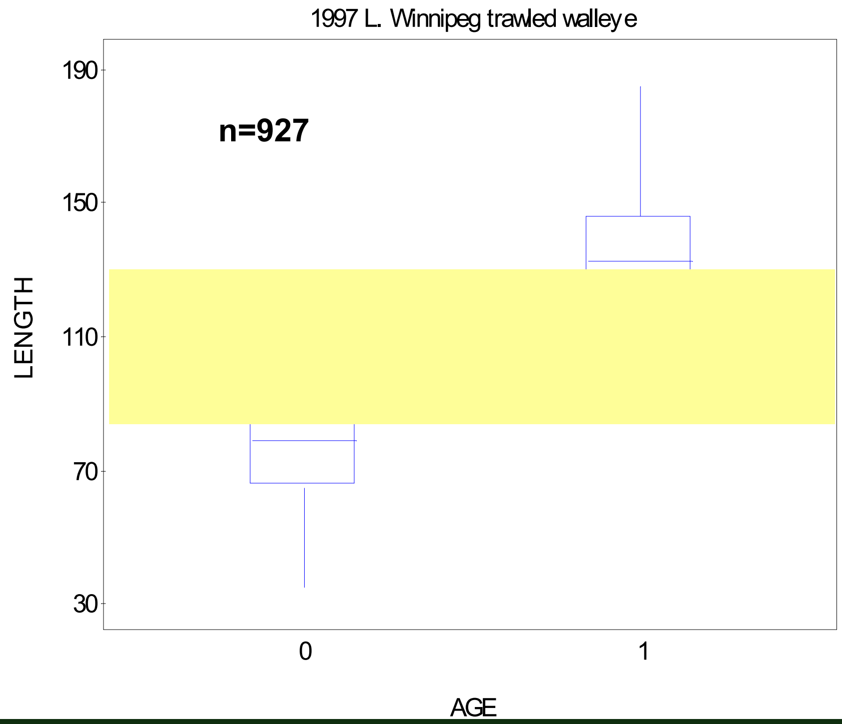

Lake Winnipeg walleye recruit abundance index
1979-2003
QUARTILES 1-3
MEAN ± 95% C.I.
MEDIAN, MIN. & MAX.
CUE age 3 (no. gang -1 night -1)
135
115
95
75
55
35
15
-5
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
TIME (year)



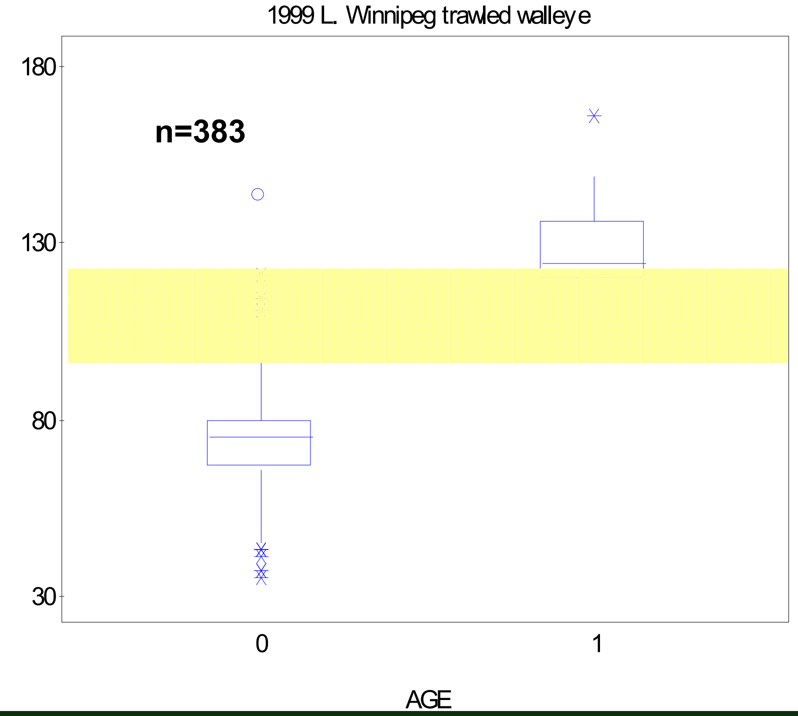
FREQUENCY
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
10 20 30 40 50 60 70 80 90 100 110 120 130 140
LENGTH CLASS (mm.)



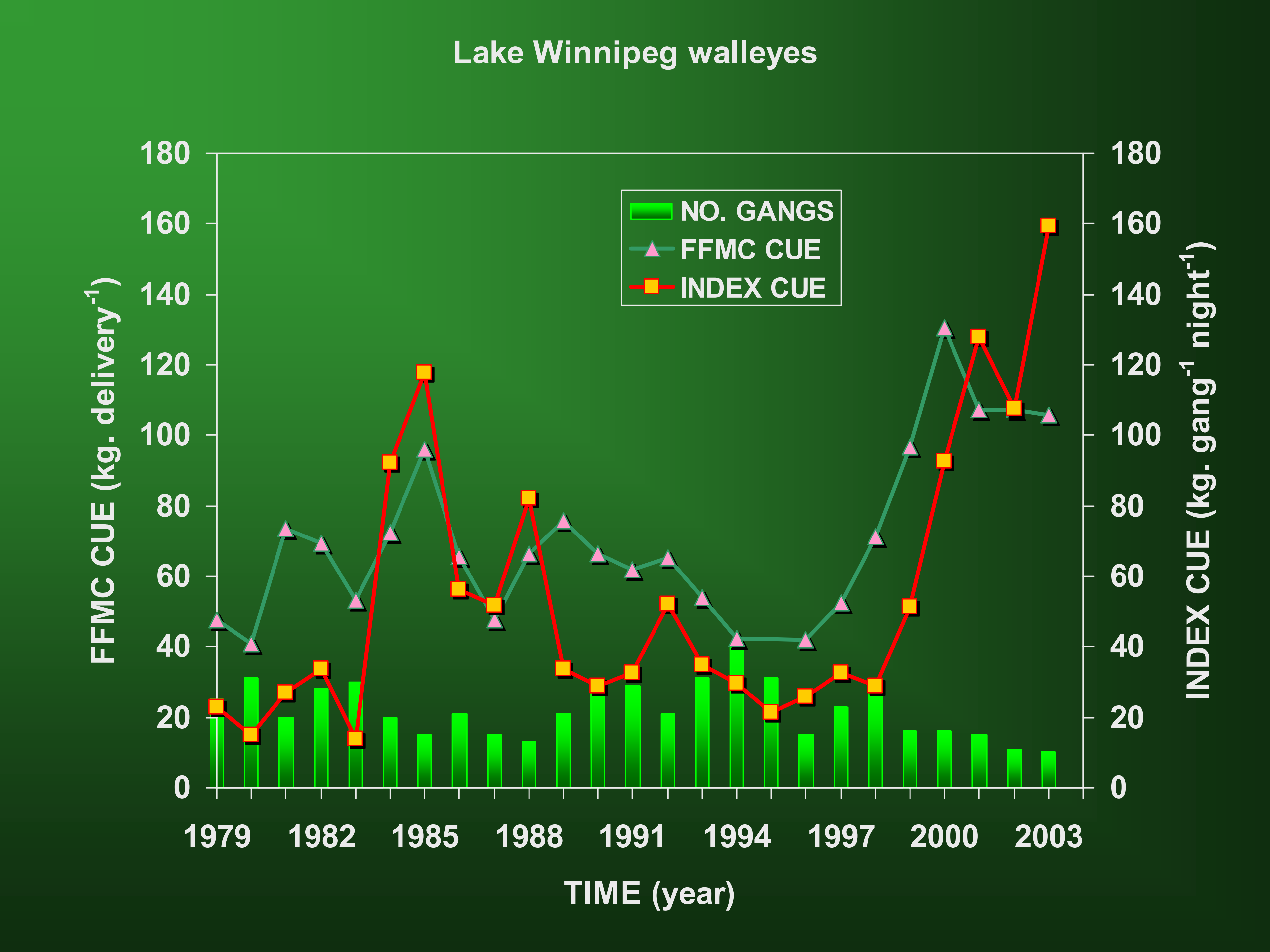
1998 L. Winnipeg trawled walleye
n=238
LENGTH
210
150
90
30
0
1
AGE



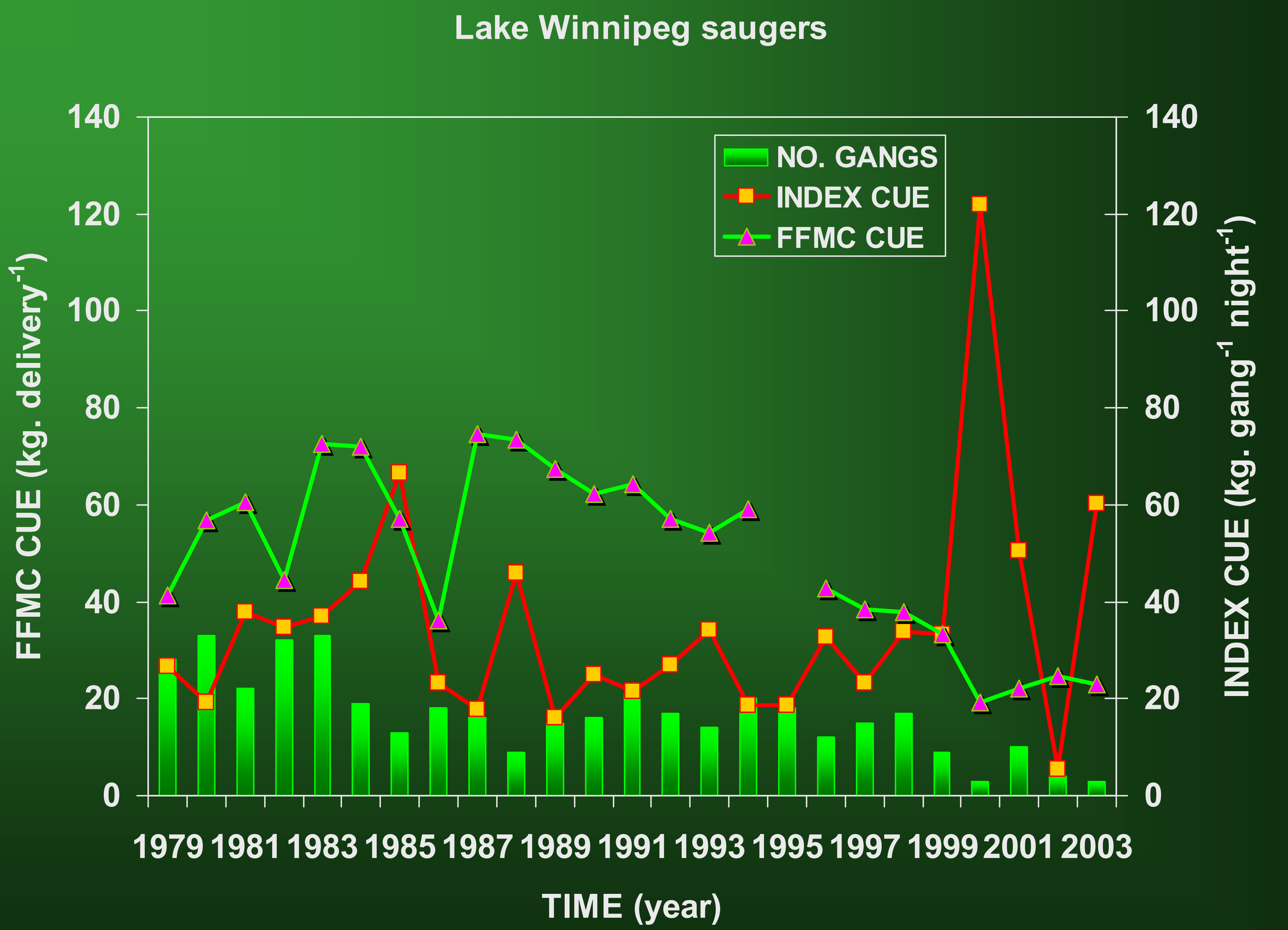
1997 L. Winnipeg trawled walleye
n=927
LENGTH
190
150
110
70
30
0
1
AGE

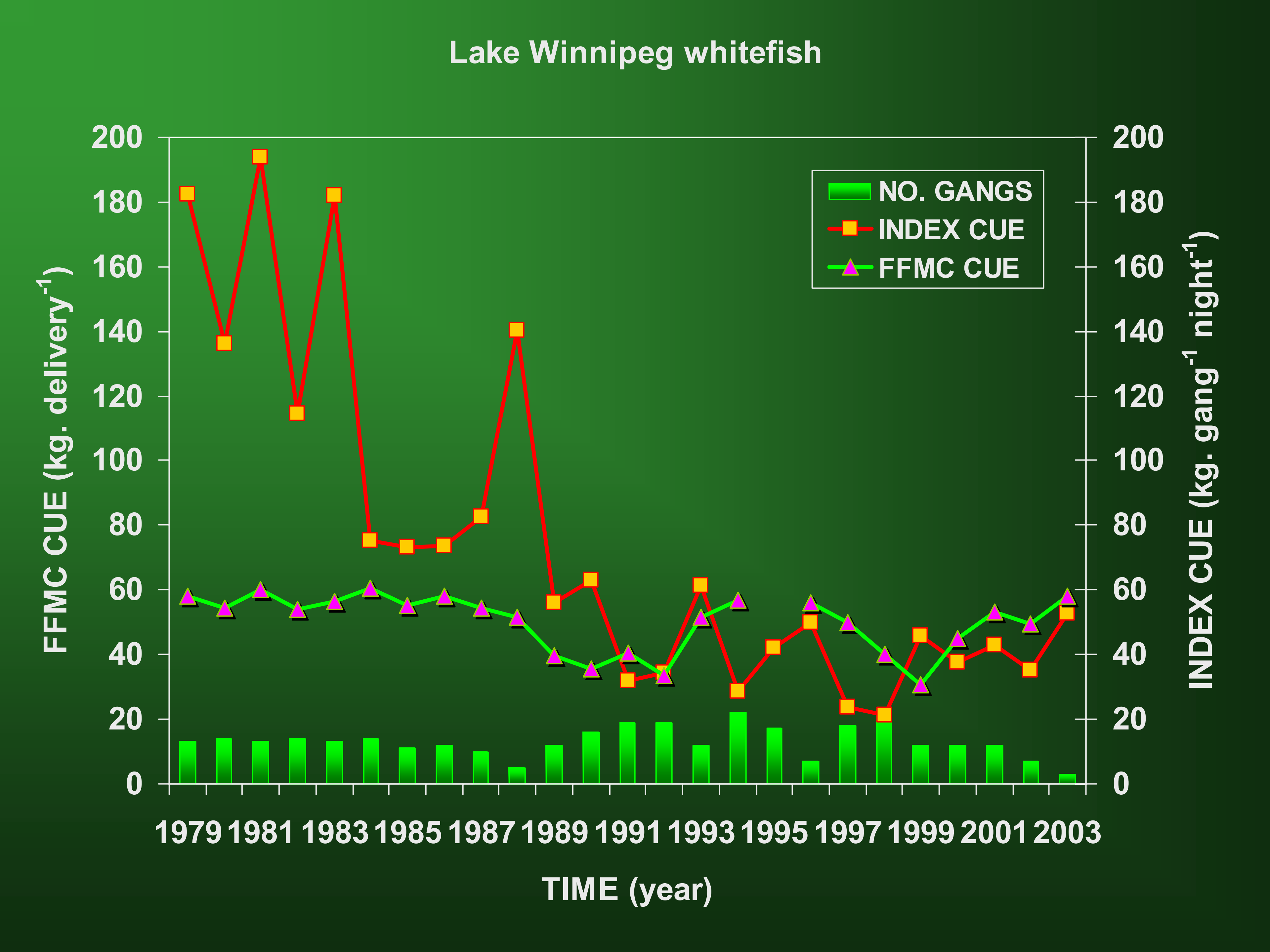


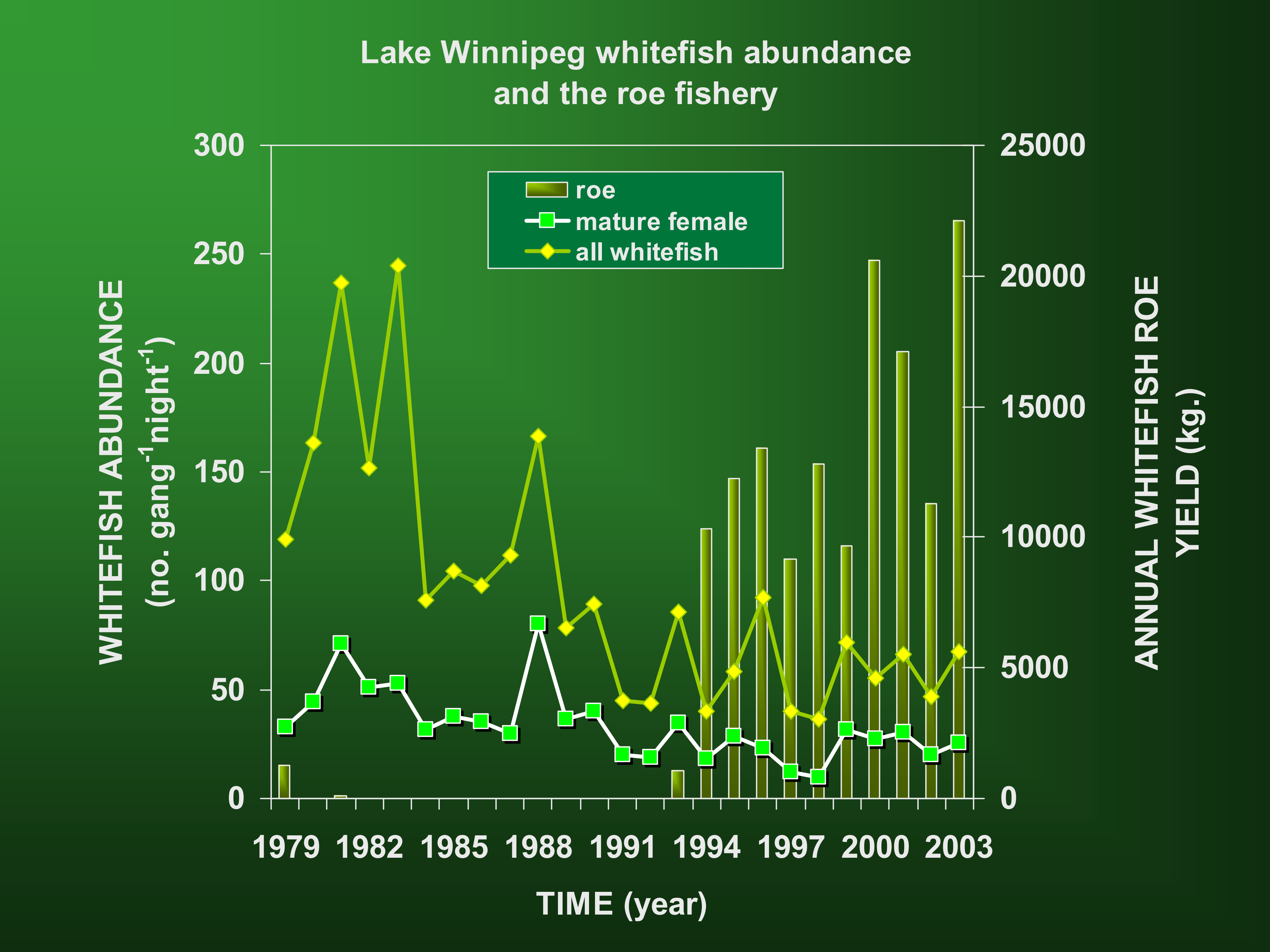
1999 L. Winnipeg trawled walleye
n=383
180
130
80
30
0
1
AGE

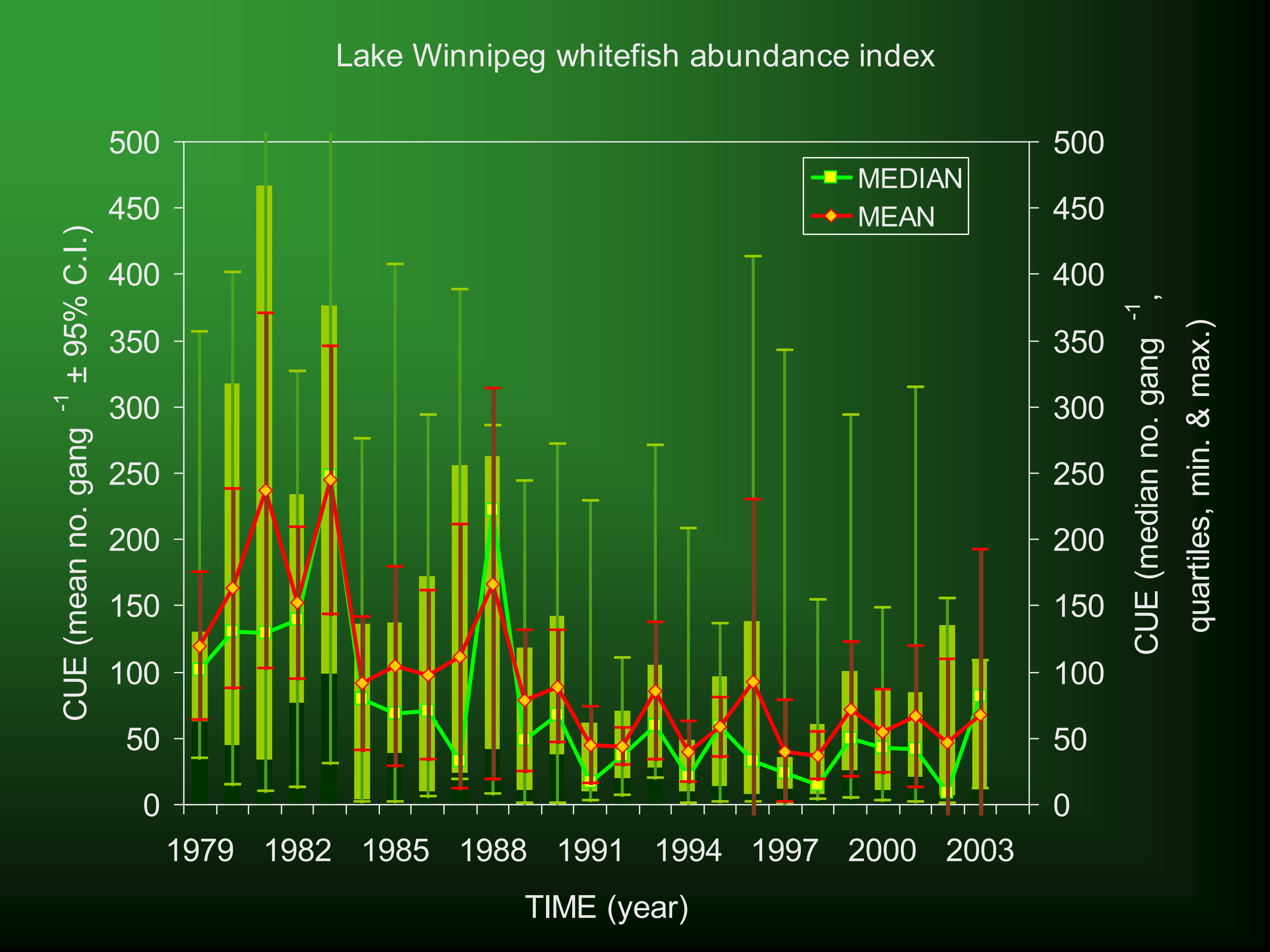


Lake Winnipeg walleyes
NO. GANGS
FFMC CUE
INDEX CUE
FFMC CUE (kg. delivery-1)
INDEX CUE (kg. gang-1 night-1)
0
20
40
60
80
100
120
140
160
180
1979
1982
1985
1988
1991
1994
1997
2000
2003
TIME (year)

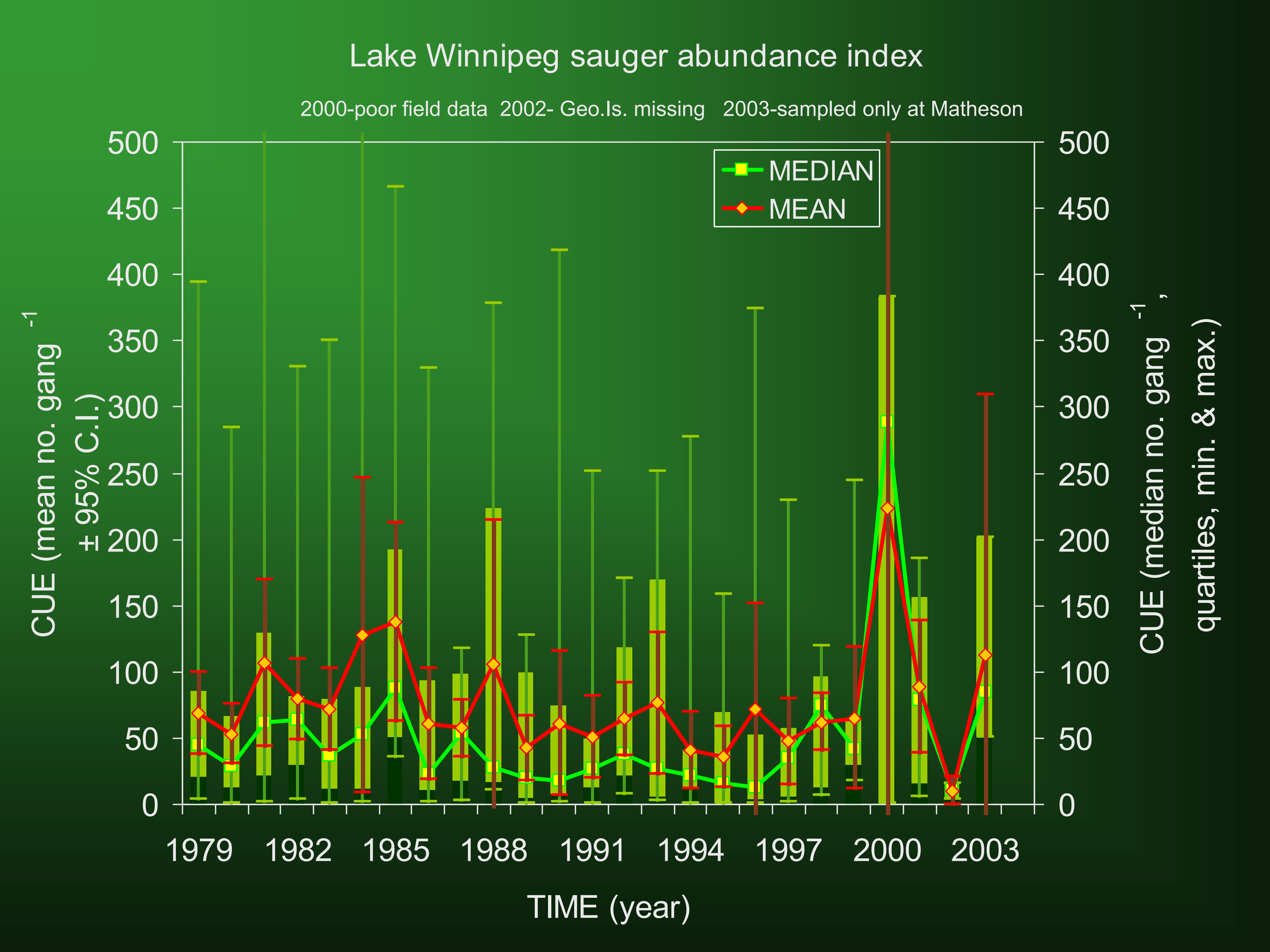

Lake Winnipeg saugers
NO. GANGS
INDEX CUE
FFMC CUE
FFMC CUE (kg. delivery^{-1})
INDEX CUE (kg. gang^{-1} night^{-1})
TIME (year)
0
20
40
60
80
100
120
140
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003


Lake Winnipeg whitefish
NO. GANGS
INDEX CUE
FFMC CUE
FFMC CUE (kg. delivery-1)
INDEX CUE (kg. gang-1 night-1)
TIME (year)
0
20
40
60
80
100
120
140
160
180
200
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003

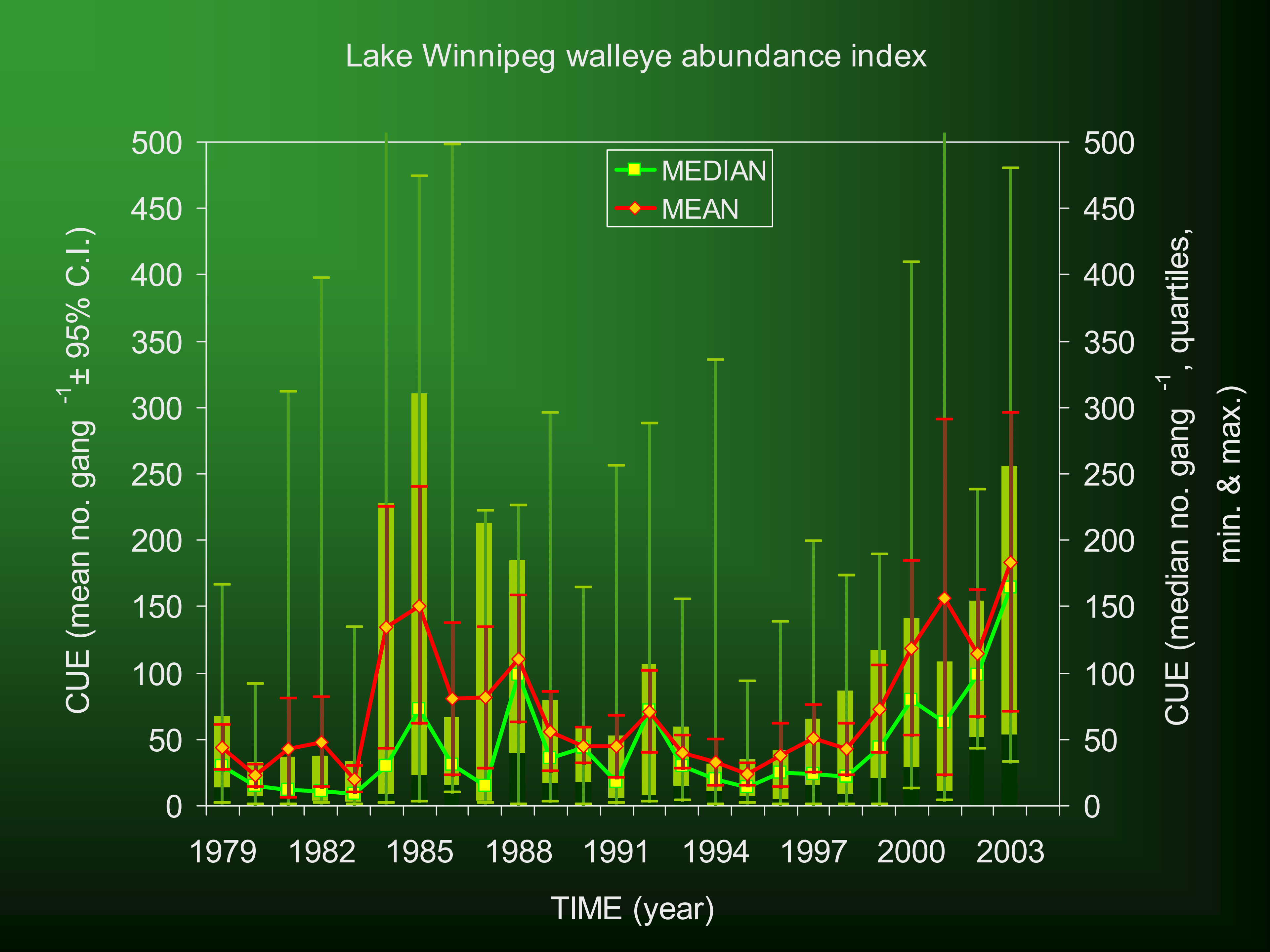

Lake Winnipeg whitefish abundance
and the roe fishery
roe
mature female
all whitefish
WHITEFISH ABUNDANCE
(no. gang-1night-1)
300
250
200
150
100
50
0
25000
20000
15000
10000
5000
0
ANNUAL WHITEFISH ROE
YIELD (kg.)
1979
1982
1985
1988
1991
1994
1997
2000
2003
TIME (year)



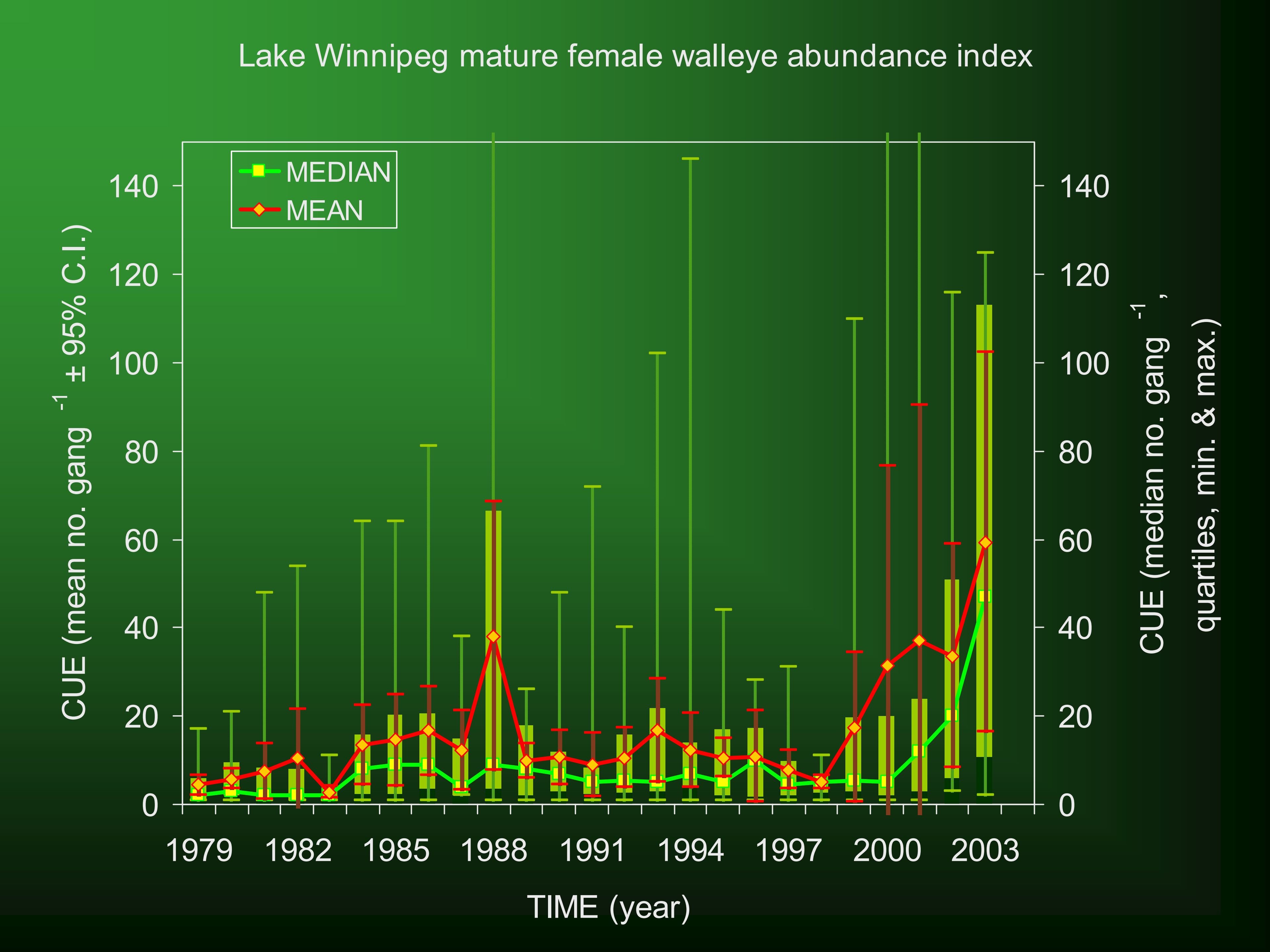
Lake Winnipeg whitefish abundance index
CUE (mean no. gang -1 ± 95% C.I.)
CUE (median no. gang -1, quartiles, min. & max.)
MEDIAN
MEAN
0
50
100
150
200
250
300
350
400
450
500
1979
1982
1985
1988
1991
1994
1997
2000
2003
TIME (year)



Lake Winnipeg sauger abundance index
2000-poor field data 2002- Geo.Is. missing 2003-sampled only at Matheson
MEDIAN
MEAN
CUE (mean no. gang -1 ± 95% C.I.)
CUE (median no. gang -1, quartiles, min. & max.)
TIME (year)
0
50
100
150
200
250
300
350
400
450
500
1979
1982
1985
1988
1991
1994
1997
2000
2003

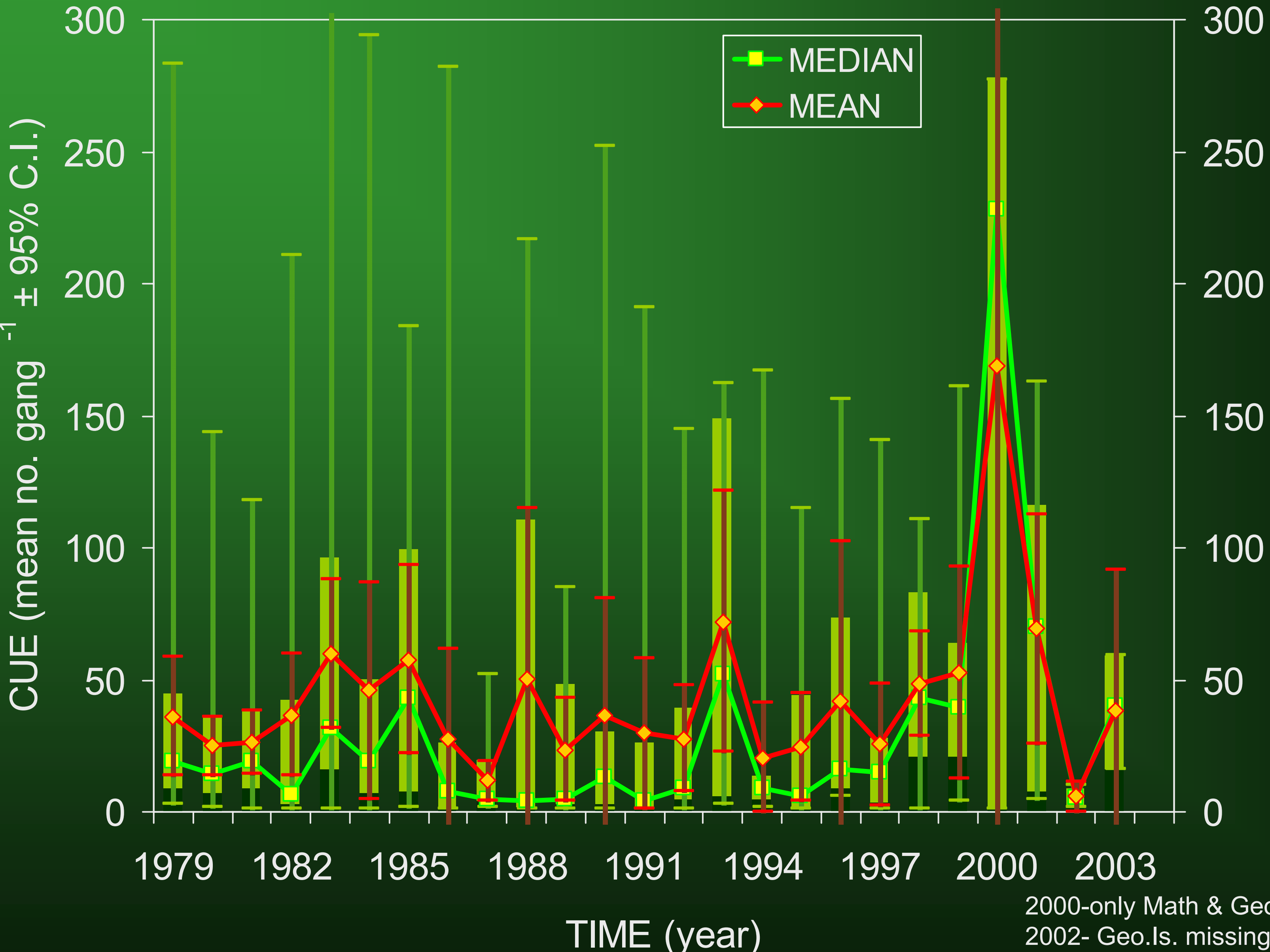


Lake Winnipeg walleye abundance index
MEDIAN
MEAN
CUE (mean no. gang -1 ± 95% C.I.)
CUE (median no. gang -1, quartiles, min. & max.)
TIME (year)
0
50
100
150
200
250
300
350
400
450
500
1979
1982
1985
1988
1991
1994
1997
2000
2003

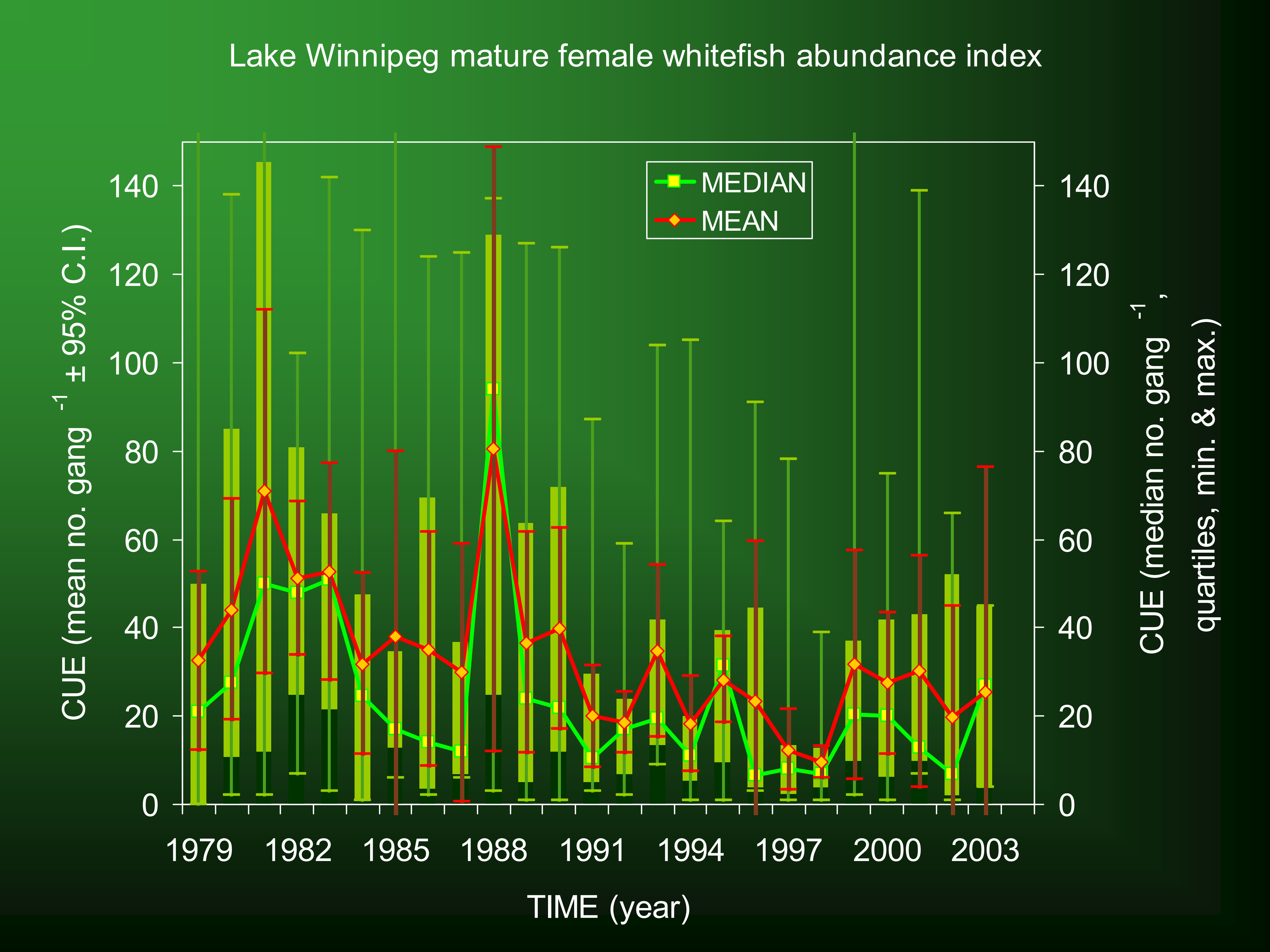


Lake Winnipeg mature female walleye abundance index
MEDIAN
MEAN
CUE (mean no. gang -1 ± 95% C.I.)
CUE (median no. gang -1, quartiles, min. & max.)
0
20
40
60
80
100
120
140
1979
1982
1985
1988
1991
1994
1997
2000
2003
TIME (year)

Lake Winnipeg mature female sauger abundance index

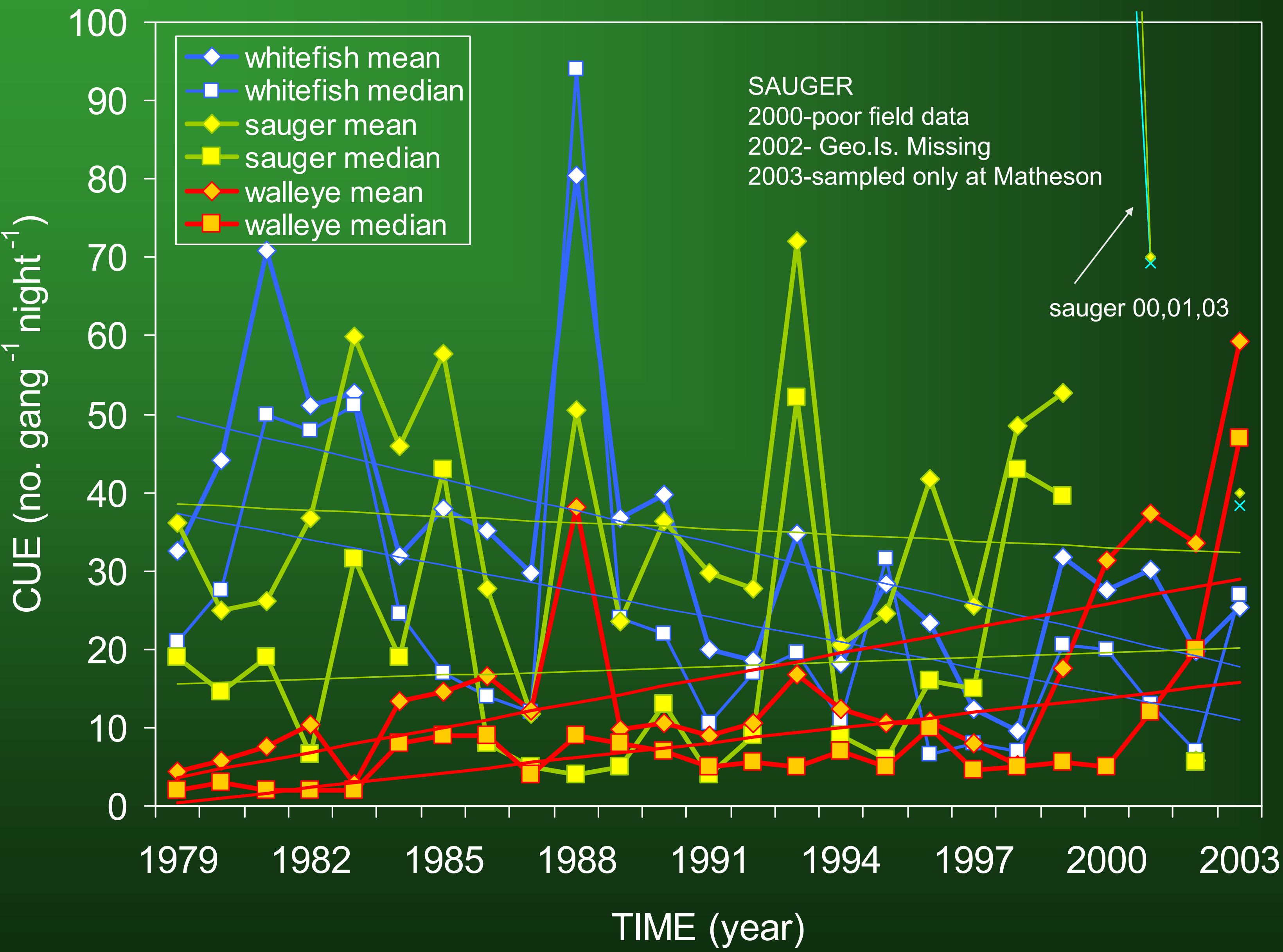


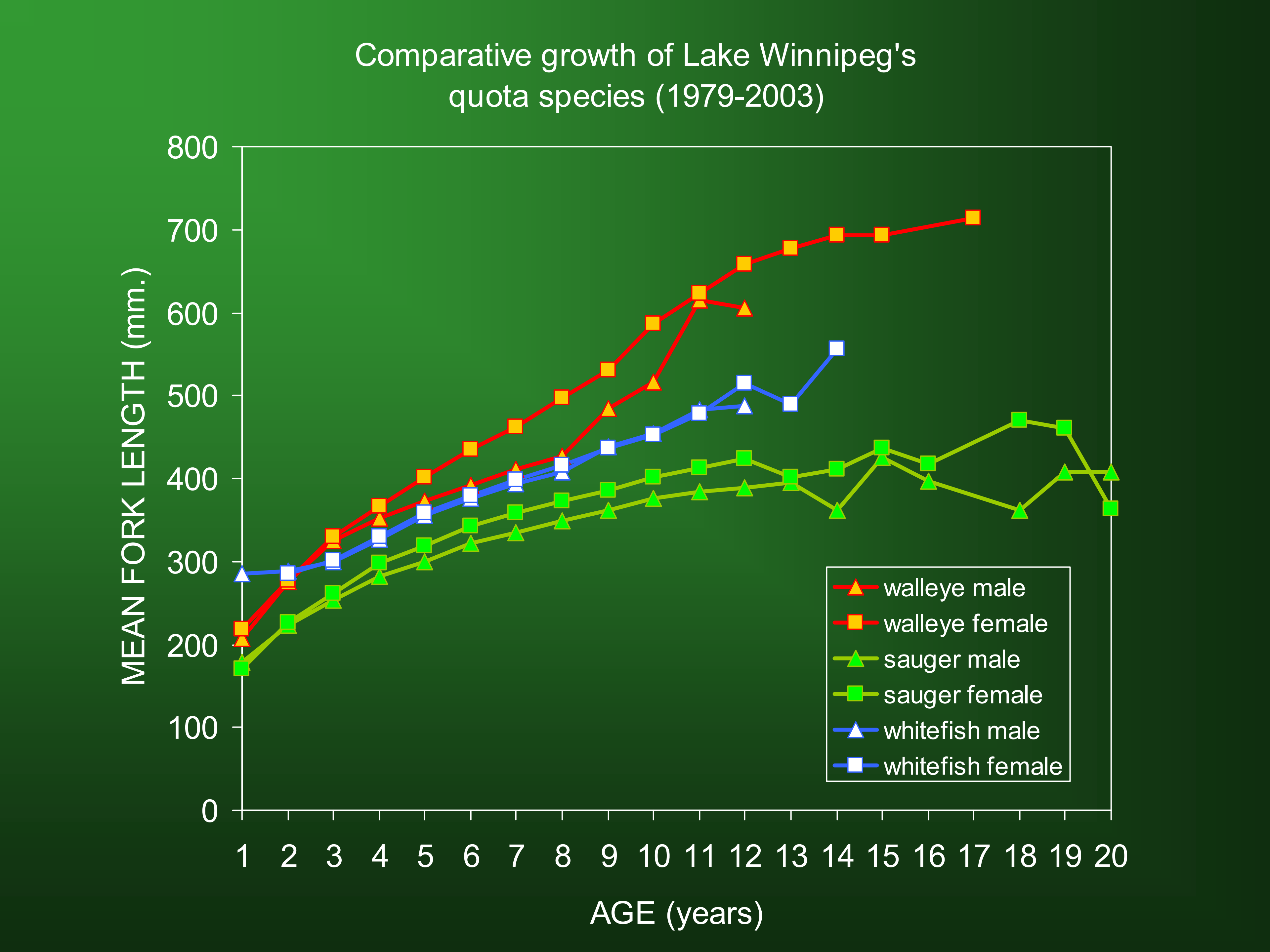
2000-only Math & Geo.Is.
2002- Geo.Is. missing, only 41 fish
2003-only Matheson

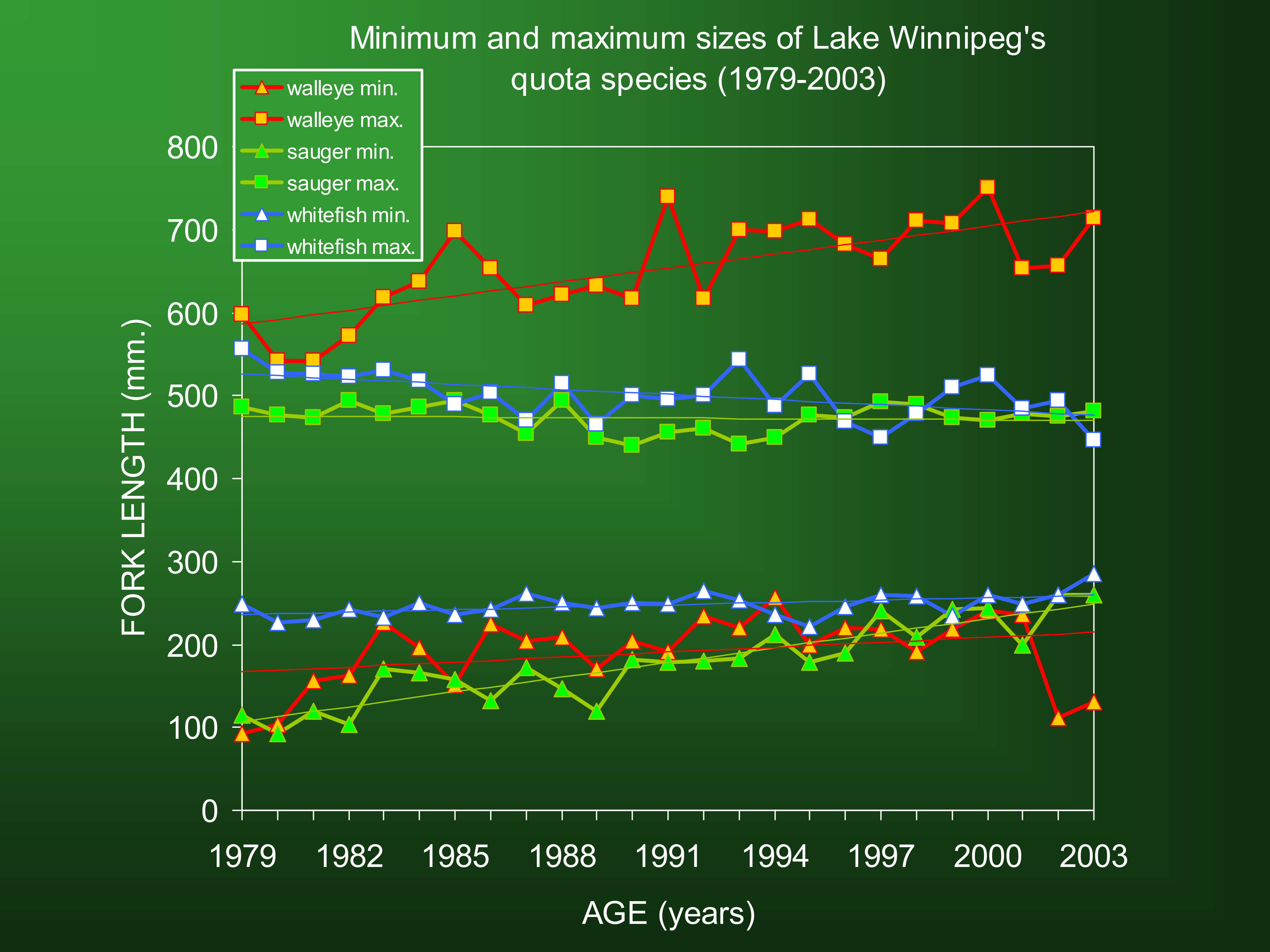


Lake Winnipeg mature female whitefish abundance index
MEDIAN
MEAN
CUE (mean no. gang -1 ± 95% C.I.)
CUE (median no. gang -1, quartiles, min. & max.)
0
20
40
60
80
100
120
140
1979
1982
1985
1988
1991
1994
1997
2000
2003
TIME (year)

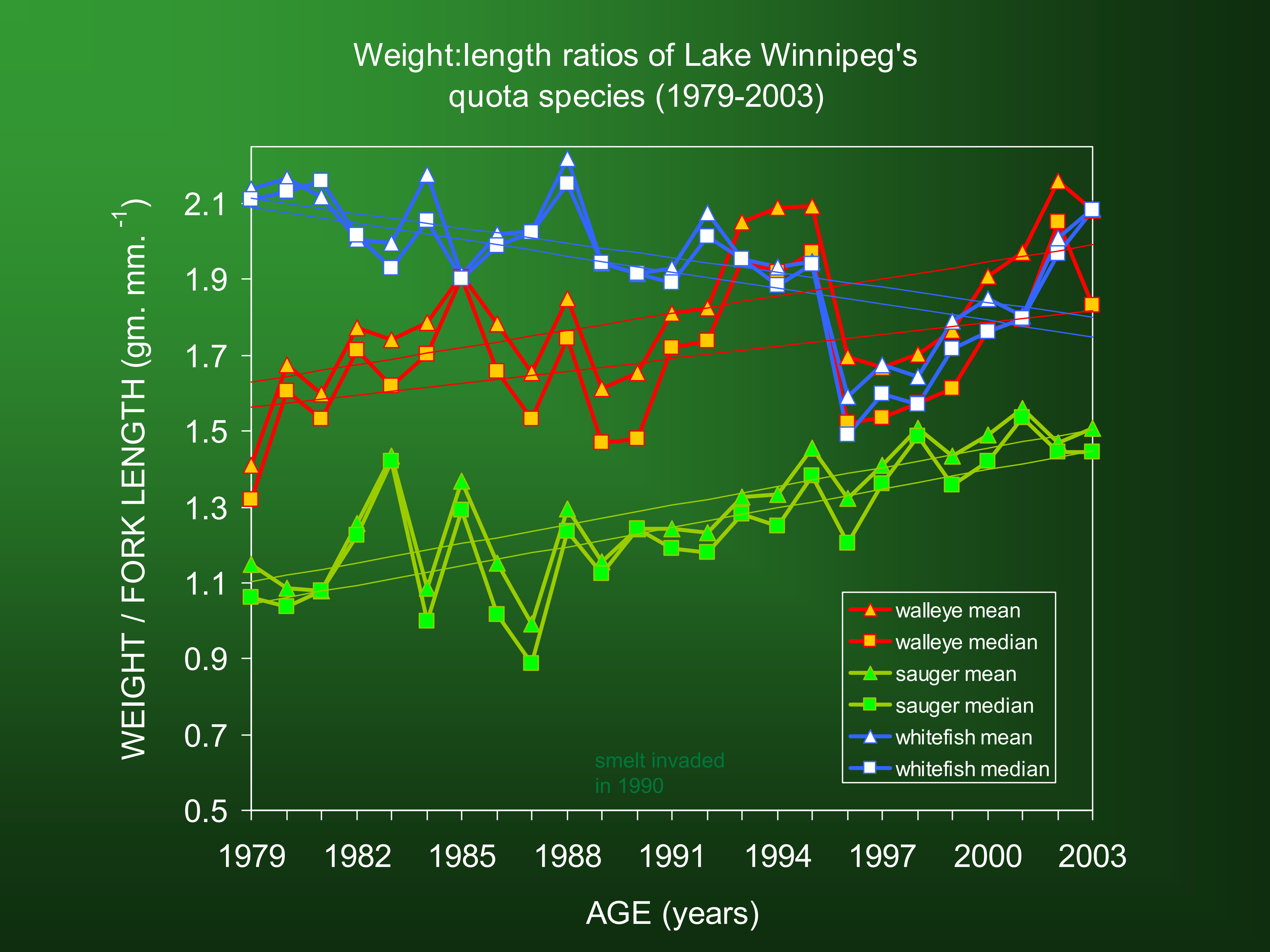
Lake Winnipeg mature female abundance comparison



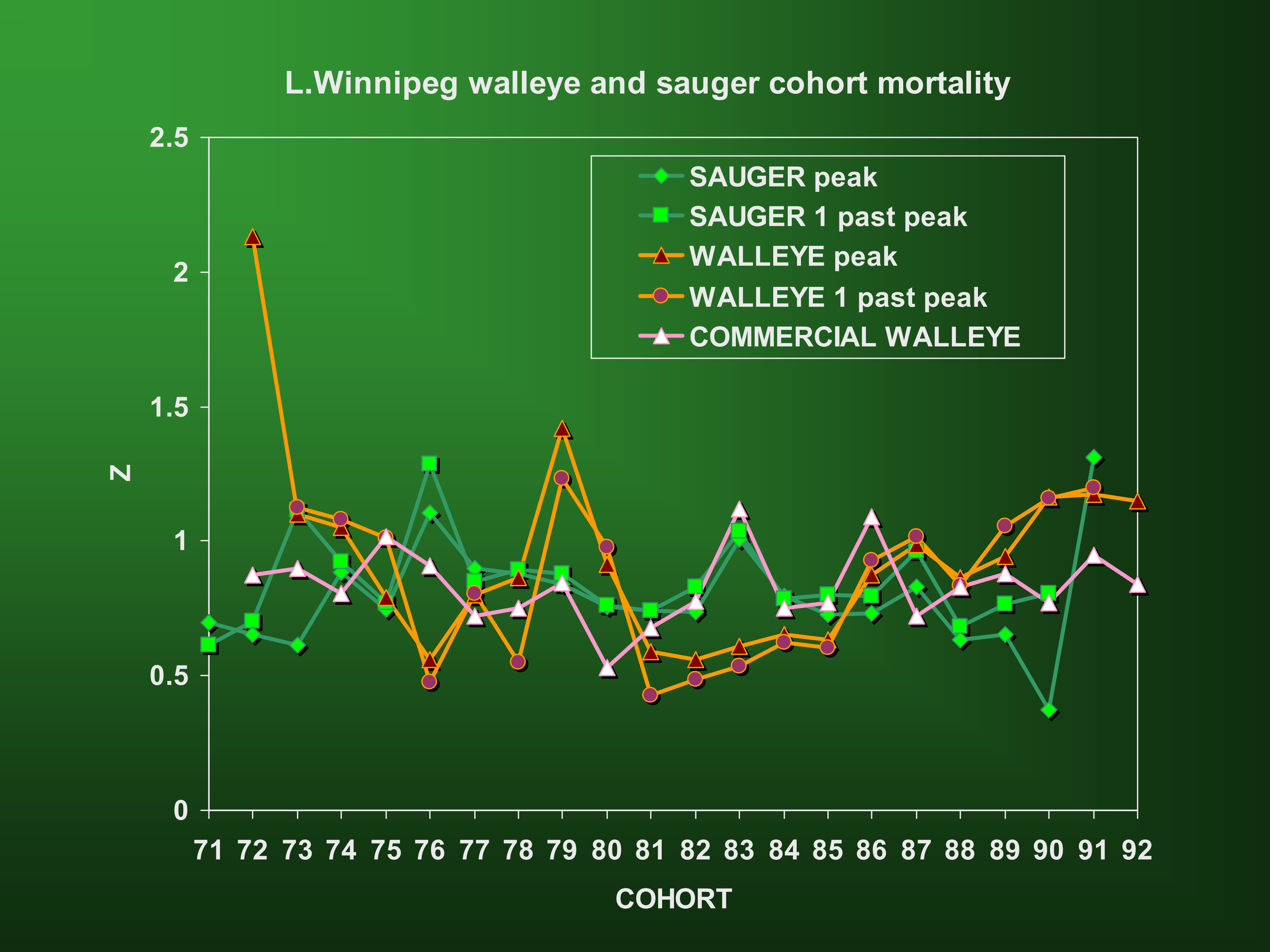

Comparative growth of Lake Winnipeg's
quota species (1979-2003)
MEAN FORK LENGTH (mm.)
0
100
200
300
400
500
600
700
800
AGE (years)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
walleye male
walleye female
sauger male
sauger female
whitefish male
whitefish female

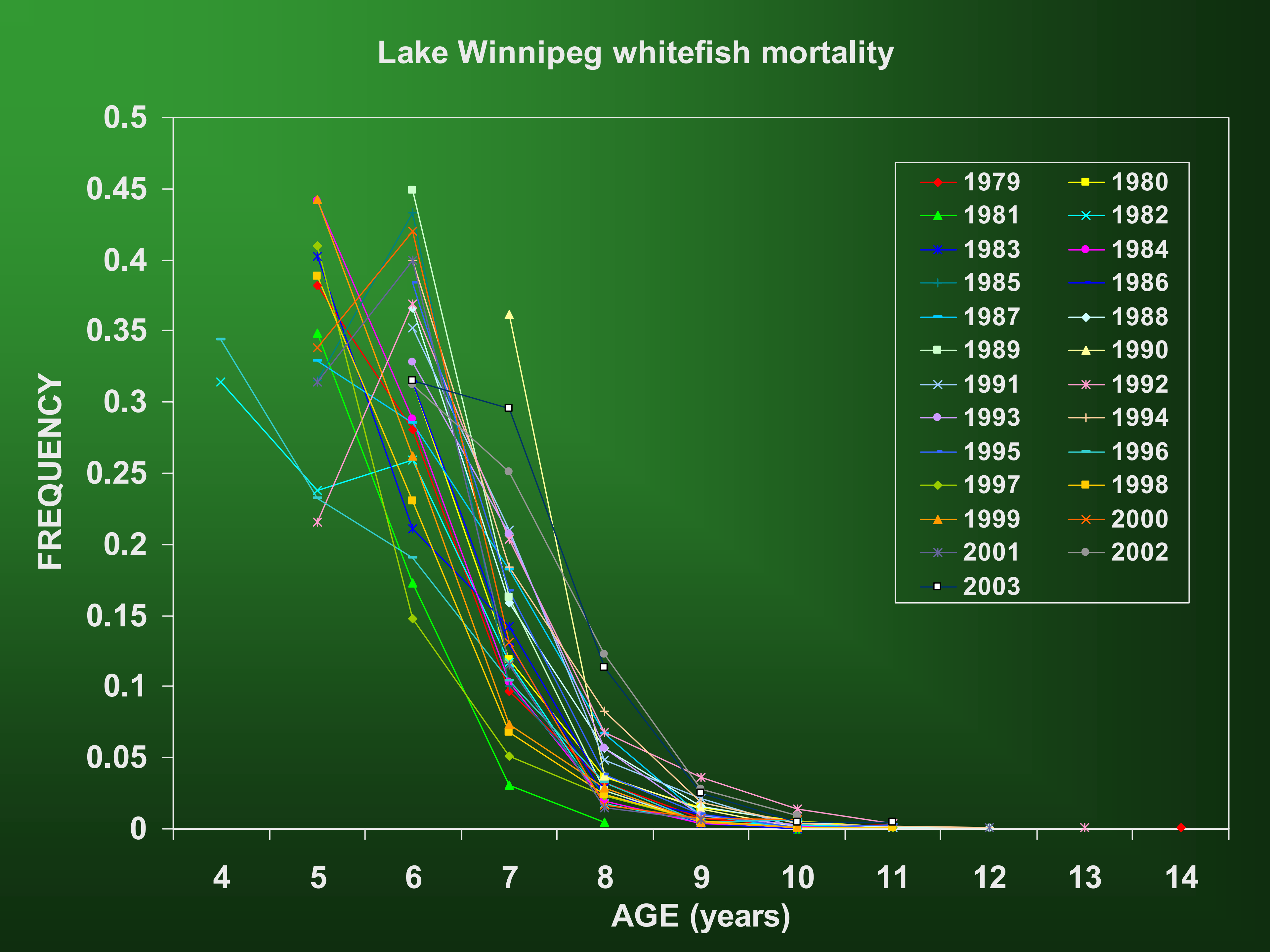


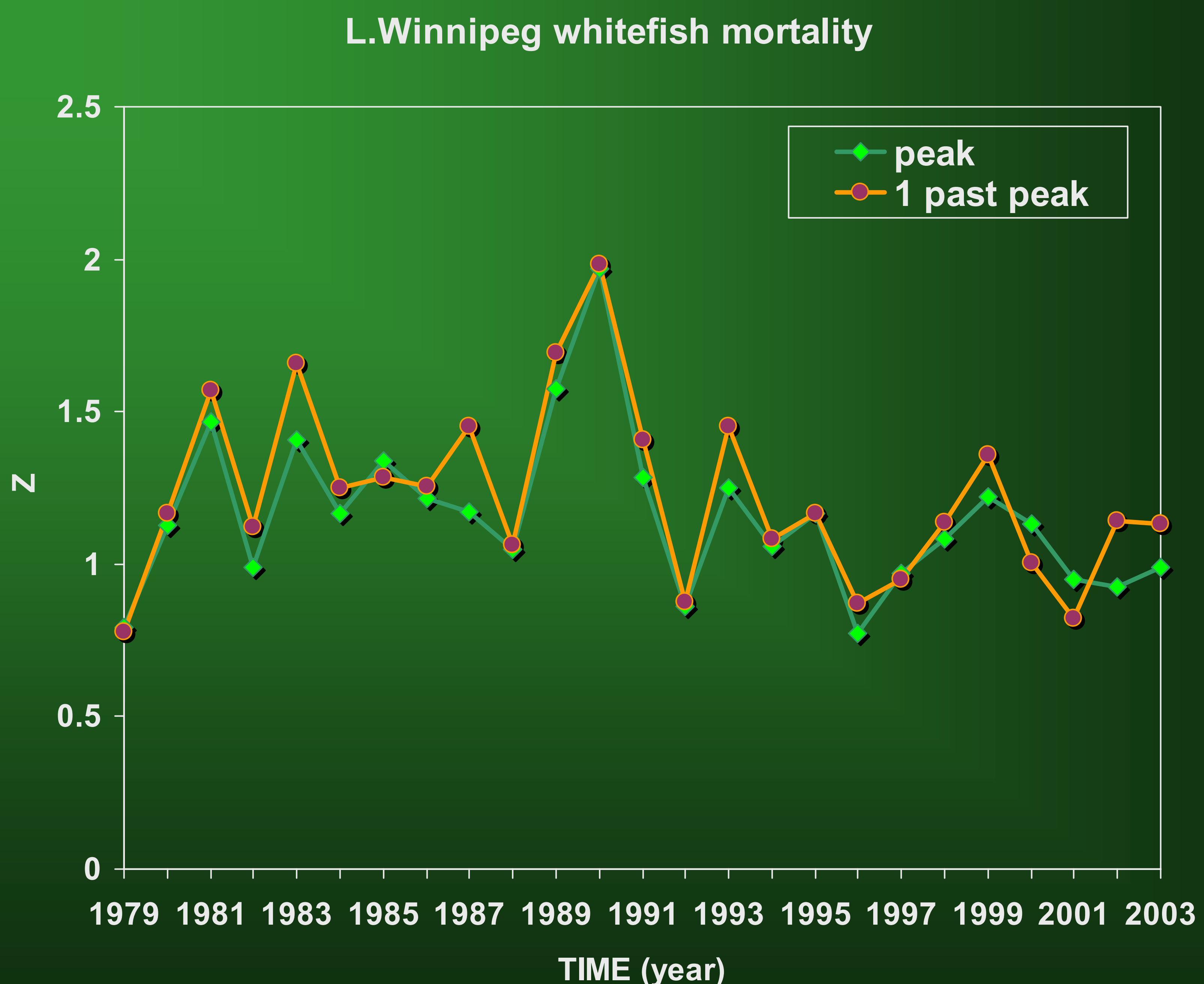
Minimum and maximum sizes of Lake Winnipeg's quota species (1979-2003)
walleye min.
walleye max.
sauger min.
sauger max.
whitefish min.
whitefish max.
FORK LENGTH (mm.)
800
700
600
500
400
300
200
100
0
1979
1982
1985
1988
1991
1994
1997
2000
2003
AGE (years)



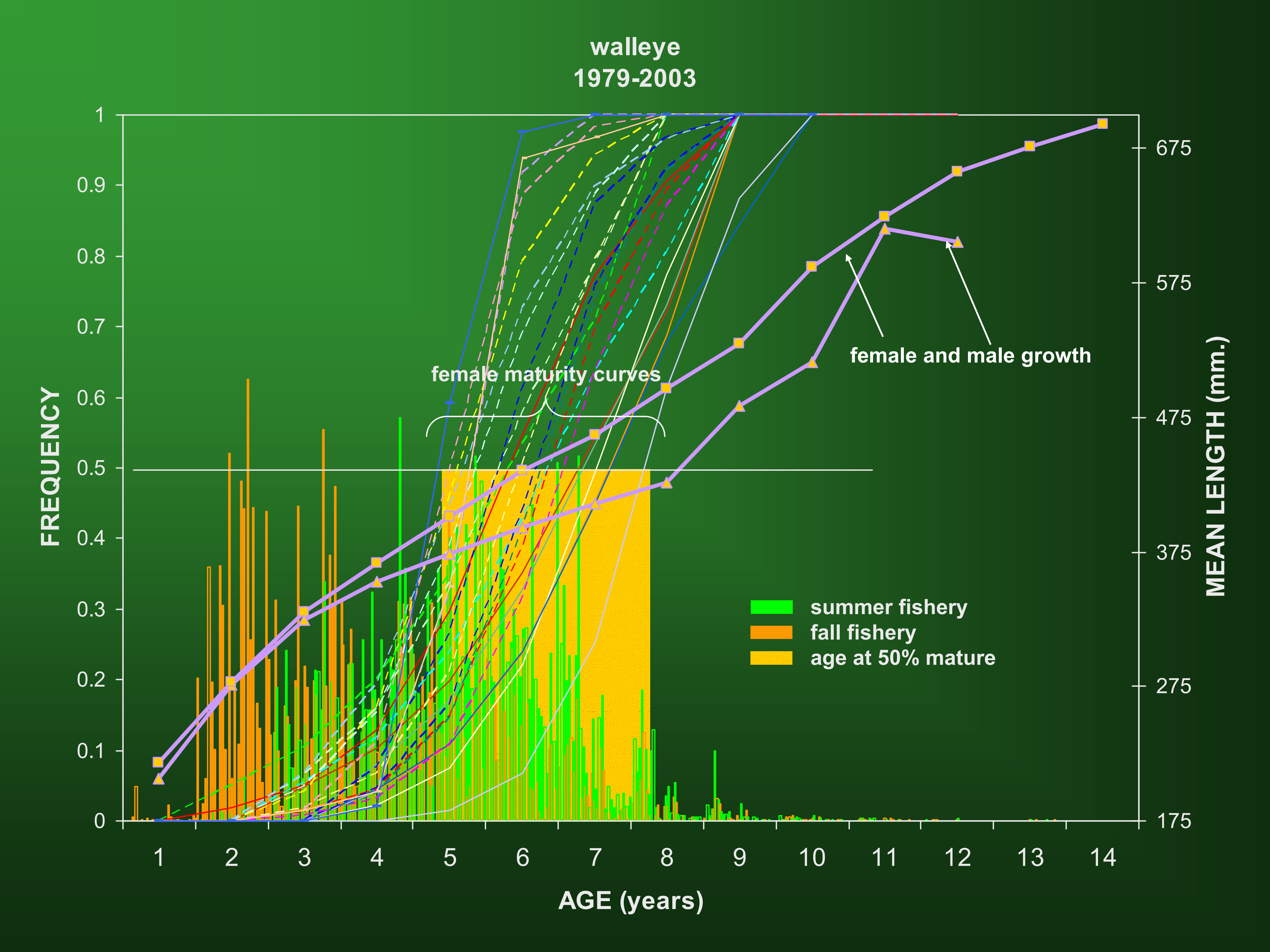
Weight:length ratios of Lake Winnipeg's
quota species (1979-2003)
WEIGHT / FORK LENGTH (gm. mm. -1)
2.1
1.9
1.7
1.5
1.3
1.1
0.9
0.7
0.5
1979
1982
1985
1988
1991
1994
1997
2000
2003
AGE (years)
smelt invaded
in 1990
walleye mean
walleye median
sauger mean
sauger median
whitefish mean
whitefish median

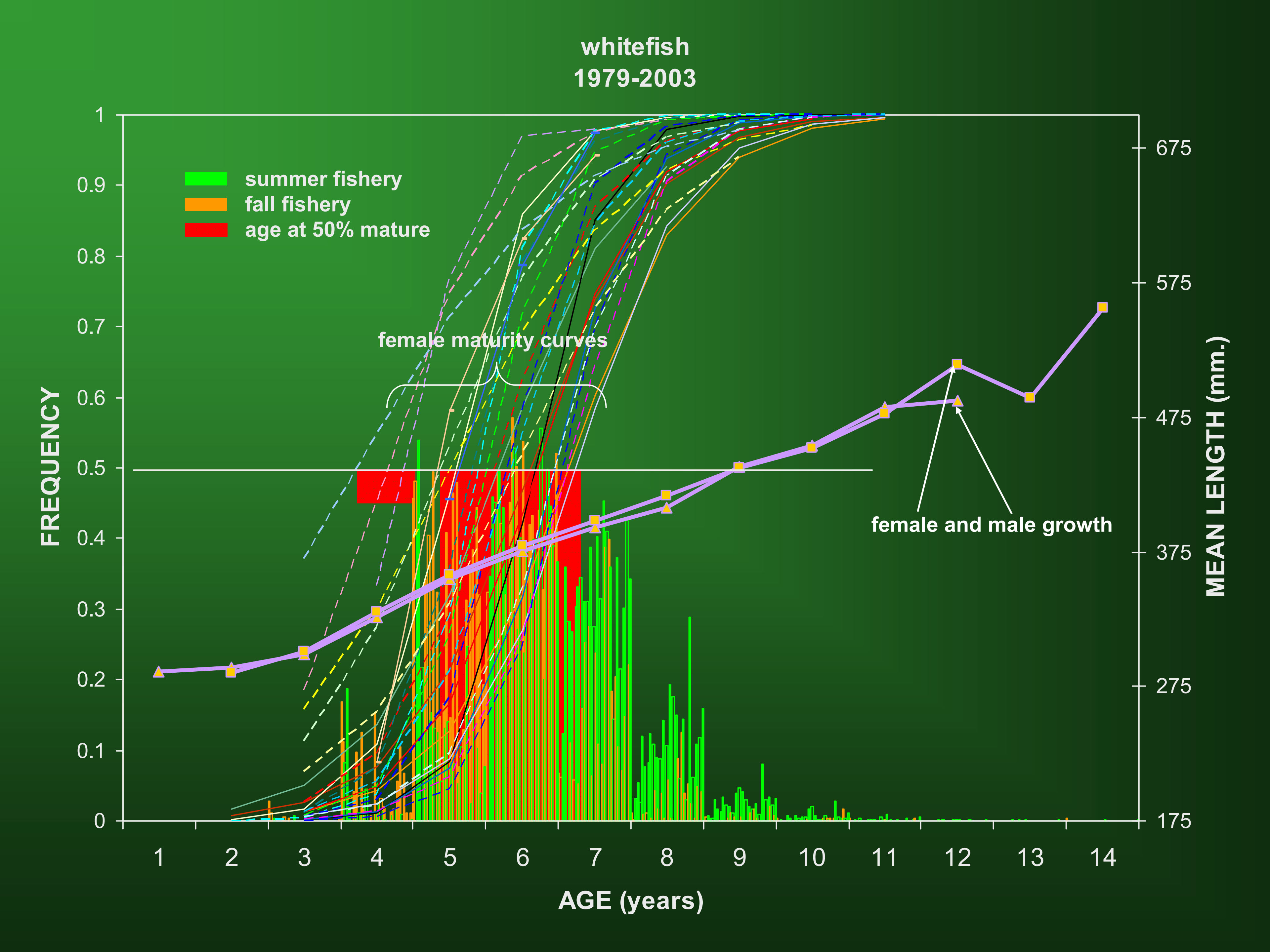

L.Winnipeg walleye and sauger cohort mortality
2.5
2
1.5
1
0.5
0
Z
SAUGER peak
SAUGER 1 past peak
WALLEYE peak
WALLEYE 1 past peak
COMMERCIAL WALLEYE
71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92
COHORT


Lake Winnipeg whitefish mortality
FREQUENCY
AGE (years)
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
4
5
6
7
8
9
10
11
12
13
14
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003

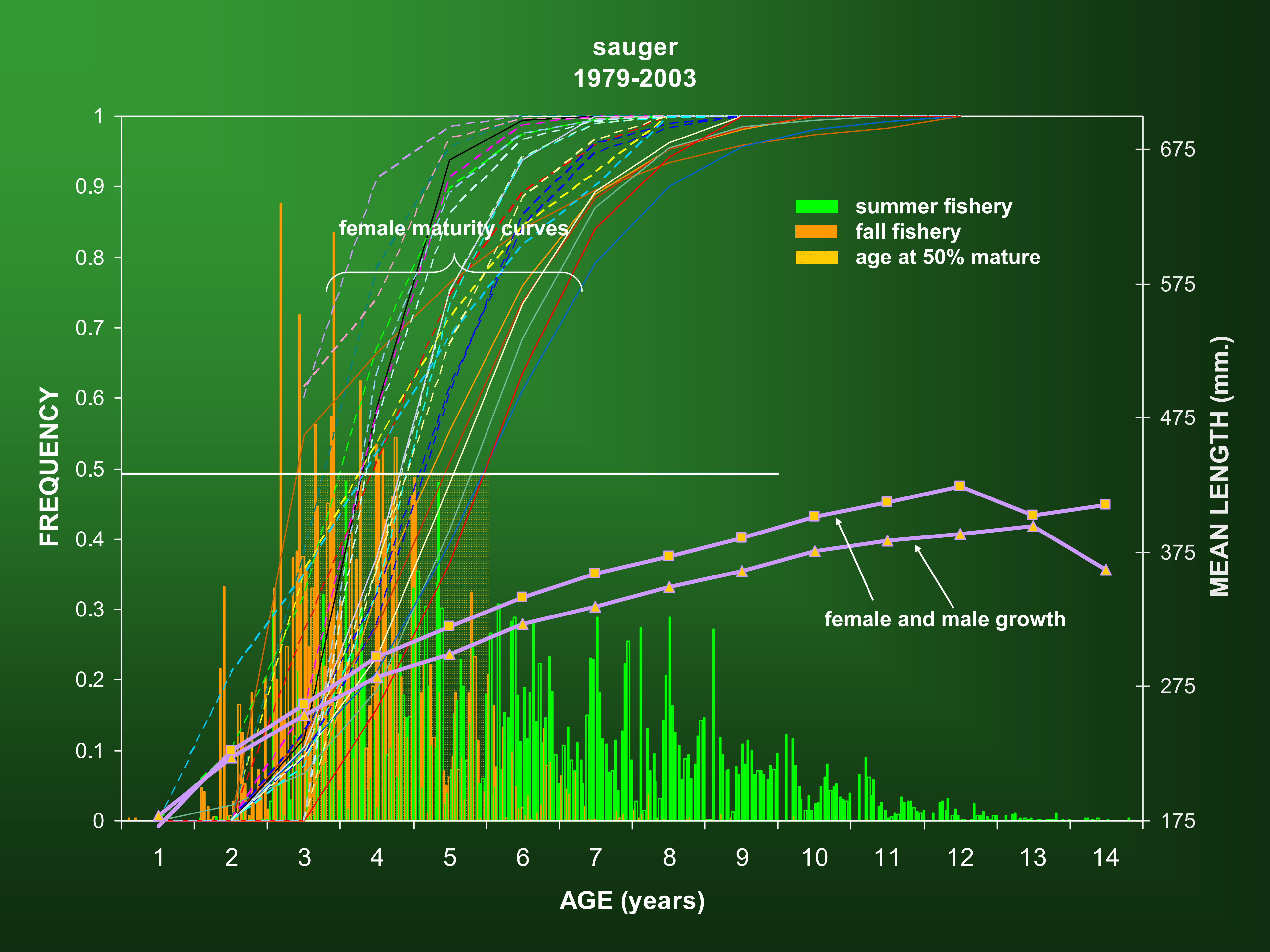


L.Winnipeg whitefish mortality
peak
1 past peak
2.5
2
1.5
1
0.5
0
Z
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
TIME (year)

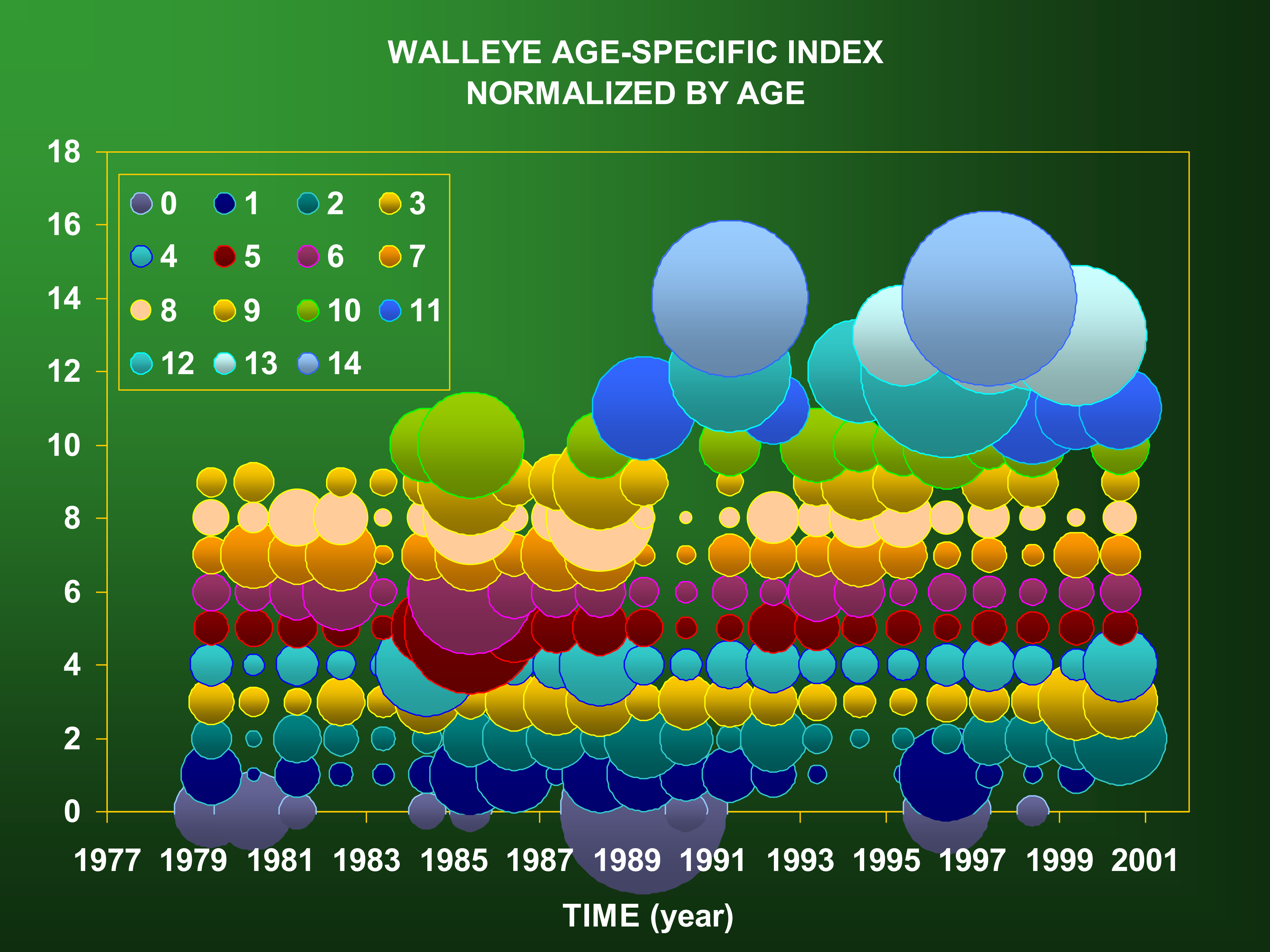

walleye
1979-2003
FREQUENCY
MEAN LENGTH (mm.)
AGE (years)
female maturity curves
female and male growth
summer fishery
fall fishery
age at 50% mature
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
175
275
375
475
575
675
1
2
3
4
5
6
7
8
9
10
11
12
13
14

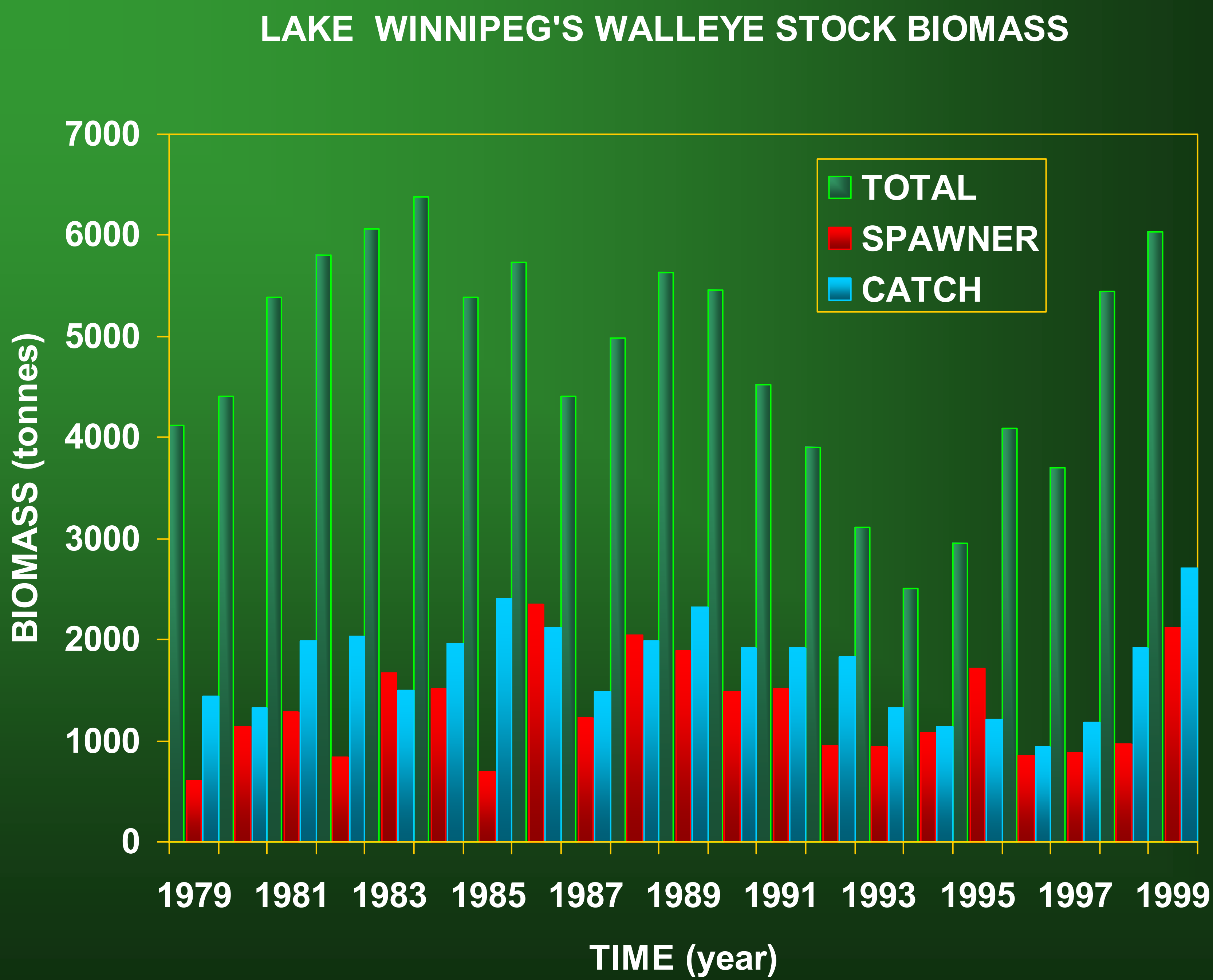


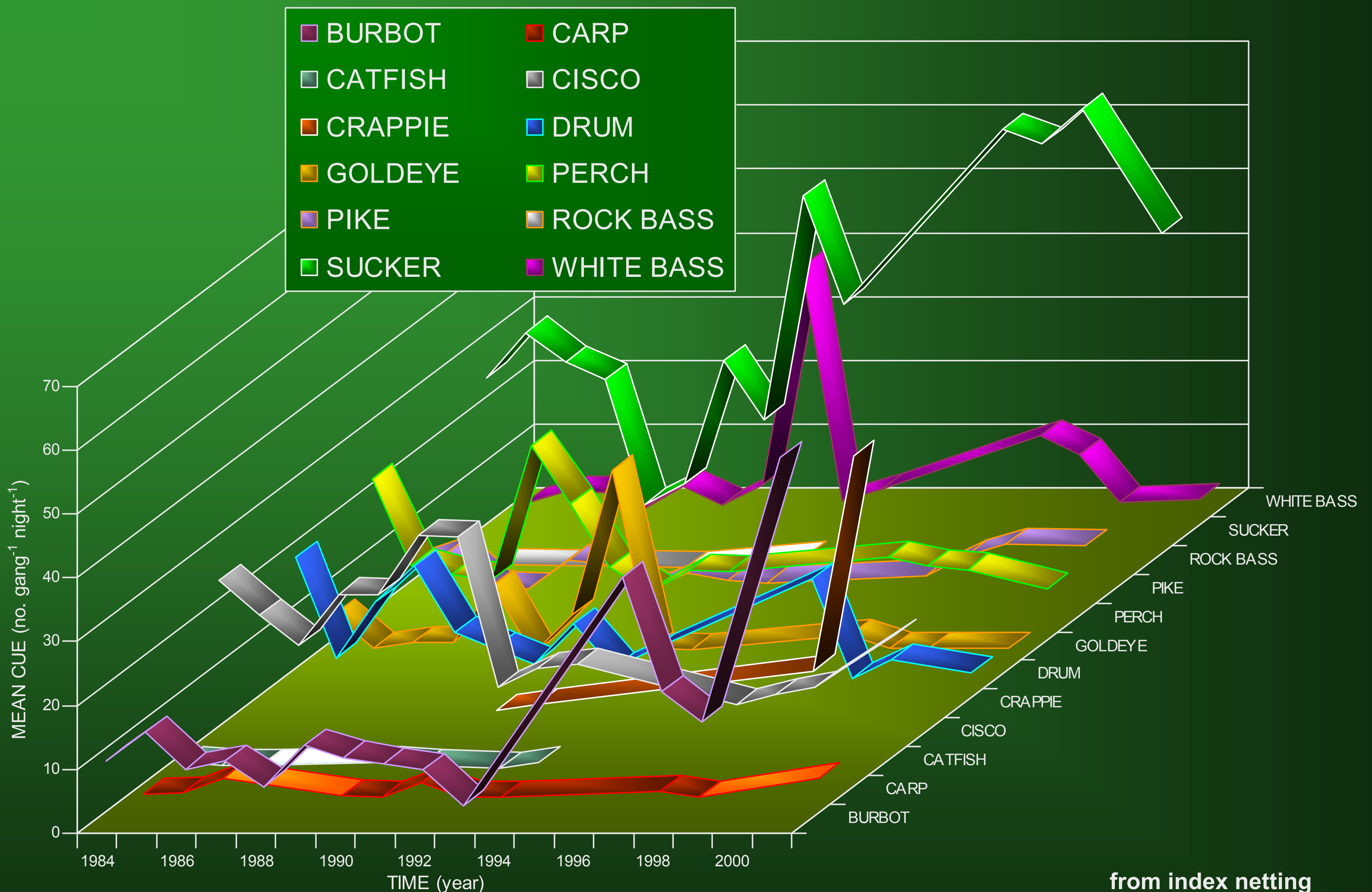
whitefish
1979-2003
summer fishery
fall fishery
age at 50% mature
female maturity curves
female and male growth
FREQUENCY
MEAN LENGTH (mm.)
AGE (years)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
175
275
375
475
575
675
1
2
3
4
5
6
7
8
9
10
11
12
13
14



sauger
1979-2003
FREQUENCY
MEAN LENGTH (mm.)
AGE (years)
summer fishery
fall fishery
age at 50% mature
female maturity curves
female and male growth
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
175
275
375
475
575
675
1
2
3
4
5
6
7
8
9
10
11
12
13
14


WALLEYE AGE-SPECIFIC INDEX
NORMALIZED BY AGE
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
18
16
14
12
10
8
6
4
2
0
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
TIME (year)


LAKE WINNIPEG'S WALLEYE STOCK BIOMASS
BIOMASS (tonnes)
TIME (year)
TOTAL
SPAWNER
CATCH
0
1000
2000
3000
4000
5000
6000
7000
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999


BURBOT
CARP
CATFISH
CISCO
CRAPPIE
DRUM
GOLDEYE
PERCH
PIKE
ROCK BASS
SUCKER
WHITE BASS
MEAN CUE (no. gang-1 night-1)
0
10
20
30
40
50
60
70
1984
1986
1988
1990
1992
1994
1996
1998
2000
TIME (year)
WHITE BASS
SUCKER
ROCK BASS
PIKE
PERCH
GOLDEYE
DRUM
CRAPPIE
CISCO
CATFISH
CARP
BURBOT
from index netting

since the late 1880s:

- **sturgeon and trout have disappeared**
- **whitefish abundance declined dramatically before the Resources Transfer Act (1930)**
- **percids became dominant**

since the late 1970s:

- **within the percids, saugers are declining while walleyes have increased due to a new, favoured prey. no perch data**
- **suckers are increasing due to maintenance of pike < 60 cm. FL**
- **exotic invasions: black crappie and smelt**

sturgeon – salmonids – percids:

- **decrease in maximum body size**
- **decrease in whitefish condition factor**
- **increase in growth and maturity rates**
- **increase in fecundity**

carp 1940s, white bass 1964, black crappies 1980s?
smelt 1990

- increased phosphorus and nitrogen loading
- increase in north basin phytoplankton
- decrease in amphipod abundance,
  1 species of mayfly disappeared from south basin
- high suspended sediment in south basin prevents algal blooms

- fishing effort increased until mid 1980s, declined until 1997
  and increased again
- quota entitlements in 1985 allow harvest of 2.69 kg. $ha.^{-1}$ $year^{-1}$
- walleye declines when annual yield > 1 kg. $ha.^{-1}$
- catch efficiency changes from cotton to nylon to mono nets
- whitefish fleet has spatially disintegrated
- abundance of whitefish and sauger is declining
- "non-FFMC" catch and effort is increasing
- maintenance of pike <60 cm. FL is allowing suckers to increase
- wide range of meshes is harmful to saugers and whitefish,
  decreases percid value, constantly removes large pike and
  increases sucker abundance

- "Local" knowledge in the form of anecdotes has no management value. "Local" knowledge in the form of catch and effort logbooks maintained by commercial fishers would be useful in determining how fisher and fish behaviors are related to hyperstability, proportionality and hyperdepletion of various stocks.

- Since 1979, no. index netting sites has declined from 27 to 3, no monitoring in 2004
- We need gut content data from the major species.
- We need trawling data for YOY walleye and sauger and whitefish to be used to annually adjust future quotas.
- We need temporal changes in abundance of other gillnetted species. This includes shortjaw cisco and the exotic species.
- We need catch and effort data from the "special permit" fishery.
- We need catch and effort data from the "domestic" fishery.

- We need to know the fish productivity of Lake Winnipeg.

Fish and Fisheries of Lake Ontario:

A Case History

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Ontario Ministry of Natural Resources

Applied Research and Development Branch

Glenora Fisheries Station, Picton, Ontario, Canada K0K 2T0

Background

- Commercial and recreational fisheries in the Great Lakes Basin are among the largest in the world.
- In the first half of the 20th century, fisheries in the Great Lakes targeted mainly large-bodied species, particularly fish such as lake trout, lake whitefish, walleye, and cisco.

- Declines of large-bodied commercial species started to become apparent in the 1940s and through the 1960s, and extirpations became common.
- This left, in the extreme, only small-bodied exotics abundant; e.g., Lake Ontario – alewife, smelt, and white perch
- The major destabilizers were:
  - overfishing
  - exotic invaders, particularly sea lamprey
  - eutrophication and habitat alteration

- This created challenges that produced positive, cooperative initiatives, creating the Great Lakes Fishery Commission (1955) and the Great Lakes Water Quality Agreement (1972).
- These fostered:
  - effective lamprey control
  - reduced phosphorus loading
  - cooperative ecosystem-based fisheries management
  - long-term fish-community indexing programs

- **Over the past three decades, we have seen some dramatic changes in ecosystems, fish populations, and community structure**

- **Many factors have been involved, the most important among these have been the anthropogenic forces associated with invasions of exotic species and global climate change**

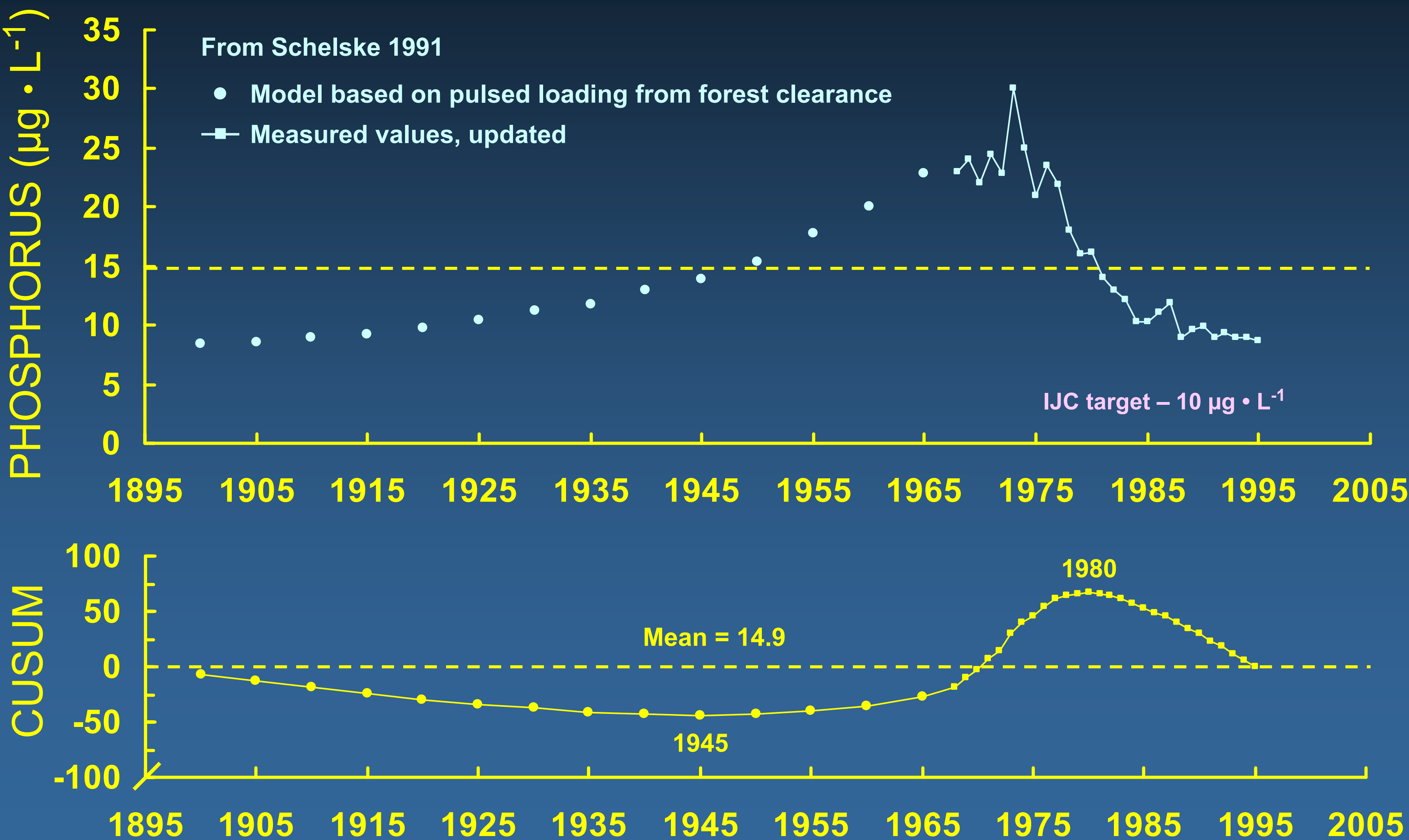
- **These have substantially affected Great Lakes fish and fisheries**

Let´s look at some Lake Ontario examples

Ecosystem Changes

Phosphorus loading, water quality and substrate changes

LAKE ONTARIO Phosphorus Historic nutrient enrichment



WATER QUALITY AND SUBSTRATE CHANGES

Yorkshire Bar (3.5 m)

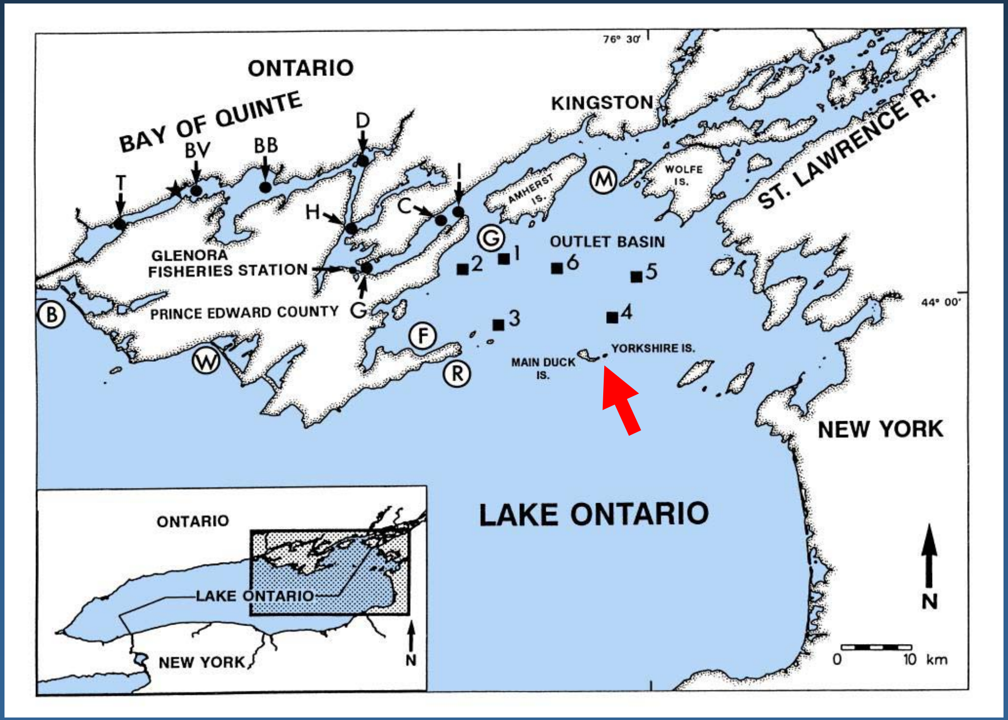
Eastern Lake Ontario

Dreissenid Invasions in the 1990s

Transparency and substrate changes

DREISSENID-INDUCED CHANGES

Eastern Lake Ontario



Yorkshire Island Bar

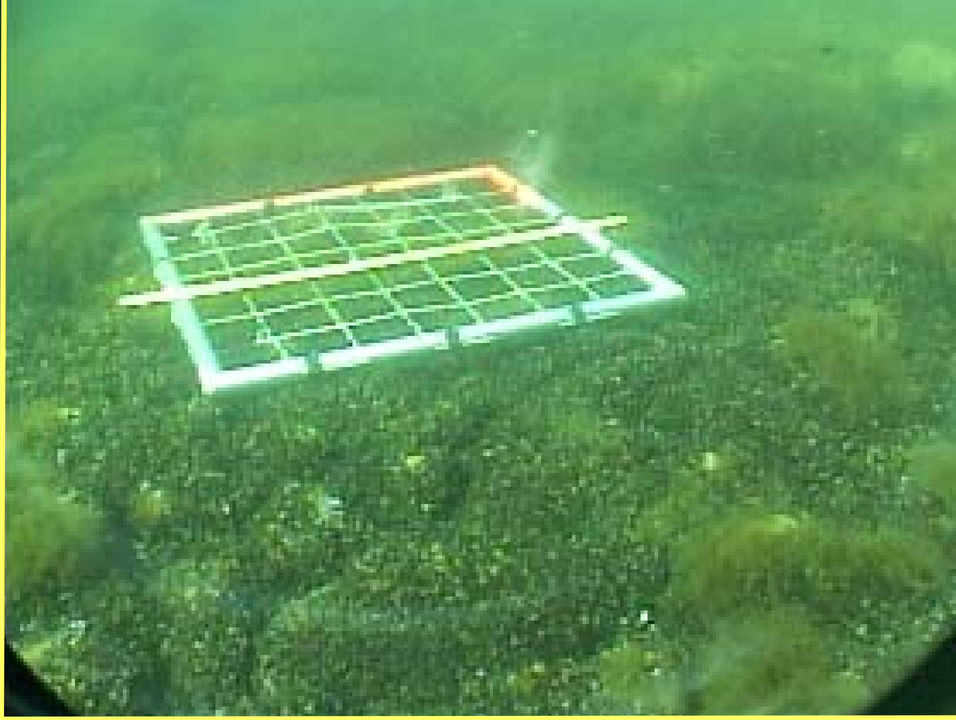
Density of live dreissenids measured at 3.5-m depth on edge of Yorkshire Bar, Yorkshire Island, eastern Lake Ontario.

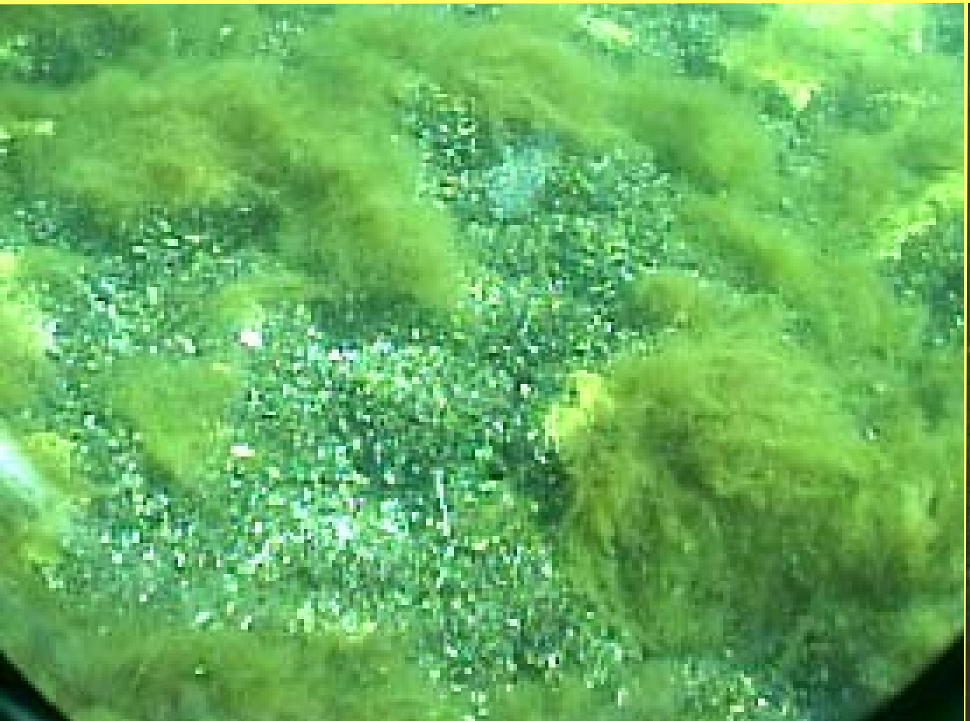
Period	Number of years	Dreissenids ($N \cdot m^{-2}$)	
		Density	Change
1988 – 1990	3	0	
1991 – 1993	3	962	+962
1994 – 1996	3	26,333	+25,371
1997 – 1999	3	20,667	– 5,666
2000	1	16,450	– 4,217
2001 – 2002	2	12,105	– 4,345
2003	1	10,504	– 1,601

- First few dreissenids were observed in fall of 1991, 50$\cdot m^{-2}$ in 1992, and 2,833$\cdot m^{-2}$ in 1993.
- In 2000, 2001, and 2003, massive quantities of dreissenid shells came inshore, filling the interstitial spaces of the rock rubble and eel habitat.
- In 2003, the substrate and interstitial spaces contained shells of 12,601 dead dreissenid$\cdot m^{-2}$; 55%of all dreissenids were dead.

ALTERATION AND LOSS OF HABITAT

Dreissenid Colonization and Shell Debris, Yorkshire Bar (3.5 m) Eastern Lake Ontario





DREISSENID SHELL DEBRIS

Onshore, Main Duck Island,

Eastern Lake Ontario

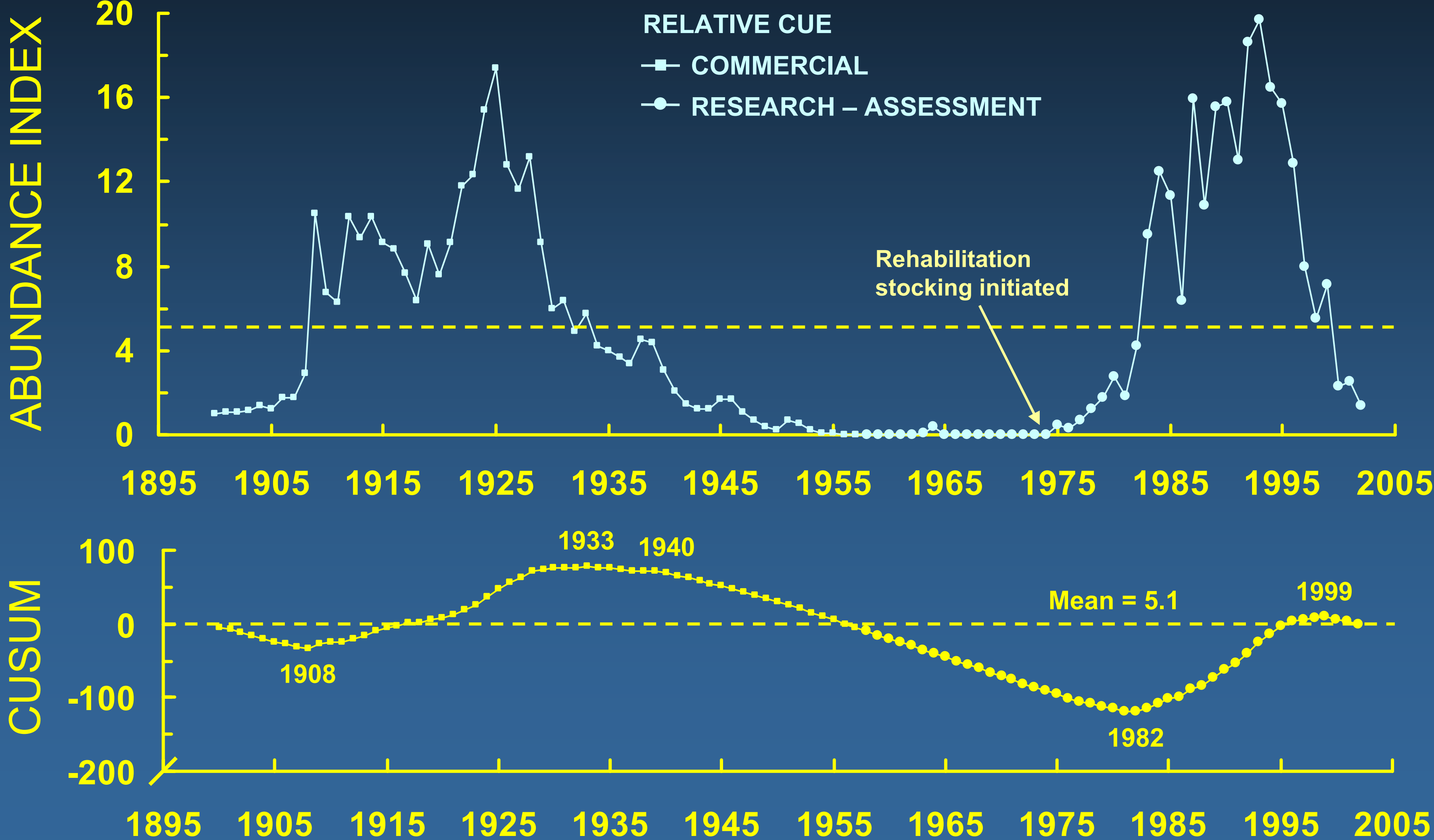
Windrows of shell debris


DREISSENID-INDUCED
TRANSPARENCY CHANGES
Aerial view, Main Duck Is. – 2003
Aerial view, Gull Pond – 2003
Aerial view, 24 m – July 2003

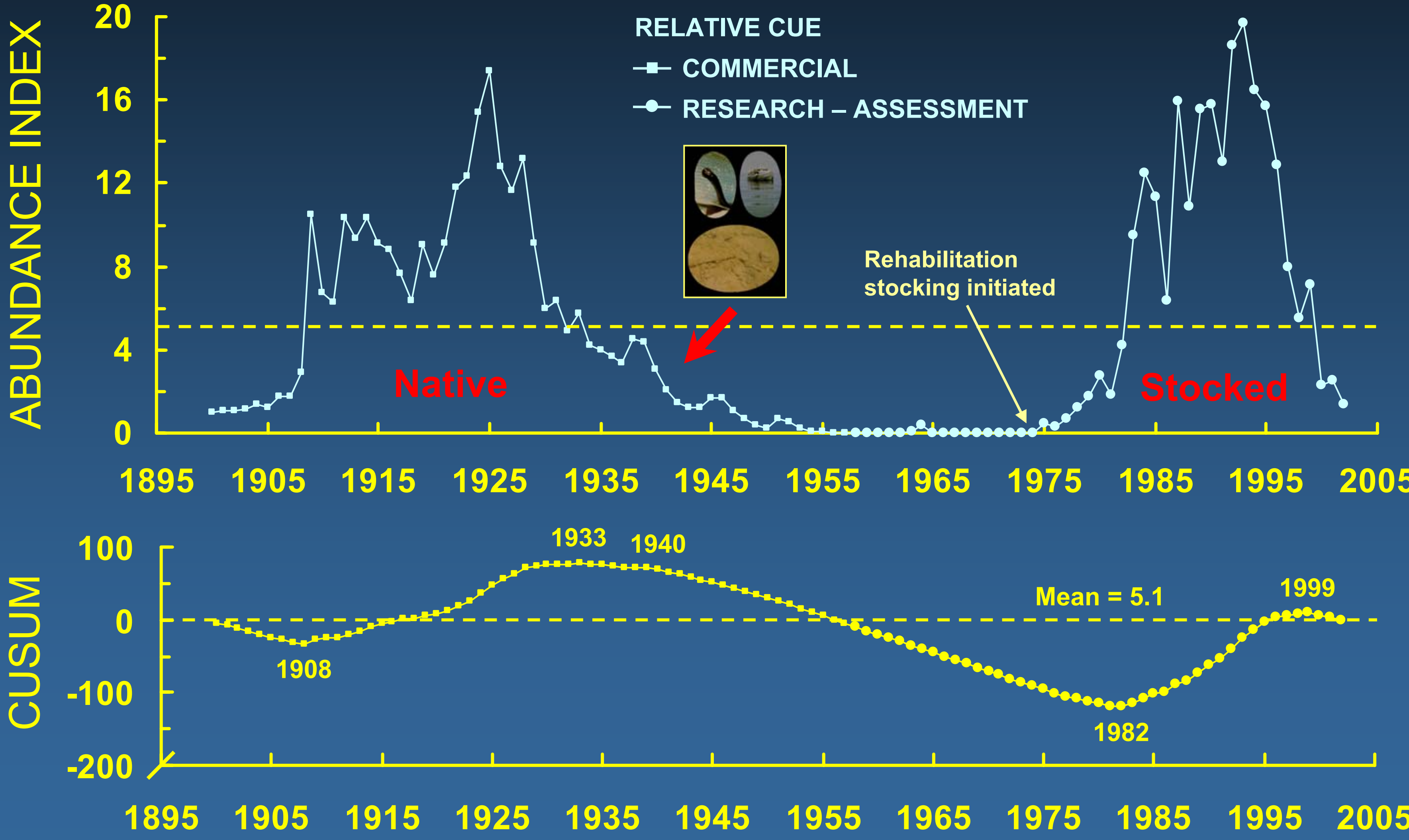
Lake Trout Dynamics, Salmonid Stocking, Total Harvest

Lamprey control, rehabilitation, increasing fishing opportunities

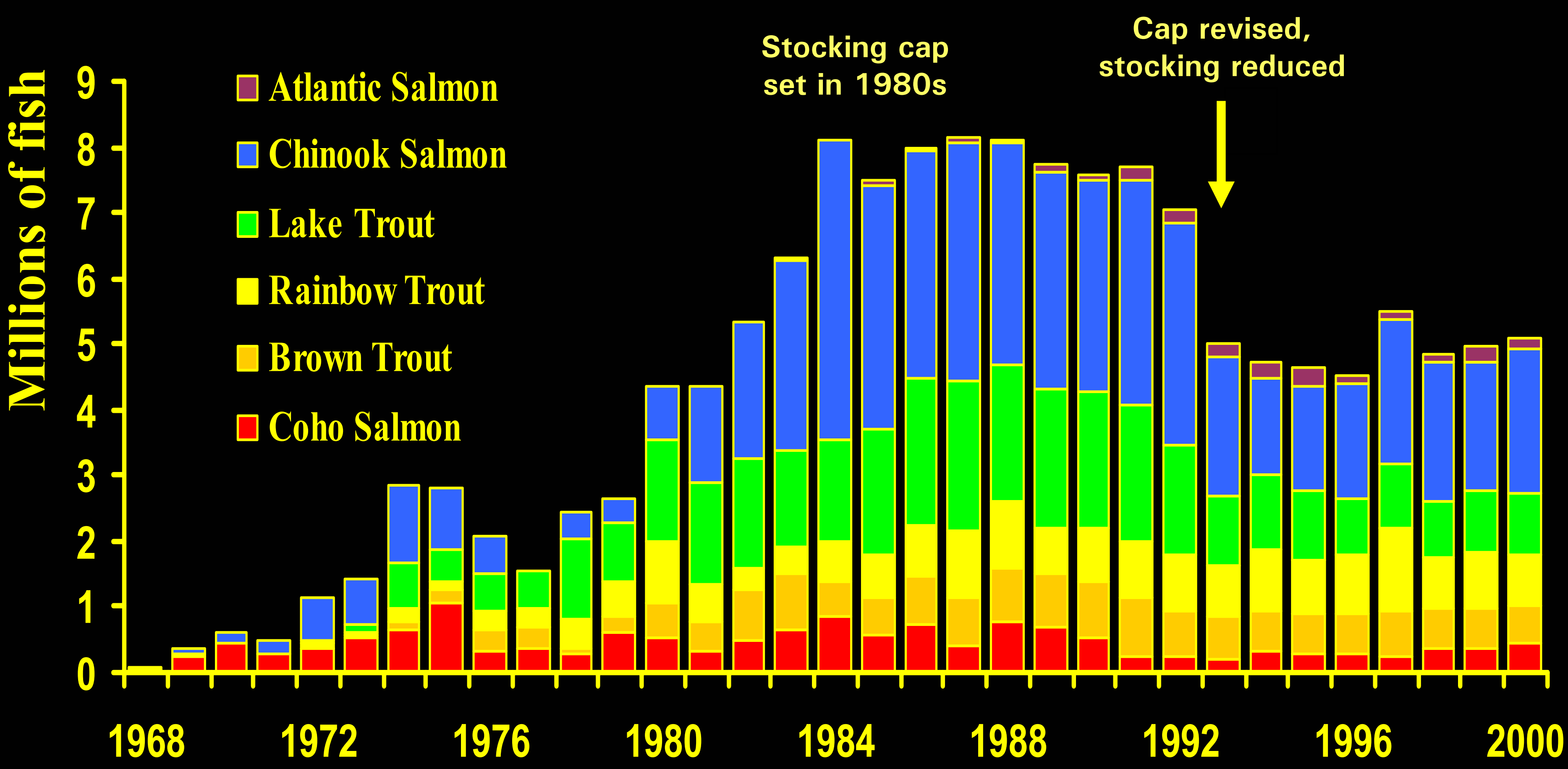
LAKE ONTARIO Lake trout



LAKE ONTARIO Lake trout

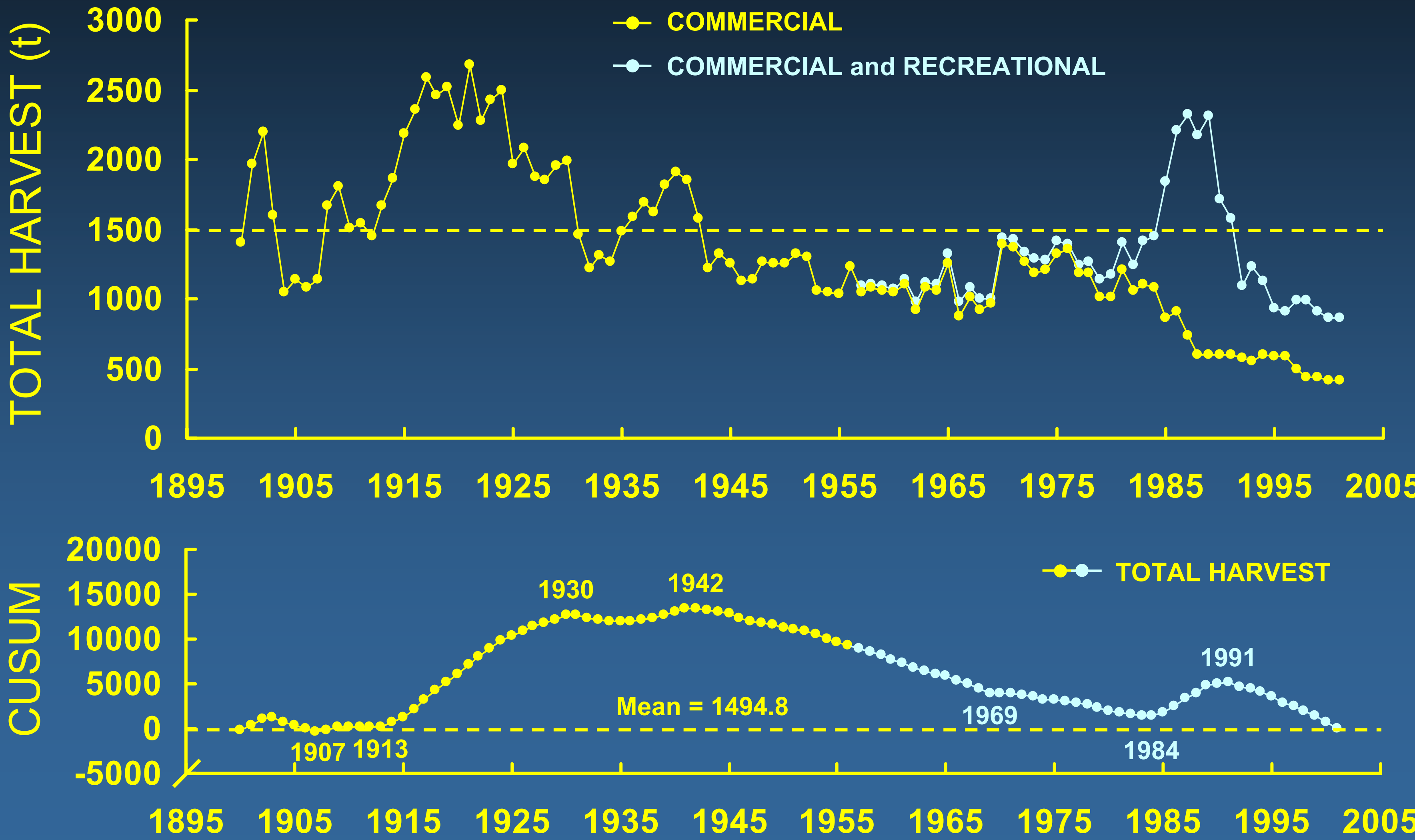


LAKE ONTARIO Stocked salmonids, 1968-2000



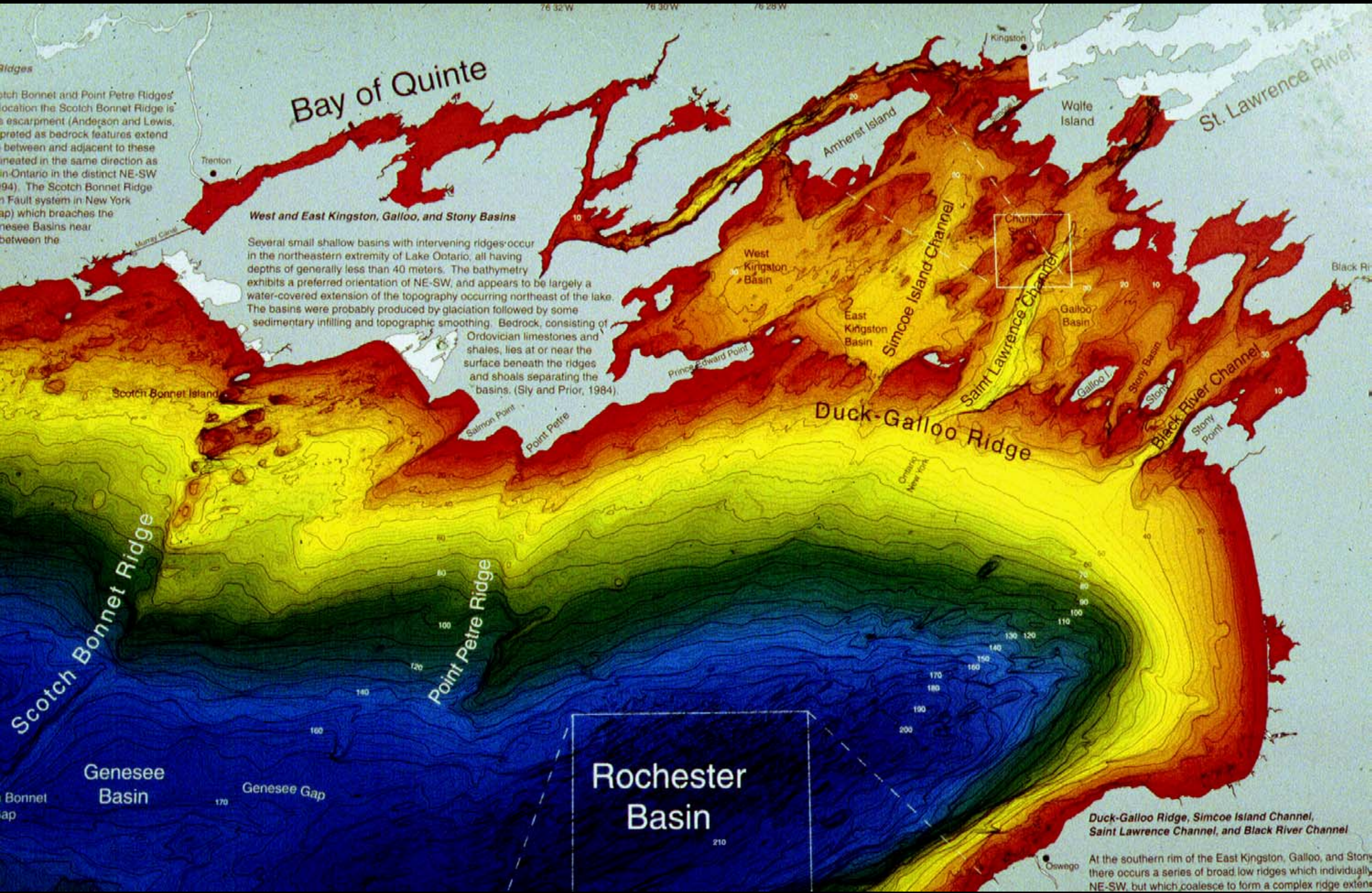
Mills et al. 2003

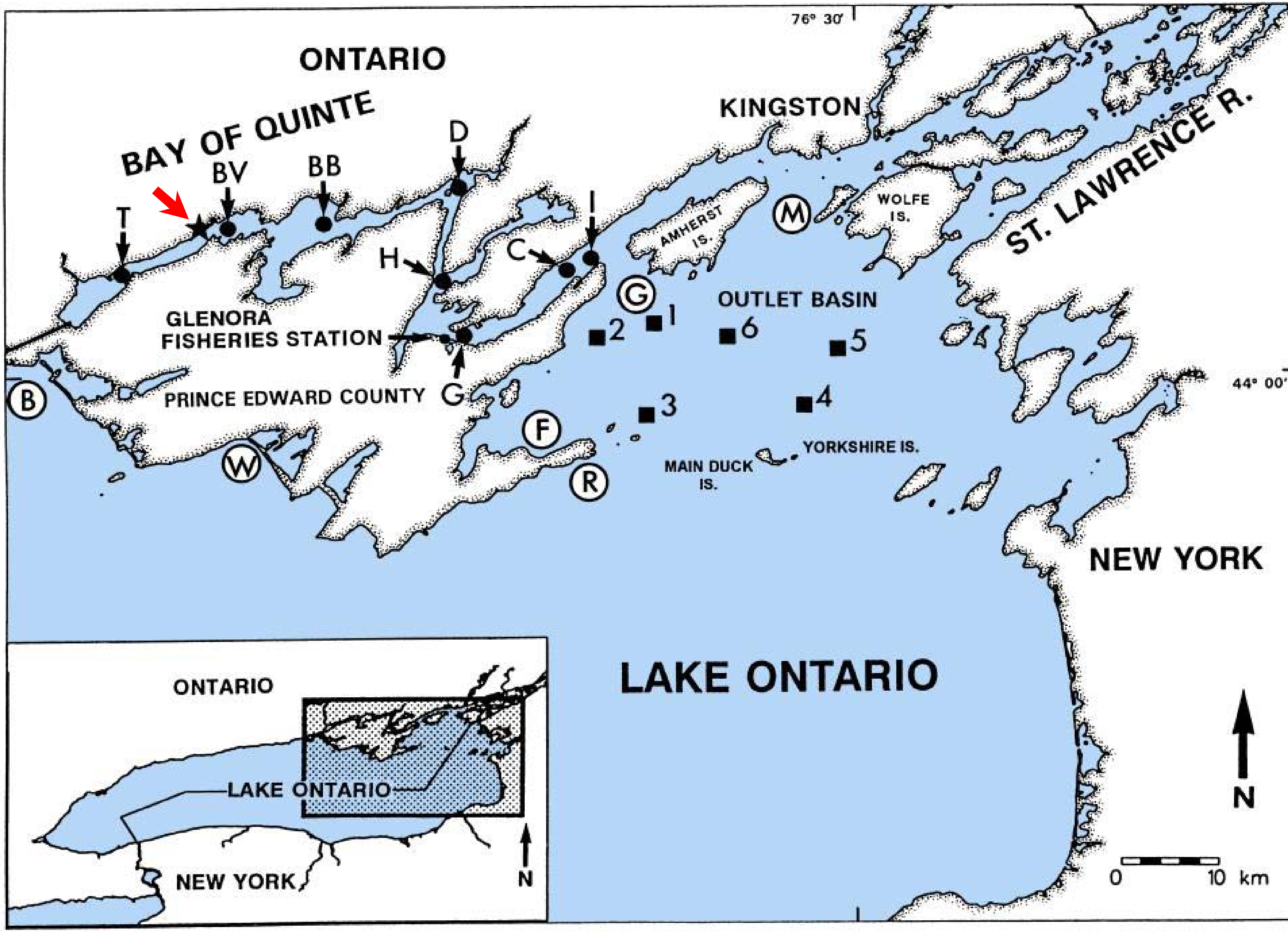
LAKE ONTARIO Commercial and recreational harvest



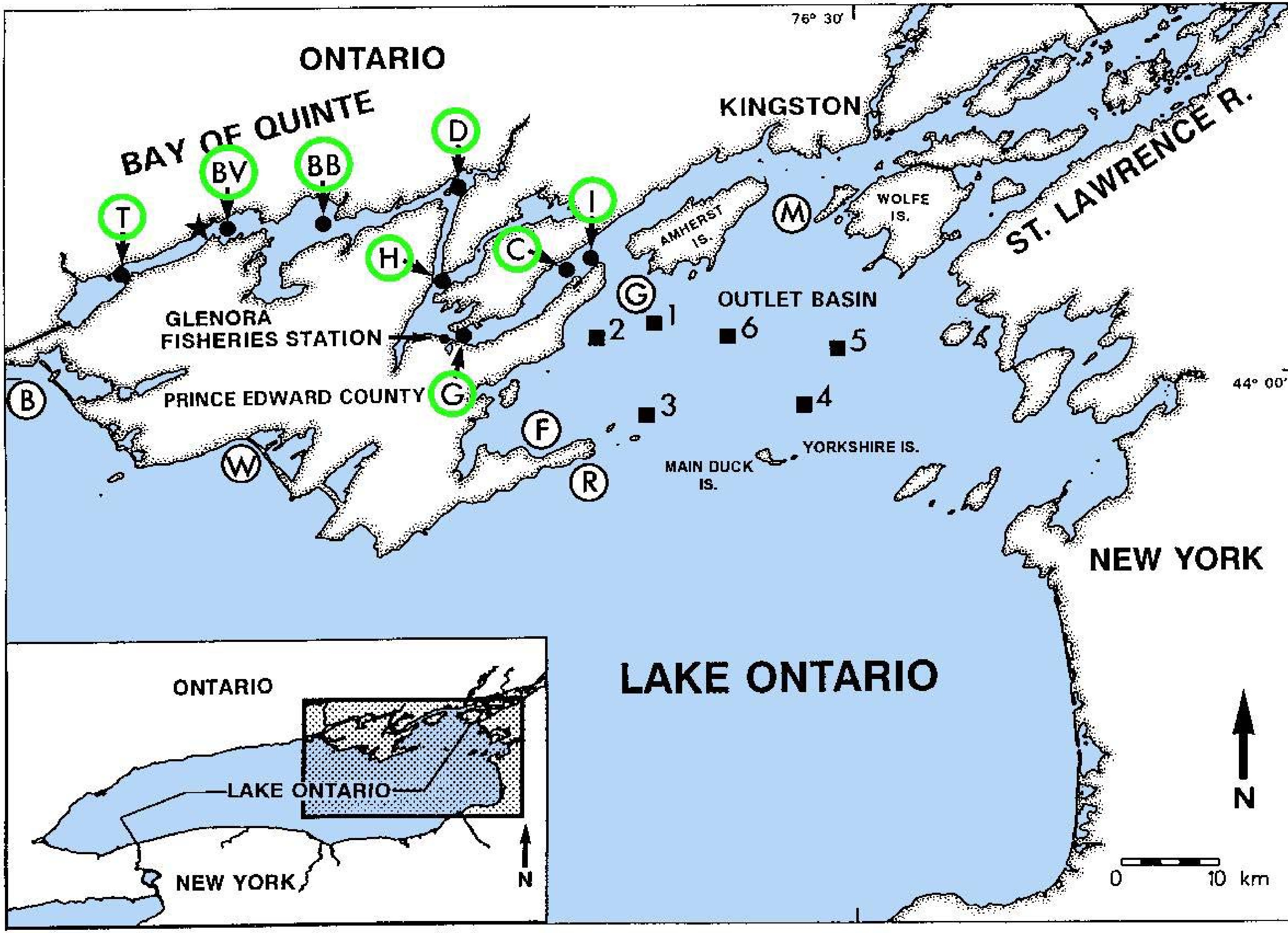
Long-Term Indexing Programs

Valuable quantitative indices for assessing population and fish community dynamics and structure


Ridges
otch Bonnet and Point Petre Ridges'
location the Scotch Bonnet Ridge is
s escarpment (Anderson and Lewis,
preted as bedrock features extend
between and adjacent to these
ineated in the same direction as
n Ontario in the distinct NE-SW
994). The Scotch Bonnet Ridge
n Fault system in New York
ap) which breaches the
nesee Basins near
between the
Trenton
Murray Canal
Bay of Quinte
Kingston
Amherst Island
Wolfe Island
St. Lawrence River
West and East Kingston, Galloo, and Stony Basins
Several small shallow basins with intervening ridges occur in the northeastern extremity of Lake Ontario, all having depths of generally less than 40 meters. The bathymetry exhibits a preferred orientation of NE-SW, and appears to be largely a water-covered extension of the topography occurring northeast of the lake. The basins were probably produced by glaciation followed by some sedimentary infilling and topographic smoothing. Bedrock, consisting of Ordovician limestones and shales, lies at or near the surface beneath the ridges and shoals separating the basins. (Sly and Prior, 1984).
West Kingston Basin
East Kingston Basin
Simcoe Island Channel
Saint Lawrence Channel
Galloo Basin
Stony Basin
Black River Channel
Black River
Prince Edward Point
Scotch Bonnet Island
Salmon Point
Point Petre
Duck-Galloo Ridge
Stony Point
Galloo I.
Ontario
New York
Scotch Bonnet Ridge
Point Petre Ridge
Genesee Basin
Genesee Gap
Rochester Basin
Duck-Galloo Ridge, Simcoe Island Channel, Saint Lawrence Channel, and Black River Channel
Oswego
At the southern rim of the East Kingston, Galloo, and Stony
there occurs a series of broad low ridges which individually
NE-SW, but which coalesce to form a complex ridge exten



76° 30'
ONTARIO
BAY OF QUINTE
KINGSTON
ST. LAWRENCE R.
D
BV
BB
T
I
H
C
AMHERST IS.
M
WOLFE IS.
G
OUTLET BASIN
GLENORA FISHERIES STATION
1
2
6
5
44° 00'
B
PRINCE EDWARD COUNTY
G
3
4
F
YORKSHIRE IS.
MAIN DUCK IS.
W
R
NEW YORK
LAKE ONTARIO
ONTARIO
LAKE ONTARIO
NEW YORK
N
N
0
10 km


76° 30′
ONTARIO
KINGSTON
BAY OF QUINTE
ST. LAWRENCE R.
D
BV
BB
T
I
M
WOLFE IS.
AMHERST IS.
H
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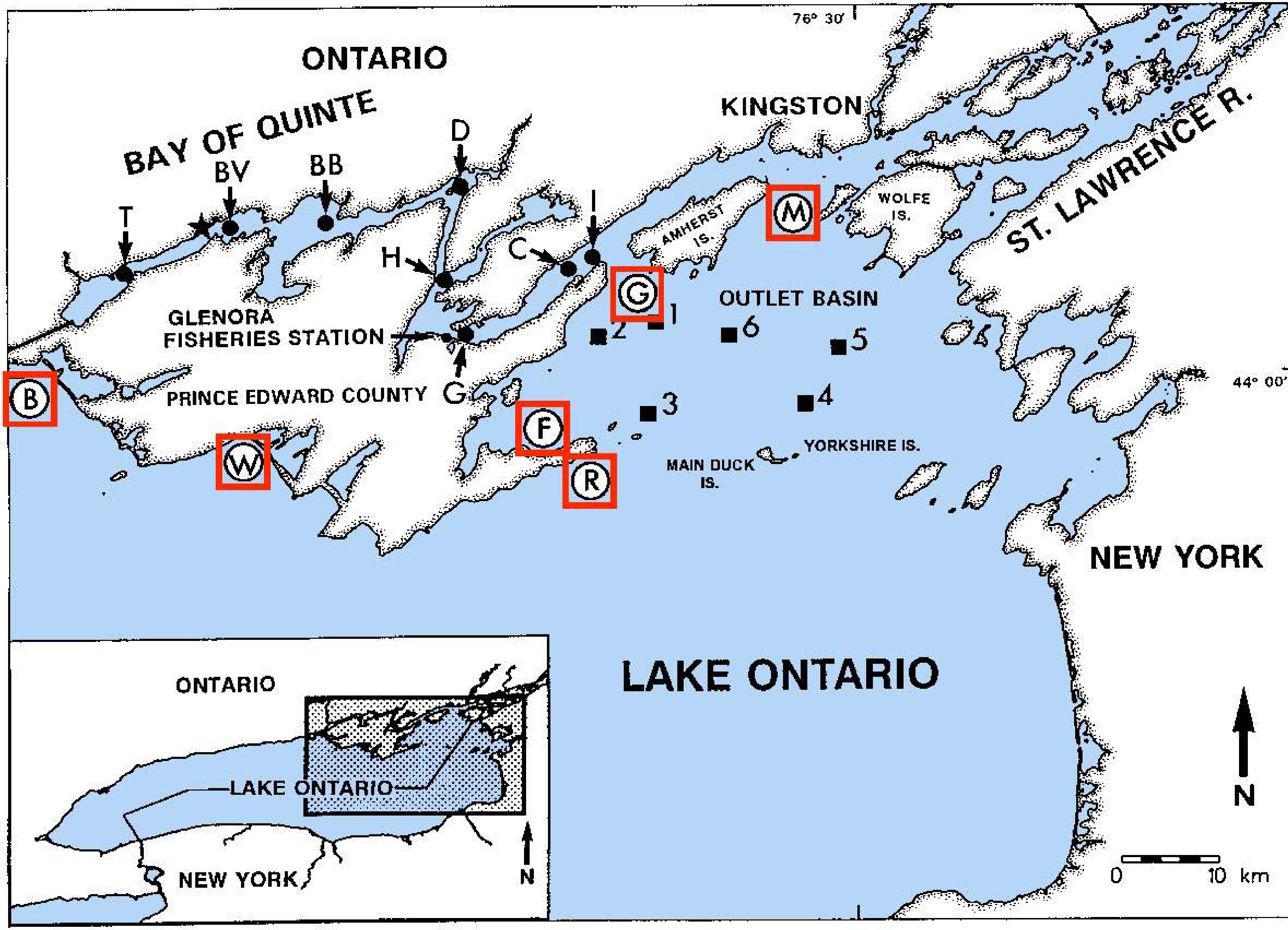
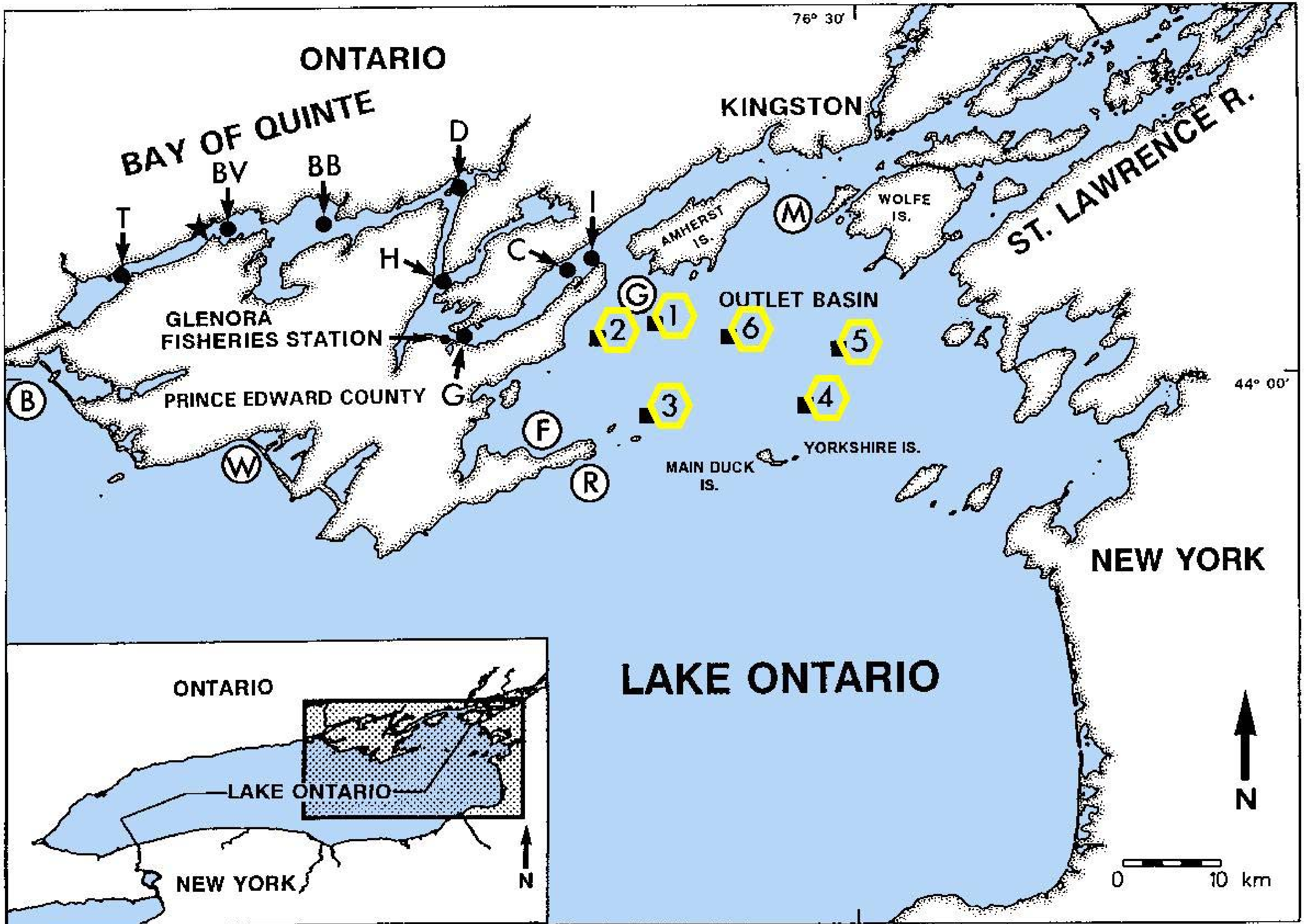
G
OUTLET BASIN
1
2
6
5
GLENORA FISHERIES STATION
44° 00′
B
PRINCE EDWARD COUNTY
G
3
4
F
YORKSHIRE IS.
MAIN DUCK IS.
W
R
NEW YORK
LAKE ONTARIO
ONTARIO
LAKE ONTARIO
NEW YORK
N
N
0
10 km



ONTARIO
BAY OF QUINTE
KINGSTON
ST. LAWRENCE R.
76° 30'
T
BV
BB
D
H
C
I
G
AMHERST IS.
WOLFE IS.
M
OUTLET BASIN
1
2
3
4
5
6
GLENORA FISHERIES STATION
PRINCE EDWARD COUNTY
B
W
F
R
44° 00'
MAIN DUCK IS.
YORKSHIRE IS.
NEW YORK
LAKE ONTARIO
N
0
10 km
ONTARIO
LAKE ONTARIO
NEW YORK
N



76° 30′
ONTARIO
BAY OF QUINTE
KINGSTON
ST. LAWRENCE R.
D
BV
BB
T
I
H
C
AMHERST IS.
M
WOLFE IS.
G
OUTLET BASIN
1
2
6
5
GLENORA FISHERIES STATION
G
PRINCE EDWARD COUNTY
B
3
4
44° 00′
F
W
R
YORKSHIRE IS.
MAIN DUCK IS.
NEW YORK
LAKE ONTARIO
ONTARIO
LAKE ONTARIO
NEW YORK
N
N
0
10 km

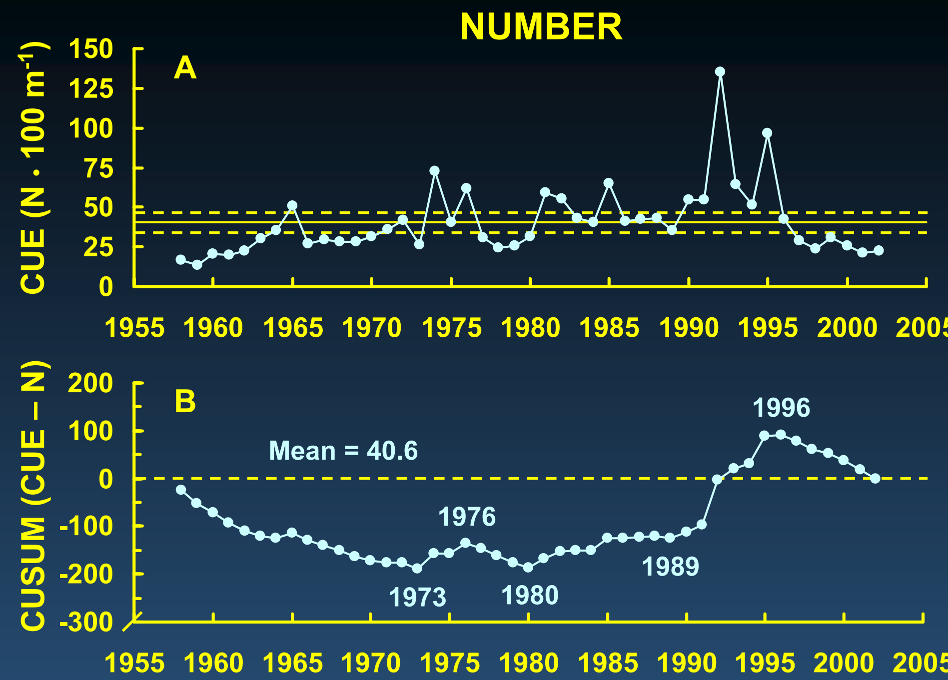
Population and Community Changes Have Been Substantial

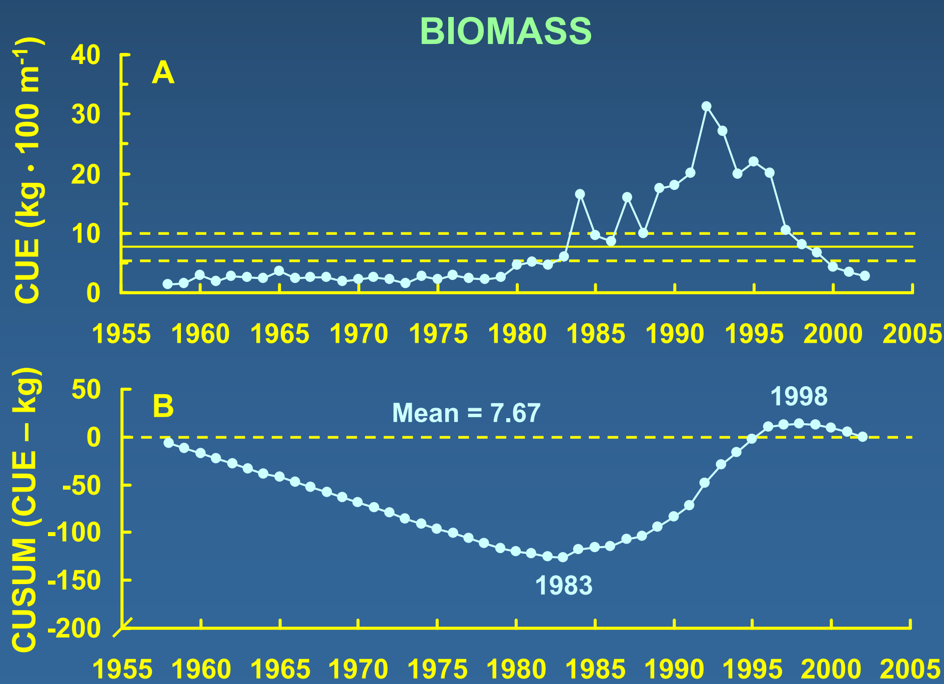
Indices for Bay of Quinte and nearshore and offshore waters of eastern Lake Ontario

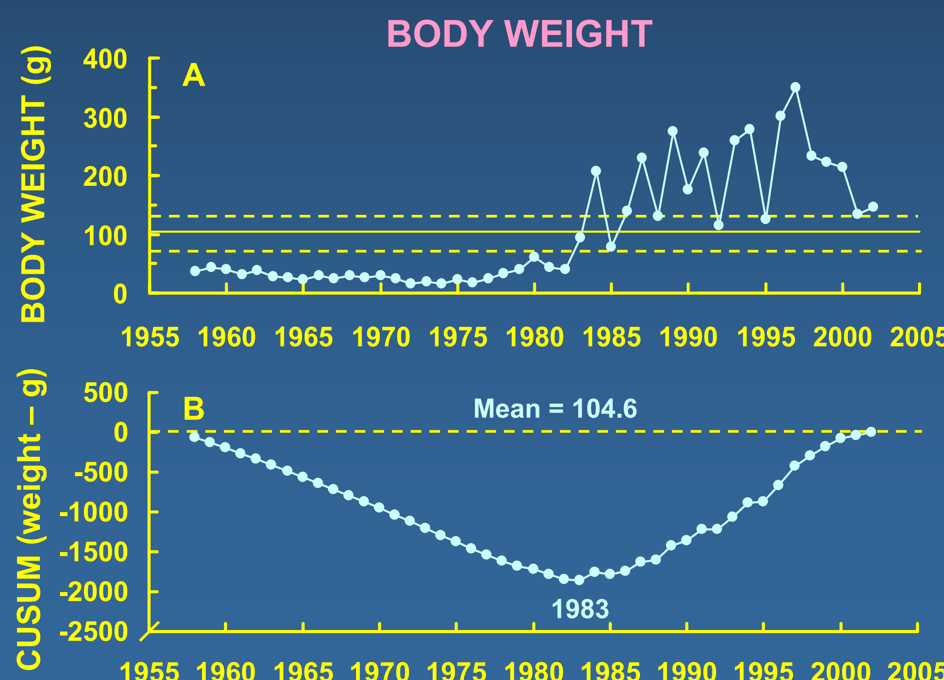
FISH ABUNDANCE

Eastern Lake Ontario and Bay of Quinte

Index of trawling and gill netting – catch •100m combined effort

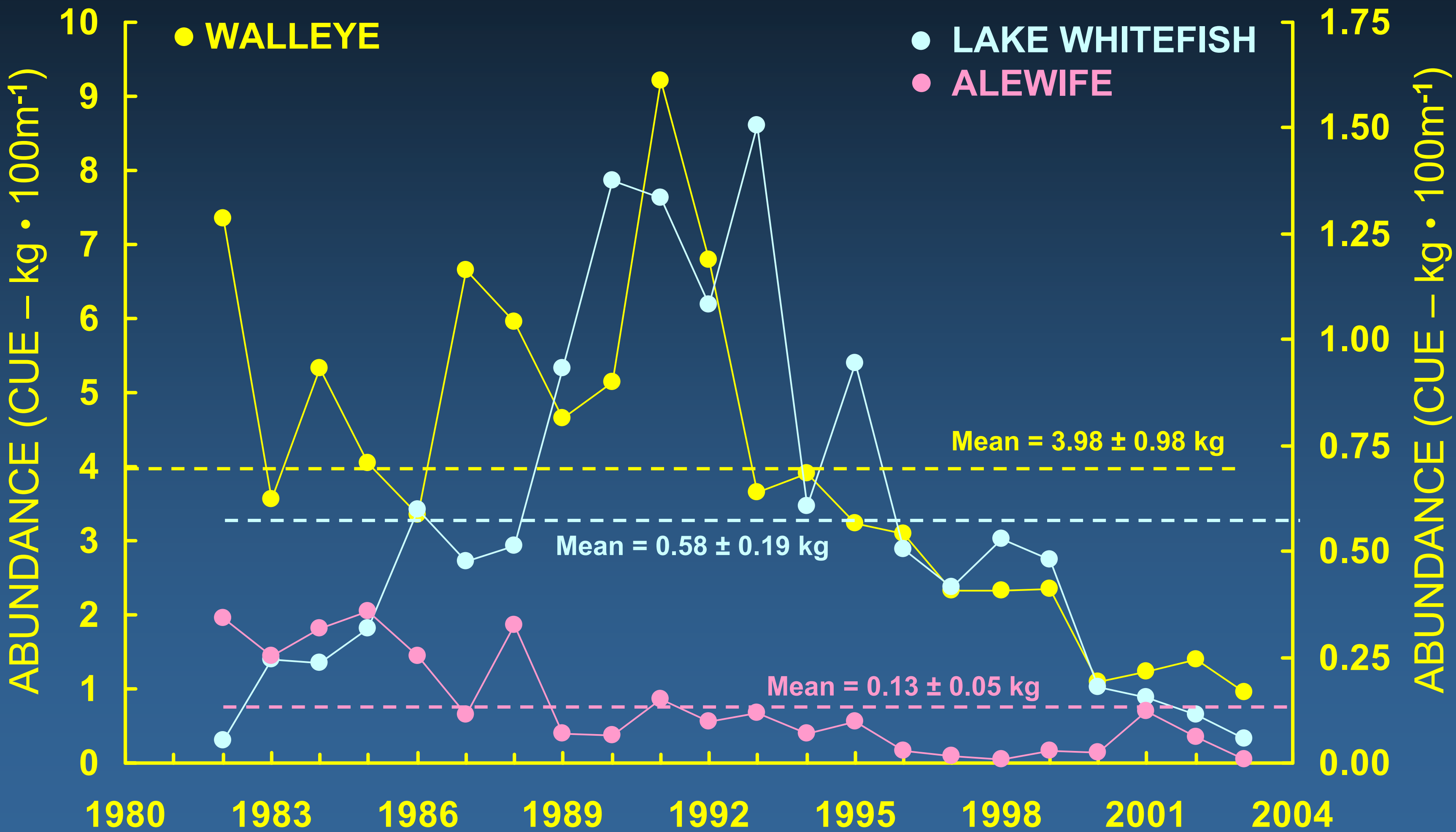






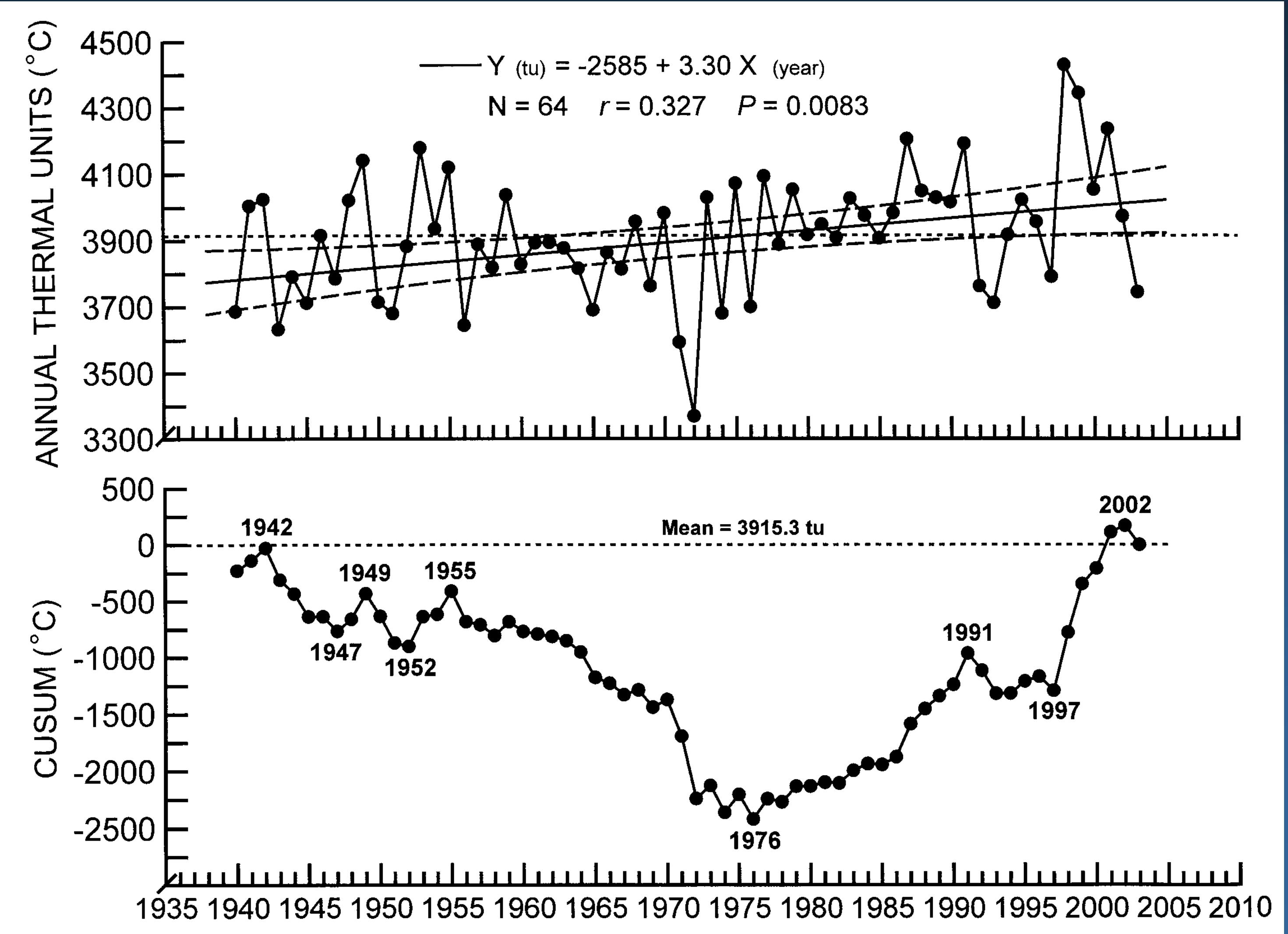
INDICES OF RELATIVE ABUNDANCE

Walleye, lake whitefish, and alewife (a walleye prey fish) biomass



CLIMATE AND GLOBAL WARMING

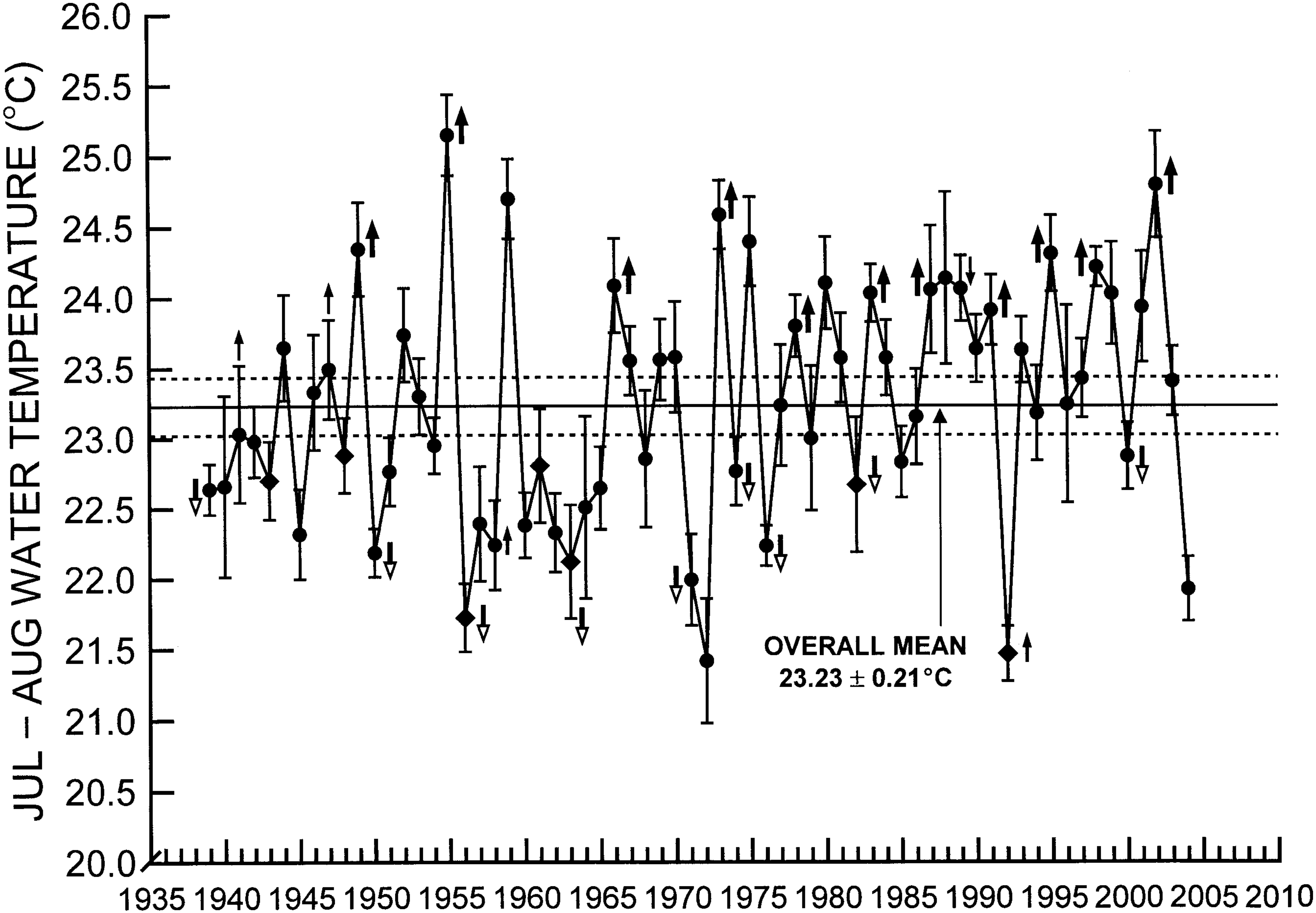
Altering recruitment and community structure



Midsummer Thermal Conditions

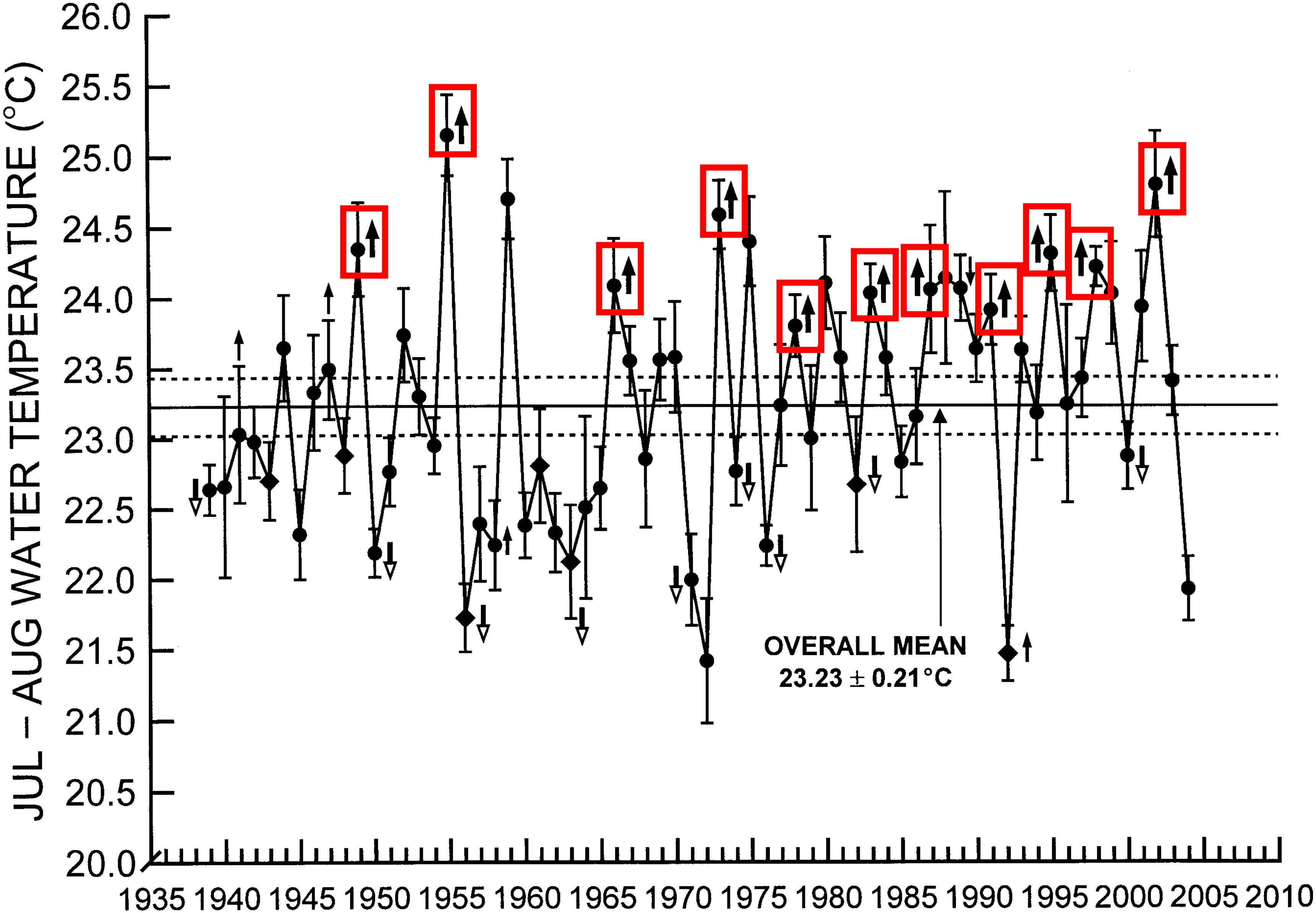
North Temperate Region

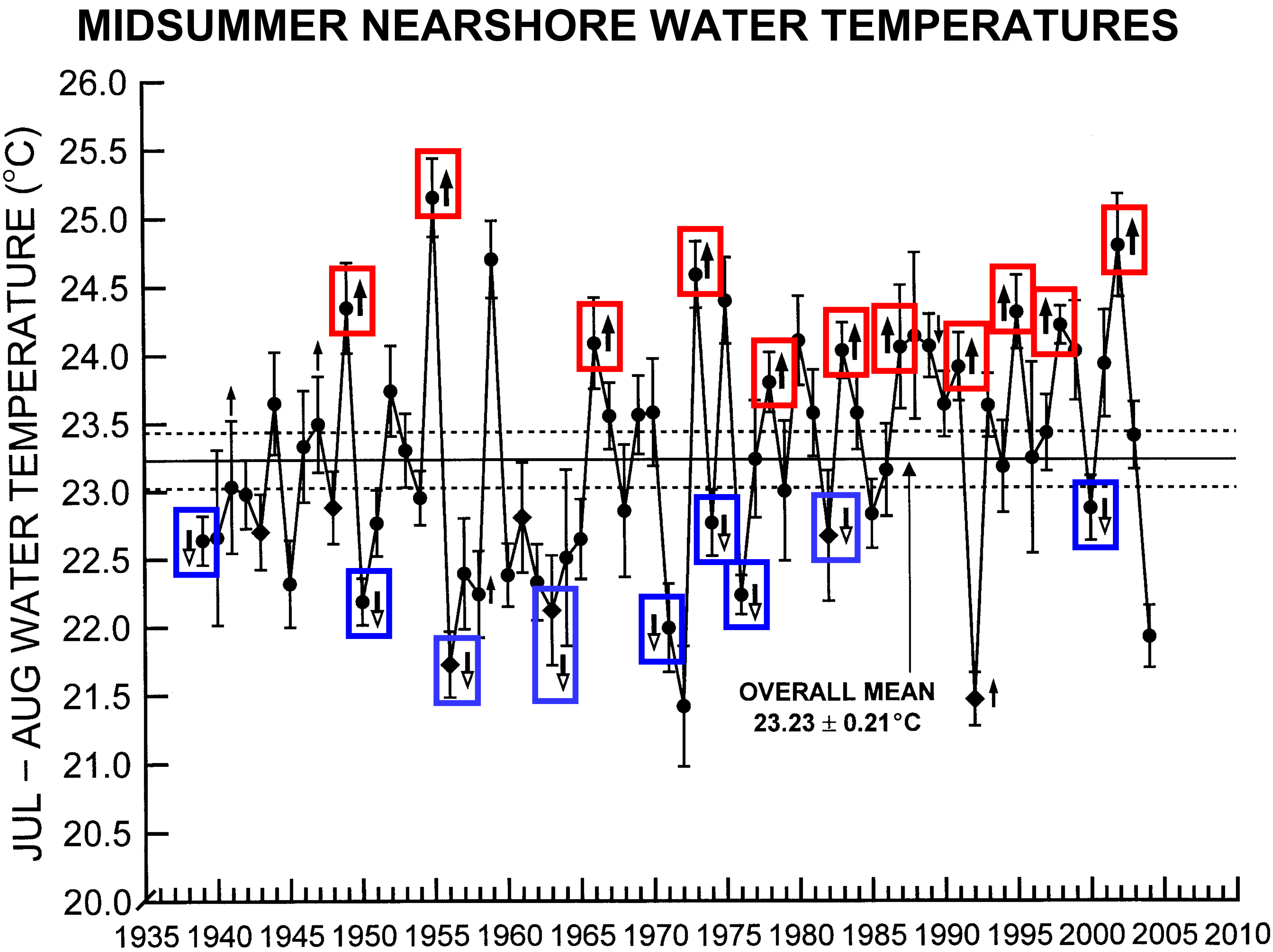
Nearshore Lake Ontario

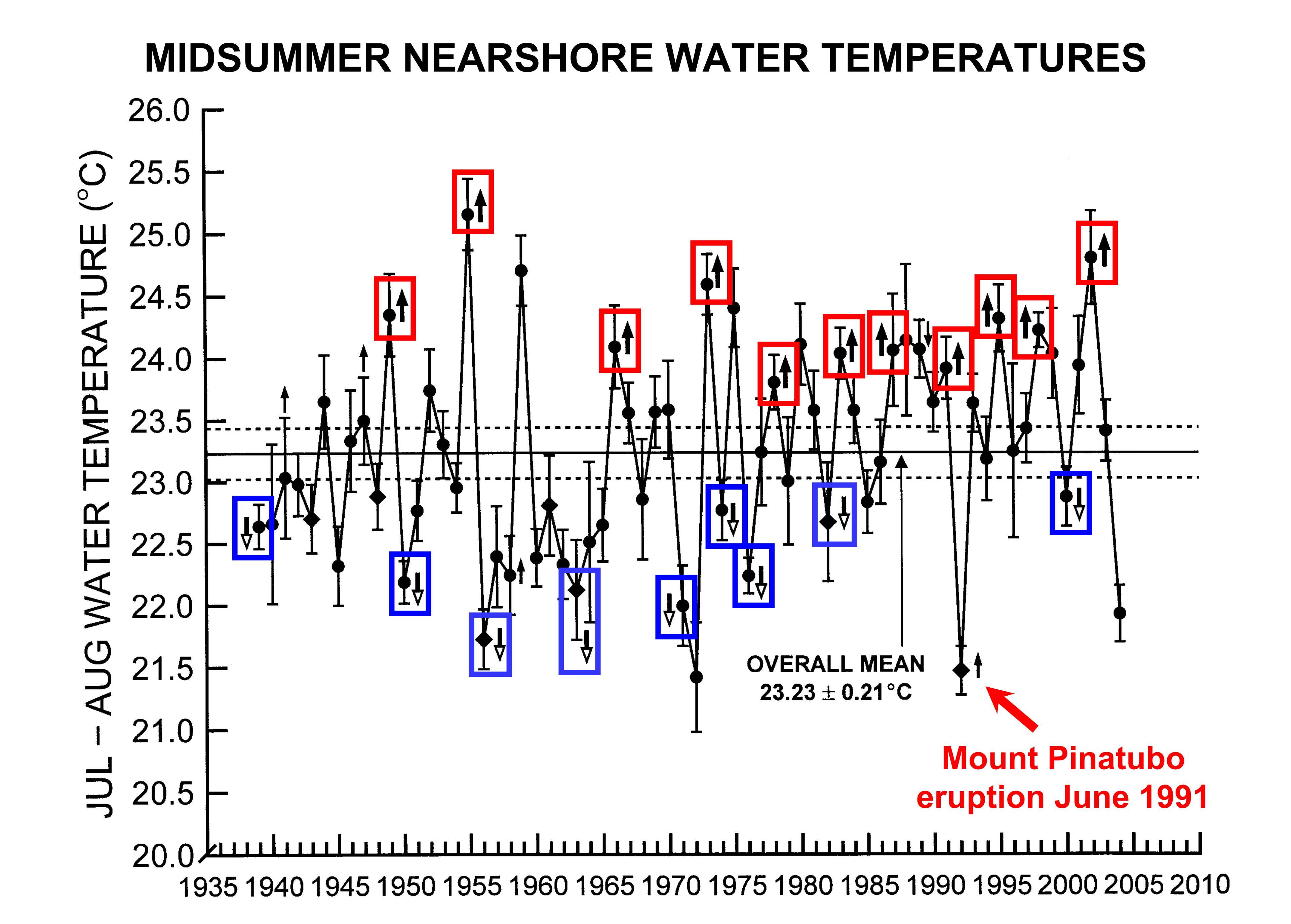


JUL – AUG WATER TEMPERATURE (°C)
26.0
25.5
25.0
24.5
24.0
23.5
23.0
22.5
22.0
21.5
21.0
20.5
20.0
1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010
OVERALL MEAN
23.23 ± 0.21°C

MIDSUMMER NEARSHORE WATER TEMPERATURES




MIDSUMMER NEARSHORE WATER TEMPERATURES
JUL – AUG WATER TEMPERATURE (°C)
26.0
25.5
25.0
24.5
24.0
23.5
23.0
22.5
22.0
21.5
21.0
20.5
20.0
1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010
OVERALL MEAN
23.23 ± 0.21°C



MIDSUMMER NEARSHORE WATER TEMPERATURES
JUL – AUG WATER TEMPERATURE (°C)
26.0
25.5
25.0
24.5
24.0
23.5
23.0
22.5
22.0
21.5
21.0
20.5
20.0
1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010
OVERALL MEAN
23.23 ± 0.21°C
Mount Pinatubo
eruption June 1991

Climate, Global Warming and Recruitment

Population dynamics, community structure, species interactions

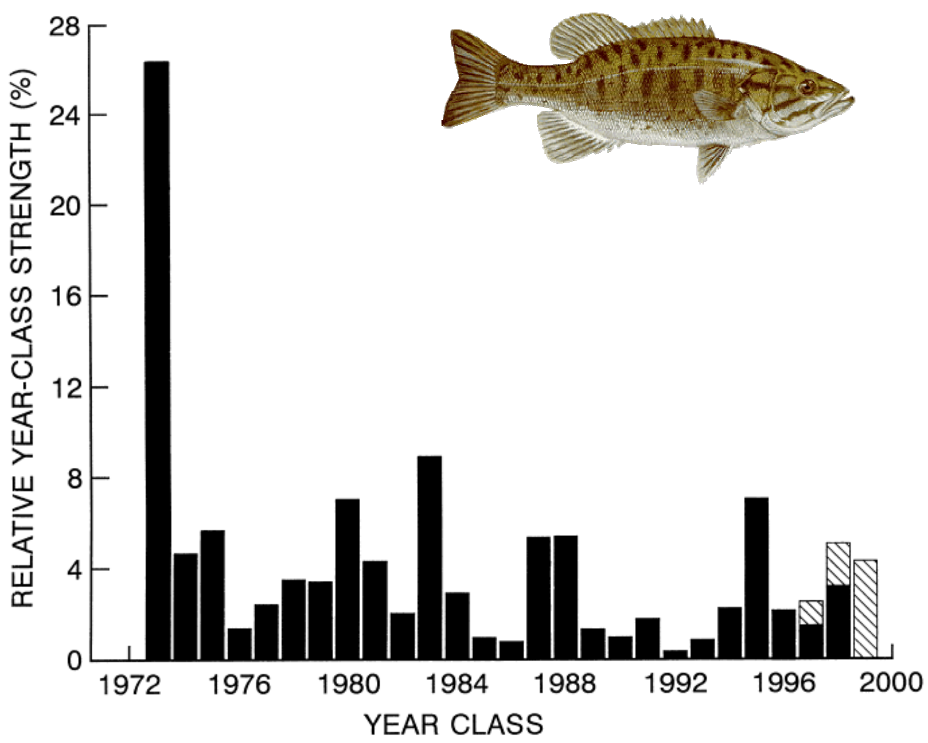
Temperature requirements of typical Lake Ontario fish of the three major thermal groupings.

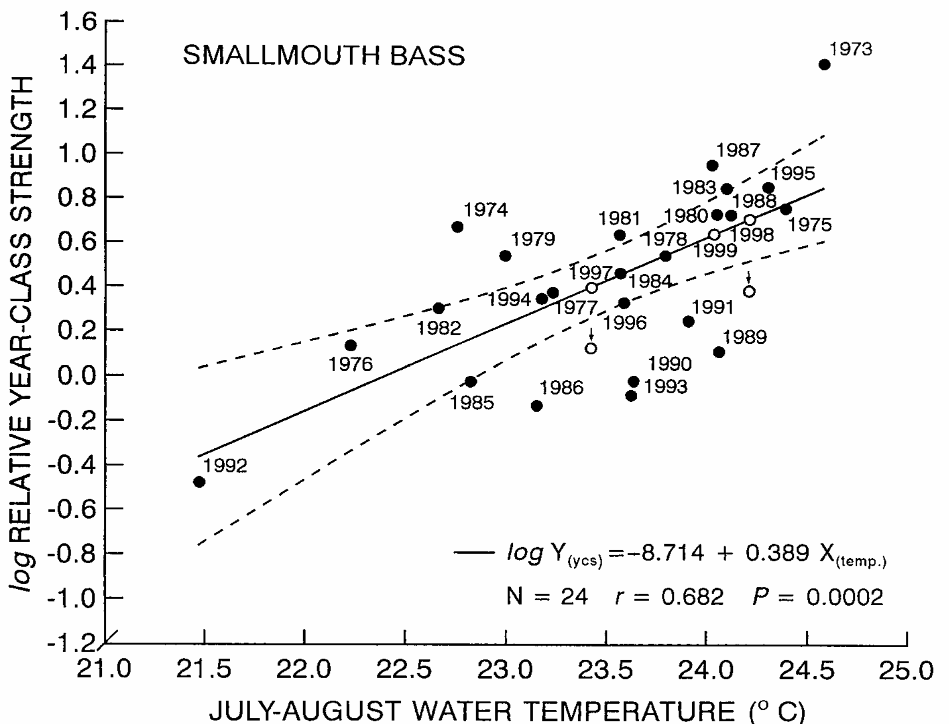
Thermal grouping	Species	Thermal habitat			
		Spawning	Optimum	Preferred	Mean
warmwater	bluegill	23.7	30.2	31.3	30.8
	largemouth bass	19.4	26.0	30.1	28.1
	smallmouth bass	18.0	27.0	27.4	27.2
	Mean	20.4	27.7	29.6	28.7
coolwater	yellow perch	9.3	22.5	23.3	22.9
	walleye	8.0	22.6	21.7	22.2
	northern pike	6.9	20.0	23.5	21.8
	Mean	8.1	21.7	22.8	22.3
coldwater	brook trout	8.7	15.0	13.0	14.0
	lake whitefish	5.7	15.2	11.1	13.2
	lake trout	10.6	11.7	11.2	11.5
	Mean	8.3	14.0	11.8	12.9

WARMWATER SPECIES

Optimum Temperature for Growth >25°C

e.g., Smallmouth bass





Relative year-class strength of smallmouth bass in eastern Lake Ontario in relation to mean July-August water temperatures.

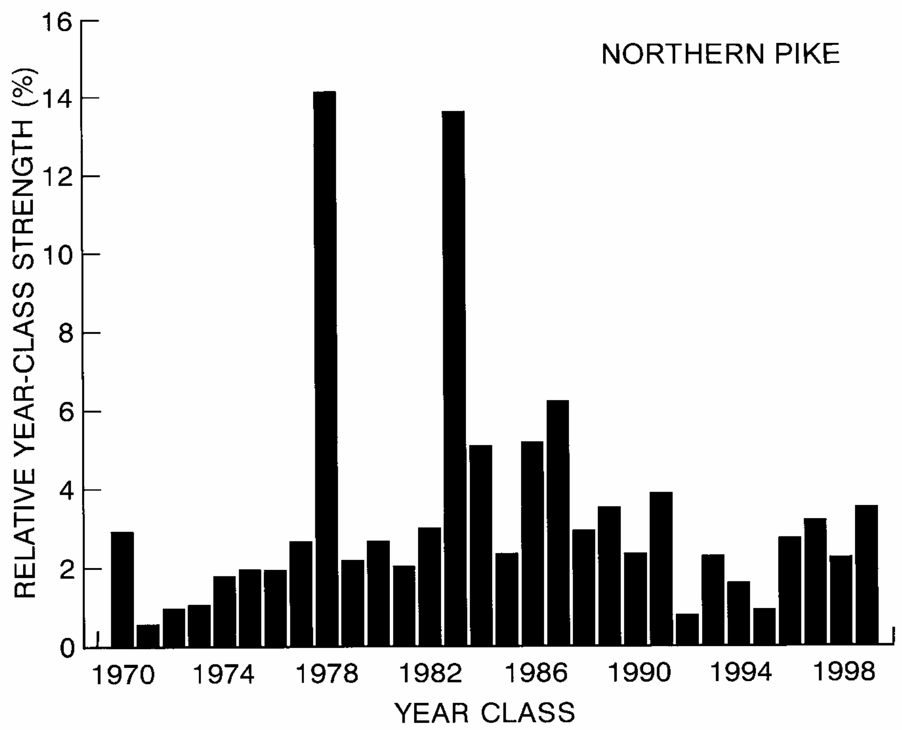
July-August water temperature		Year-class strength	
Mean	Deviation	Relative	Fold change
20.42[a]	-3.00	0.17	-14.65
21.42	-2.00	0.42	-6.00
22.42	-1.00	1.02	-2.45
23.42	0	2.49	0
24.21	+0.79	5.05	+2.03
24.33	+0.91	5.63	+2.26
24.42	+1.00	6.10	+2.45
25.42	+2.00	14.94	+6.00
26.42[a]	+3.00	36.59	+14.69

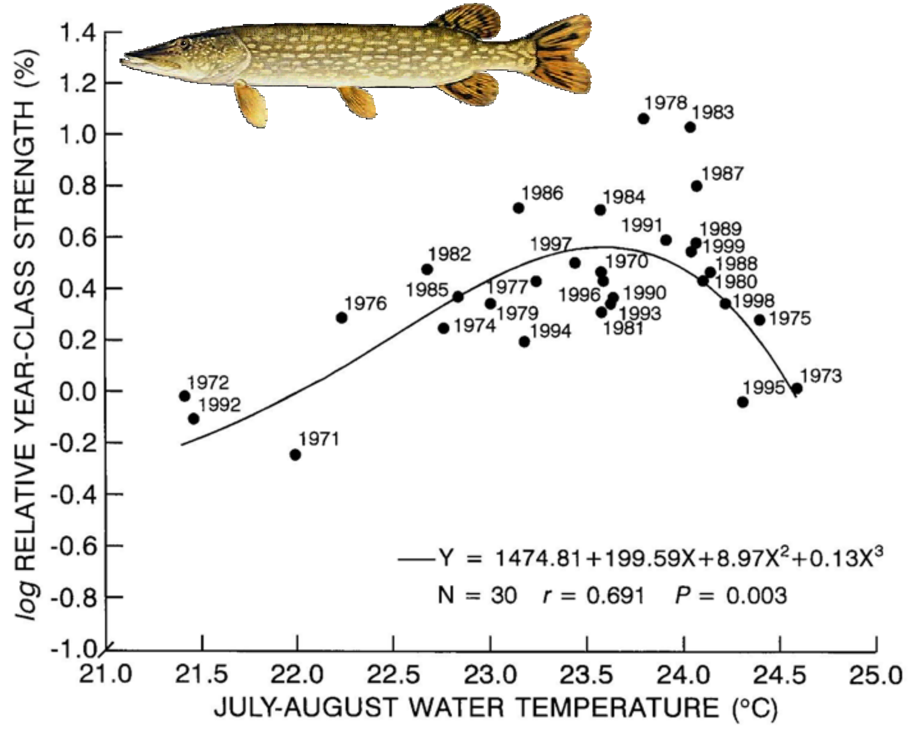
[a] Extrapolated

COOLWATER SPECIES

Optimum Temperature for Growth 15 – 25°C

e.g., Northern pike



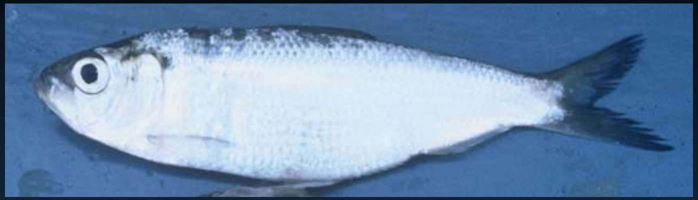


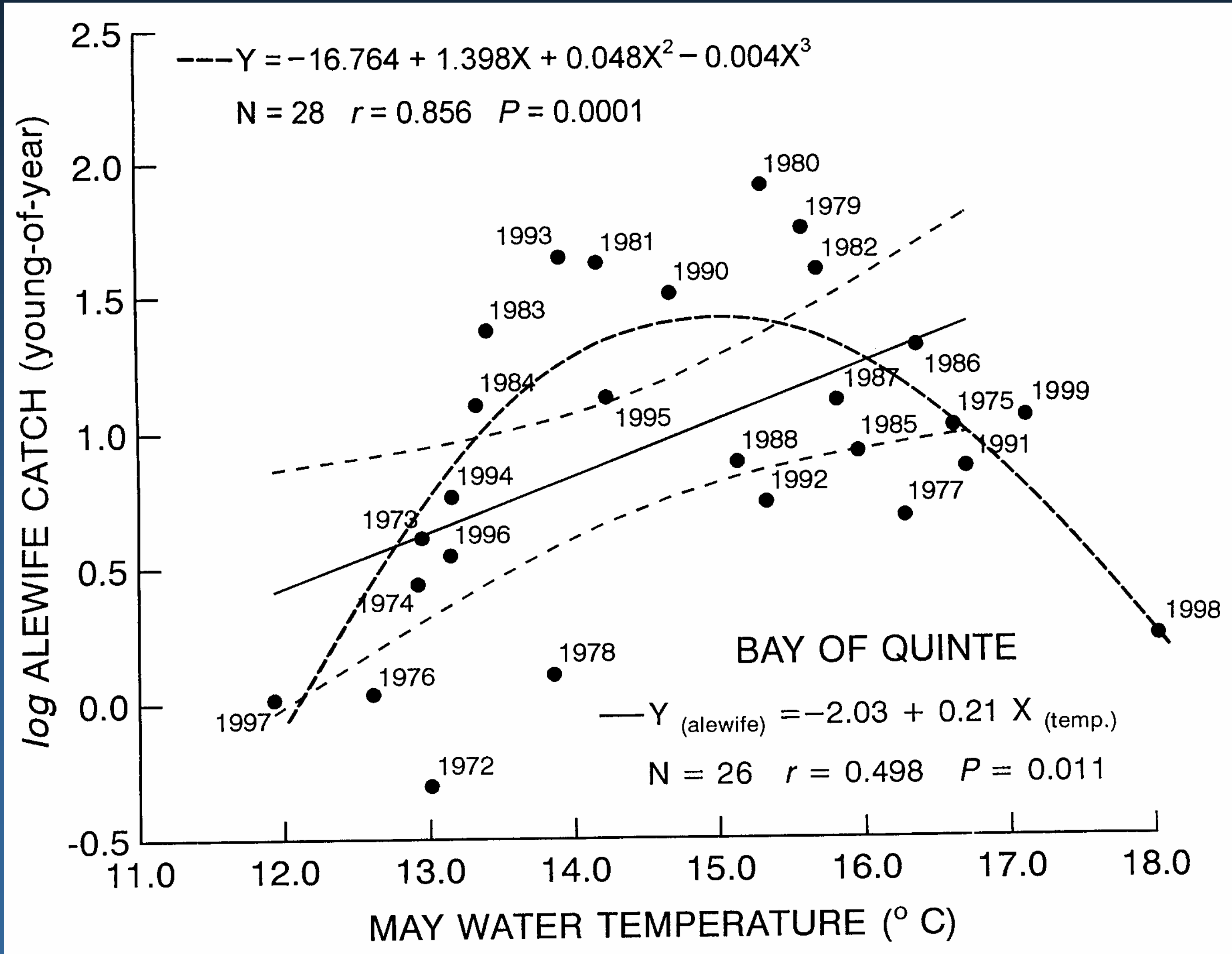
Relative year-class strength of northern pike in the Bay of Quinte in relation to mean July-August water temperatures.

July-August water temperature		Year-class strength	
Mean	Deviation	Relative	Fold change
20.42[a]	-3.00	0.35	-10.23
21.42	-2.00	0.78	-4.59
22.42	-1.00	1.51	-2.37
23.42	0	3.58	0
23.59	+0.17	3.68	+0.03
24.21	+0.79	2.30	-1.56
24.33	+0.91	1.84	-1.95
24.42	+1.00	1.51	-2.37
25.42	+2.00	0.20	-17.90

[a] Extrapolated

COOLWATER SPECIES
e.g., Alewife

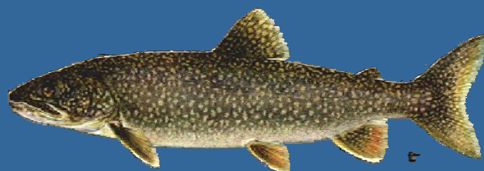


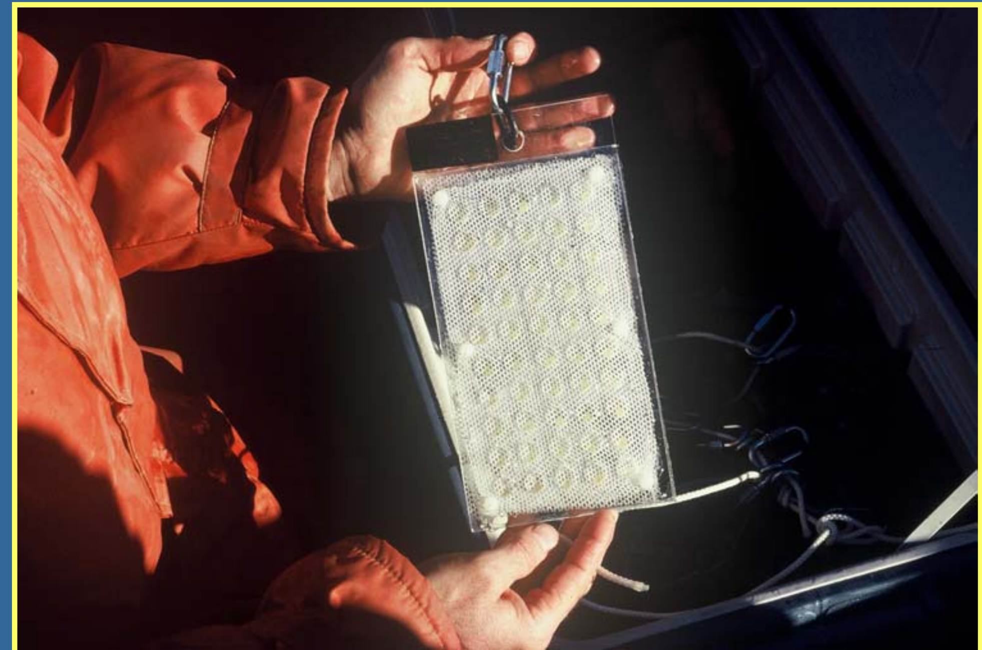


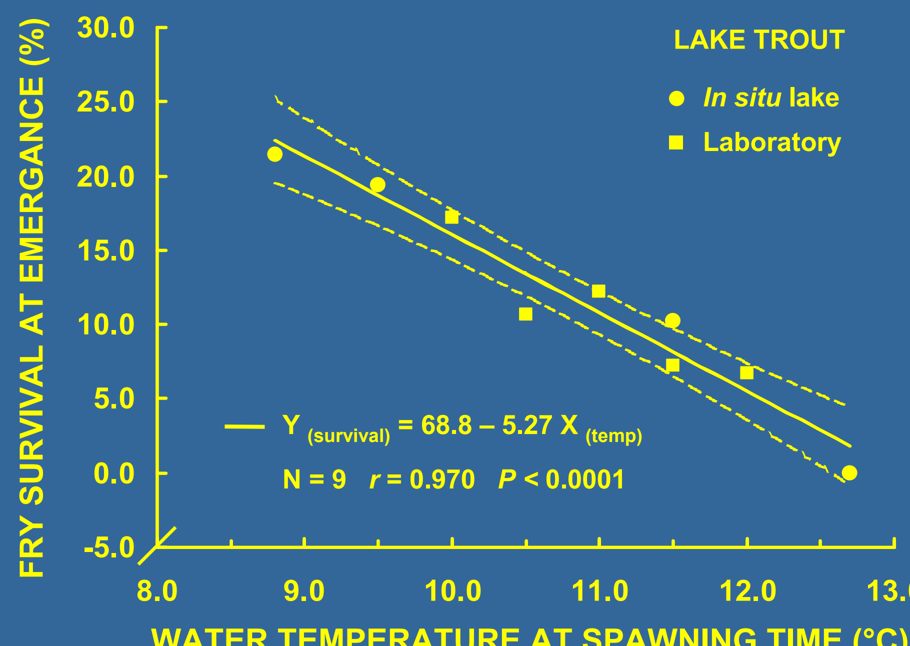
COLDWATER SPECIES

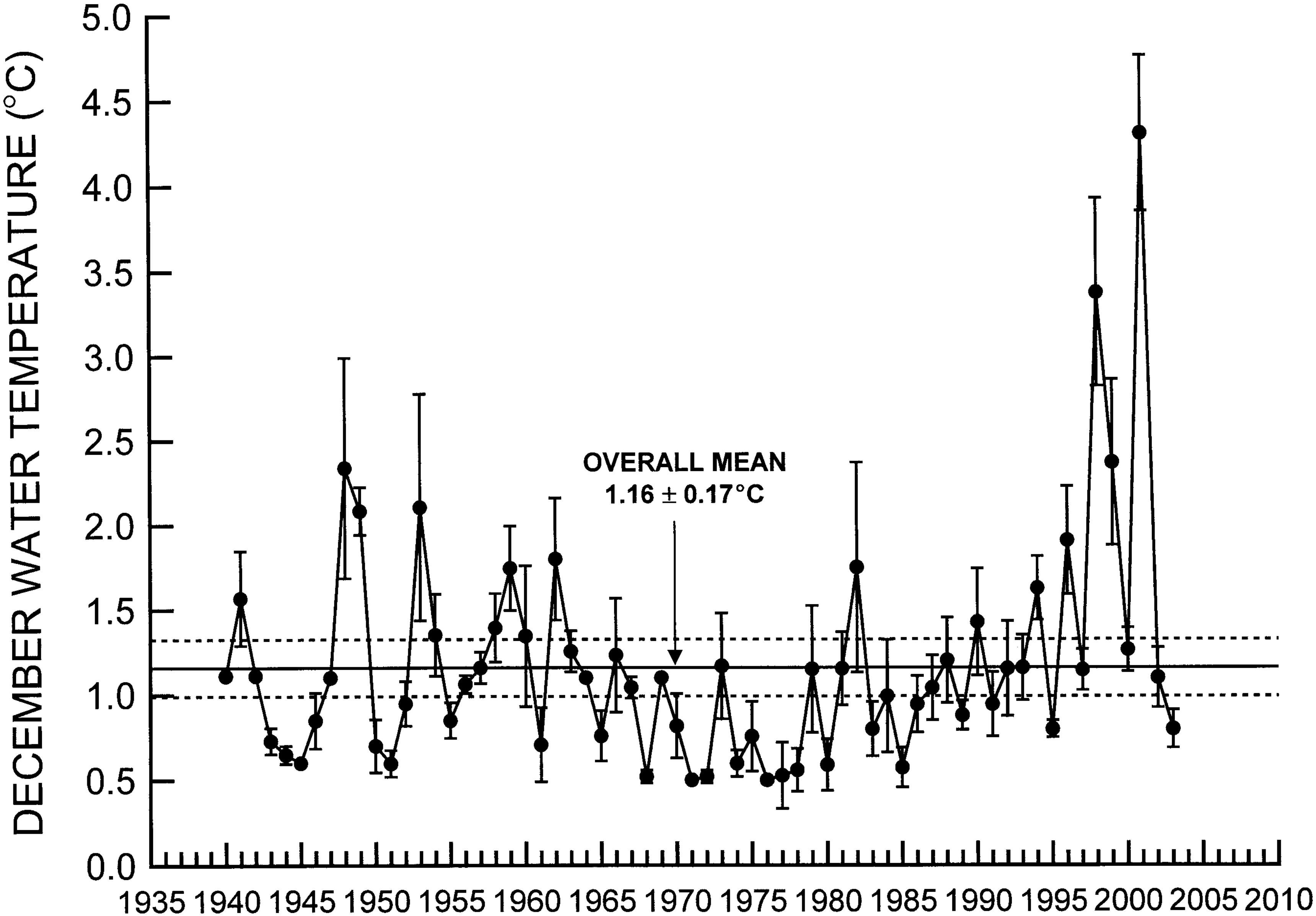
Optimum Temperature for Growth <15^{o}C

e.g., Lake trout









DECEMBER WATER TEMPERATURE (°C)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
OVERALL MEAN
1.16 ± 0.17°C
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010

Survival of lake trout fry at emergence time in spring in eastern Lake Ontario in relation to temperature at spawning time the preceding fall. Temperatures at spawning are averaged for the last two weeks in October and the first week in November.

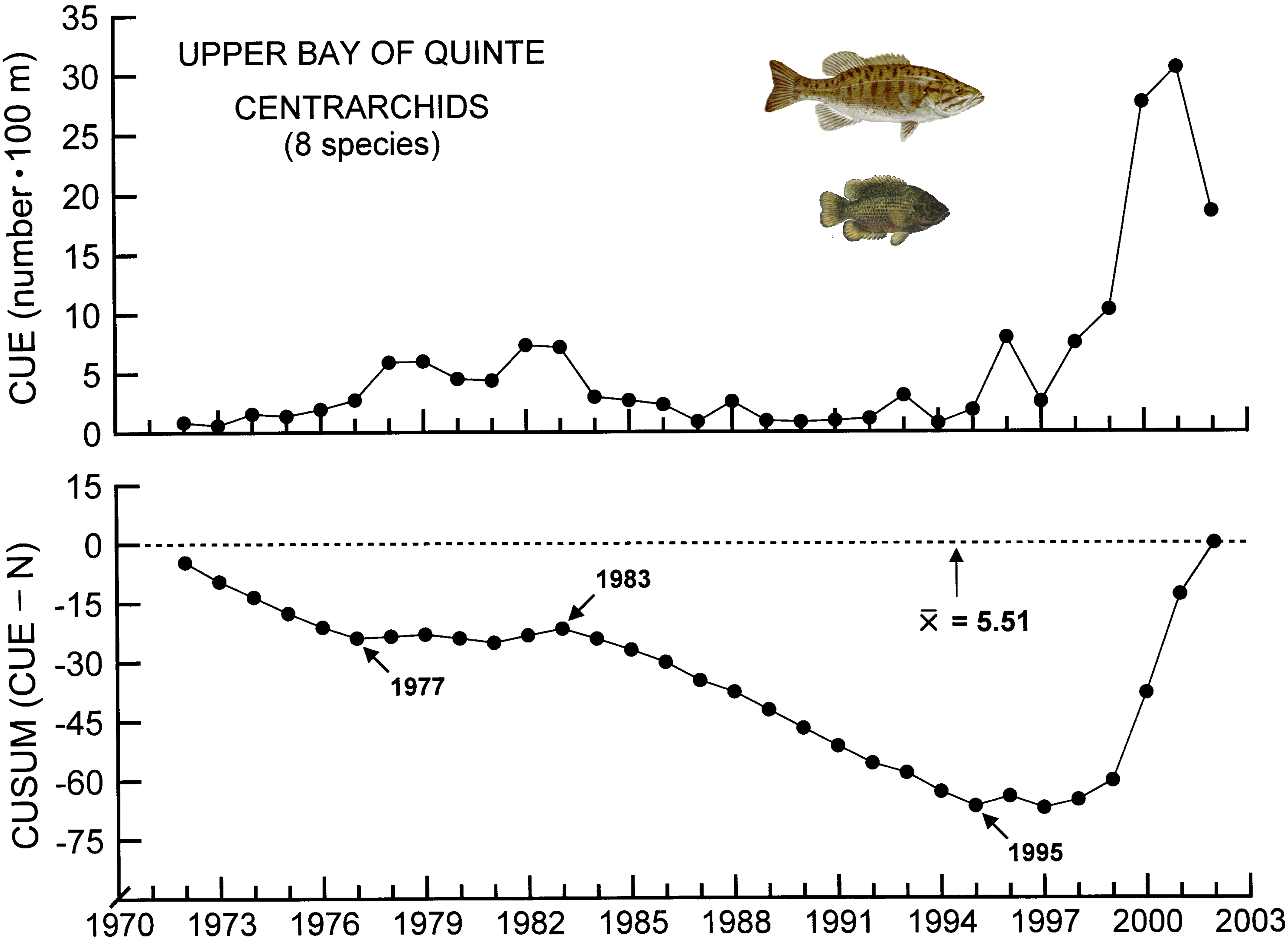
Water temperatures at spawning		Survival at emergence	
Mean	Deviation	Mean (%)	Fold change
6.84[a]	-3.00	32.45	+1.92
7.84[a]	-2.00	27.18	+1.67
8.84	-1.00	22.53	+1.35
9.84	0	16.65	0
10.84	+1.00	11.37	-1.47
11.84	+2.00	6.93	-2.40
12.84	+3.00	0.83	-20.06

[a] Extrapolated

Summary of changes in relative recruitment and community structure for typical warmwater, coolwater, and coldwater species in relation to an increasing temperature regime of 1-3°C.

Thermal grouping / Species	Recruitment change			Community structure (%)		
	+1°C	+2°C	+3°C [a]	0°C	+1°C	+2°C
Warmwater						
smallmouth bass	+2.5x	+6.0x	+14.7x	33	69[b]	93[c]
Coolwater						
northern pike	-2.4x	-17.9x		33	12	1
Coldwater						
lake trout	-1.5x	-2.4x	-20.1x	33	19	6

[a] Extrapolated
[b] Recruitment would increase by 2.1x with a 1°C increase
[c] Recruitment would increase by 2.8x with a 2°C increase


UPPER BAY OF QUINTE
CENTRARCHIDS
(8 species)
CUE (number • 100 m)
35
30
25
20
15
10
5
0
CUSUM (CUE − N)
15
0
-15
-30
-45
-60
-75
1983
1977
1995
X̄ = 5.51
1970
1973
1976
1979
1982
1985
1988
1991
1994
1997
2000
2003

Climate and exotic species interactions

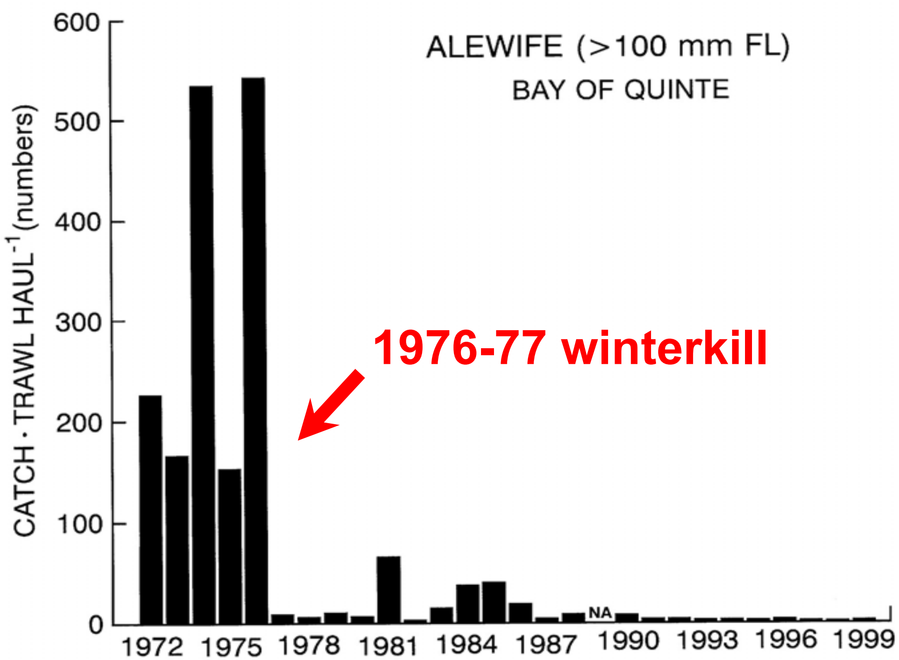
Recruitment, population dynamics, community structure

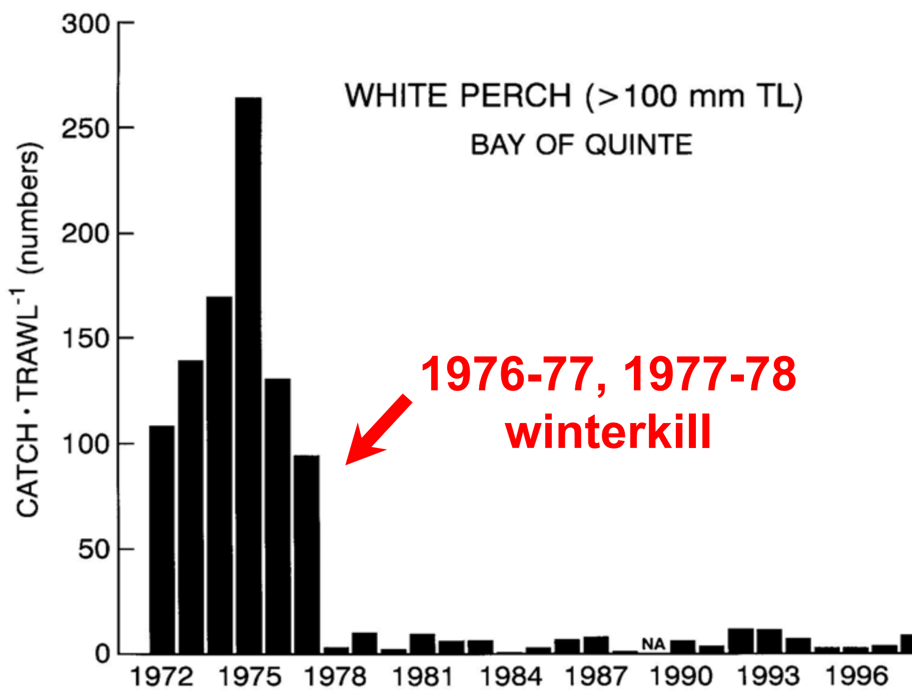
CATASTROPHIC DIE-OFFS

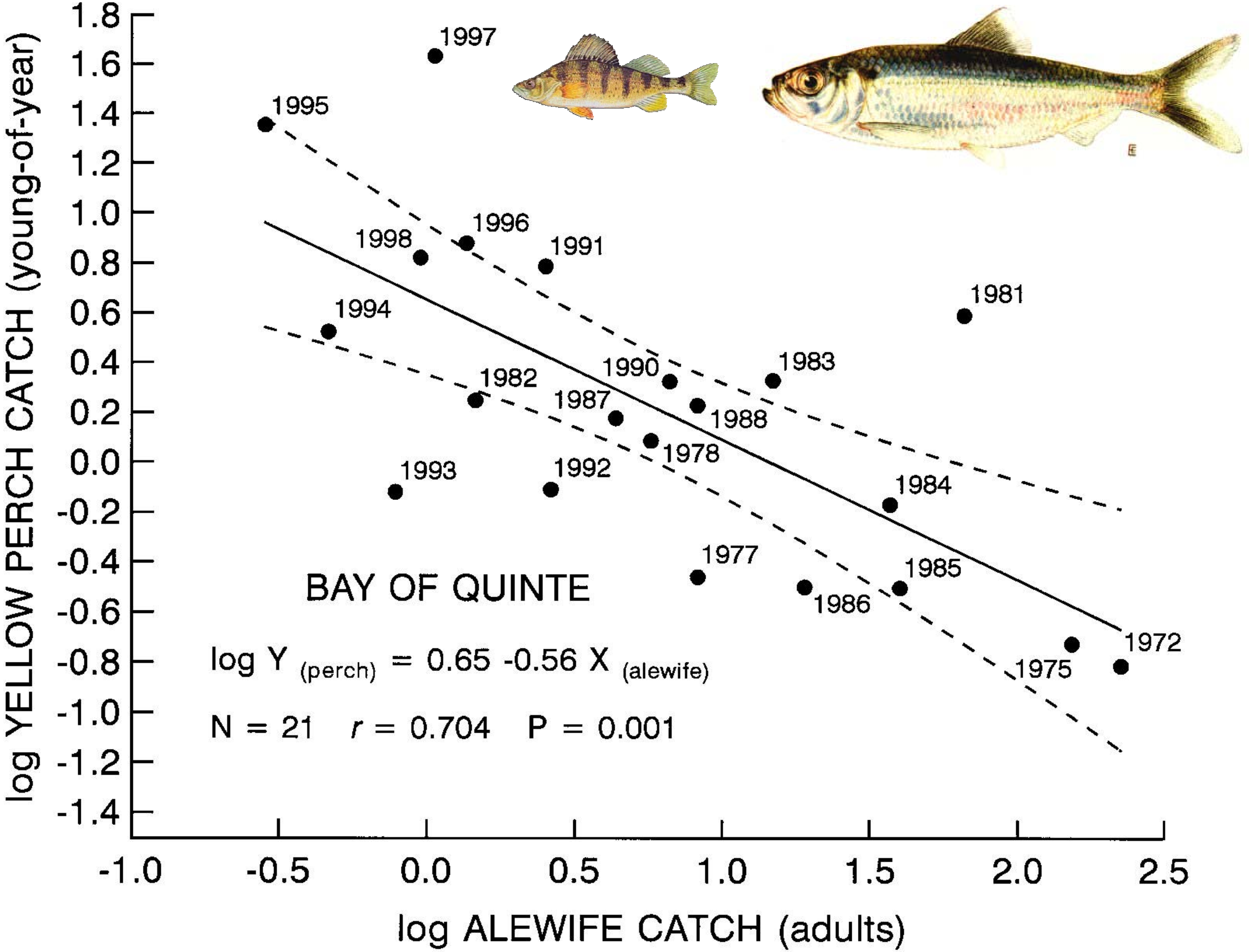
Winterkills of thermally ill-adapted exotic species

Alewife

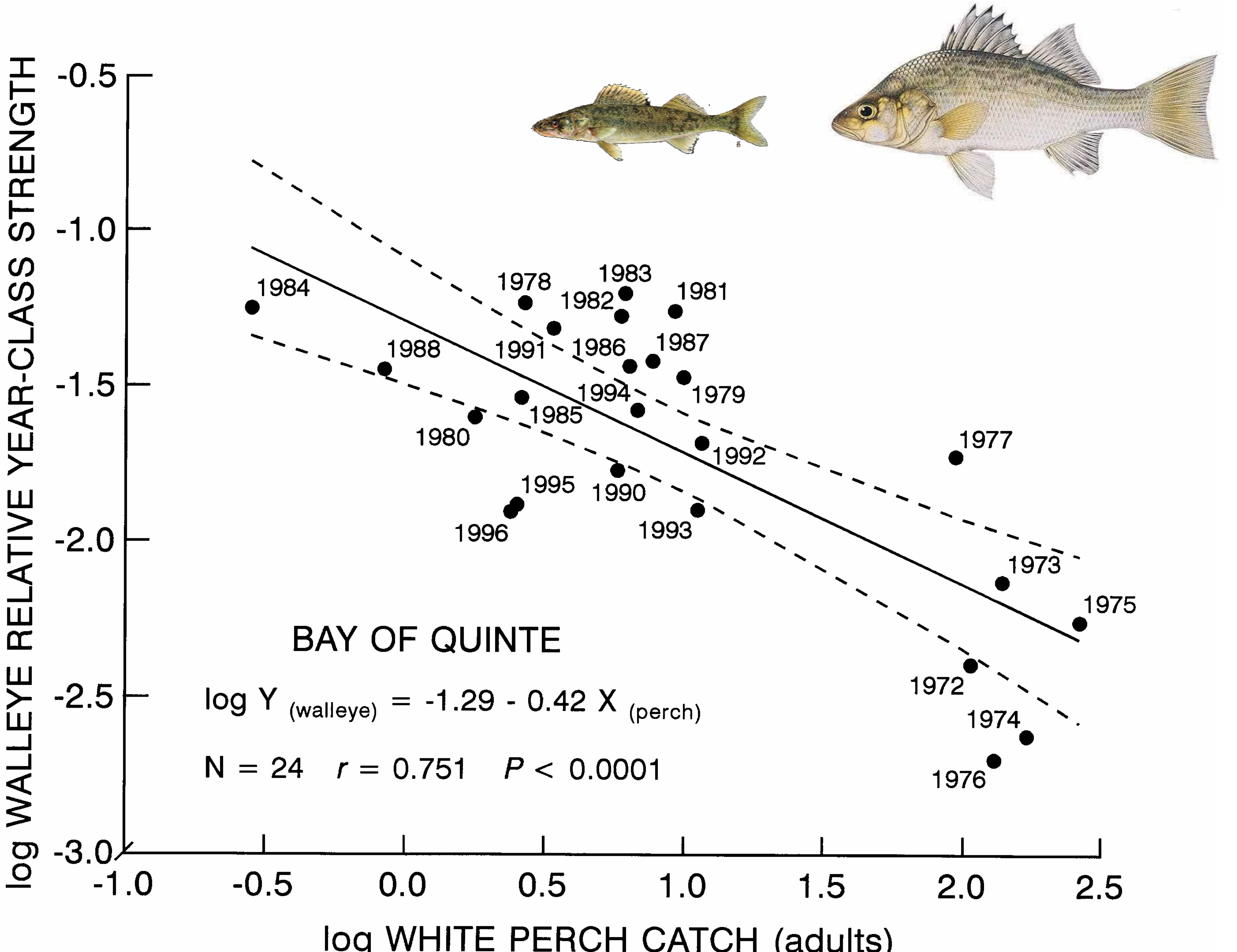
White perch







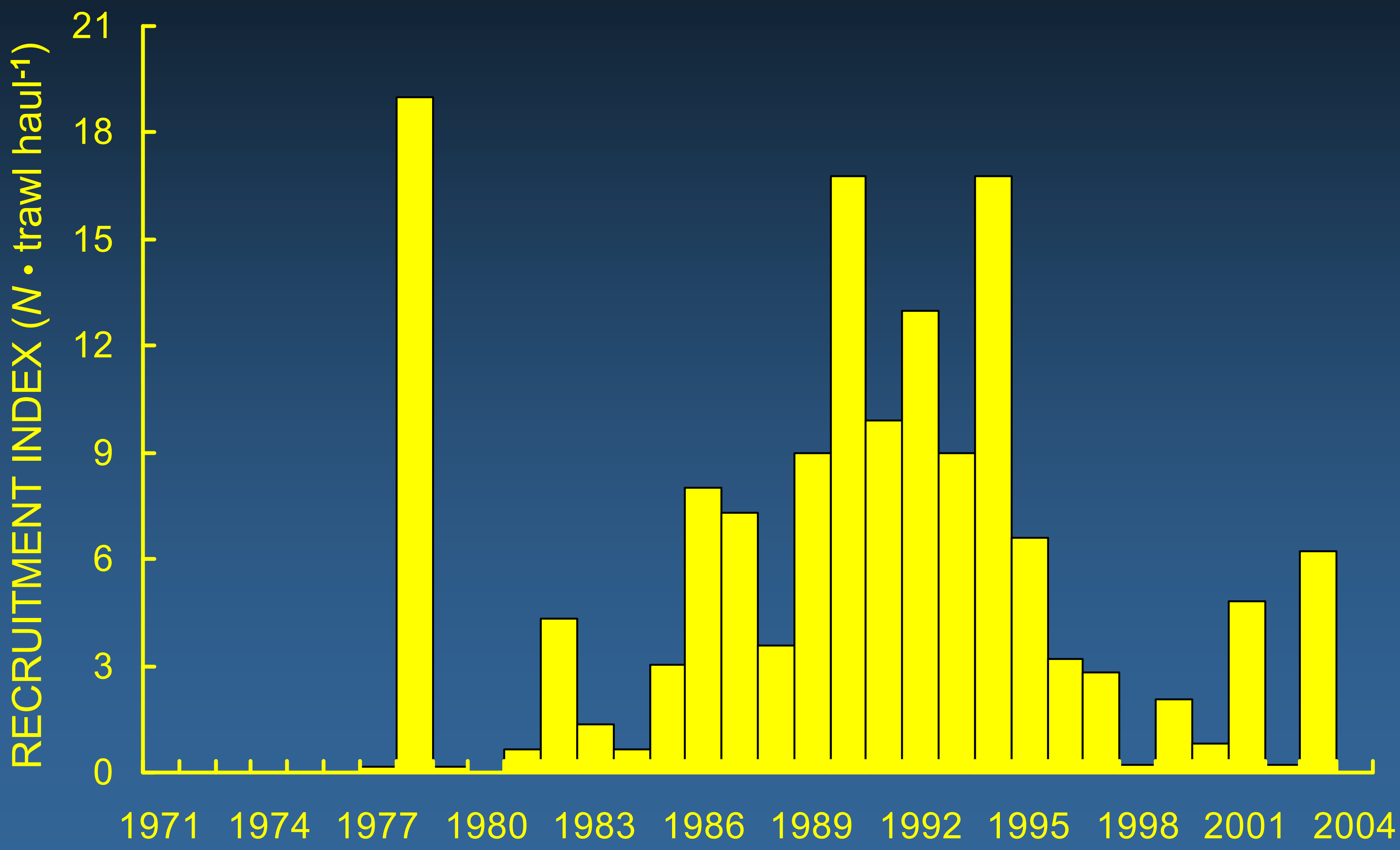
log YELLOW PERCH CATCH (young-of-year)
log ALEWIFE CATCH (adults)
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
2.5
1997
1995
1996
1998
1991
1981
1994
1990
1983
1982
1987
1988
1978
1993
1992
1984
1977
1985
1986
1972
1975
BAY OF QUINTE
log Y (perch) = 0.65 -0.56 X (alewife)
N = 21 r = 0.704 P = 0.001



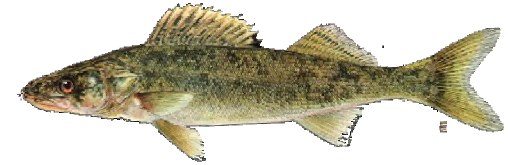
log WALLEYE RELATIVE YEAR-CLASS STRENGTH
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
2.5
log WHITE PERCH CATCH (adults)
1984
1978
1983
1982
1981
1988
1991
1986
1987
1979
1994
1985
1980
1992
1977
1995
1990
1996
1993
1973
1975
1972
1974
1976
BAY OF QUINTE
log Y (walleye) = -1.29 - 0.42 X (perch)
N = 24 r = 0.751 P < 0.0001

RECRUITMENT INDEX

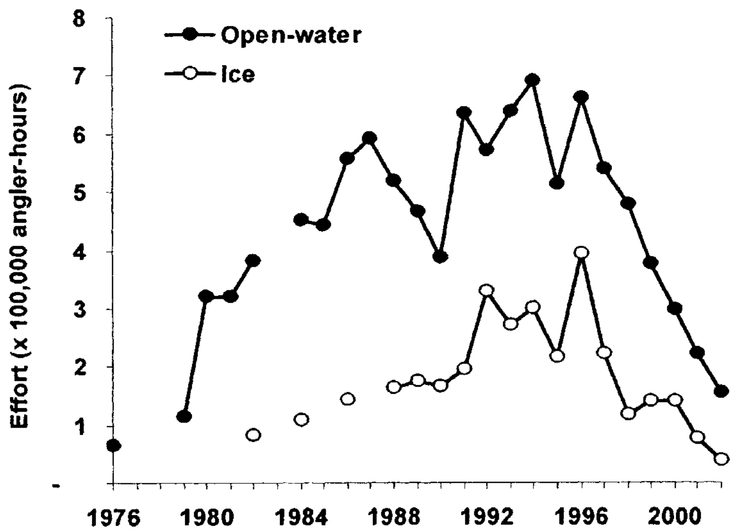
Walleye young-of-the-year, a cool-water fish

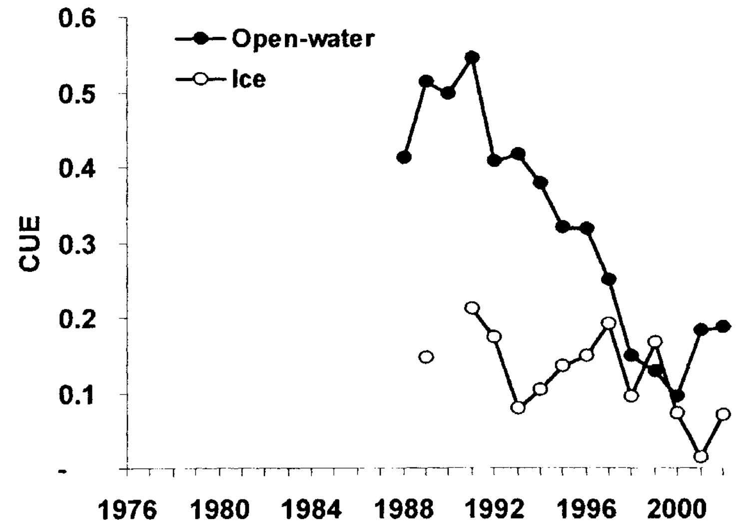


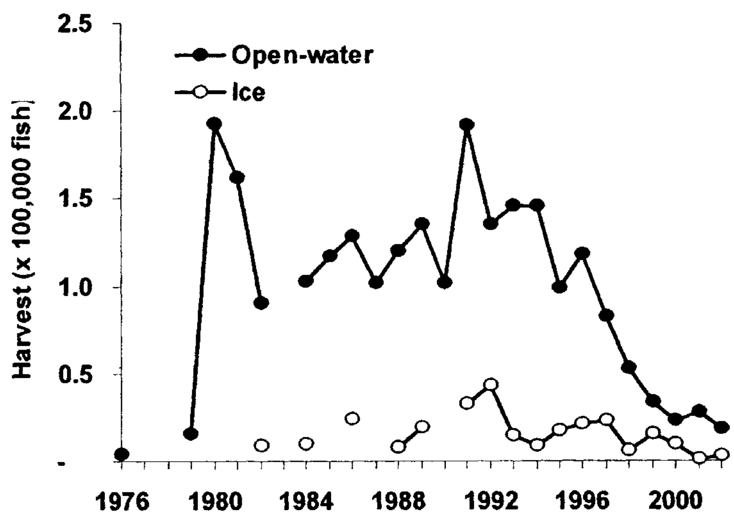
WALLEYE RECREATIONAL FISHERIES

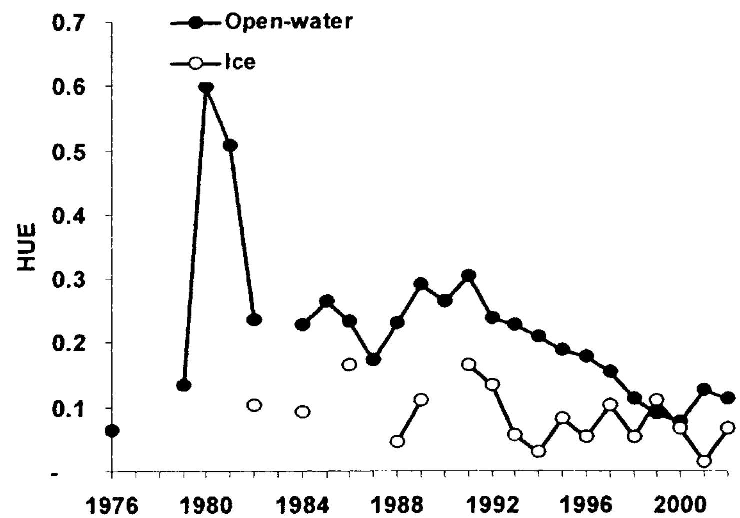


Effort, catch, and harvest for open-water and ice fisheries, Bay of Quinte

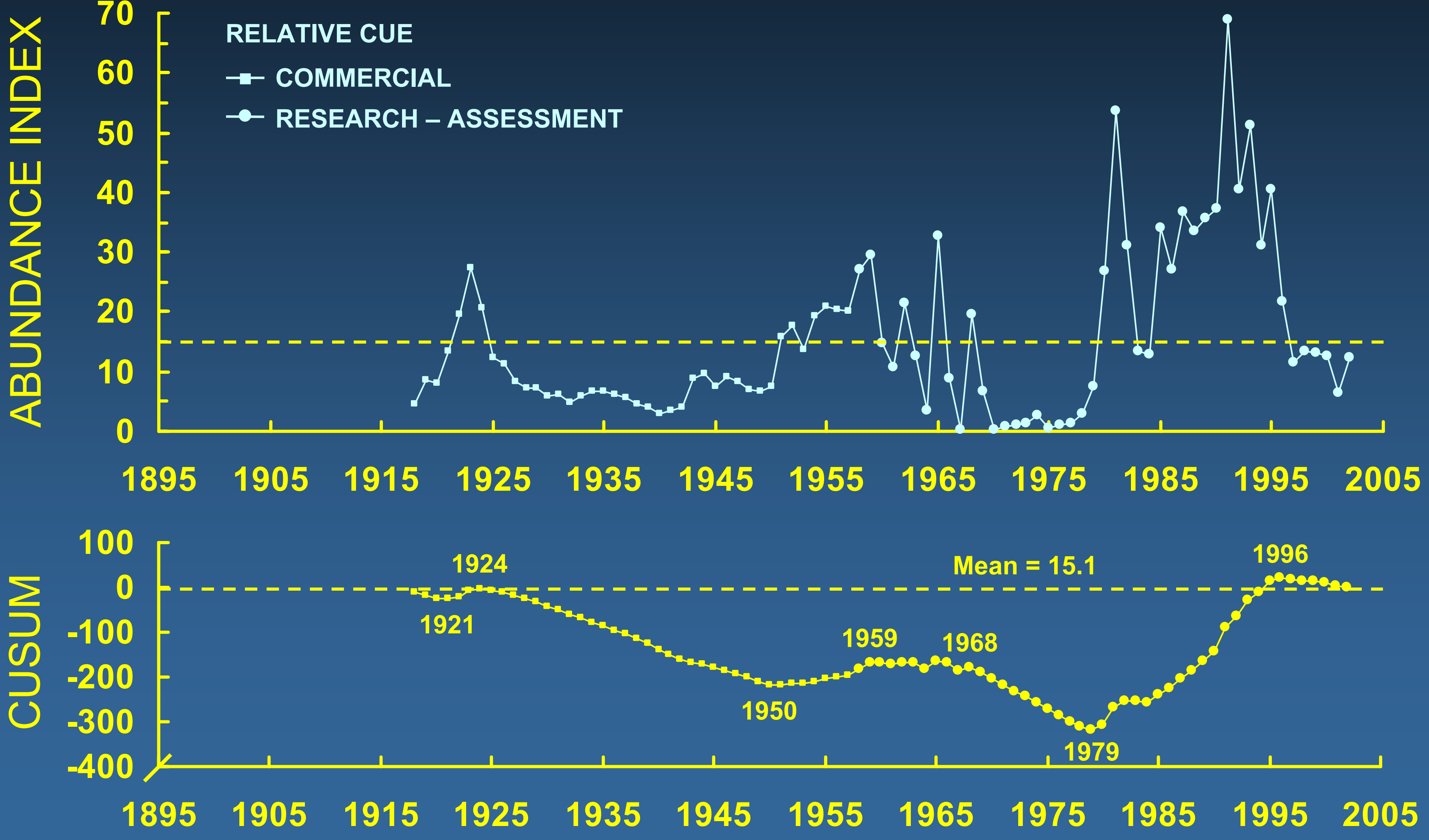




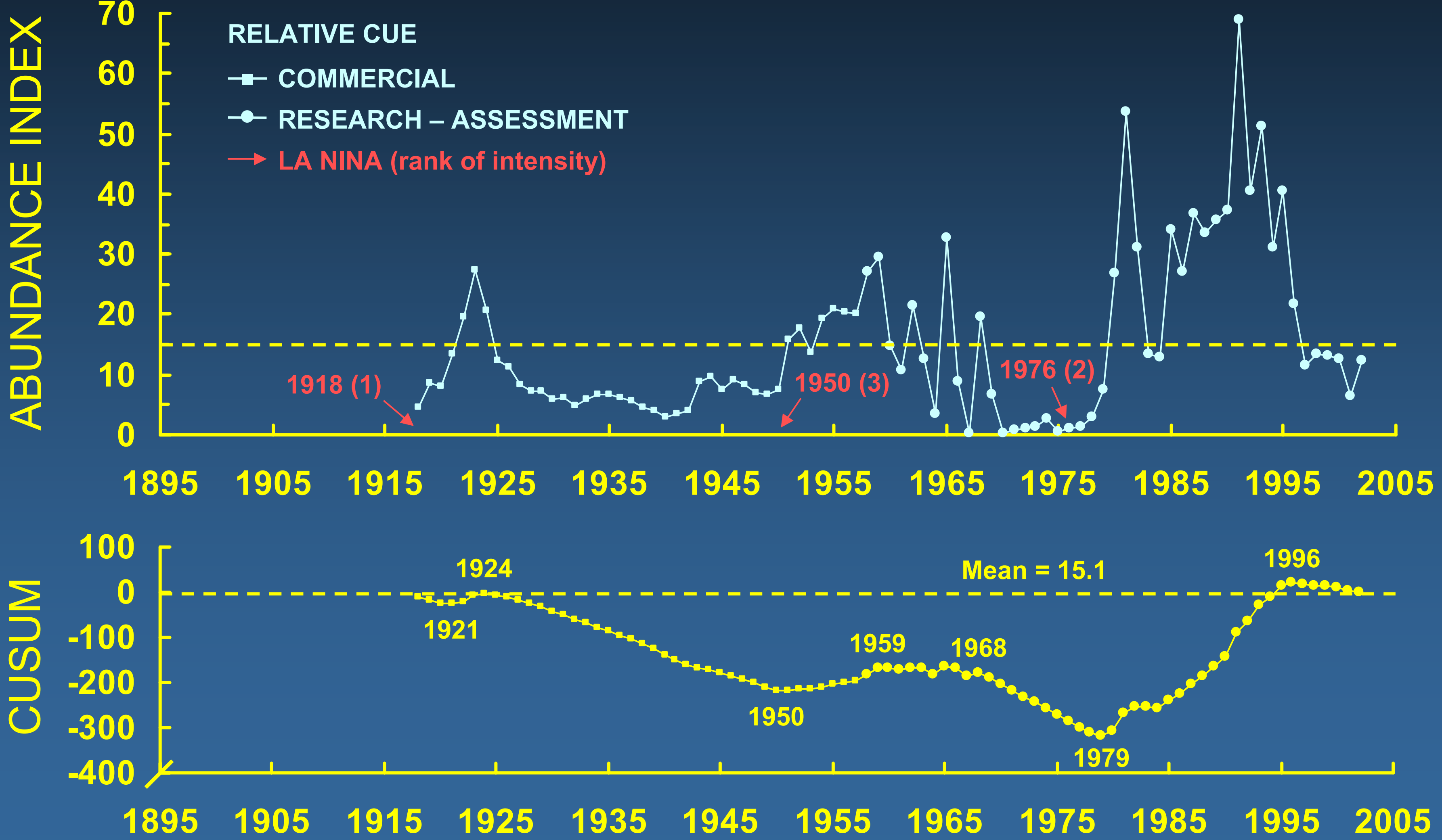




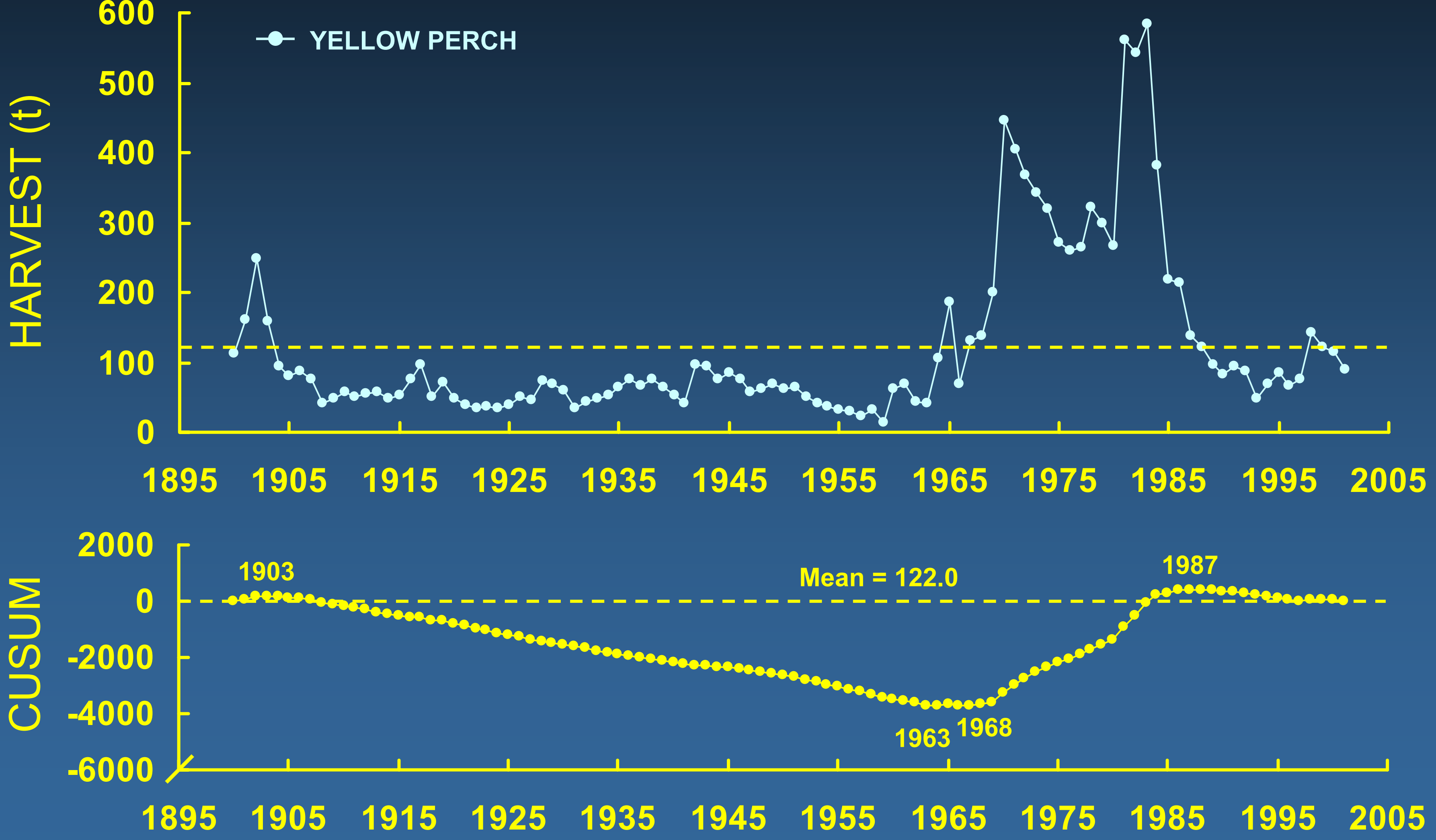
LAKE ONTARIO Walleye



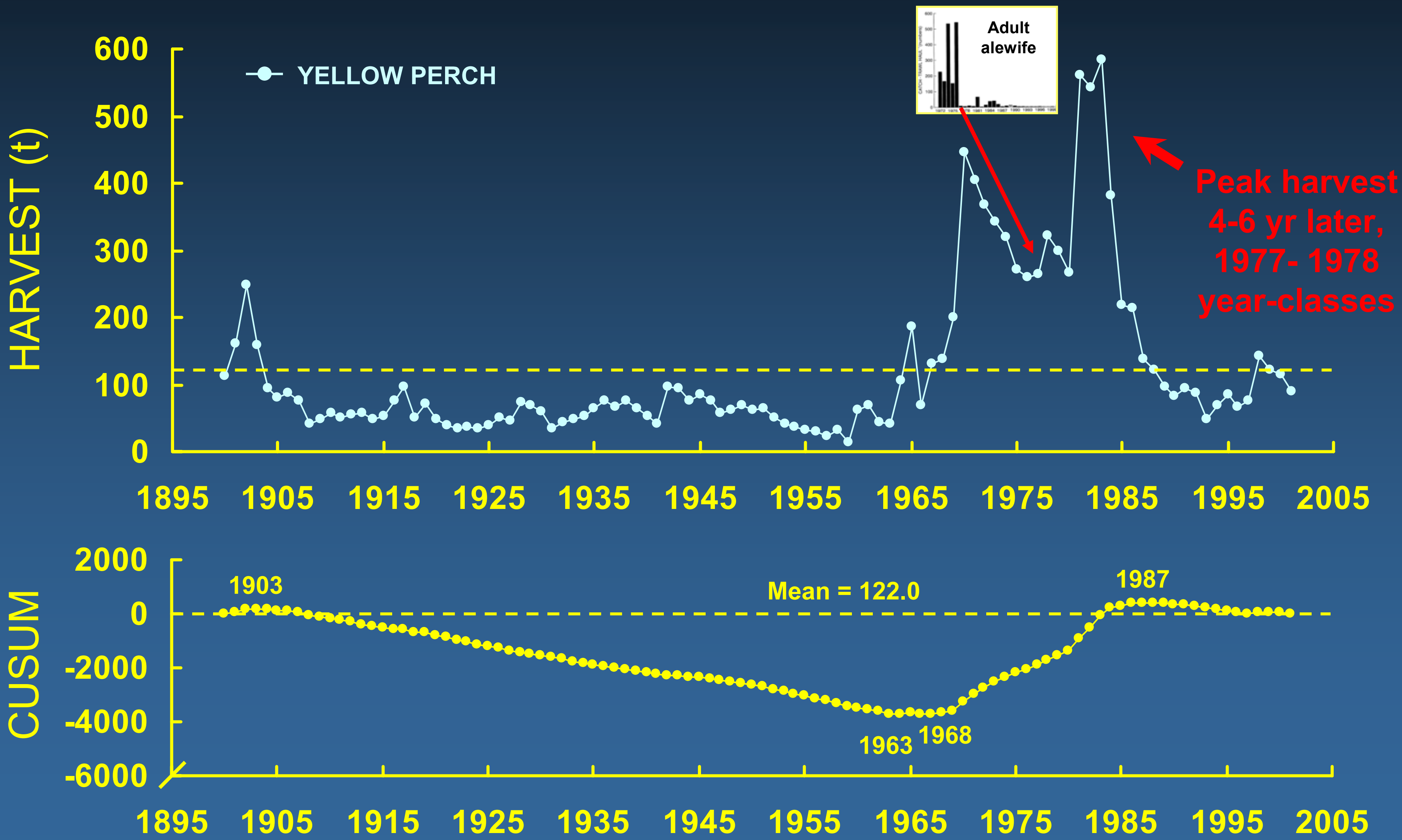
LAKE ONTARIO Walleye



LAKE ONTARIO Yellow perch



LAKE ONTARIO Yellow perch

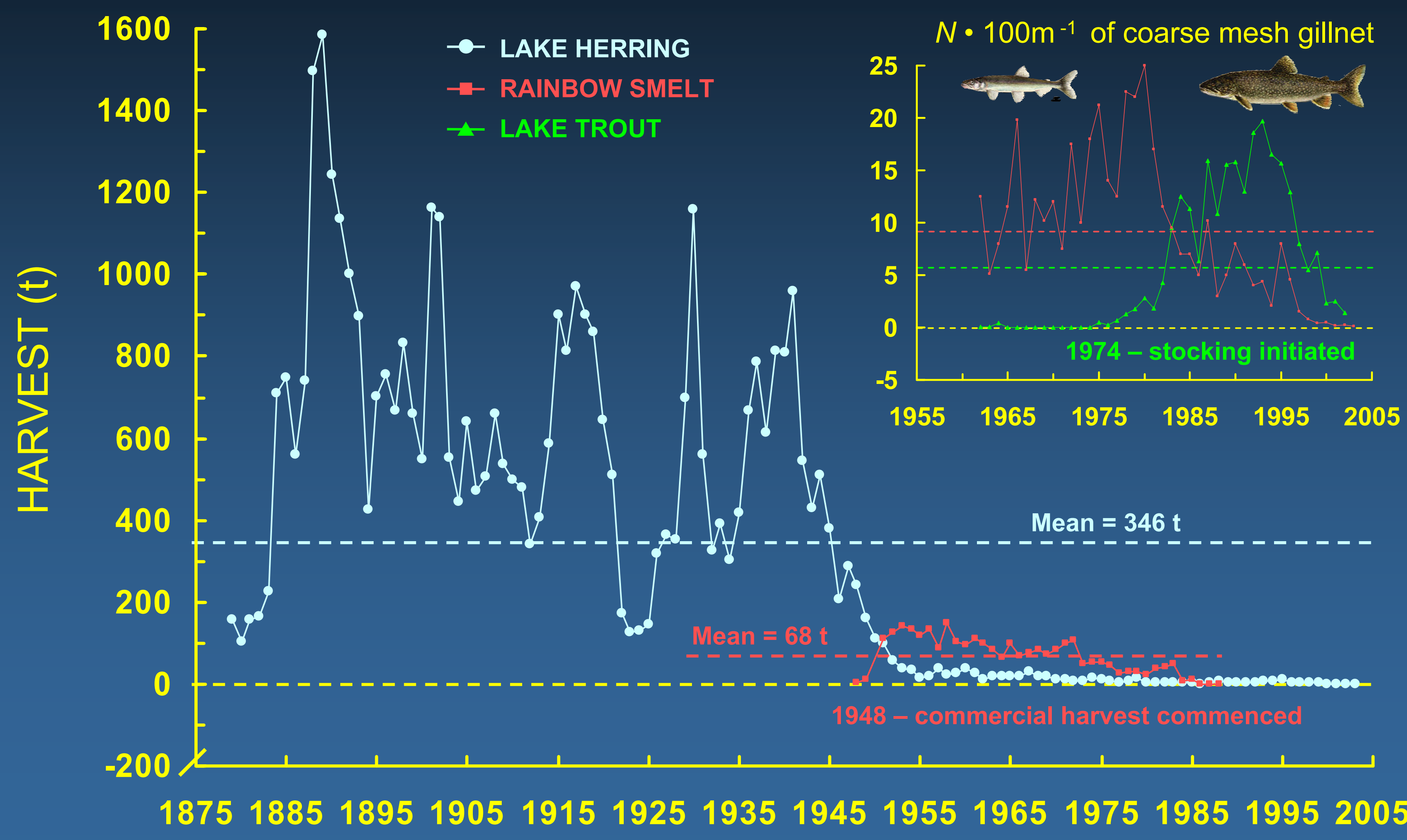


Rainbow Smelt and Predator-Prey Interaction

Lake trout, lake herring, and lake whitefish

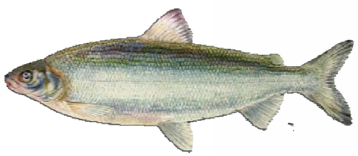
LAKE ONTARIO

Lake herring
Rainbow smelt

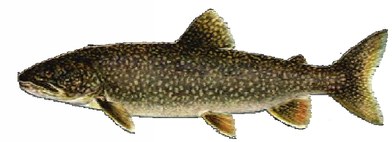


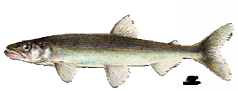
LAKE TROUT, RAINBOW SMELT, LAKE WHITEFISH INTERACTIONS

From 1974 to 1991

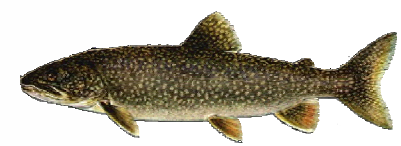


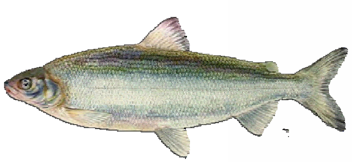
1. Log CUE = -0.66 + 0.97 log CUE
   (whitefish) *(lake trout 4 years earlier)*
   N = 13 $r = 0.97$ $P < 0.001$



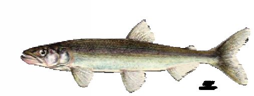


2. Log CUE = 0.91 - 0.29 log CUE
   (smelt) *(lake trout 4 years earlier)*
   N = 13 $r = 0.84$ $P < 0.001$





3. Log CUE = 1.77 - 2.77 log CUE
   (whitefish) *(smelt)*
   N = 18 $r = 0.83$ $P < 0.001$



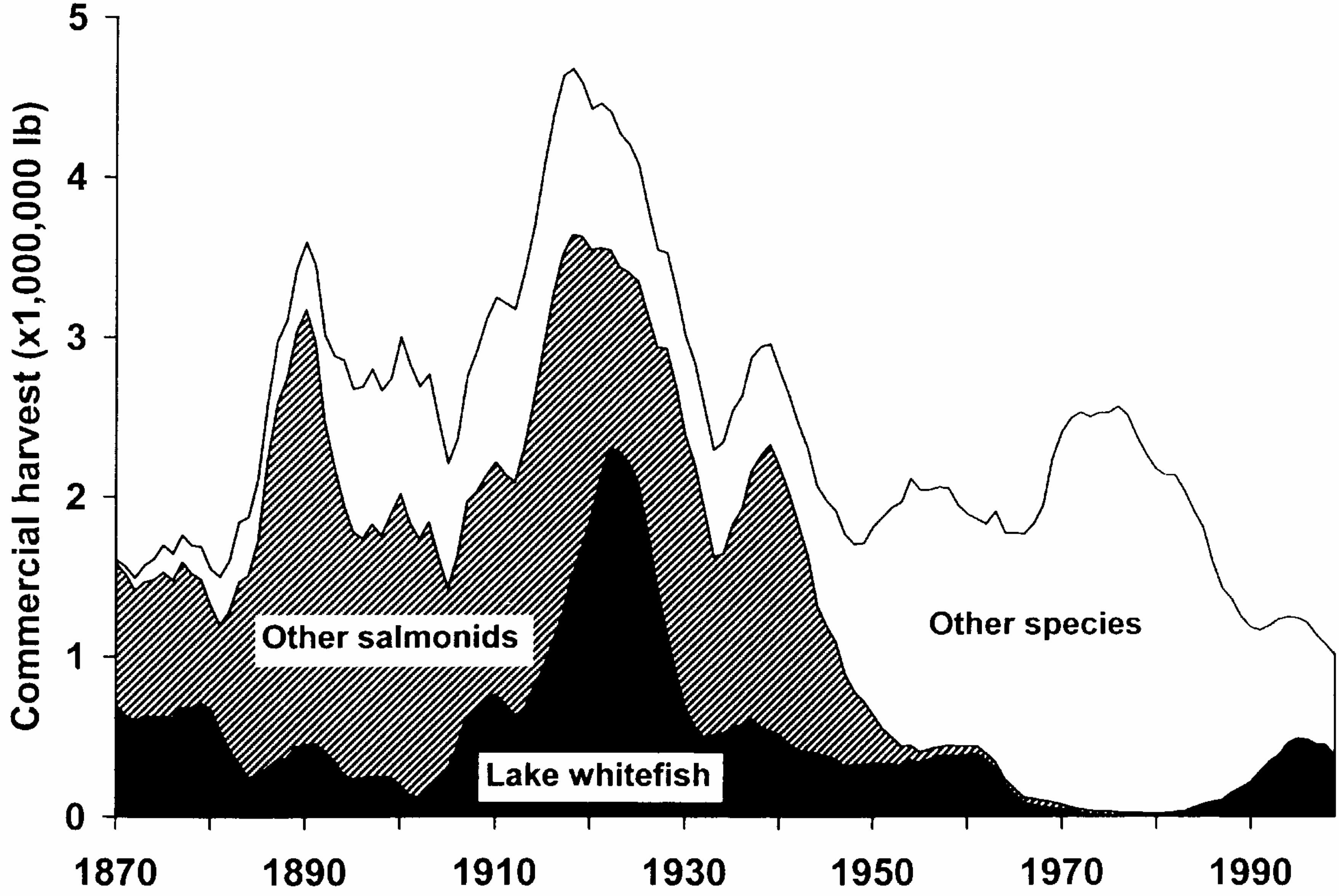
Lake Whitefish

Recruitment, climate, productivity, and invading dreissenids

Dynamics and Production of Lake Whitefish, an Important Commercial Species in Lake Ontario

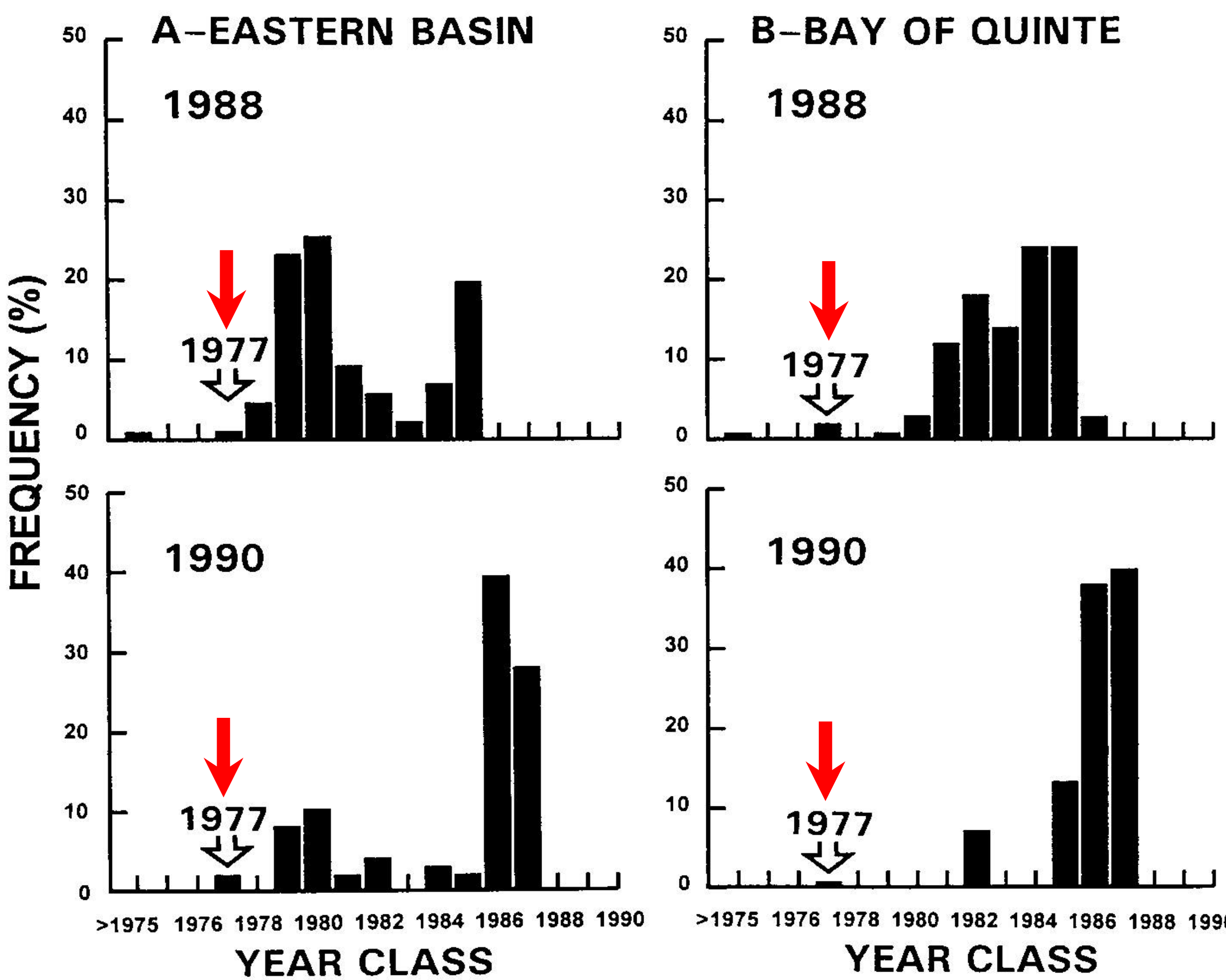
- Recruitment enhanced by decreased fishing pressure and fry predation, P control, and extremely cold fall and winter
- Growth and condition negatively affected by invading dreissenids and *Diporeia* declines

LAKE ONTARIO   Commercial harvest, lake whitefish

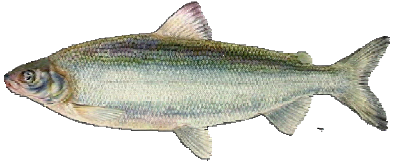


RECENT RESURGENCE OF LAKE ONTARIO LAKE WHITEFISH

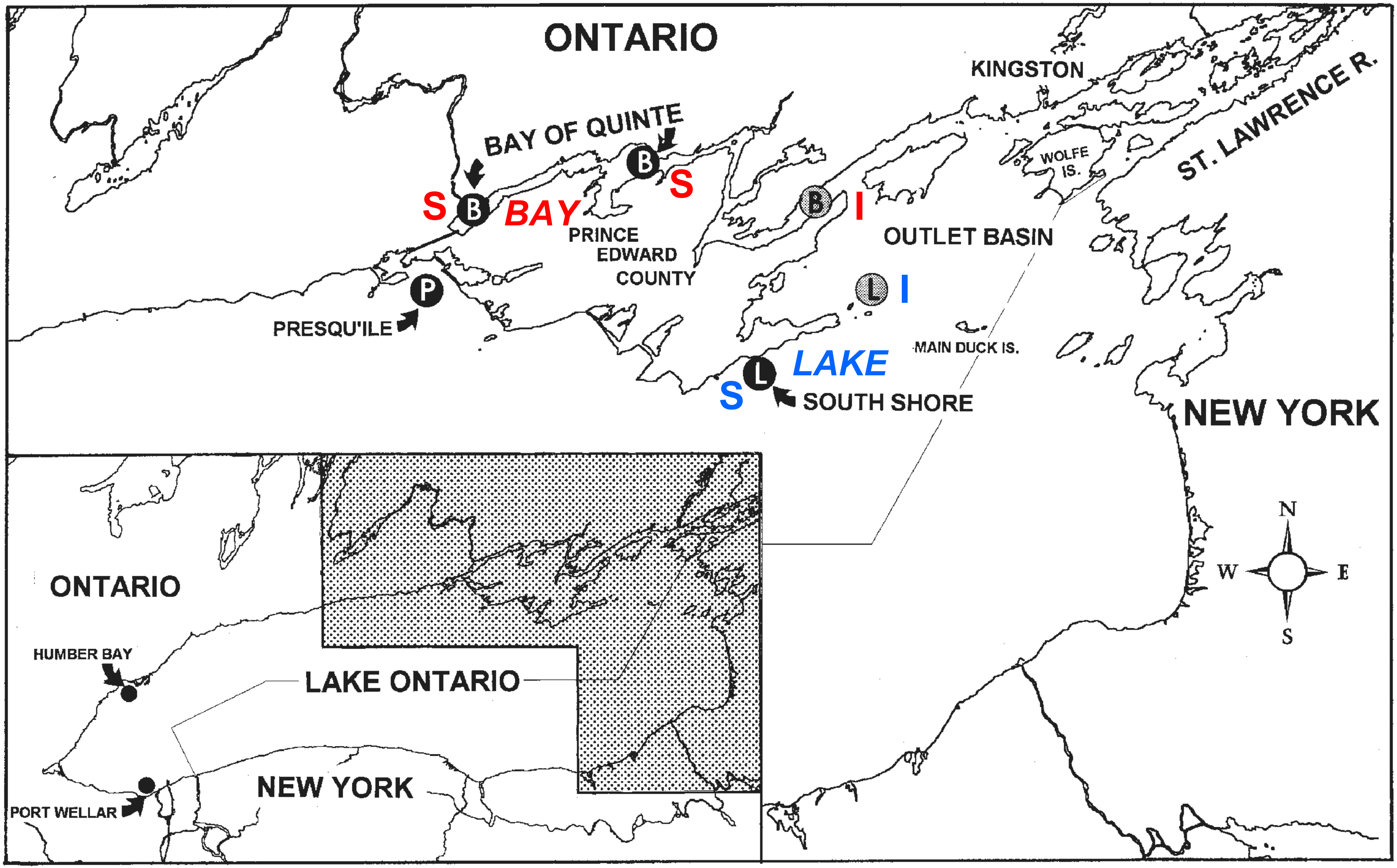
Began with the 1977 year-class for both *BAY* and *LAKE* stocks



LAKE WHITEFISH STOCKS, LAKE ONTARIO

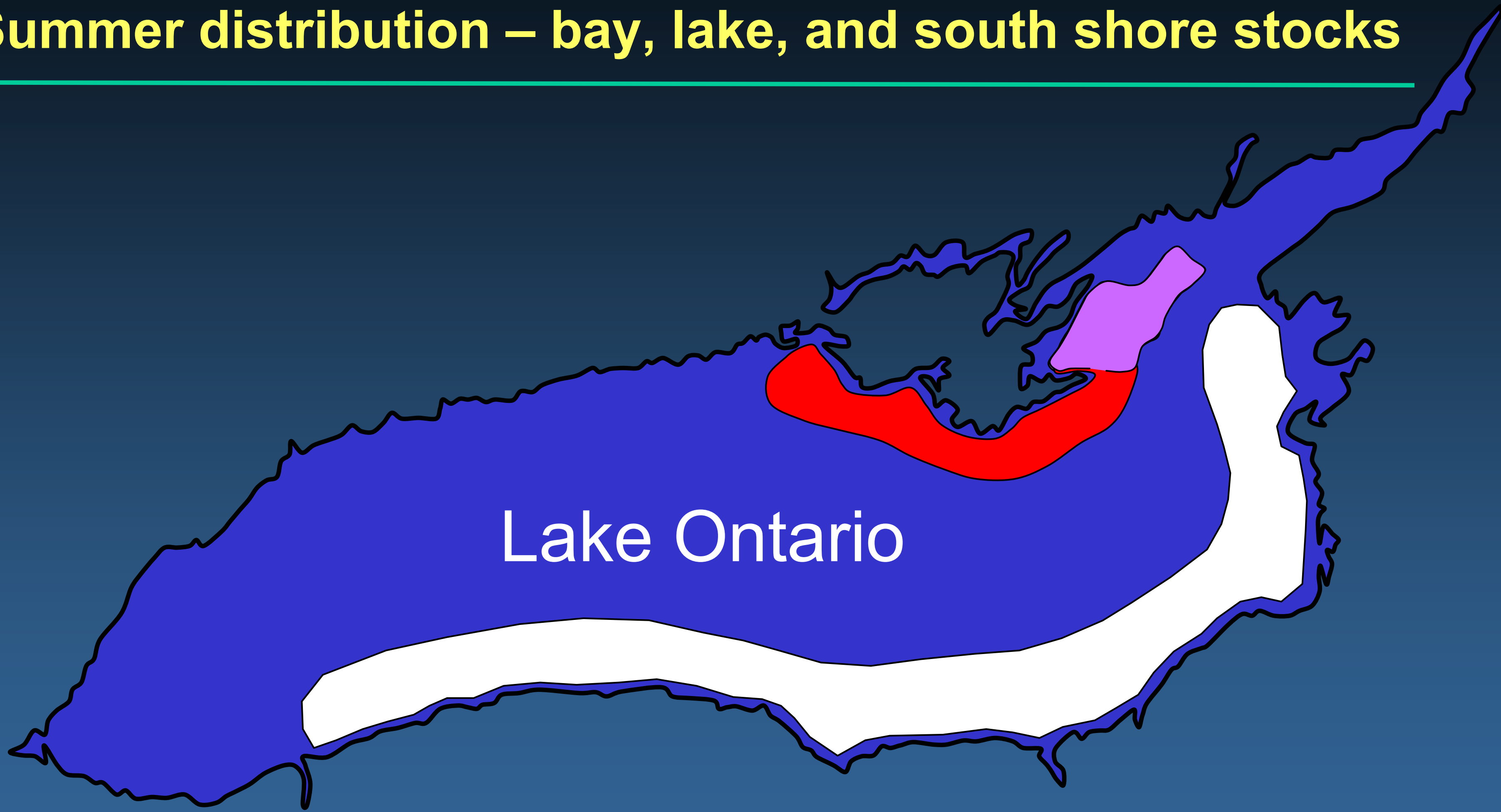


BAY and *LAKE* spawning and recruitment indexing locations



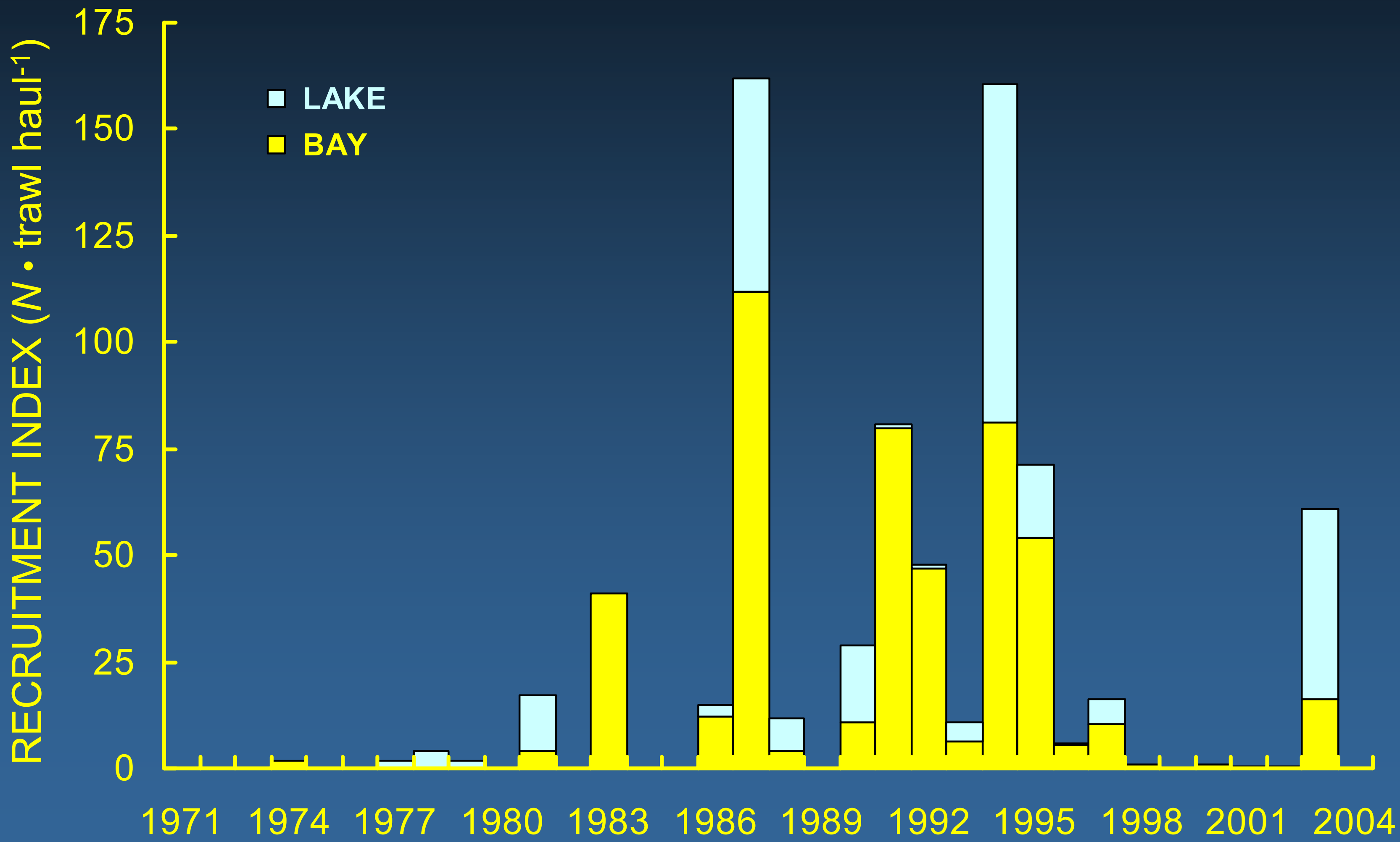
LAKE WHITEFISH STOCKS, EASTERN LAKE ONTARIO

Summer distribution – bay, lake, and south shore stocks



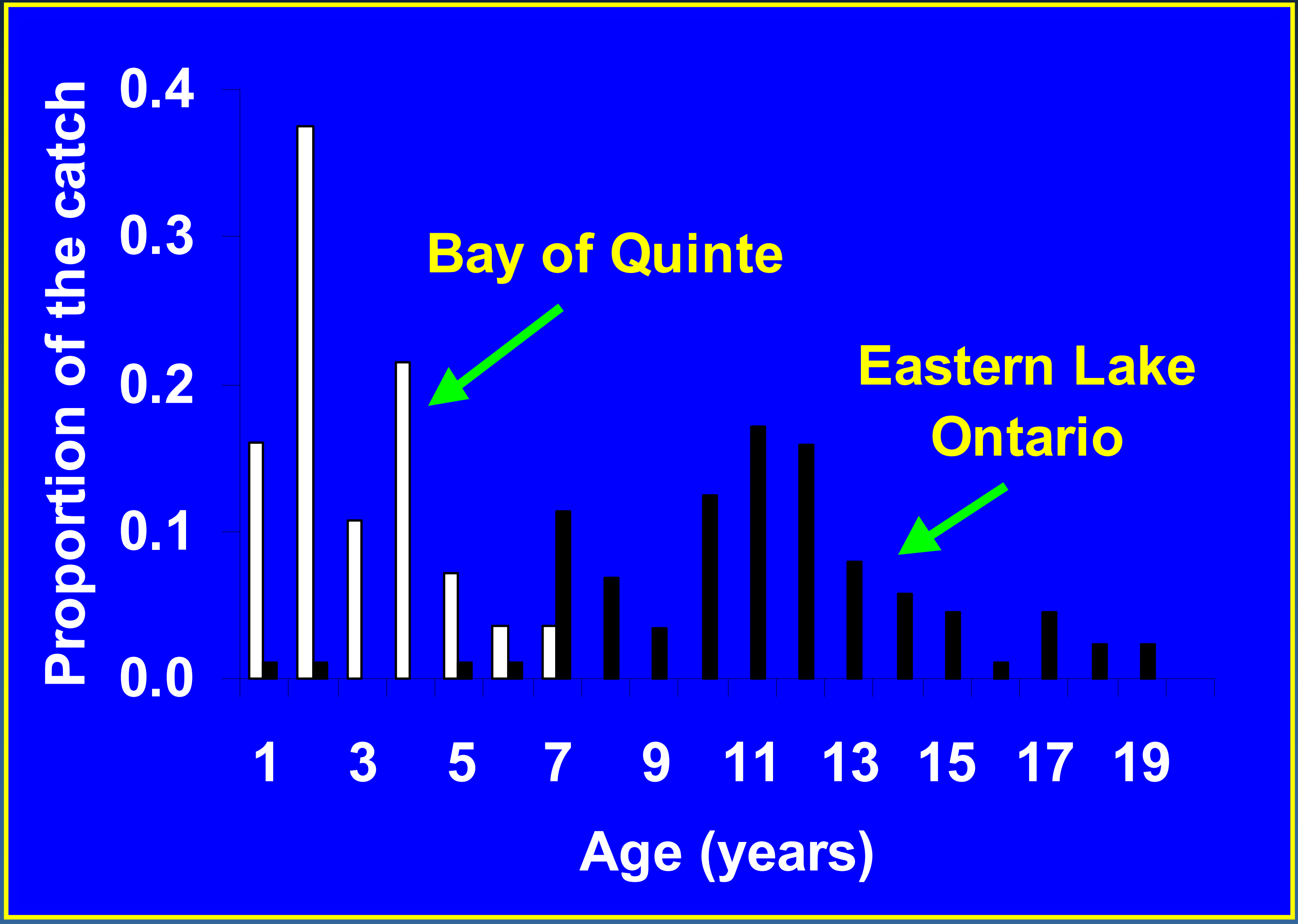
RECRUITMENT INDEX

Lake whitefish young-of-the-year, a cold-water fish

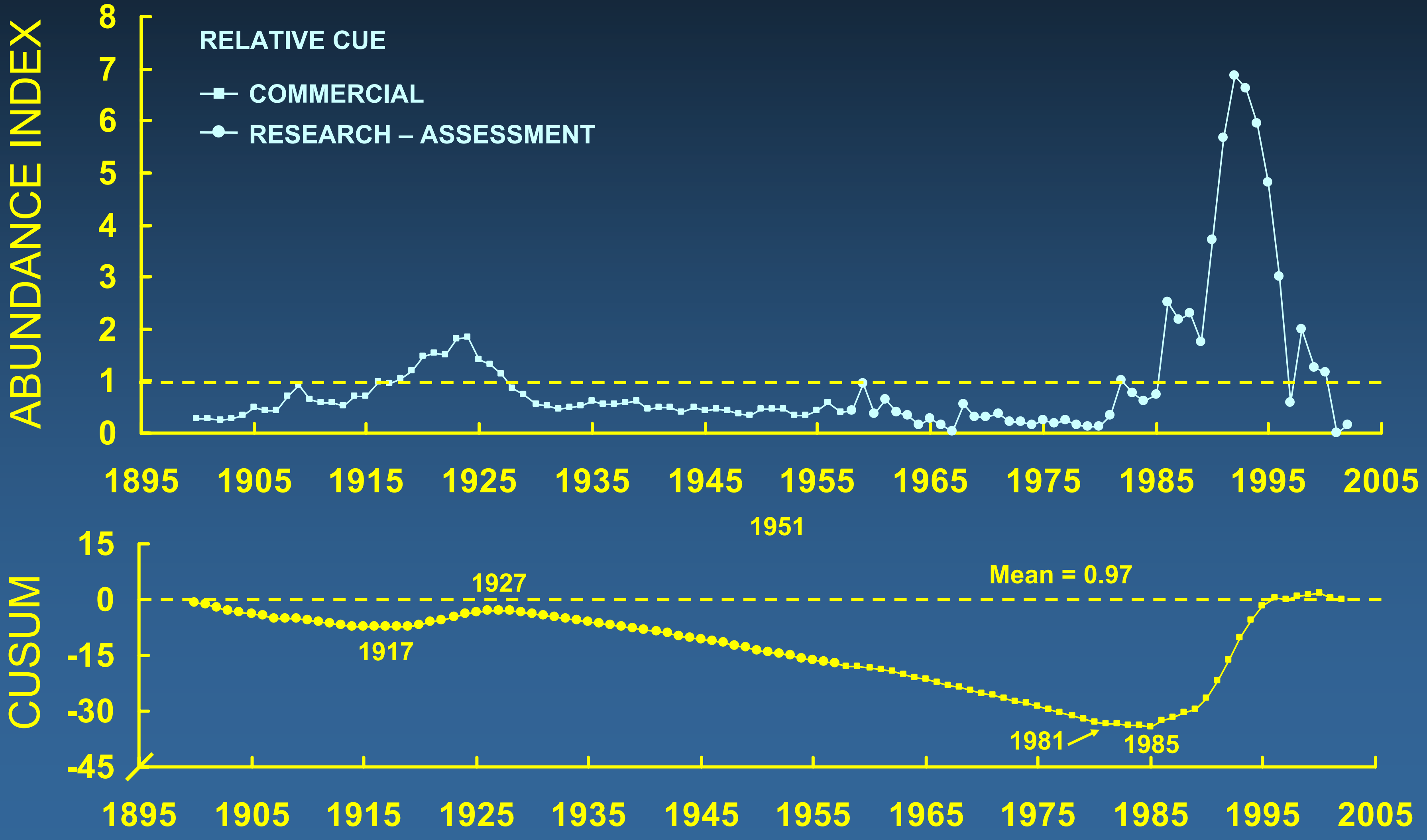


AGE DISTRIBUTIONS

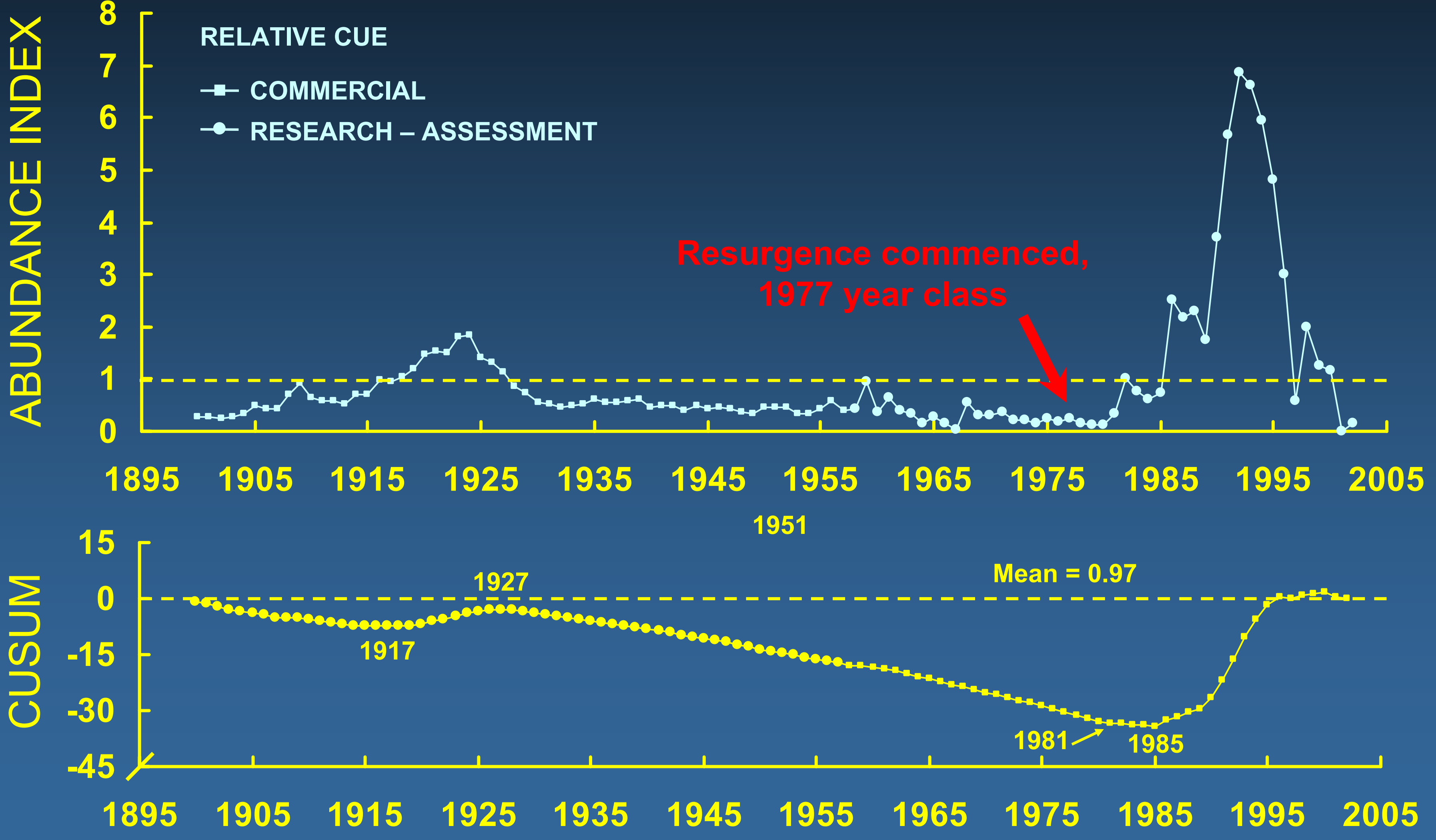
Lake whitefish, *BAY* and *LAKE* stocks



LAKE ONTARIO Lake whitefish

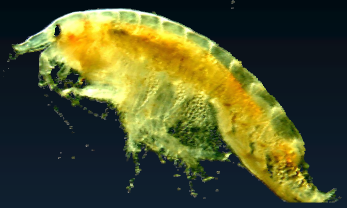


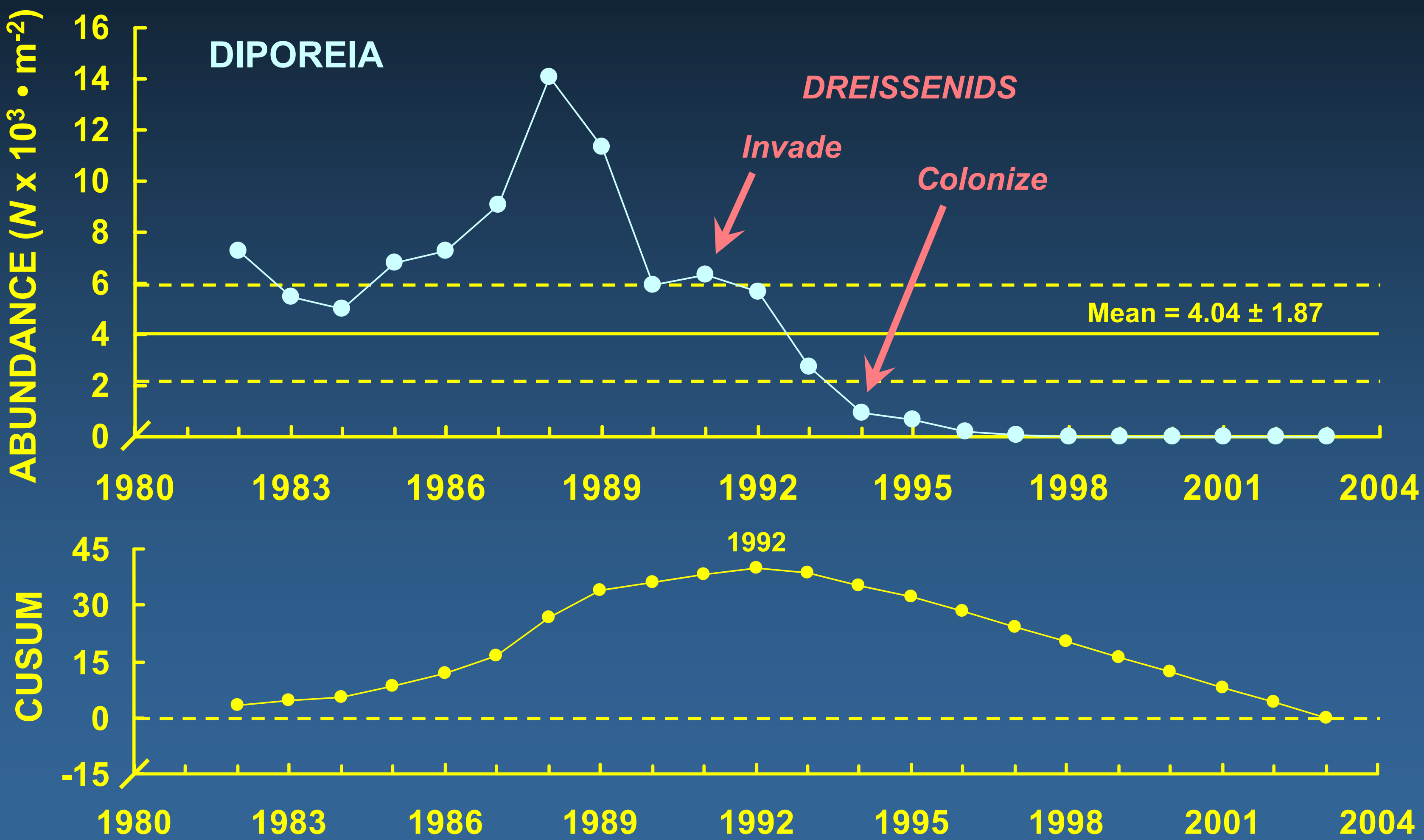
LAKE ONTARIO Lake whitefish



ABUNDANCE OF DIPOREIA

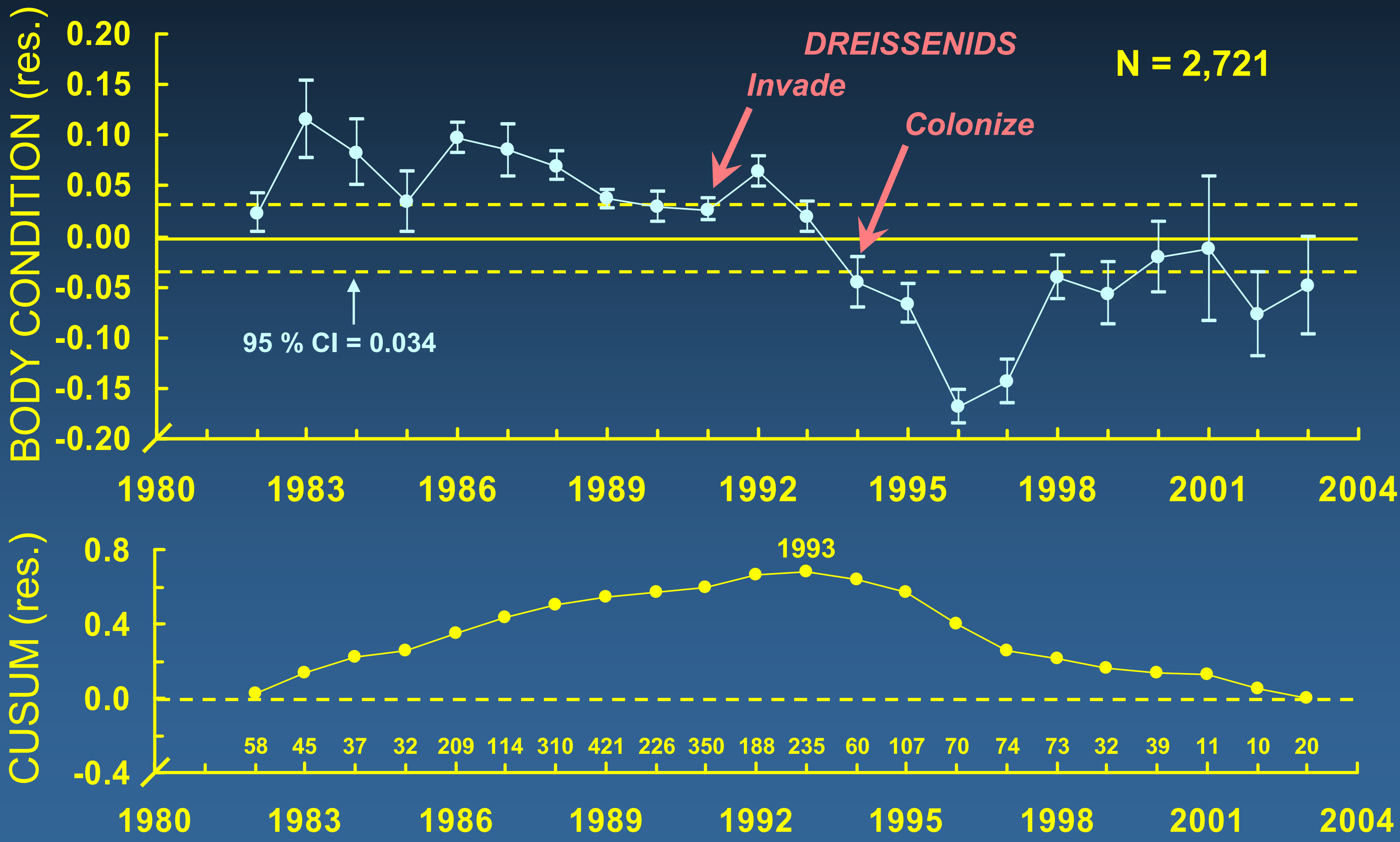
An important benthic prey species of lake whitefish





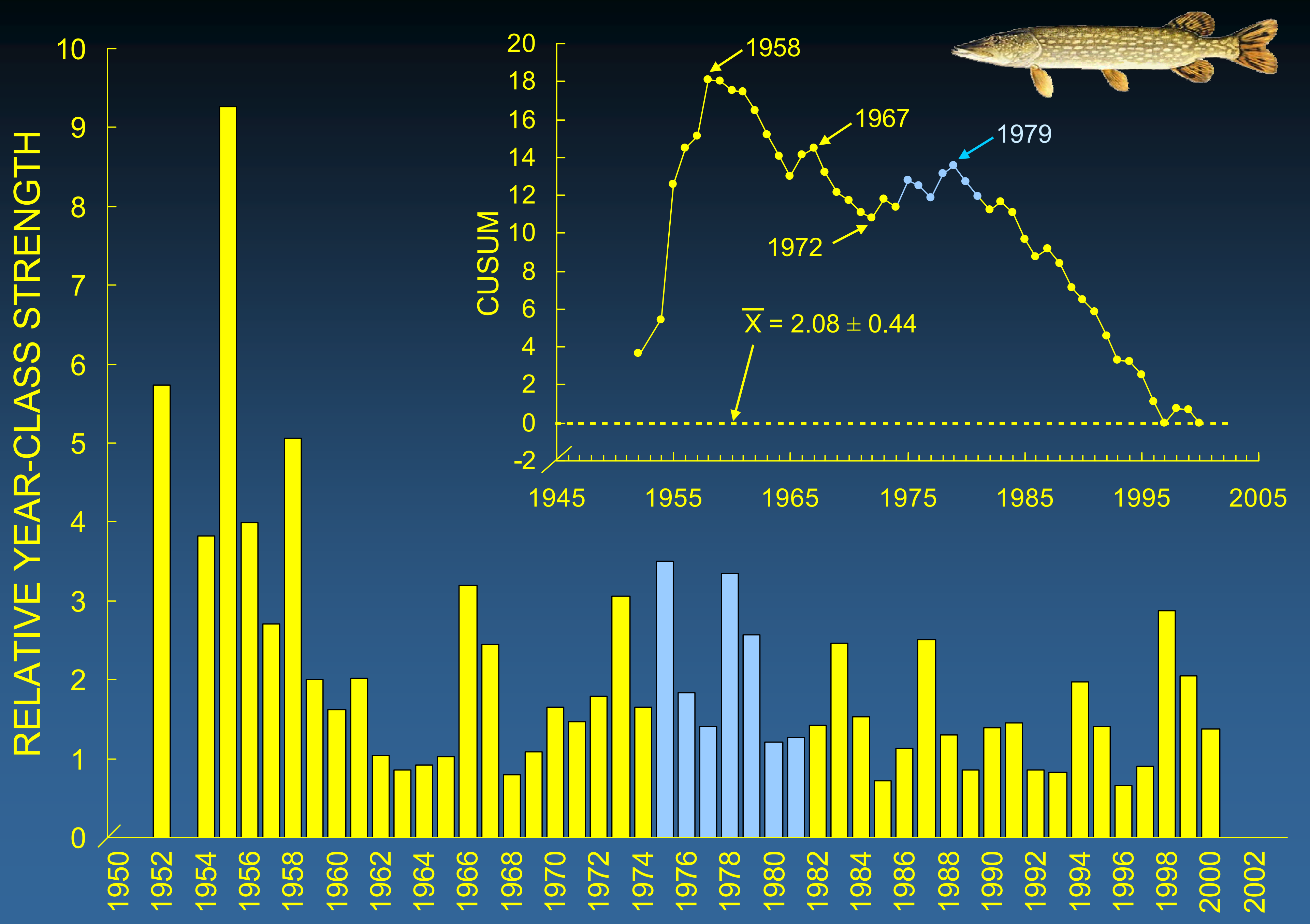
BODY CONDITION, MATURE LAKE WHITEFISH

Deviation from the midsummer length-weight relationship



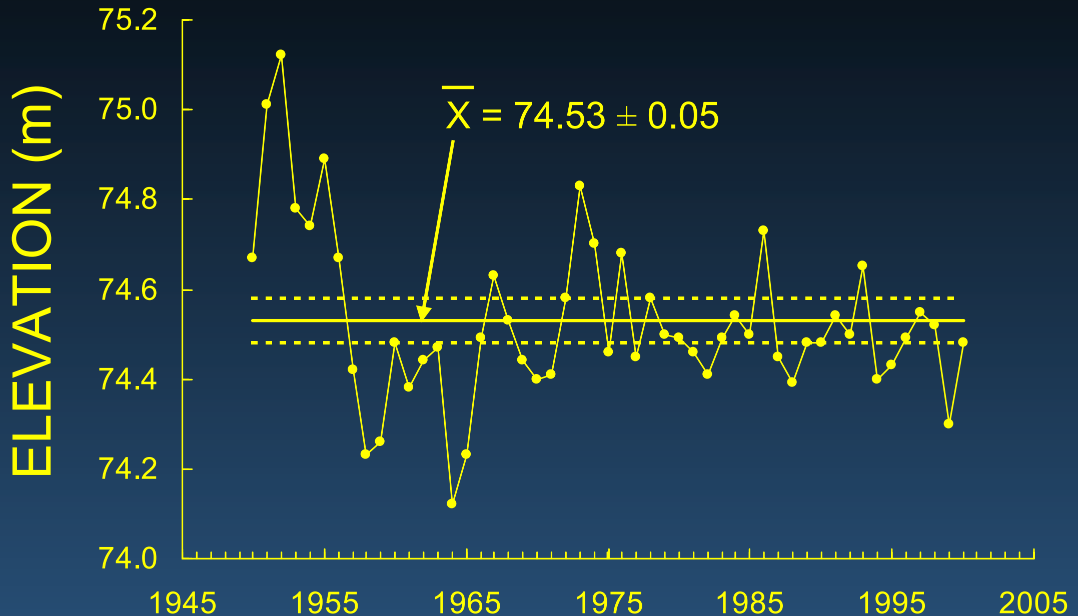
Northern Pike

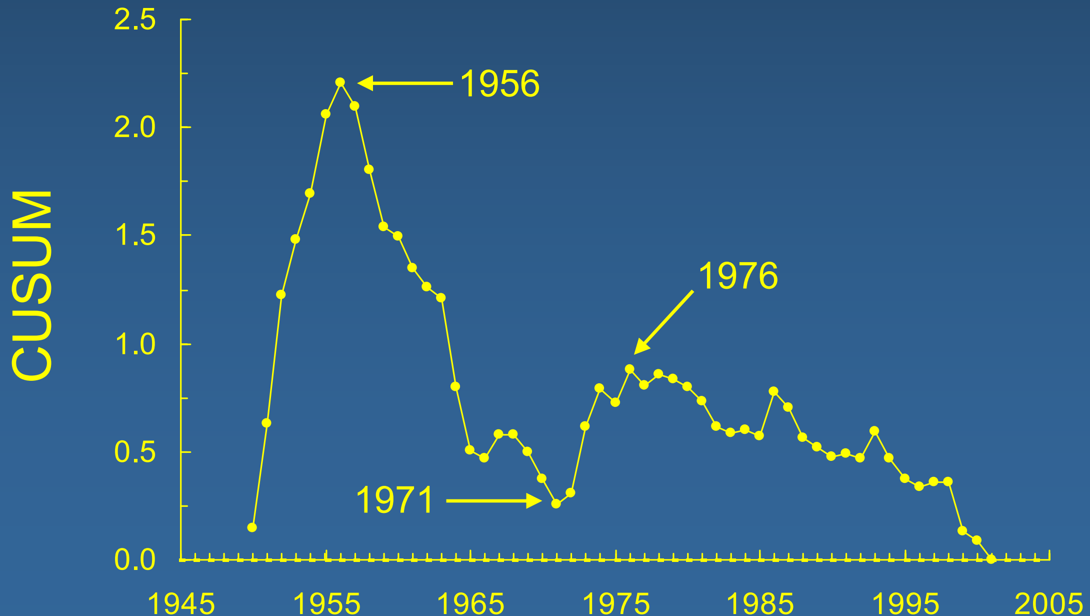
Alteration of water level and loss of wetland habitat


RELATIVE YEAR-CLASS STRENGTH
0
1
2
3
4
5
6
7
8
9
10
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
CUSUM
20
18
16
14
12
10
8
6
4
2
0
-2
1945
1955
1965
1975
1985
1995
2005
1958
1967
1979
1972
X̄ = 2.08 ± 0.44

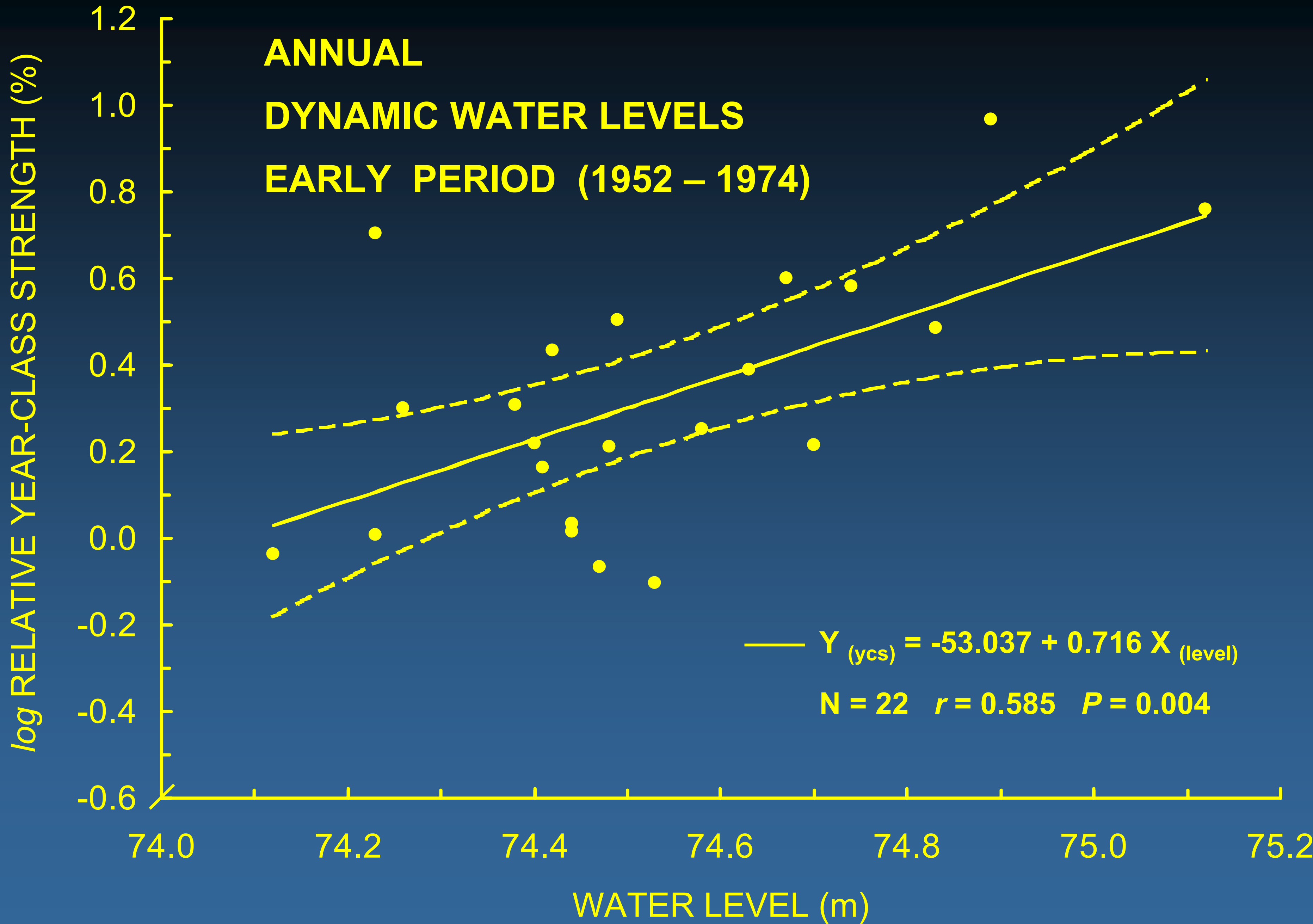
ST. LAWRENCE R. — MEAN ANNUAL WATER ELEVATION

Spawning habitat





Nursery habitat

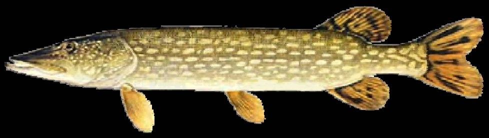


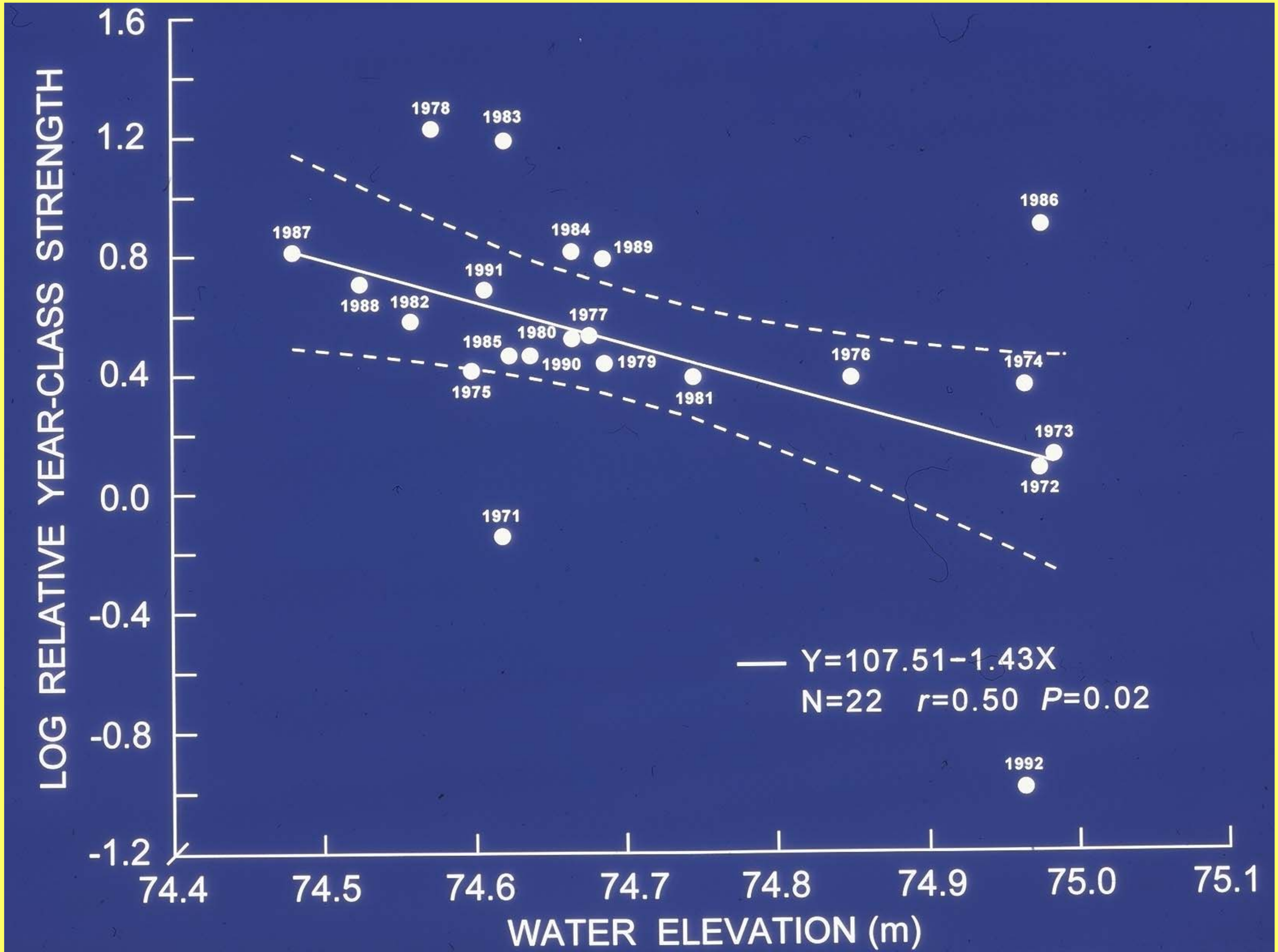
ANNUAL
DYNAMIC WATER LEVELS
EARLY PERIOD (1952 – 1974)
log RELATIVE YEAR-CLASS STRENGTH (%)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
74.0
74.2
74.4
74.6
74.8
75.0
75.2
WATER LEVEL (m)
Y (ycs) = -53.037 + 0.716 X (level)
N = 22 r = 0.585 P = 0.004

ANNUAL

STABILIZED WATER LEVELS

LATER PERIOD (1972 – 1992)





In Summary:

- Over the past three decades, we have seen profound ecological changes in the Great Lakes ecosystems and fish communities; some, indeed many, have not been to our liking
- Stresses associated with anthropogenic forces, such as exotic species invasions and global climate change, are creating an uncertain future for Great Lakes food webs, fish, and fisheries
- Long-term ecological studies and time series must continue in order to enhance scientific understanding and management of these important resources

Lake Winnipeg

Habitat Impacts and Alterations

Past, Present and Future

Keith Kristofferson
Impact Assessment Biologist
Fisheries and Oceans, Winnipeg

Introduction and Background

Department of Fisheries and Oceans Canada

Habitat Management Branch

- Mandate
- What is Fish Habitat
- Federal Fisheries Act
- Habitat Management Policy

DFO Mandate

Strengthening Fish Habitat Protection in Canada's Inland Provinces

DFO's Vision

Safe, healthy, productive waters and aquatic ecosystems, for the benefit of present and future generations

DFO Mandate

Many fish stocks are declining due to pressure on fish habitat.

Habitat conservation is critical to ensure continuation of Canada's commercial, recreational and subsistence fisheries.

Commercial resource valued at more than $13 billion annually in Canada and $30 million annually in Manitoba.

No habitat - No fish.

What is Fish Habitat?

Fisheries Act definition of Fish Habitat :

"spawning grounds and nursery, rearing, food supply, migration and any other areas on which fish depend directly or indirectly in order to carry out their life processes"

Section 34(1)

Fish Habitat

Lakes

Rivers, Streams, Creeks

Intermittent Watercourses

Man Made Drains

Wetlands

What is Fish Habitat?

Water Quality

Water Quantity

In-water Structure

Riparian Vegetation

Aquatic Plants

Substrate

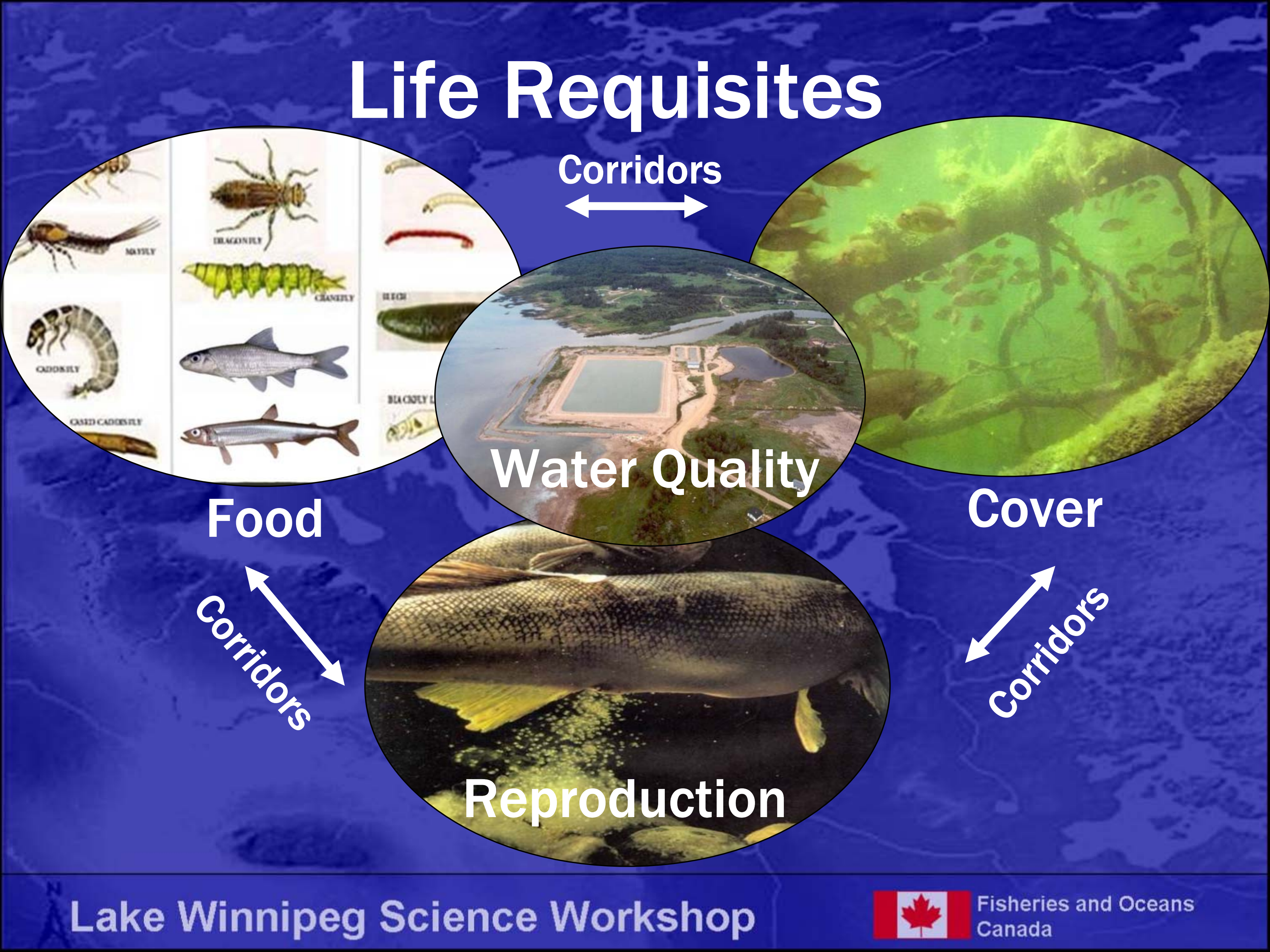
Channel Features

Woody Debris

FISH HABITAT

Life Requisites

Spawning, Rearing, Nursery, Feeding, Overwintering, Migration


Life Requisites
Corridors
Water Quality
Food
Cover
Corridors
Corridors
Reproduction
Lake Winnipeg Science Workshop
Fisheries and Oceans
Canada

Fisheries Act

Section 35 (1)

- prohibits works or undertakings that could result in the harmful alteration, disruption or destruction of fish habitat.

Section 35(2)

- allows the Minister or designate to authorize the harmful alteration, disruption or destruction of habitat.

Section 36(3)

- Prohibits the deposit of a deleterious substance in water frequented by fish.

Fisheries Act

Section 20

- safe passage around obstructions.

Section 22

- appropriate water flows at obstructions.

Section 30

- fish guards or screens where needed.

Section 32

- prohibits destruction of fish by means other than fishing.

Fisheries Act

Harmful Alteration, Disruption or Destruction (HADD) of Fish Habitat (Section 35)

- Any change to the physical, biological, or chemical attributes of habitat that adversely affects the habitat's ability to provide the basic life requisites (spawning, rearing, nursery, overwintering, feeding, migration).

DFO Policy

<u>From the Policy for the Management of Fish Habitat</u>

- Balance unavoidable habitat loss with habitat replacement
- Ensure "No Net Loss" on a project by project basis
- Overall goal is a Net Gain in Productive Capacity

In accordance with the Policy, a *Fisheries Act* Authorization is not issued unless compensation measures to ensure No Net Loss are developed.

Geographic, Geologic, Hydrologic Settings

- Geographic-Geologic
- Ecological Zones
- Bathymetry
- Lake Winnipeg Watershed
- Hydrologic inflow and outflow

Geographic- Geologic Setting

The lake lies along the boundary between two physiographic and climatic zones:

<u>East</u>: Precambrian Shield with high rainfall and water yield,

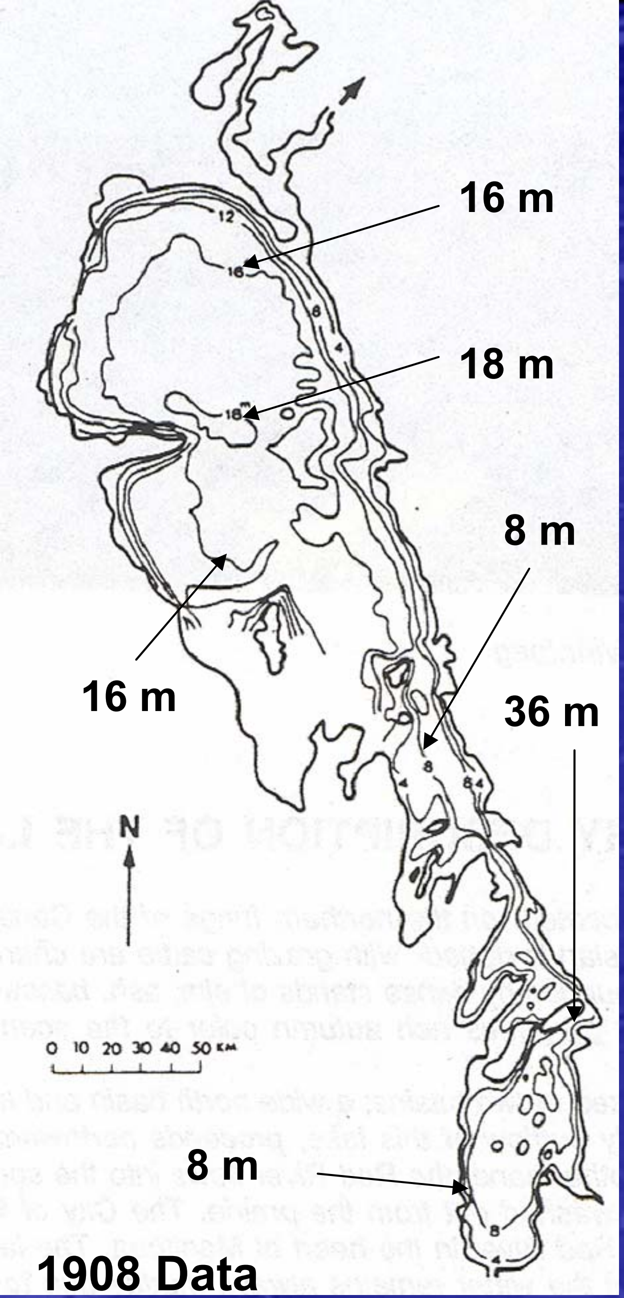
<u>West</u>: Paleozoic Sediments with low rainfall and water yield

Ecological Zones

Characterized by boreal forest to the east, aspen parkland and boreal forest to the west and northwest, and prairie landscapes to the south and southwest.

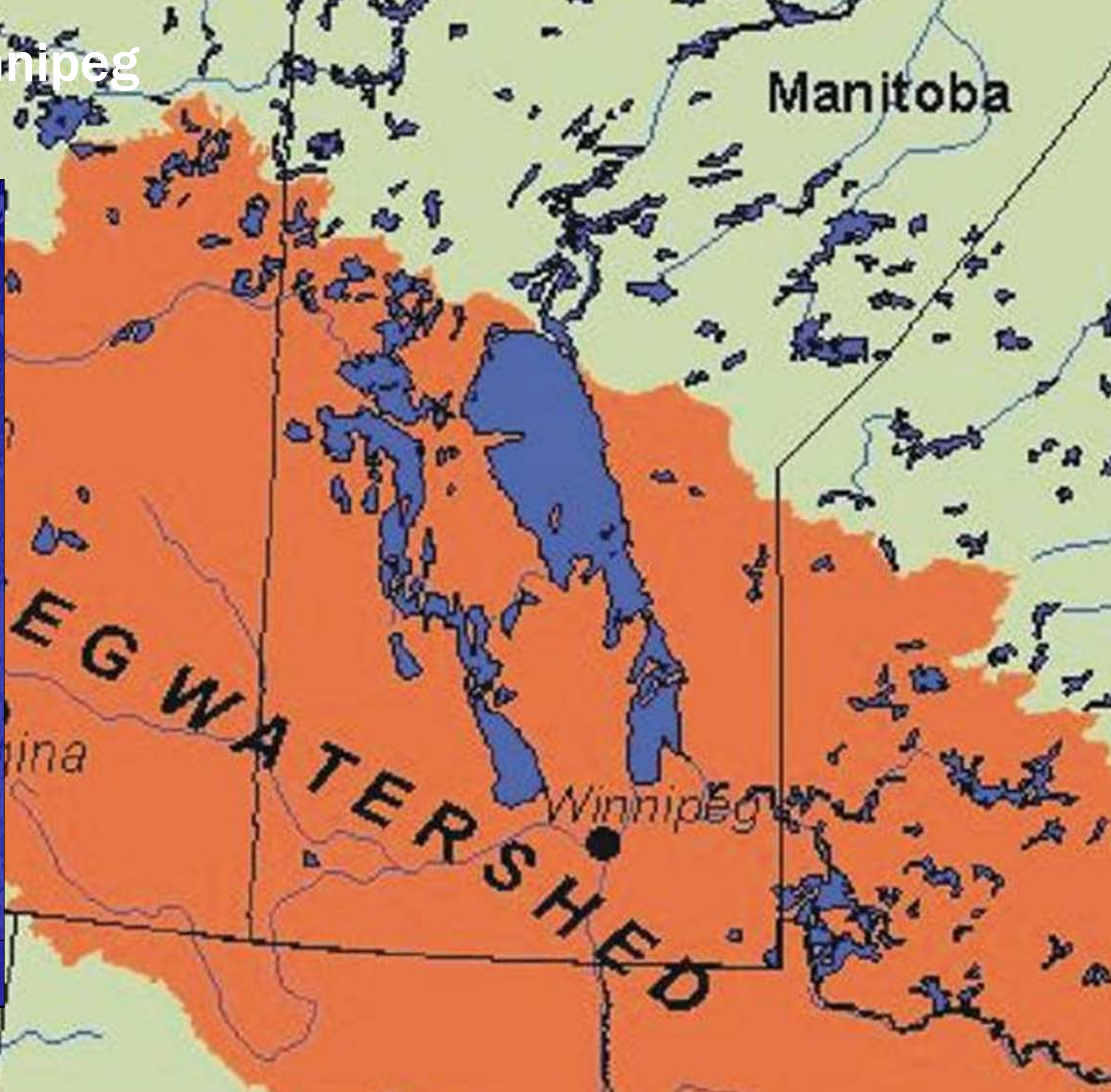
Bathymetric Map

- The Northern Basin is larger and deeper at 17,520 km² and averaging 13.3 m deep.
- The Southern Basin (including the Narrows) is smaller and shallower at 6,230 km² and averaging 8.3 m deep.
- The deepest part of the lake is a hole near Black Island 36 m (118 ft) deep



The Lake Winnipeg Watershed

- The Lake Winnipeg Watershed is 39 times its surface area
- The Lake Erie Watershed is only 3 times its surface area



Hydrological Setting

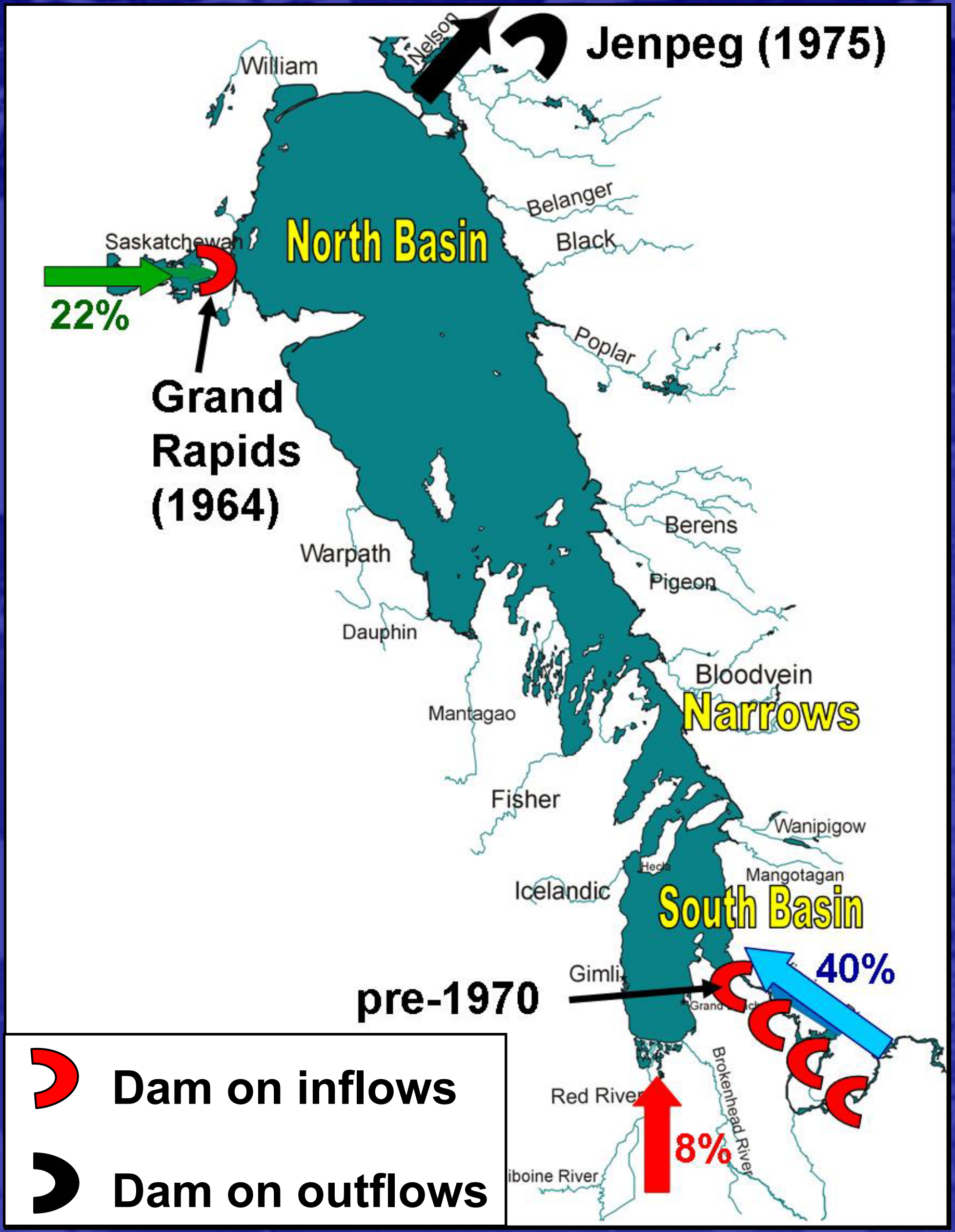
3 dominant inflows

- Saskatchewan R. 22%
- Winnipeg River 40%
- Red River 8%
- All other tribs 19%
- Precipitation 11%

1 outflow

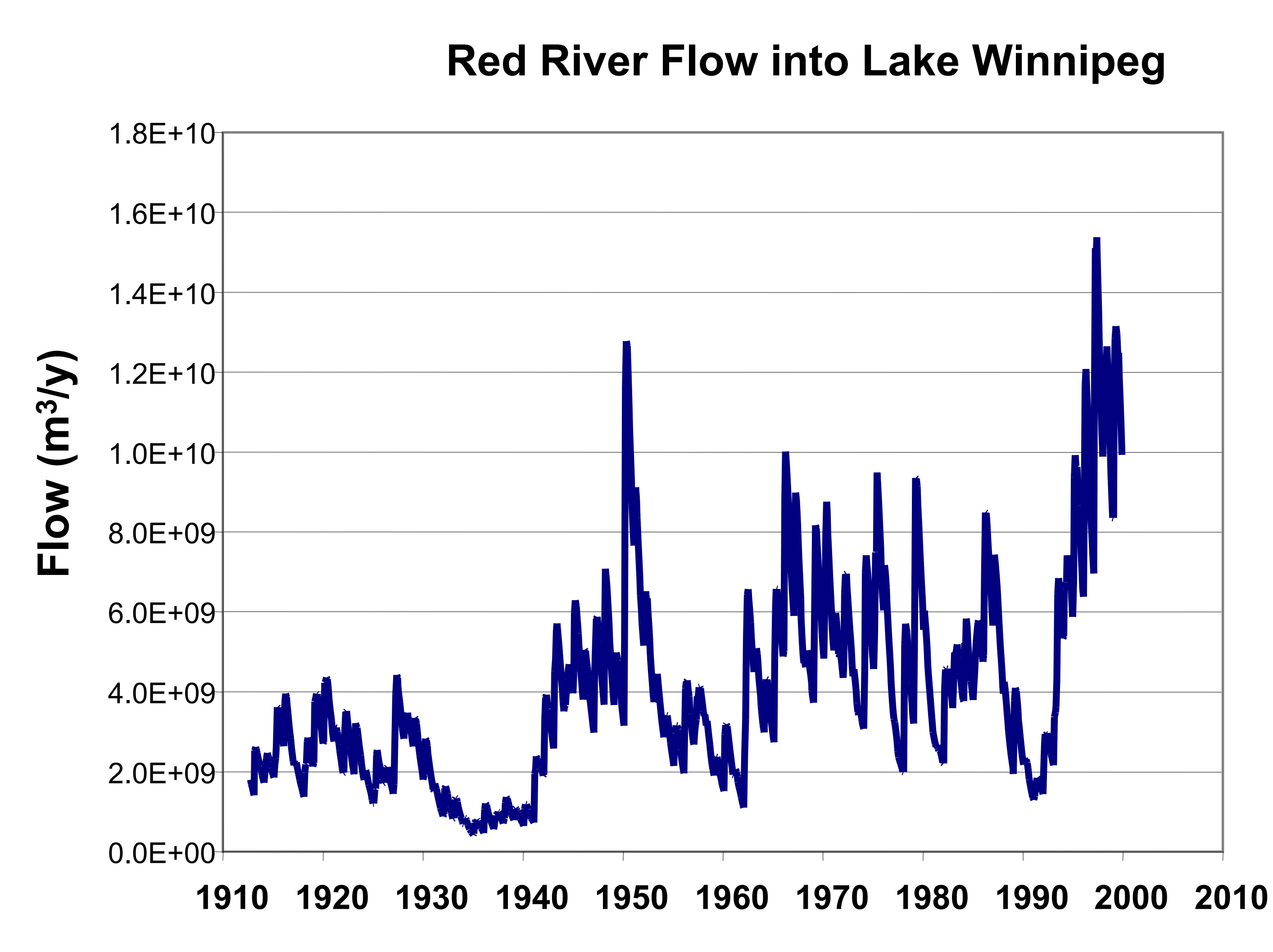
- Nelson River

3rd largest hydro reservoir



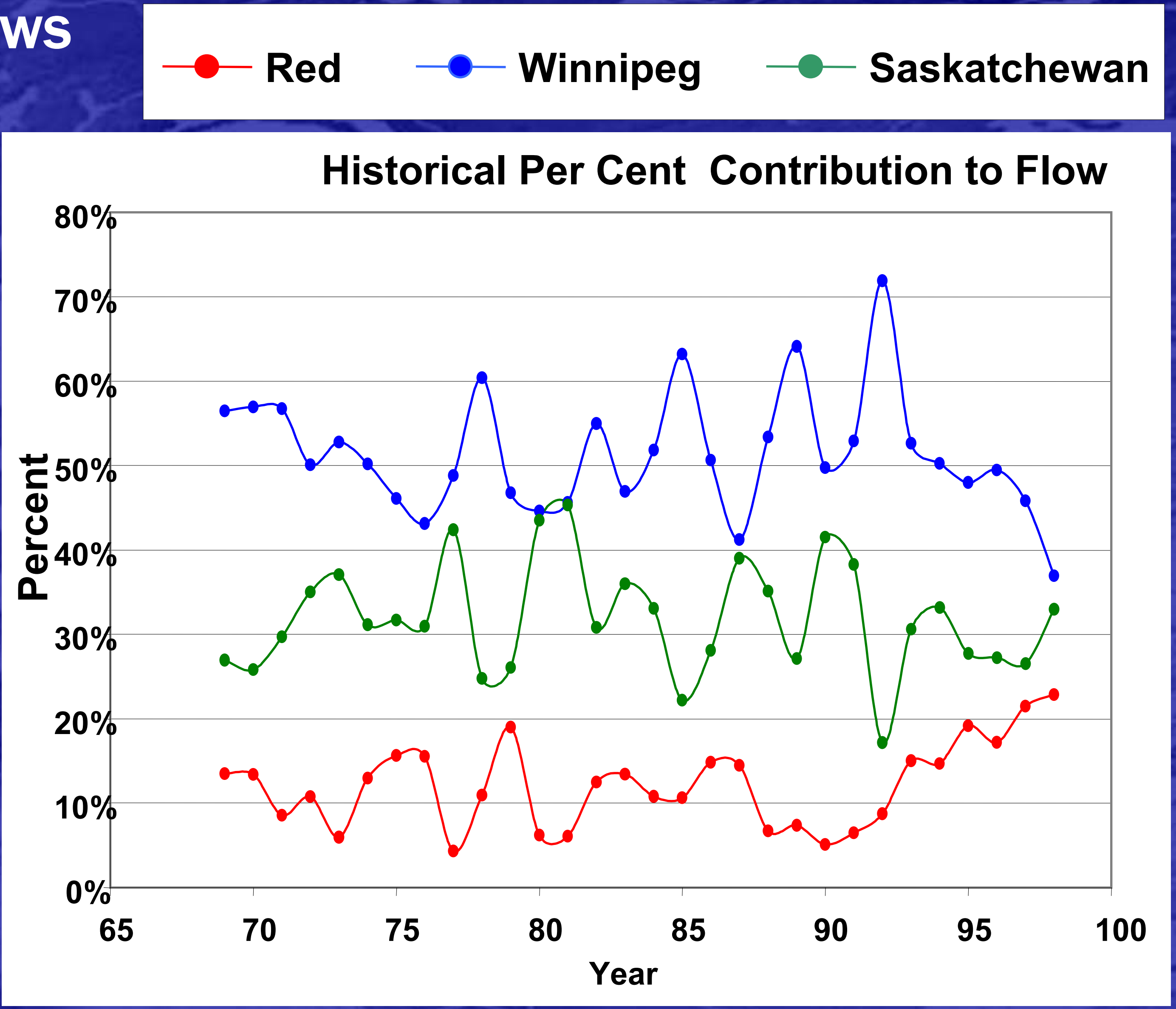
Red River Annual Flows

- Total annual flows in the Red River have been increasing since the early 1900's



Historical Inflows

- The relative proportions of inflow that each of the major tributaries provides has been changing

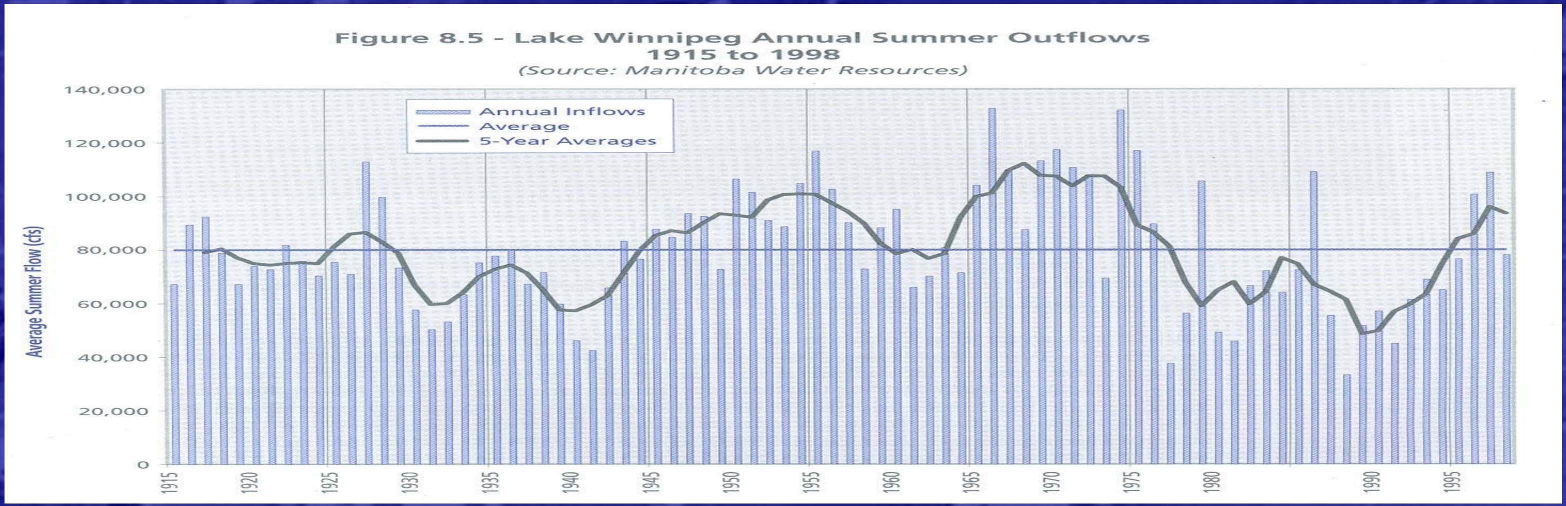


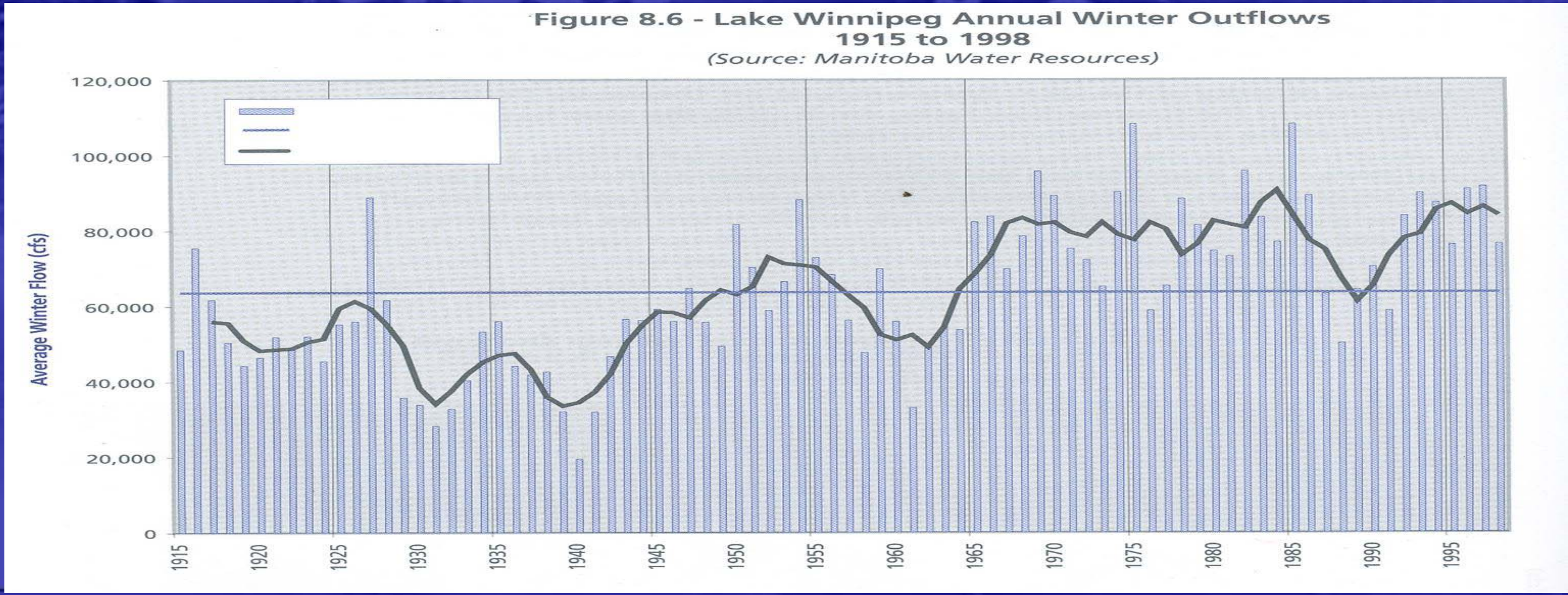
Macro Habitat Impacts

Water Quality, Quantity and Large-Scale Habitat Alterations

- Mean Summer and Winter inflow and outflow
- Mean monthly water levels
- Mean monthly water temperatures
- Land use practices
- Nutrient loading and water clarity
- Algal and Invertebrate communities

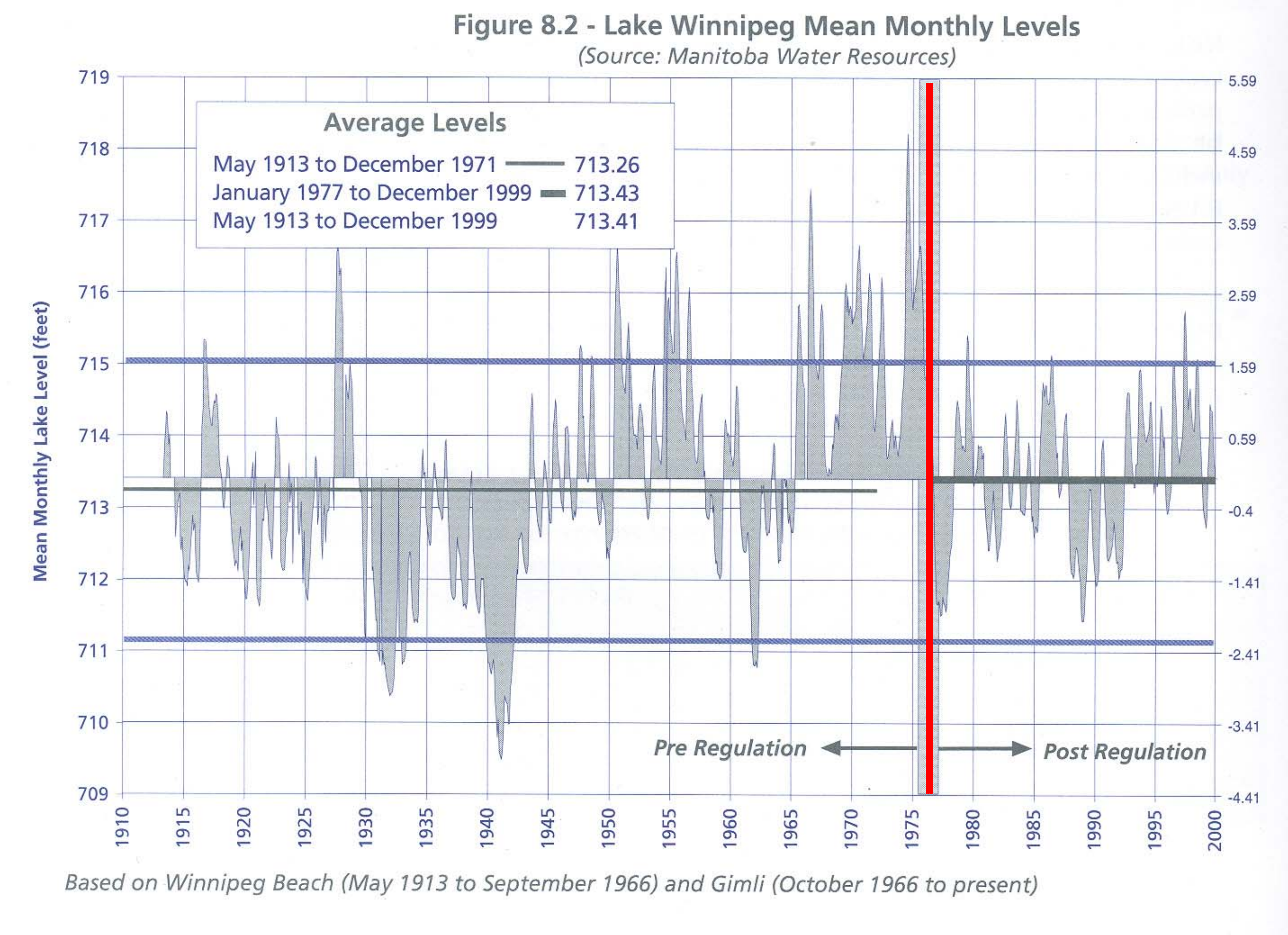
Summer Outflows Winter Outflows



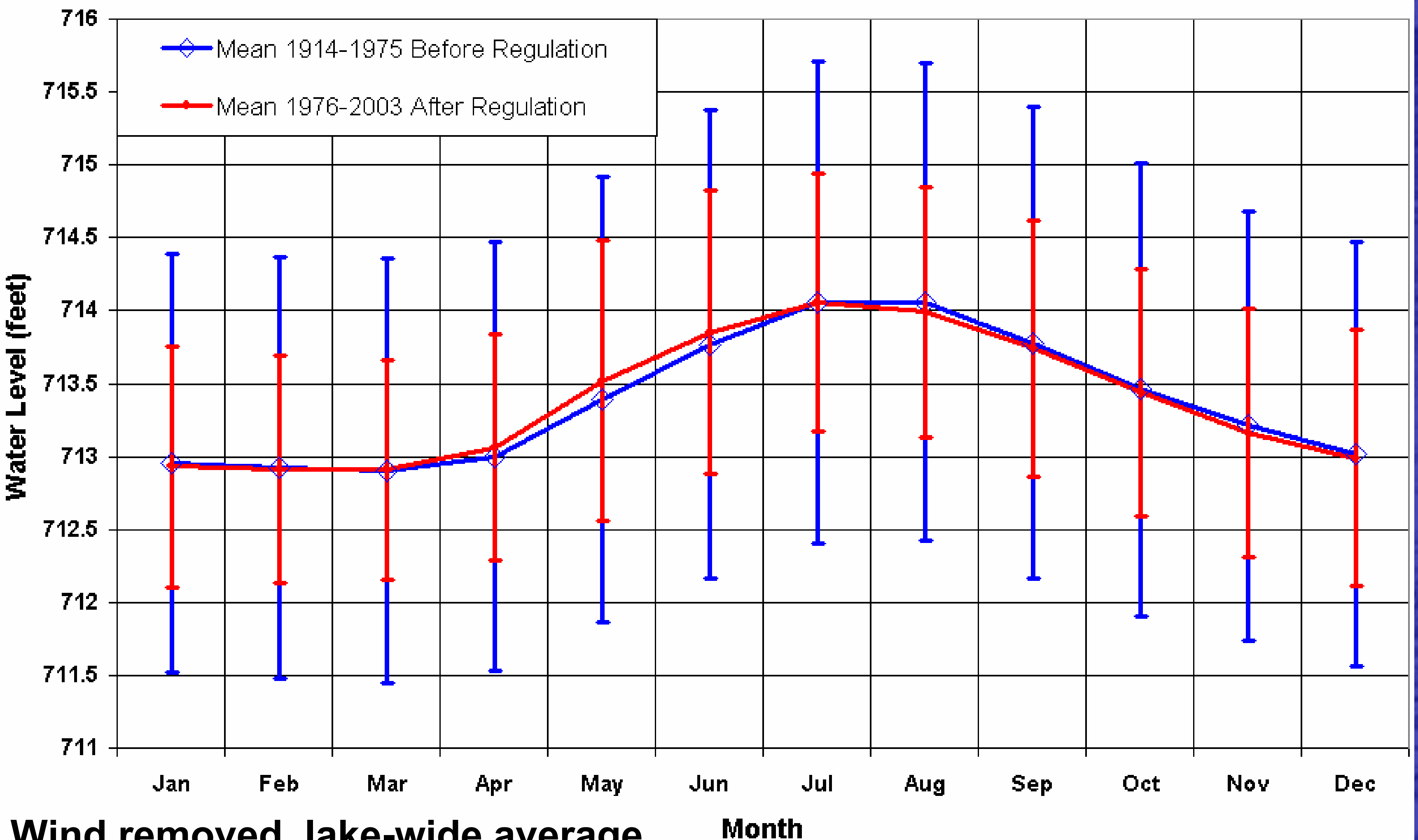


Mean Monthly Water Levels

- Additional outflow channels (hydro regulation) have reduced lake fluctuations



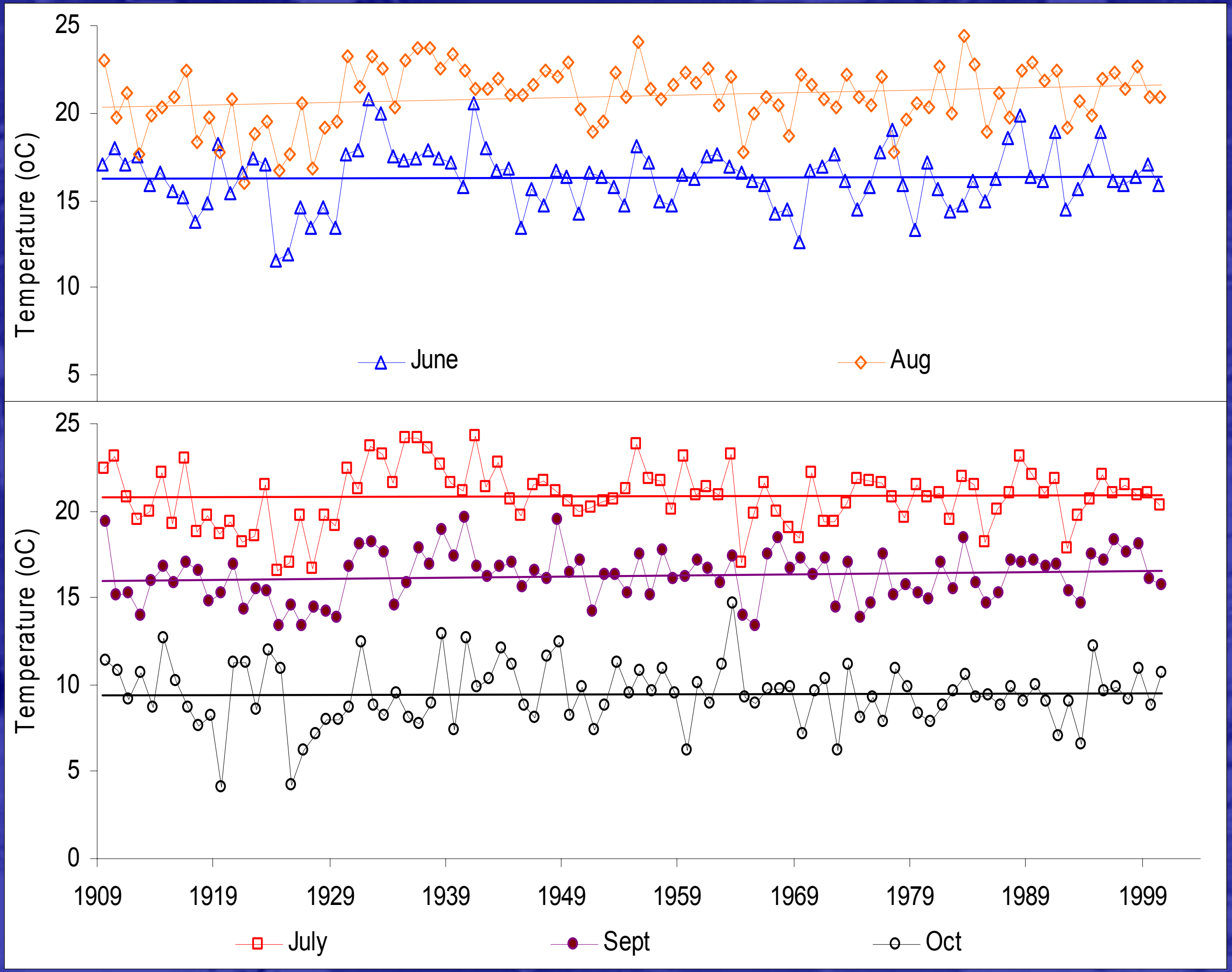
Mean Monthly Water Levels



Wind removed, lake-wide average

Water Temperatures (south basin 1909 – 2000)

- Only August with significant (95%) non-zero linear trend which increased 1.4°C over century (McCullough)
- Climate Change?



Drainage

- Increased erosion, sediments, and nutrients in part from increased runoff due to drainage and agricultural land clearing
- Especially evident in the Red River basin

Drainage

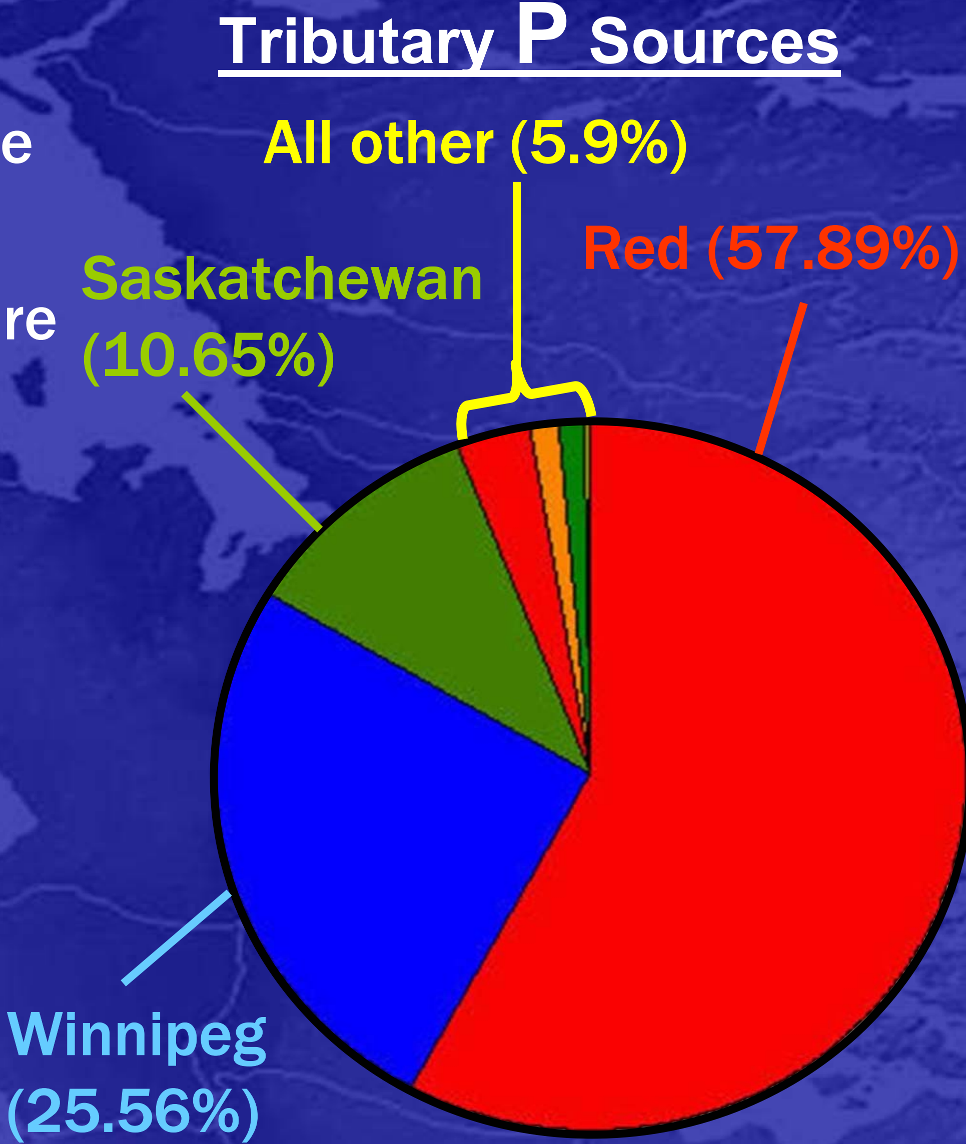
- Large scale head-cutting and erosion are possible from some drainage activities

Livestock

Cattle access, feedlots and other livestock operations damage riparian habitat and contribute nutrients

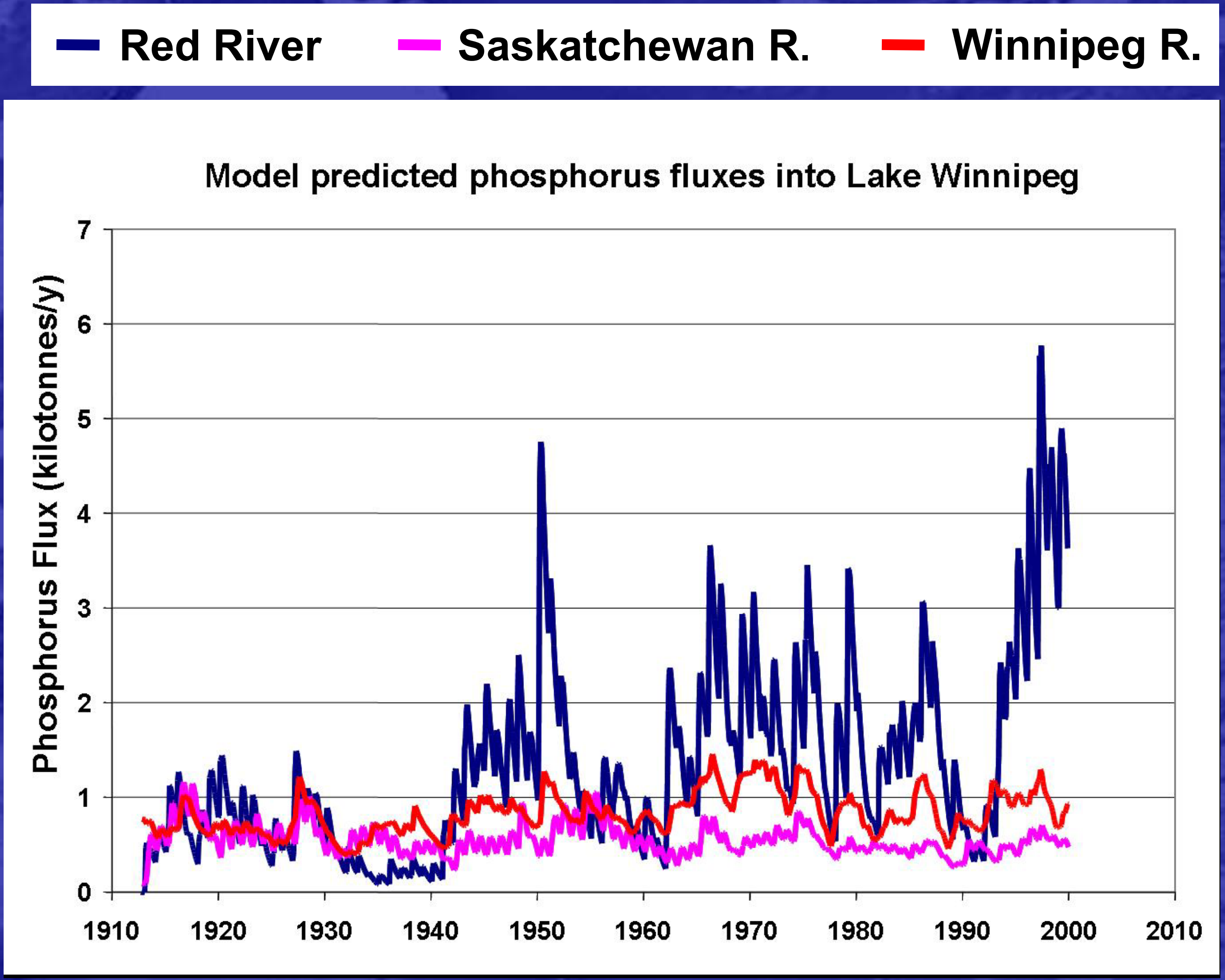
Nutrient Loading

- Input of N and P from rivers are increasing (Red River).
- Levels of N and P in the lake are increasing.
- Incidence and severity of algal bloom formation seem to be increasing.
- Rate of sedimentation in the north basin is increasing.
- Algal populations in lake are shifted to nitrogen fixing blue greens.



Model of Historical Nutrient Loading

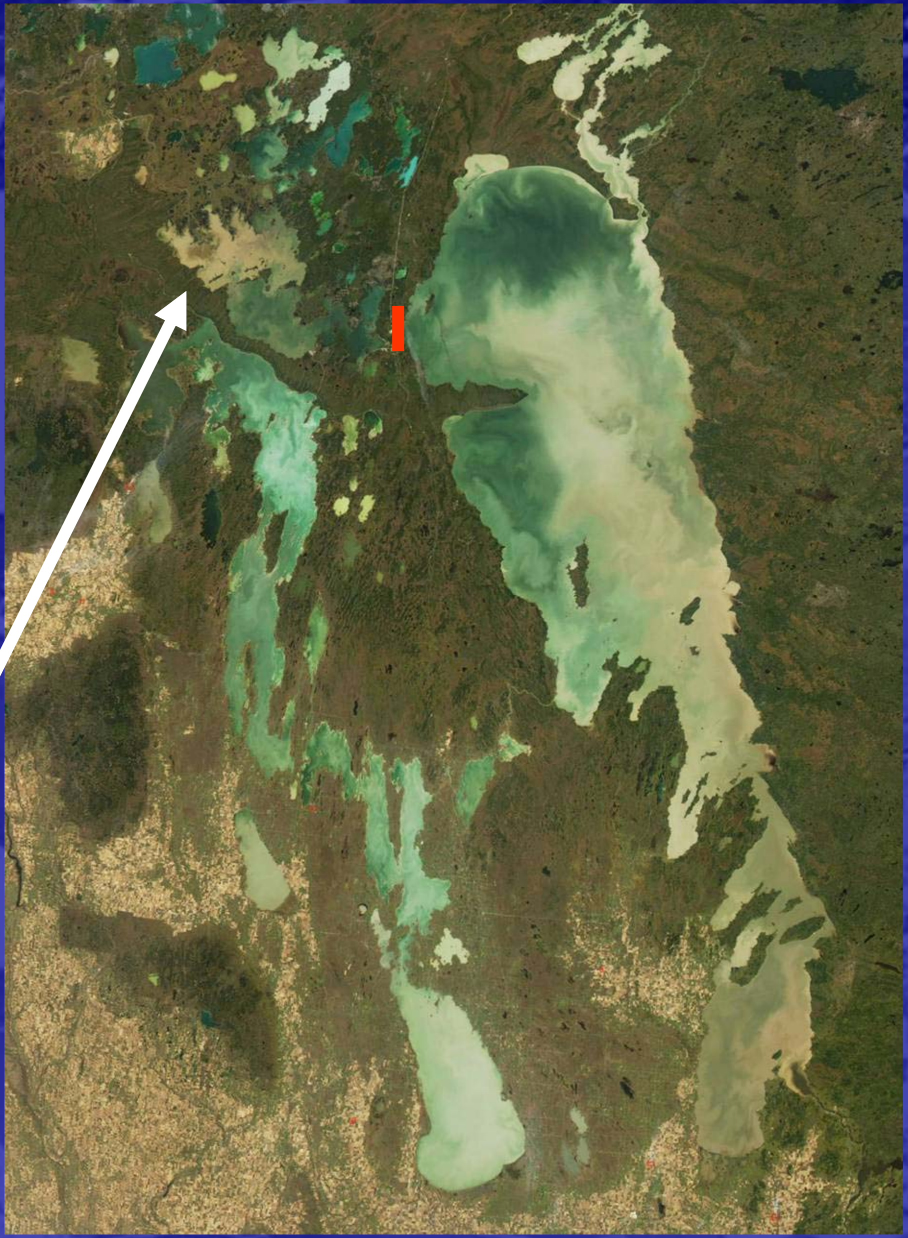
- Predicted relative proportions of P entering from each of the major tributaries
- The Red River P loading is predicted to increase



Water Clarity

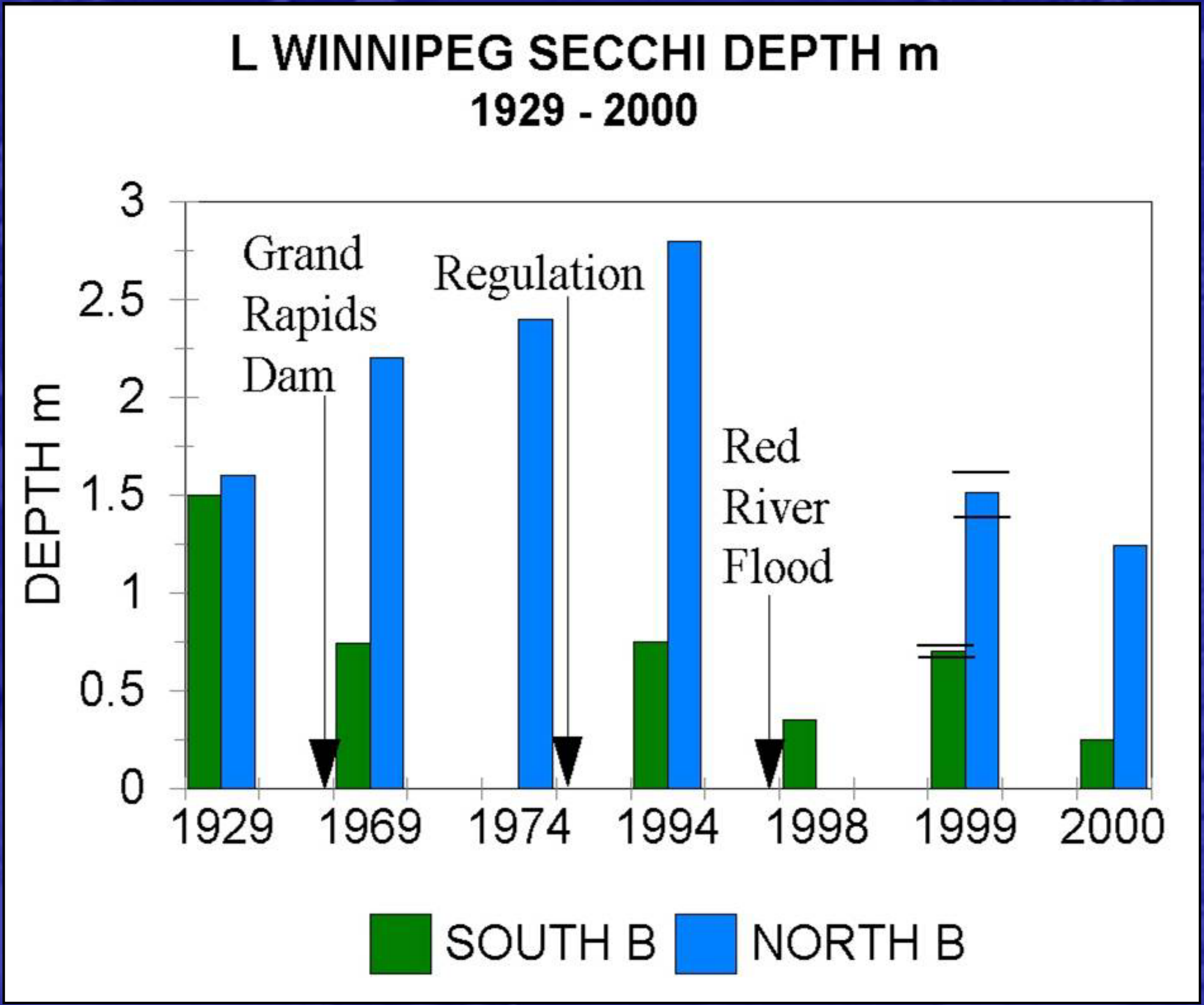
- October 2004 satellite imagery indicating the most northerly transport of sediment into the North Basin from the Red and Assiniboine Rivers caused in part by a large wind seiche event
- Sediment from the Saskatchewan River is trapped by Cedar Lake

(▍ Grand Rapids Dam)



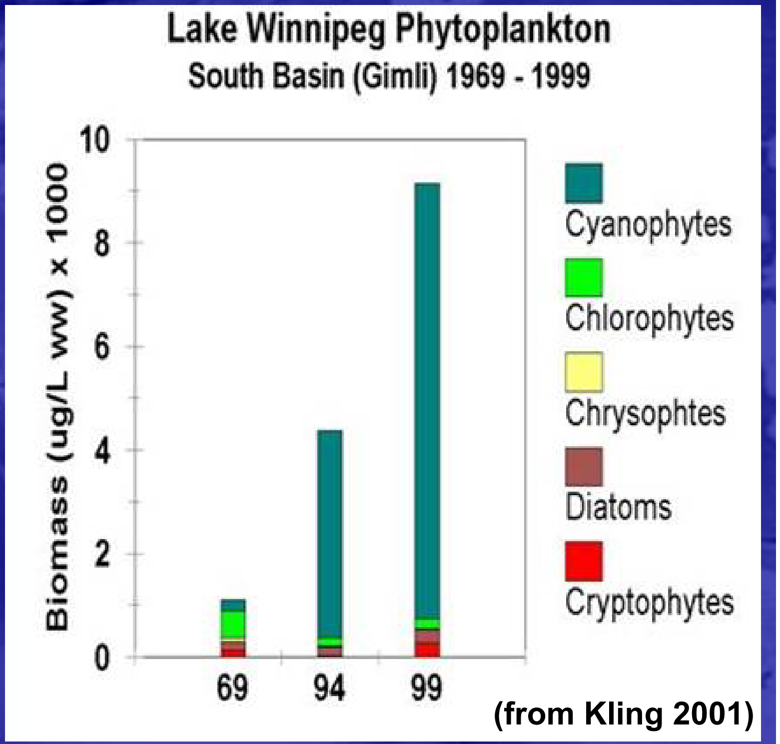
Water Clarity

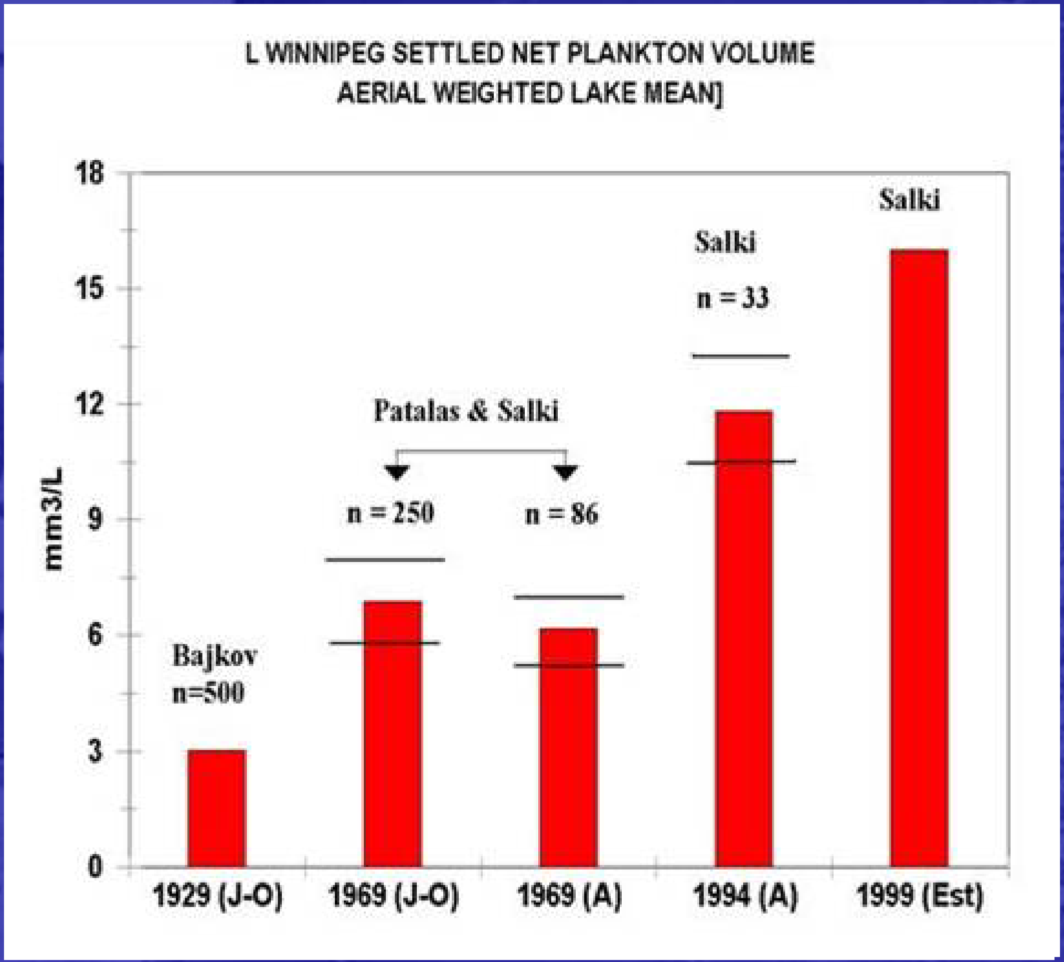
- Reduced sediments from the Saskatchewan River
- Increased nutrients and sediments from the Red River



Phytoplankton

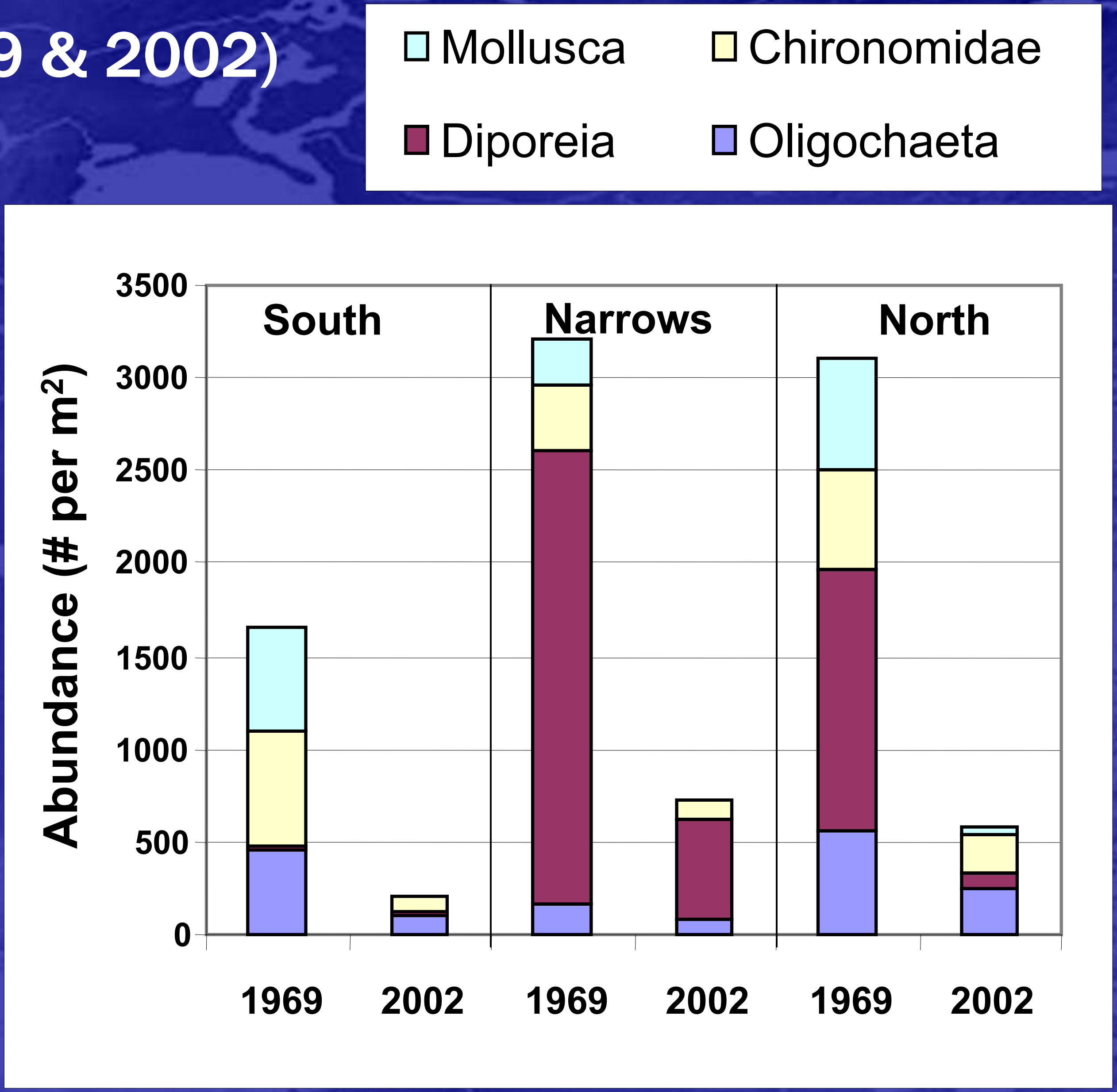
Historical catches





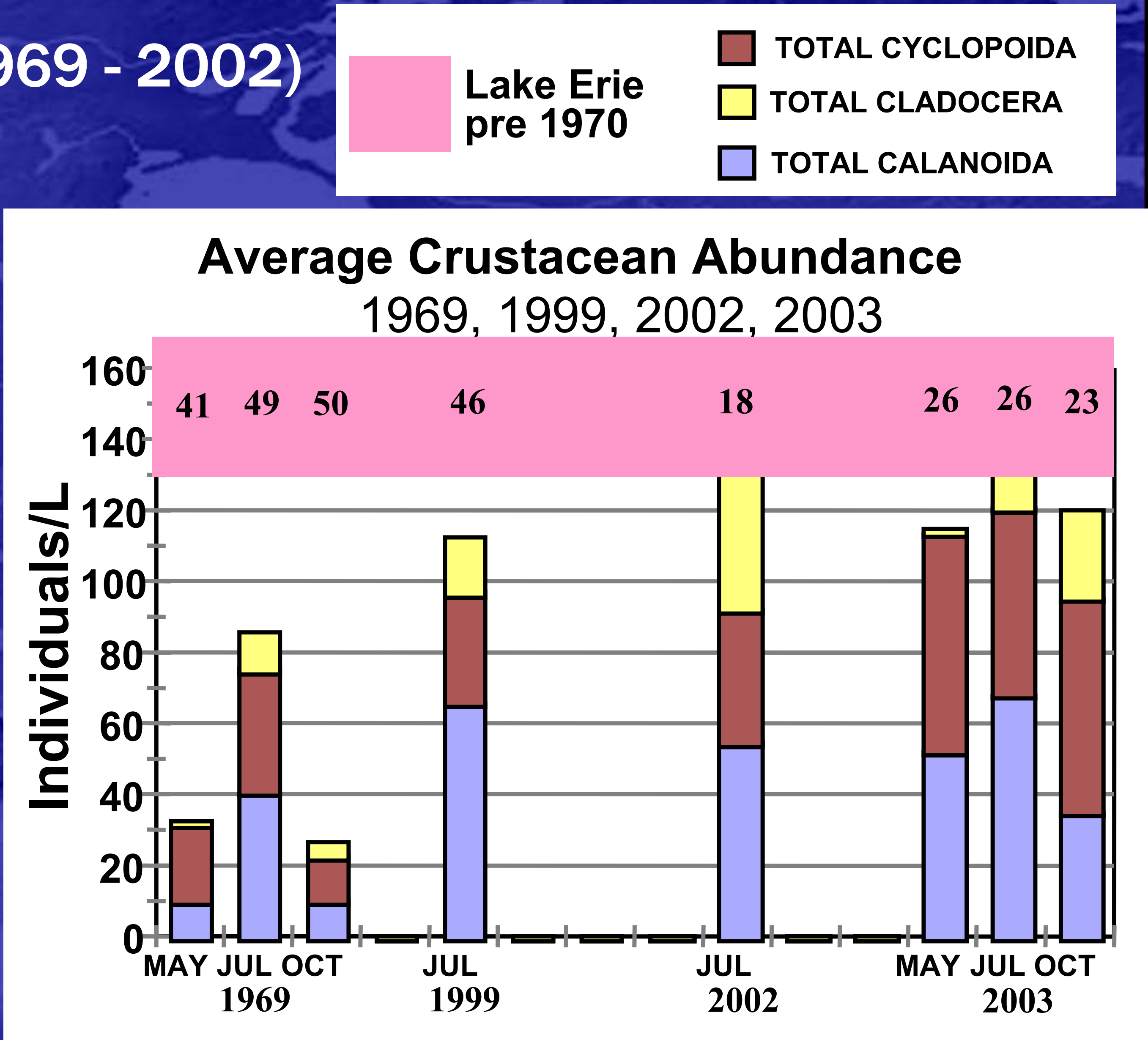
Zoobenthos (1969 & 2002)

- substantial decrease in abundance in all basins
- major decline in amphipods (North and Narrows)



Crustaceans (1969 - 2002)

- Increase in total abundance
- At or near levels seen in Lake Erie in the 1960's



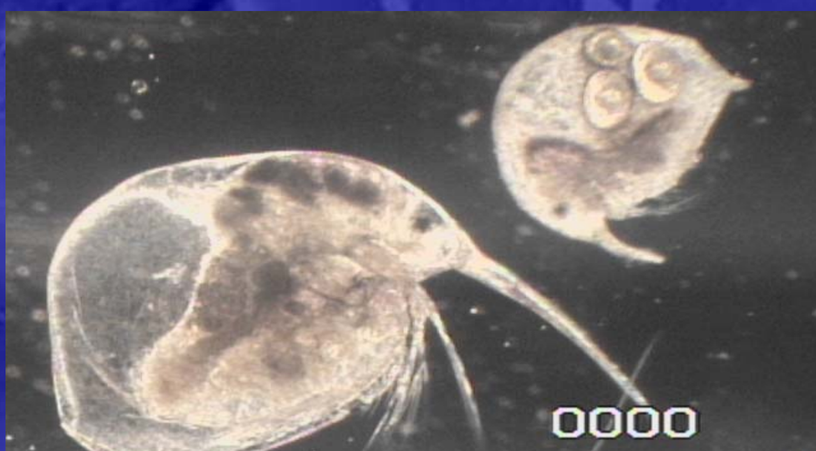
Exotic and Threatened Species

- Exotic and introduced species
- Species at Risk Act (SARA)

Exotic Species

- Rainbow Smelt
- White Bass
- Carp
- Smallmouth Bass
- Exotic Zooplankton
- Zebra Mussels?

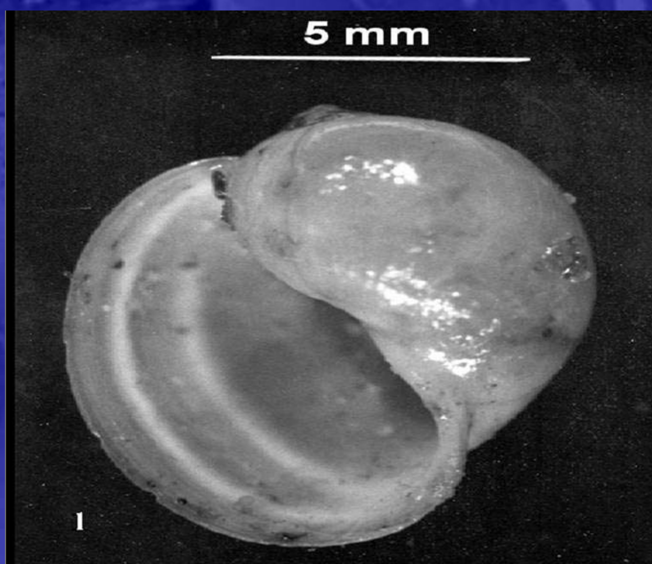


Eubosmina coregoni

SARA Species

- Carmine Shiner
- Silver Chub
- Shortjaw Cisco
- Bigmouth Buffalo
- Chestnut Lamprey
- Physa Snail



SARA Species

Species At Risk can be:
- Endangered
- Threatened
- Of Special Concern

Schedule 1 species are listed as of June 2003.

Schedule 2 and 3 are awaiting further review

www.speciesatrisk.gc.ca

APPENDIX I

Prairies Area- Aquatic Species At Risk
Updated - April 2004

Table 1: Species occurring in the Prairies Area that are currently on Schedules 1-3.

Scientific Name	Common Name	COSEWIC Status (year)	SARA Schedule	Prairie Province(s) in which species is found
Fish				
Notropis percobromus	Carmine shiner	THR (2001)	1	Manitoba
Hybognathus argyritis	Western silvery minnow	THR (2001)	1	Alberta
Macrhybopsis storeriana	Silver chub	SC (2001)	1	Manitoba
Coregonus zenithicus	Shortjaw cisco	THR (2003)	2*	Manitoba, Sask., Alberta
Ictiobus cyprinellus	Bigmouth buffalo	SC (1989)	3**	Manitoba, Saskatchewan
Ichthyomyzon castaneus	Chestnut lamprey	SC (1991)	3**	Manitoba, Saskatchewan
Ichthyomyzon fossor	Northern brook lamprey	SC (1991)	3**	Manitoba
Mulluscs				
Physa sp.	Lake Winnipeg Physa Snail	END (2002)	*	Manitoba

* pending public consultation for addition to Schedule 1
** awaiting re-assessment

Legend

END – Endangered
THR – Threatened
SC – Special Concern

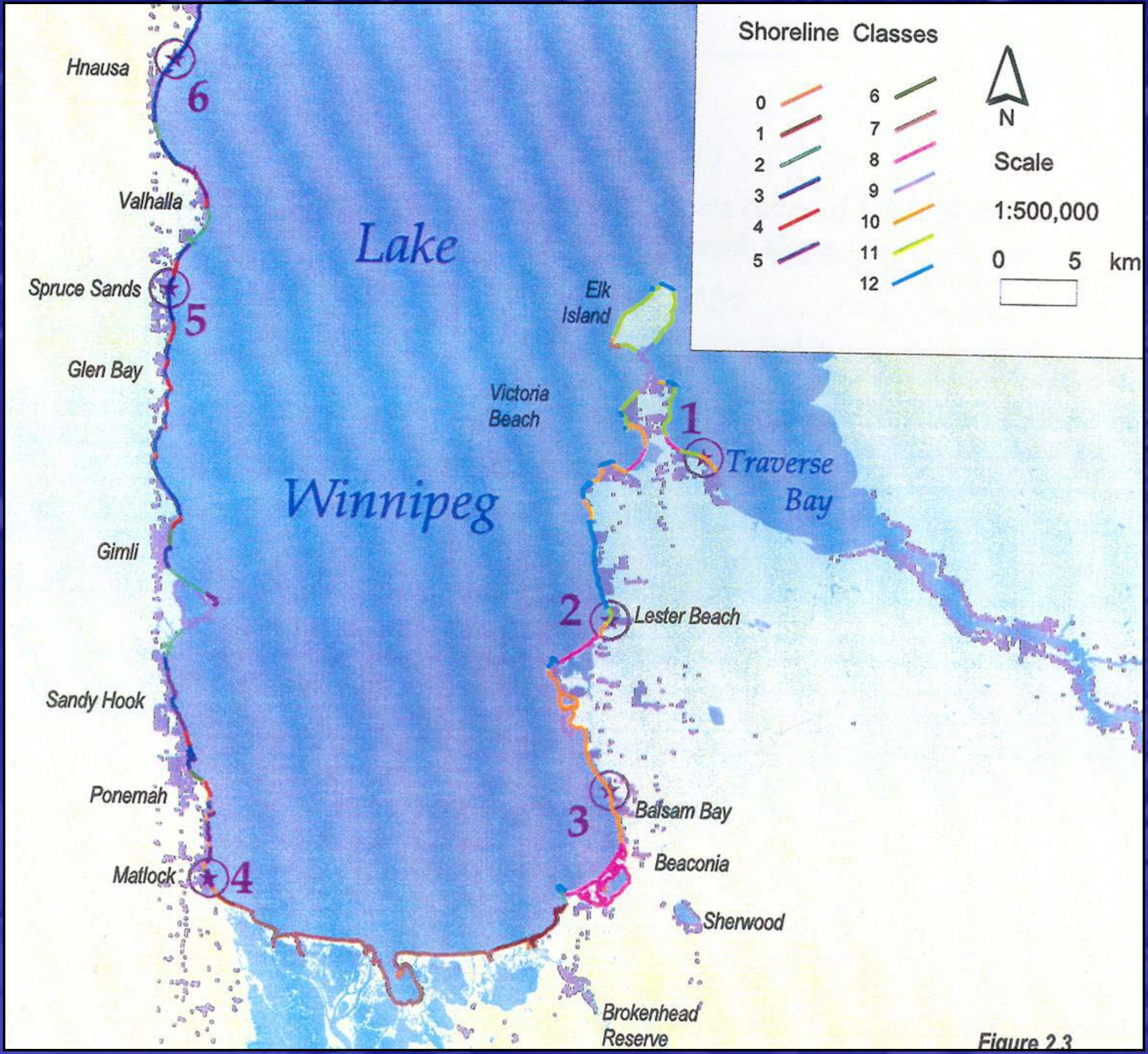
Micro Habitat Alterations

Smaller But Numerous Cumulative Impacts

- South Basin Shoreline Classifications
- South Basin Alongshore Currents
- East Shore Natural Habitats
- East Shore Altered Habitats
- West Shore Natural Habitats
- West Shore Altered Habitats
- Y-O-Y Walleye and Sauger Catches
- Drainage Mitigation

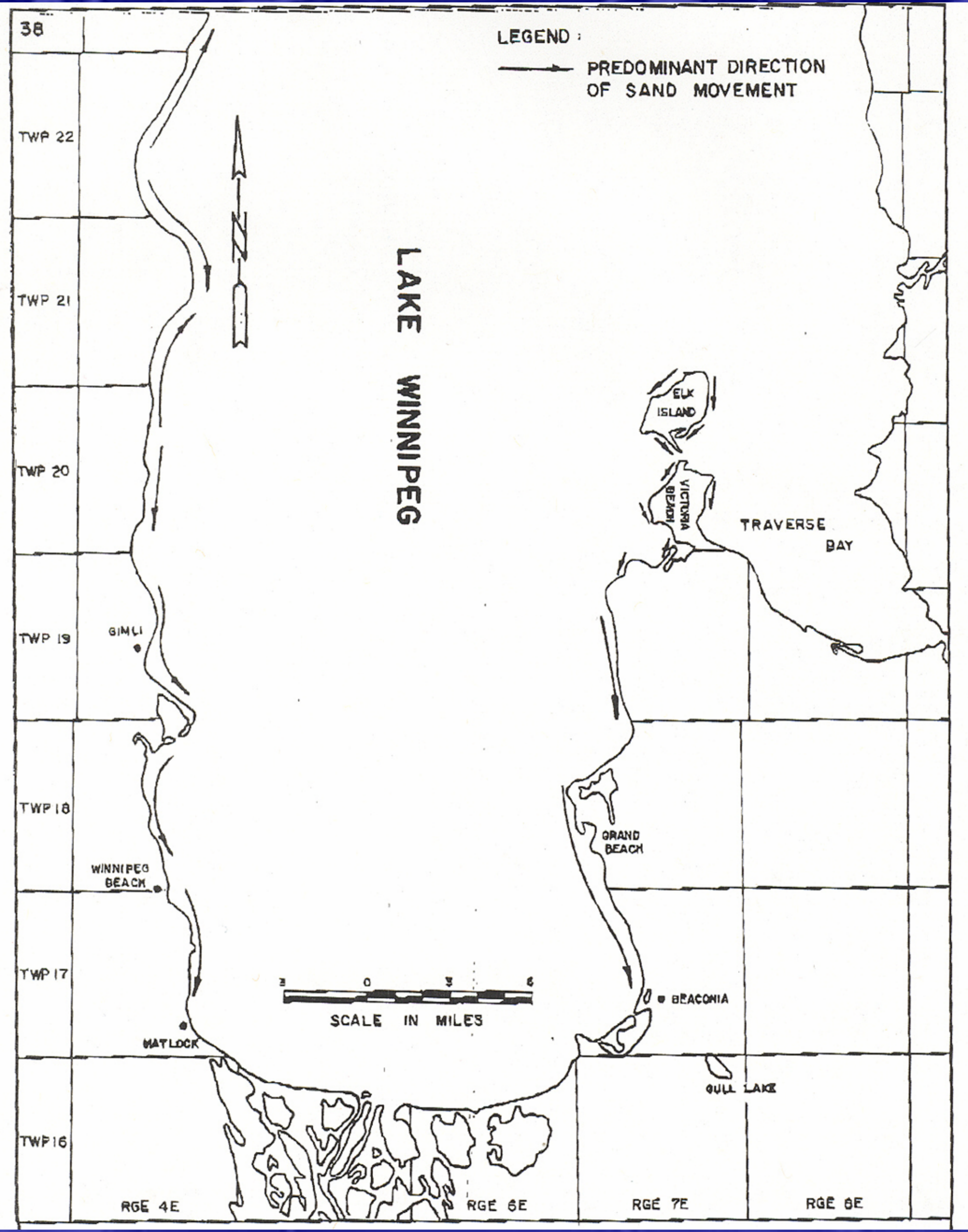
Shoreline Classes

- Map of Geological features affecting erosion of the shorelines in the South Basin
- Types range from organic cover underlain by lacustrine clay to stony clay till to silty sand with cobble and boulders



Alongshore Currents

- Changing sediment transport throughout the South Basin



Natural Habitats

West shoreline

- Rocky shoal from the air and the ground
- Exposed during low water periods 711.3 feet asl

Natural Habitats

West shoreline

- Random rock placements
- Good for spawning, rearing and nursery

Altered Habitats

West shoreline

- Groyne and shoreline stabilization

Altered Habitats

West shoreline

- Groynes built by removing native armor stone result in scalloped and eroded shorelines

Altered Habitats

West shoreline

- Some works are of considerable size
- Cumulative impacts from extensive shoreline developments

Natural Habitats

East shoreline

- Extensive and diverse natural rock outcrops

Natural Habitats

East shoreline

- Rocky points exposed during low water
- Variable rock size and density

Altered Habitats

East shoreline

- Beach Creation is a common activity

Altered Habitats

East shoreline

- Some works are of considerable size removing rocky shorelines and riparian habitat

Altered Habitats

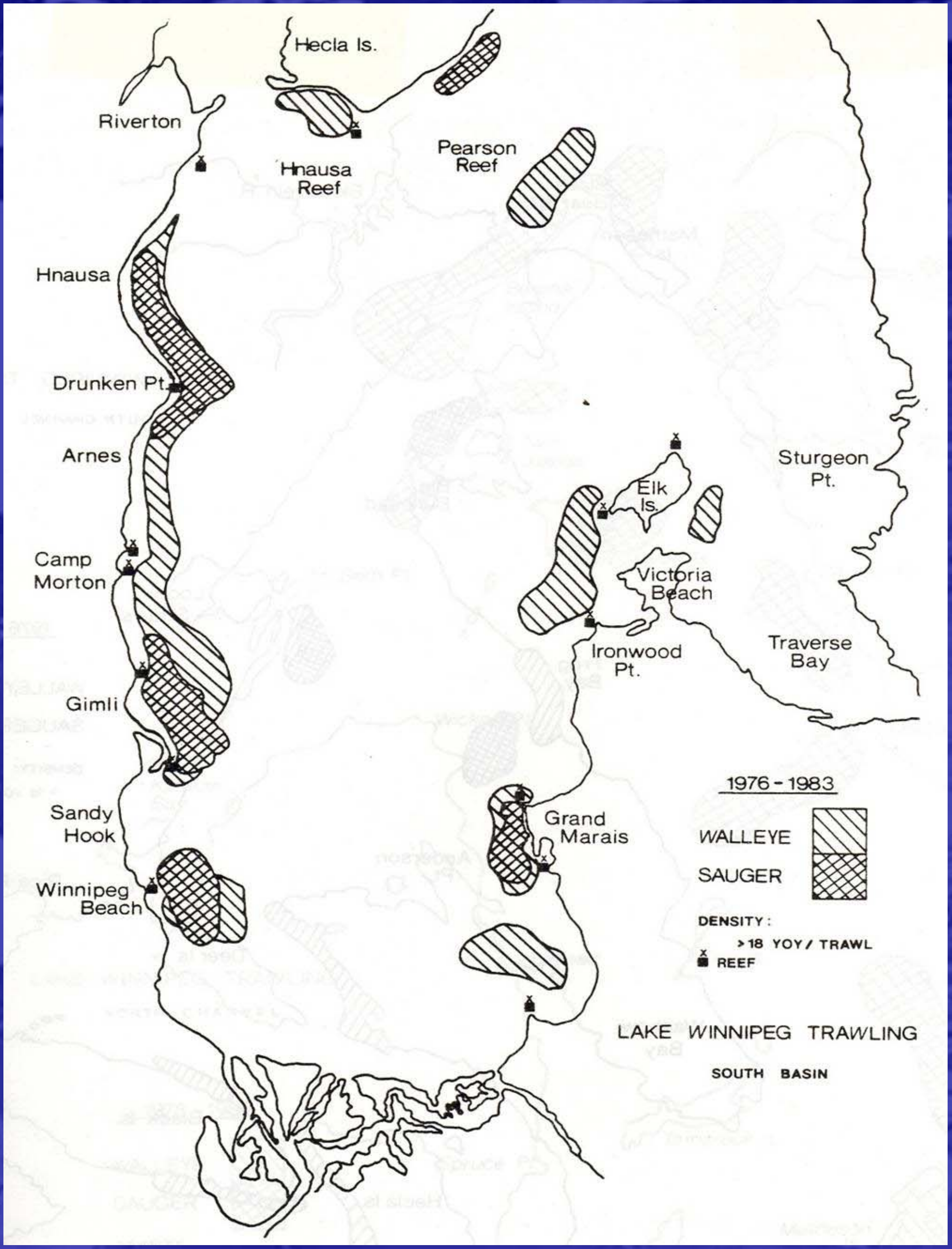
East shoreline

- Groynes are found on the east shore as well

Trawl Catches

South Basin

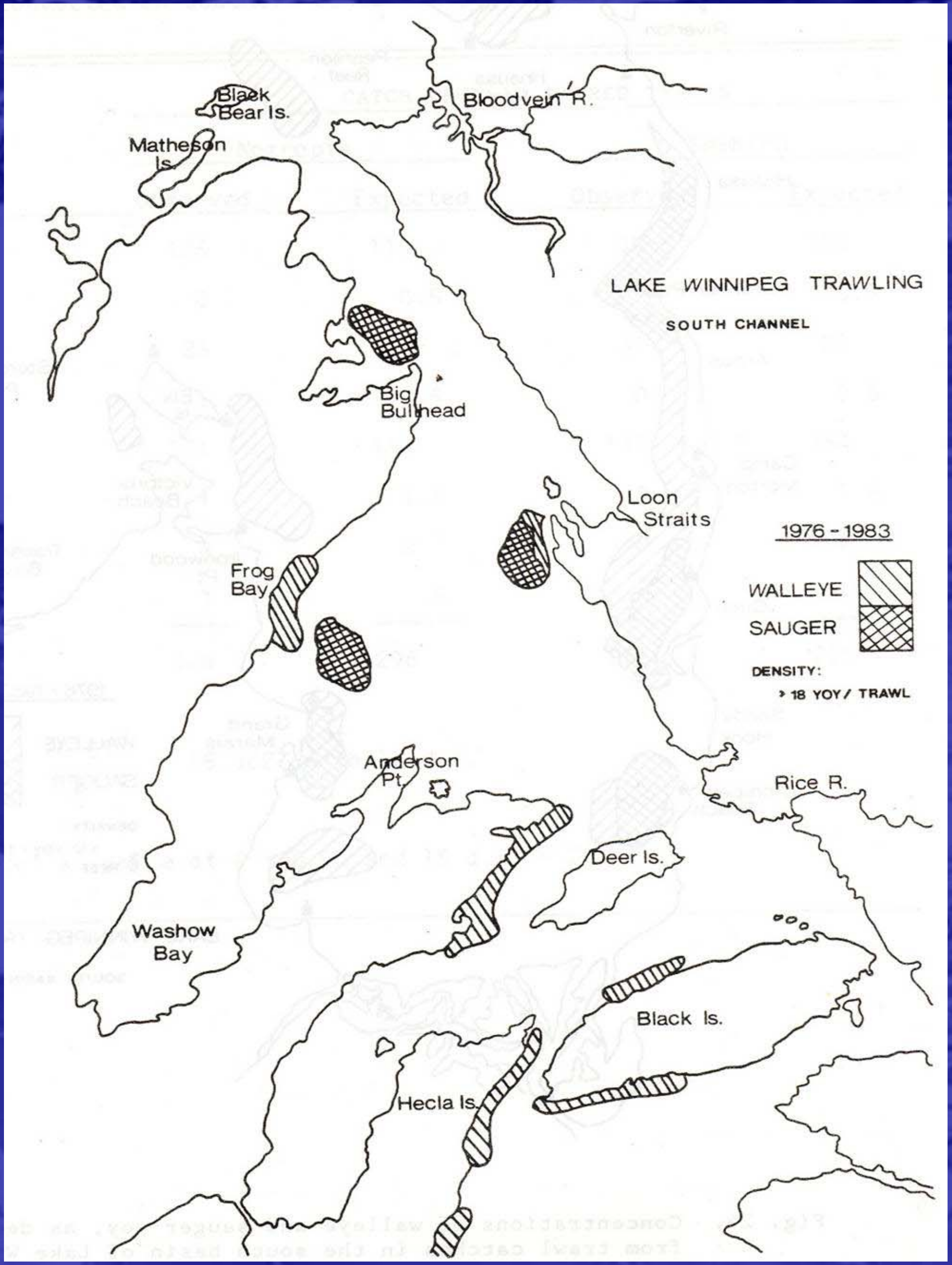
- Young-of-the-year Walleye and Sauger trawl catches 1976-1983
- Indicate discrete areas of concentrated spawning, nursery and rearing activity



Trawl Catches

<u>South Channel</u>

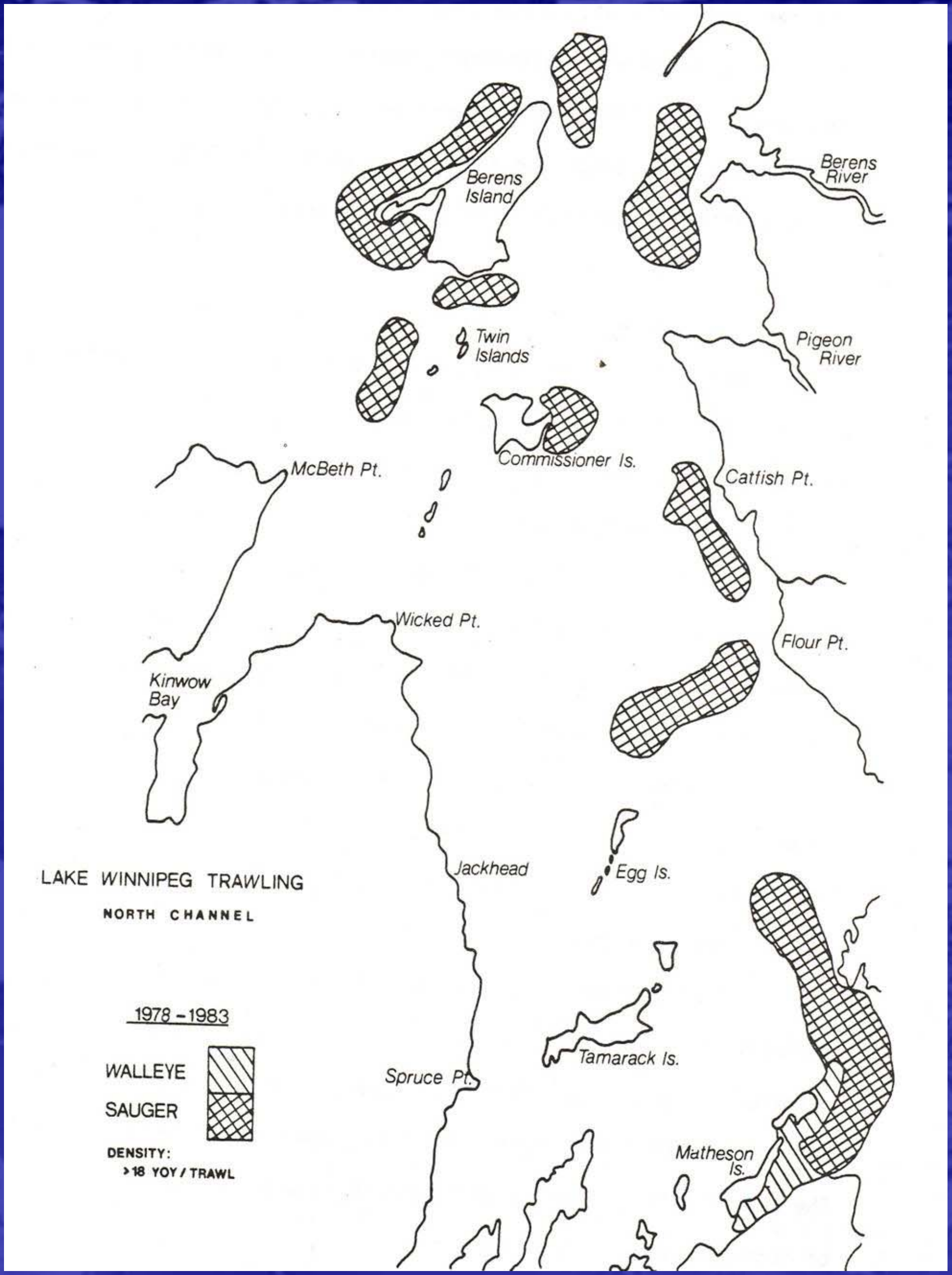
- Young-of-the-year Walleye and Sauger trawl catches 1976-1983
- Indicate discrete areas of concentrated spawning, nursery and rearing activity



Trawl Catches

North Channel

- Young-of-the-year Walleye and Sauger trawl catches 1976-1983
- Indicate discrete areas of concentrated spawning, nursery and rearing activity



Drainage Protection

Rock Armoring

- Erosion protection through better design and mitigation measures

Summary and Conclusions

- Numerous Existing and Potential Macro Impacts on the Productive Capacity of Fish Habitat may be occurring as a result of changes in:
  - Hydrological Flow Regime
  - Nutrient Loading
  - Sedimentation Rate Increases
- Phytoplankton, Zooplankton and Zoobenthos responses to altered habitat parameters as reflected in changes in abundance and species composition
- Increases in exotic and invasive species introductions and abundance

Summary and Conclusions

- Micro impacts to the Productive Capacity of Fish Habitat, concentrated in the South Basin have resulted from extensive shoreline alterations:
  - Shoreline Stabilizations
  - Groyne Construction
  - Recreational and Beach Developments

What Needs To Be Done?

- Identify research and information gaps to develop a Lake Winnipeg ecosystem model
- Conduct research in a comprehensive and collaborative manner
- Establish linkages of perturbations to existing or potential impacts on fish habitat
- Identify and inventory productive capacity of Lake Winnipeg in an ecological context
- Eliminate, mitigate and rehabilitate any damage to the Ecosystem

Research Needs

- Collection of basic inventories of representative habitat classes e.g. using sonar mapping technology by DFO
- Use of historical satellite imagery to establish linkages relating the optical quality of the water column to pelagic and benthic components using trawls and benthic grabs currently being examined by DFO and CEOS U of M Geography Department

Ongoing Research

- An expansion of the benthic sampling program currently being undertaken by Dr. Brenda Hann from the U of M Zoology Department (Graduate Student Program)
- Refining our understanding of productive capacity by measuring carbon and nitrogen fixation and planktonic community structure by DFO
- Determining the status of COSEWIC listed species by DFO

Current Management Initiatives

- Ensure appropriate implementation of sedimentation and erosion control measures throughout the watershed basin, particularly within the western and southern agricultural and urban development areas, through individual project reviews (DFO Habitat Management)
- Work with the Lake Winnipeg Shoreline Erosion Technical Committee (SETC) to re-configure micro habitat alterations to their former role in providing natural erosion protection and fish spawning, feeding and rearing habitat


The End....
N
Lake Winnipeg Science Workshop
Fisheries and Oceans
Canada

Lessons Learned from the Great Lakes: Fish Habitat Science

Burlington

- Ken Minns
- Susan Doka
- John Fitzsimons
- Marten Koops
- Bob Randall
- Cindy Chu
- Carolyn Bakelaar
- Kathy Seifried
- Bud Timmins

Sault Ste. Marie

- Karen Smokorowski
- Tom Pratt

Fisheries and Oceans Canada
Great Lakes Laboratory for Fisheries and Aquatic Sciences

Outline

1. Regional scale Fish Habitat Classification Model: Severn Sound, Georgian Bay
2. Empirical data – application in the Great Lakes
3. Large scale projects: IJC water level regulation and climate change
4. Lessons learned from Fish Habitat Science

Fish Habitat Classification Model

Objective: Science-based approach for fish habitat assessment and classification in Severn Sound.


DEVELOPMENT OF A FISH HABITAT CLASSIFICATION MODEL FOR LITTORAL AREAS OF SEVERN SOUND, GEORGIAN BAY, A GREAT LAKES' AREA OF CONCERN

C.K. Minns[1], P. Brunette[2], M. Stoneman[1], K. Sherman[3], R. Craig[4], C. Portt[5], and R.G. Randall[1]

[1] Great Lakes Laboratory for Fisheries and Aquatic Sciences, Fisheries and Oceans Canada, Bayfield Institute, PO Box 5050, 867 Lakeshore Road, Burlington, Ontario L7R 4A6

[2] Baytech Environmental, PO Box 71074, Burlington, Ontario L7T 4J8

[3] Severn Sound Environmental Association, PO Box 100, Wye Marsh Wildlife Centre, Midland, Ontario L4R 4K6

[4] Ontario Ministry of Natural Resources, Midhurst District, 2284 Nursery Road, Ontario L0L 1X0

[5] C. Portt & Associates, 56 Waterloo Avenue, Guelph, Ontario N1H 3H5

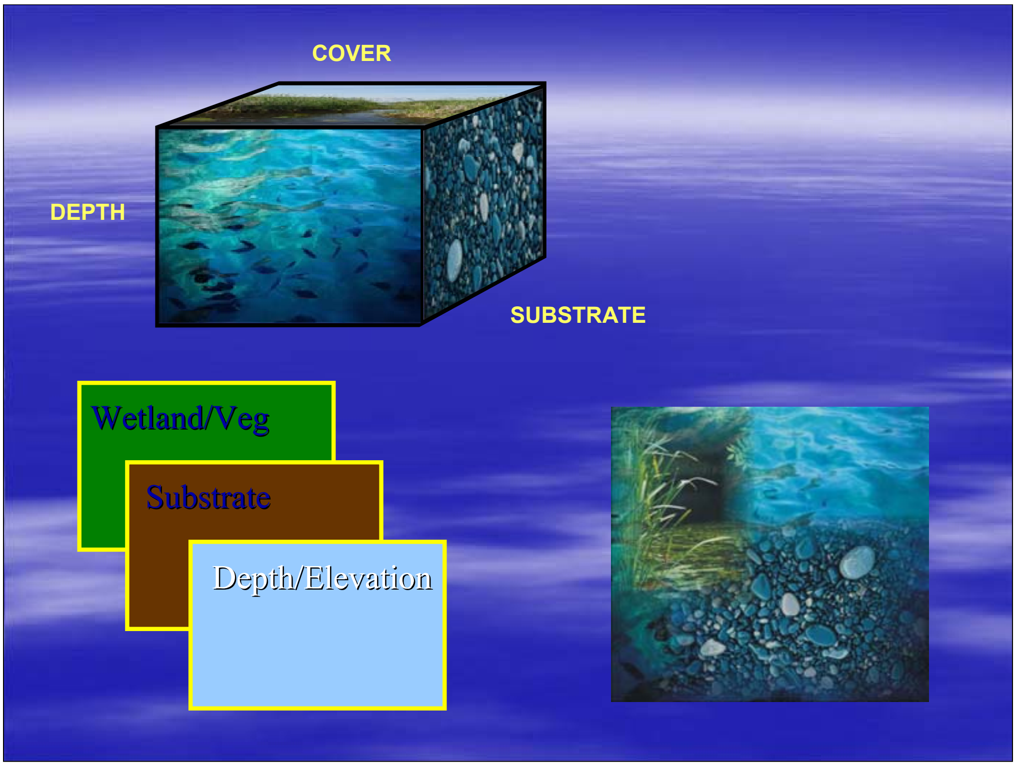
August 1999

Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 2490

Fisheries and Oceans Canada Pêches et Océans Canada

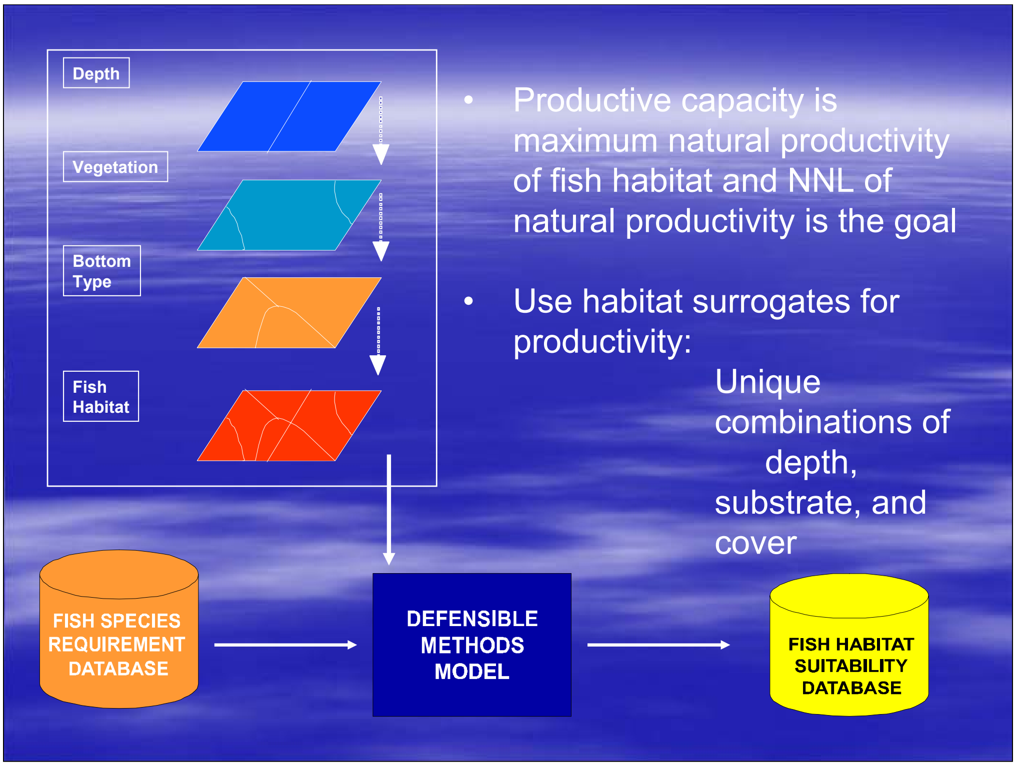
Methods:

- Develop GIS-based habitat database
- Defensible Methods based framework for a Fish Habitat Suitability Model
- Map shorelines areas as being Red, Yellow or Green, representing gradients in fish productivity
- Products: Minns et al. 1999; http://caburgisweb/severn.htm

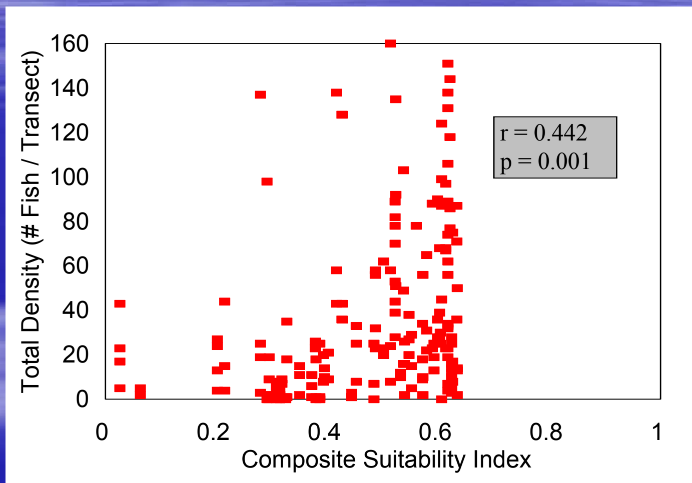

COVER
DEPTH
SUBSTRATE
Wetland/Veg
Substrate
Depth/Elevation

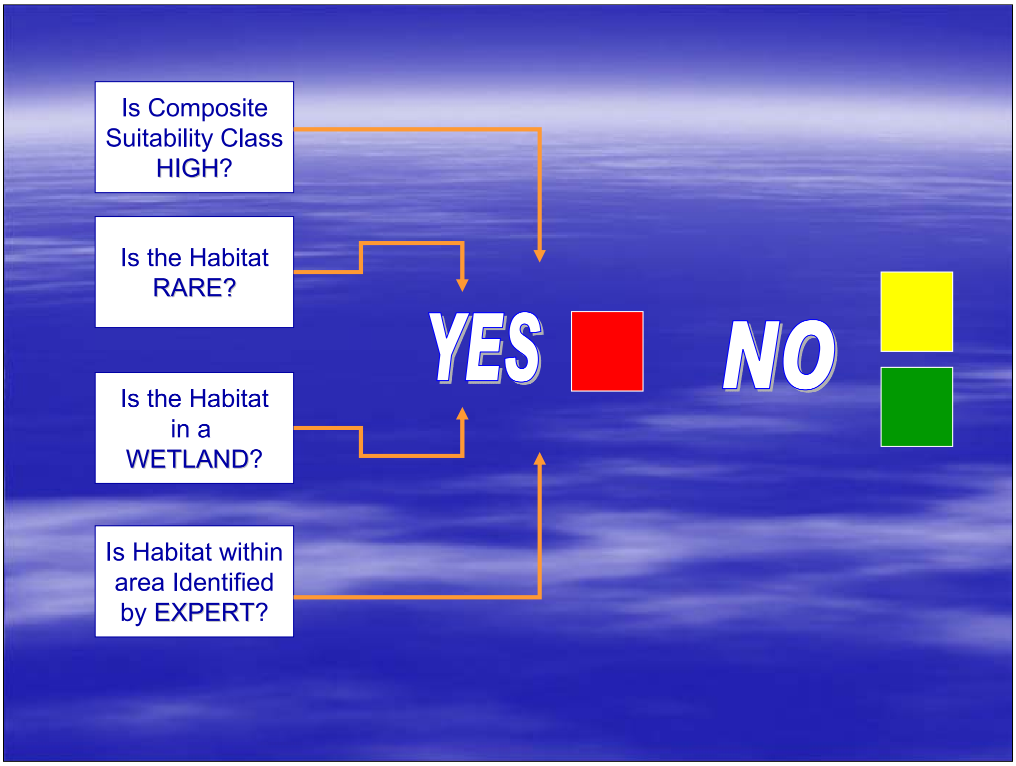
Fish habitat suitability database

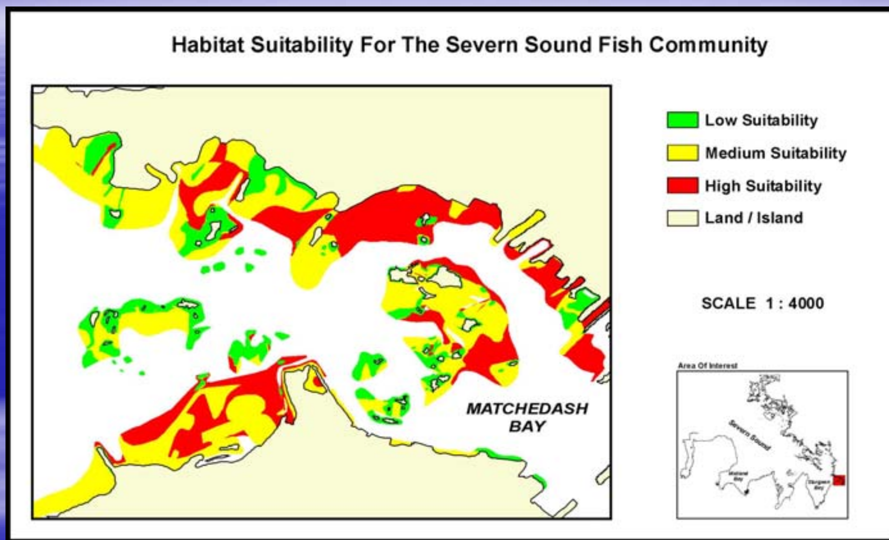
- Whole Great Lakes fish assemblage
- **Thermal** (warm, cool, cold) & **Trophic** (piscivore or not) groups
- Life stages (adults, nursery, spawning)
- Charts of suitability vs depth+substrate by cover types
- Literature-based


Depth
Vegetation
Bottom Type
Fish Habitat
• Productive capacity is maximum natural productivity of fish habitat and NNL of natural productivity is the goal
• Use habitat surrogates for productivity:
Unique combinations of depth, substrate, and cover
FISH SPECIES REQUIREMENT DATABASE
DEFENSIBLE METHODS MODEL
FISH HABITAT SUITABILITY DATABASE

Model calibration and validation




Is Composite Suitability Class HIGH?
Is the Habitat RARE?
Is the Habitat in a WETLAND?
Is Habitat within area Identified by EXPERT?
YES
NO



Regional scale: classified 343 km of shoreline (0 – 1.5 m water depth)

Empirical Data

Coastal exposure as a first-order predictor of the productive capacity of coastal habitat in the Great Lakes

Objective:

Quantify the relationship between coastal exposure,habitat, and fish occurrence and density

- Maximum effective fetch, substrate, cover, and water temperature
- Fish species and assemblages

Methods:

Model data set (n=100)

- Coastal wetlands, shore, harbours
- Lake Erie and Lake Ontario
- 1994

Validation data set (n=273)

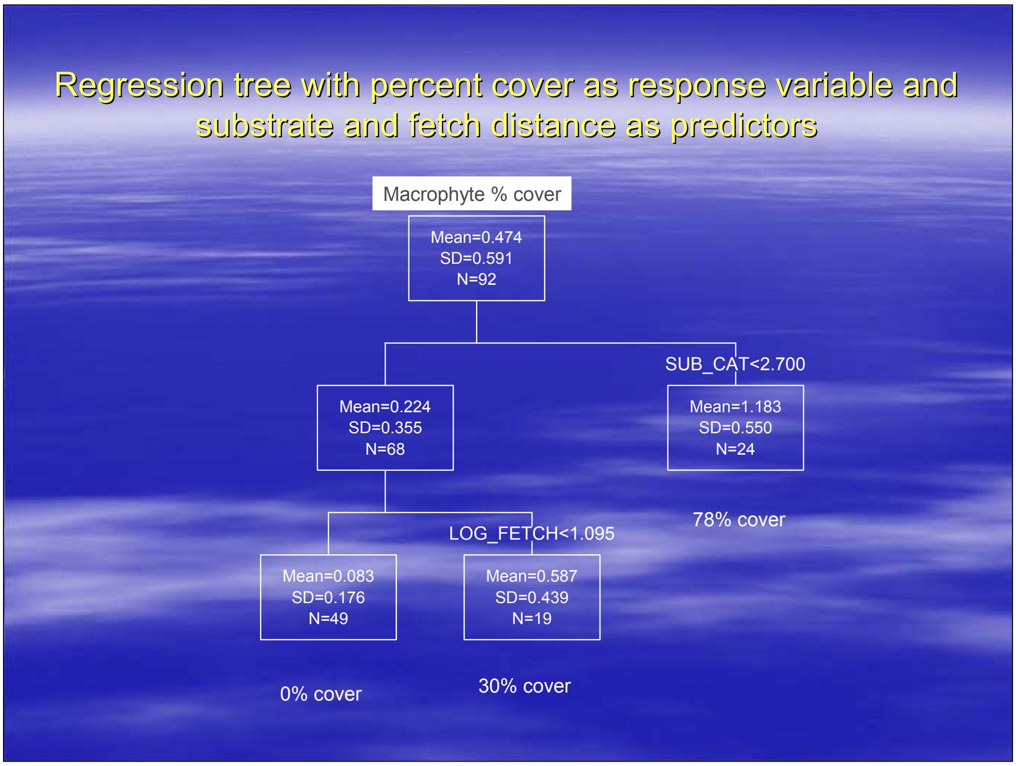
- Coastal wetlands, shore, embayments
- Lake Ontario and Georgian Bay
- Before and after 1994

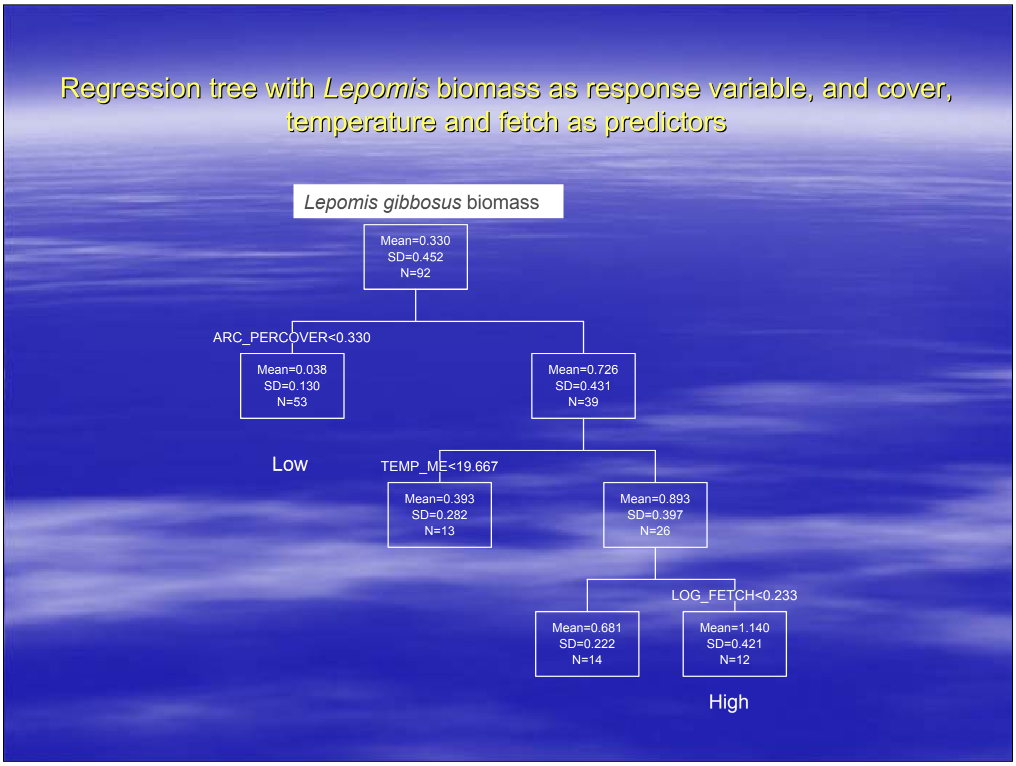
Statistics: Regression trees, ANOVA, Chi-square

Randall, Minns and Brousseau. Canadian Science Advisory Secretariat Research Document 2004/087

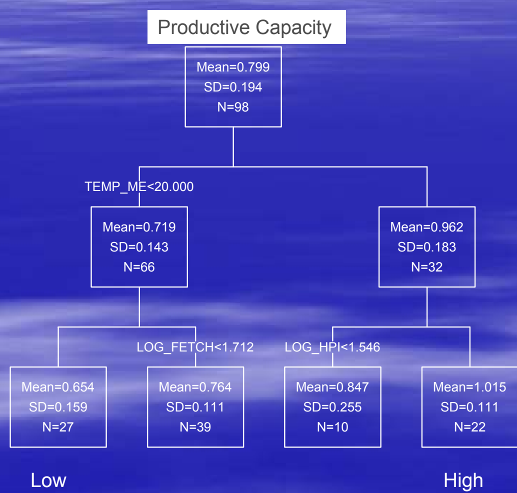
Regression Tree

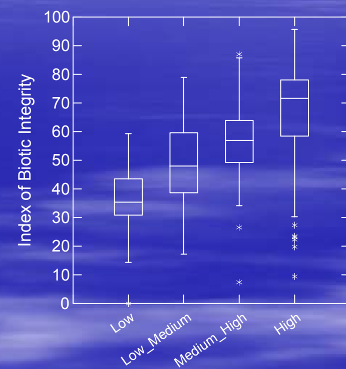
Response Variables	Predictor Variables
Lepomis biomass	Fetch
Perca biomass	% Cover
Alosa biomass	Substrate size
HPI (biomass)	Water temperature
IBI (richness)	[HPI]


Regression tree with percent cover as response variable and substrate and fetch distance as predictors
Macrophyte % cover
Mean=0.474
SD=0.591
N=92
SUB_CAT<2.700
Mean=0.224
SD=0.355
N=68
Mean=1.183
SD=0.550
N=24
78% cover
LOG_FETCH<1.095
Mean=0.083
SD=0.176
N=49
Mean=0.587
SD=0.439
N=19
0% cover
30% cover

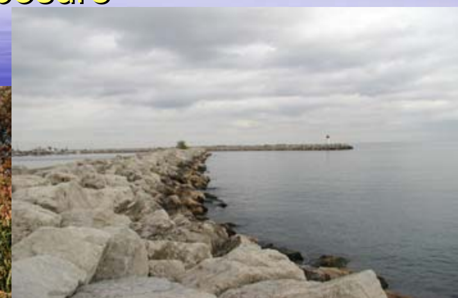

Regression tree with Lepomis biomass as response variable, and cover, temperature and fetch as predictors
Lepomis gibbosus biomass
Mean=0.330
SD=0.452
N=92
ARC_PERCOVER<0.330
Mean=0.038
SD=0.130
N=53
Mean=0.726
SD=0.431
N=39
Low
TEMP_ME<19.667
Mean=0.393
SD=0.282
N=13
Mean=0.893
SD=0.397
N=26
LOG_FETCH<0.233
Mean=0.681
SD=0.222
N=14
Mean=1.140
SD=0.421
N=12
High

Determination of habitat productive capacity using temperature, fetch and biomass as predictors





Great Lakes shoreline habitats showing a gradient in coastal exposure



Application

1. The substrate/fetch model can be used to predict macrophyte occurrence
2. Predictive models can be used to map the productive capacity of extensive coastal regions of Great Lakes
3. Map of productive capacity is the first step in a two-stage approach for evaluating management needs

Field Experiments

Wood Removal

Habitat Addition

reef construction

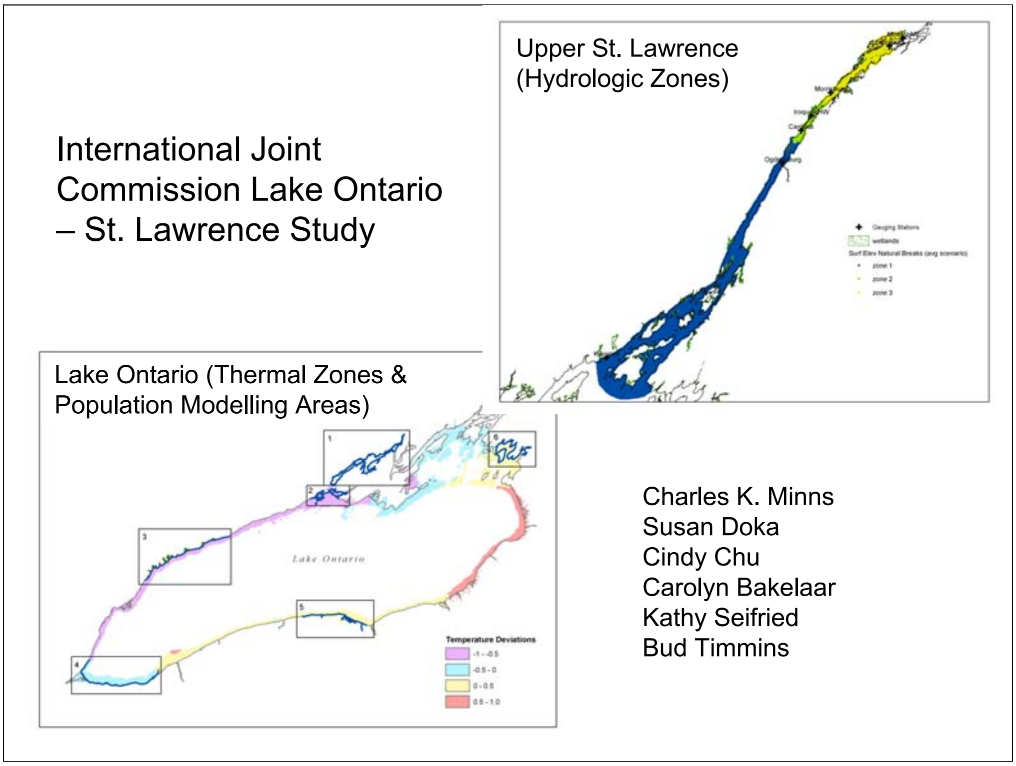
wetland construction

brush-bundle addition

Fish Habitat Science: Lessons from Field Experiments

- Method for measuring habitat-dependent process rates and production (system)
- Determination of threshold (non-linear) responses to habitat alteration
- Effectiveness of compensation and mitigation
- Uncertainty and risk analisis
- Results can be extrapolated to Great Lakes
- Communication and collaboration is important

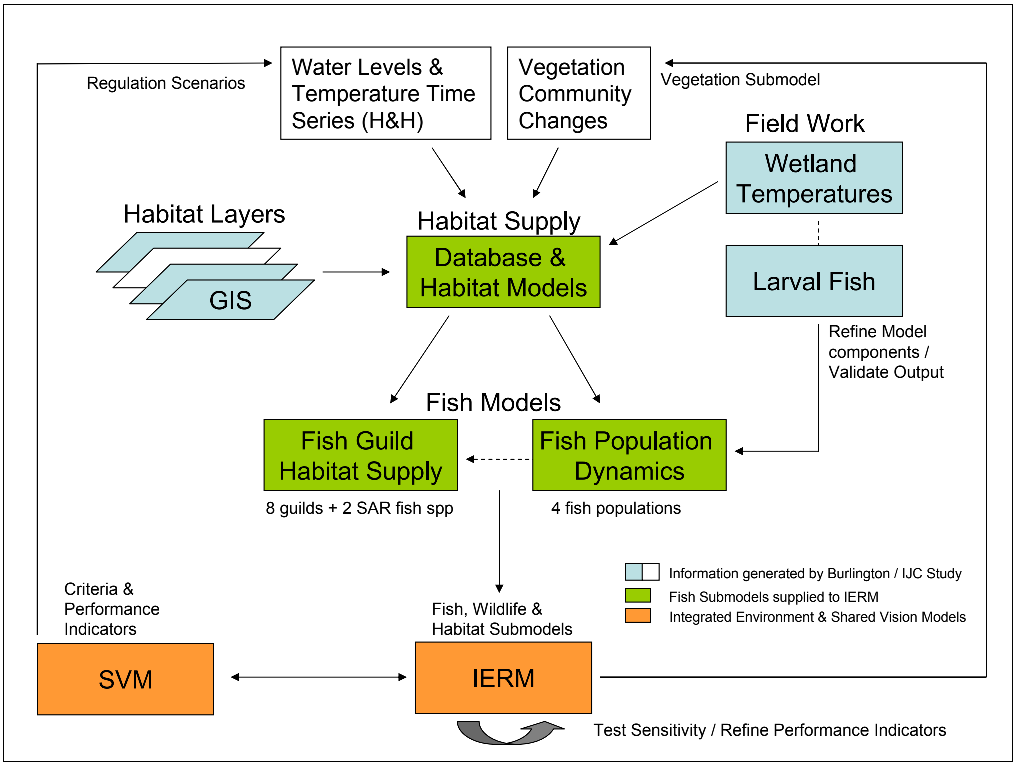
Randall, R.G., C.K. Minns, T.C. Pratt and K.E. Smokorowski. 2004. Science Technology Transfer Workshop – Science Contributions Towards Improving Fish Habitat Management. Canadian Science Advisory Secretariat Proceedings Series 2004/010. (http://www.dfo-mpo.gc.ca/csas/Csas/English/Publications/Proceedings_e.htm)



Maps show the areas where models are being applied: Lake Ontario up to 20m contour (low water datum) and all of the Upper St. Lawrence

For modelling, thermal zones were determined for the lake used in temperature models to feed into both guild, SAR and pop models

Boxes are selected areas are used for population modelling.

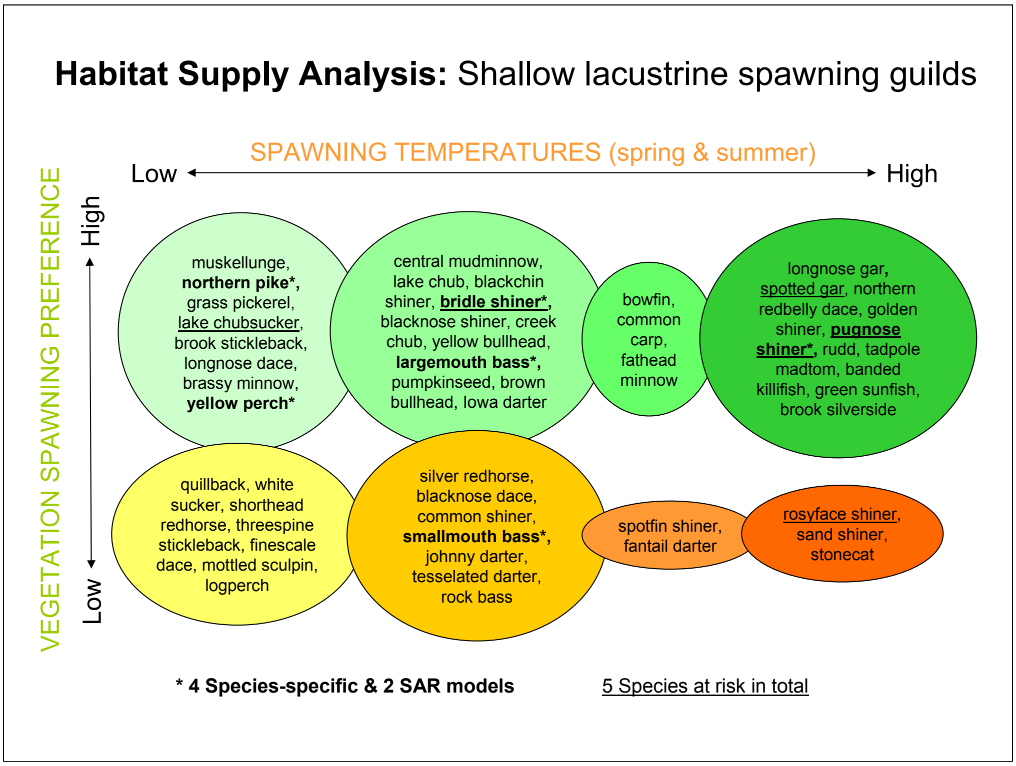


Habitat Layers include: Elevation/Bathymetry, Emergent Wetland Areas, Shore Types (some data in-house some supplied by study)

Habitat Variables (Original/Derived/Modelled): Substrate Type, Temperatures, Vegetation, Water Depth .

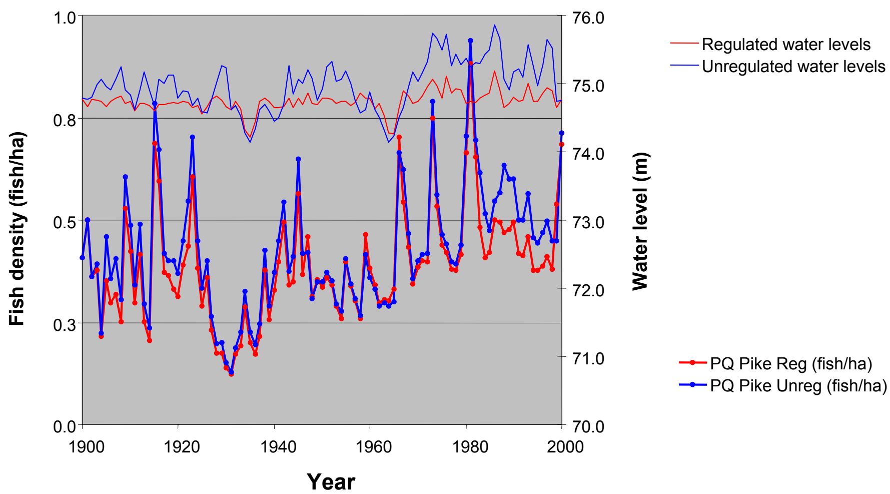
Fish guilds**:** shallow water spawners at 4 temperature ranges with vegetated or nonvegetated preferences

Representative sport fish models: northern pike, largemouth bass, smallmouth bass, yellow perch

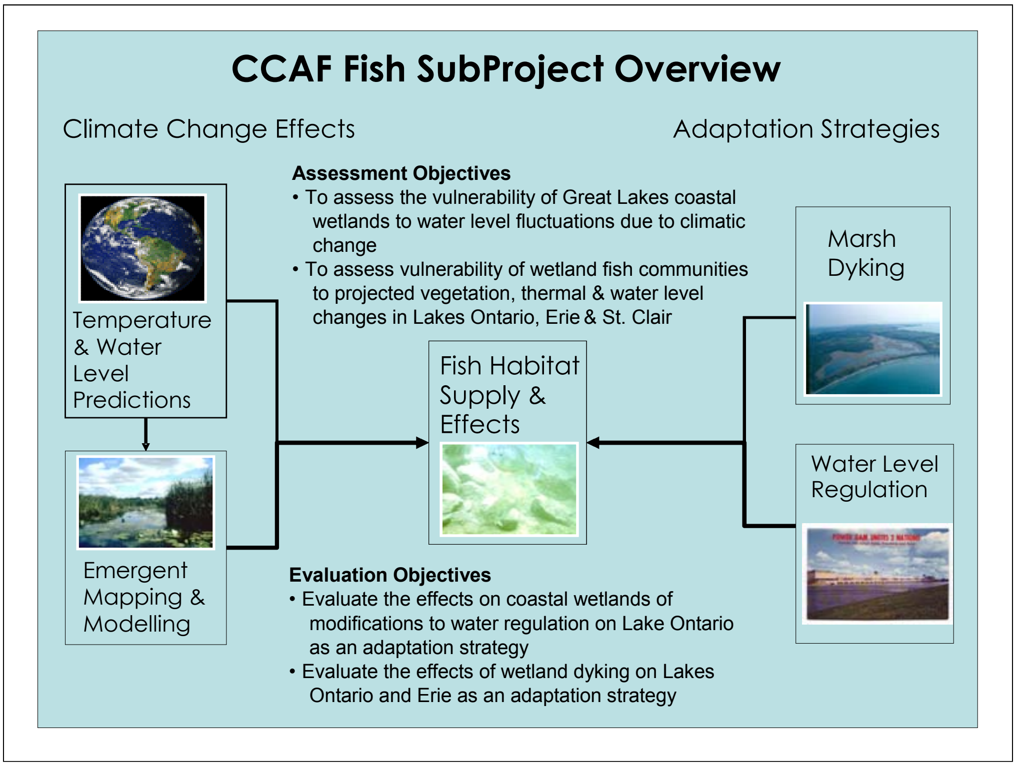


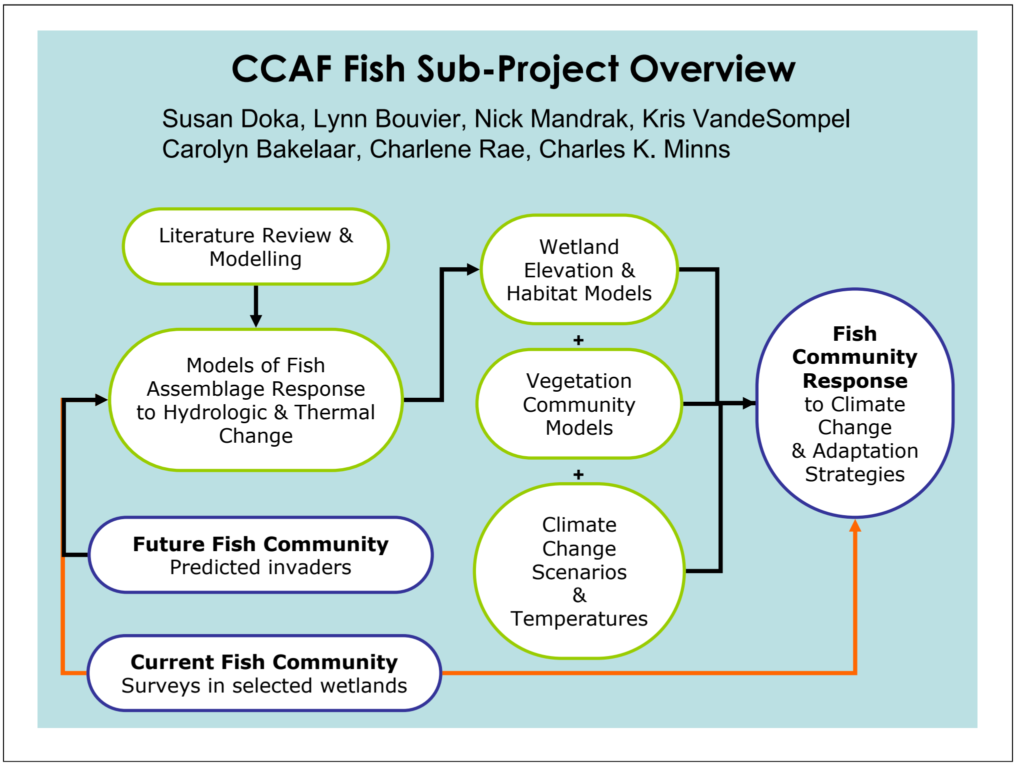
Guilds are shallow water spawners that either use or don't use vegetation and are present in lacustrine areas of Lake Ontario and Upper St. Lawrence

Northern pike population densities in Presqu'ile Bay, Lake Ontario under regulated and unregulated conditions



Water levels for Lake Ontario range between 74-76 m ASL; Regulated lower than unregulated (both are simulated levels)


CCAF Fish SubProject Overview
Climate Change Effects
Adaptation Strategies
Assessment Objectives
• To assess the vulnerability of Great Lakes coastal wetlands to water level fluctuations due to climatic change
• To assess vulnerability of wetland fish communities to projected vegetation, thermal & water level changes in Lakes Ontario, Erie & St. Clair
Temperature & Water Level Predictions
Emergent Mapping & Modelling
Fish Habitat Supply & Effects
Marsh Dyking
Water Level Regulation
Evaluation Objectives
• Evaluate the effects on coastal wetlands of modifications to water regulation on Lake Ontario as an adaptation strategy
• Evaluate the effects of wetland dyking on Lakes Ontario and Erie as an adaptation strategy



Orange arrows indicate field work

Black arrows are models

Field Survey: Methodology

Coastal Wetland Locations

Comparison of Fish Communities in Barrier (Natural & Dyked) versus Open Wetlands

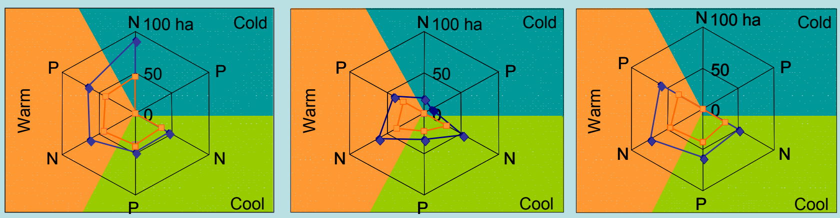
Results

Field Work: Coastal wetland fish community sampled in 2003 barrier and open marshes

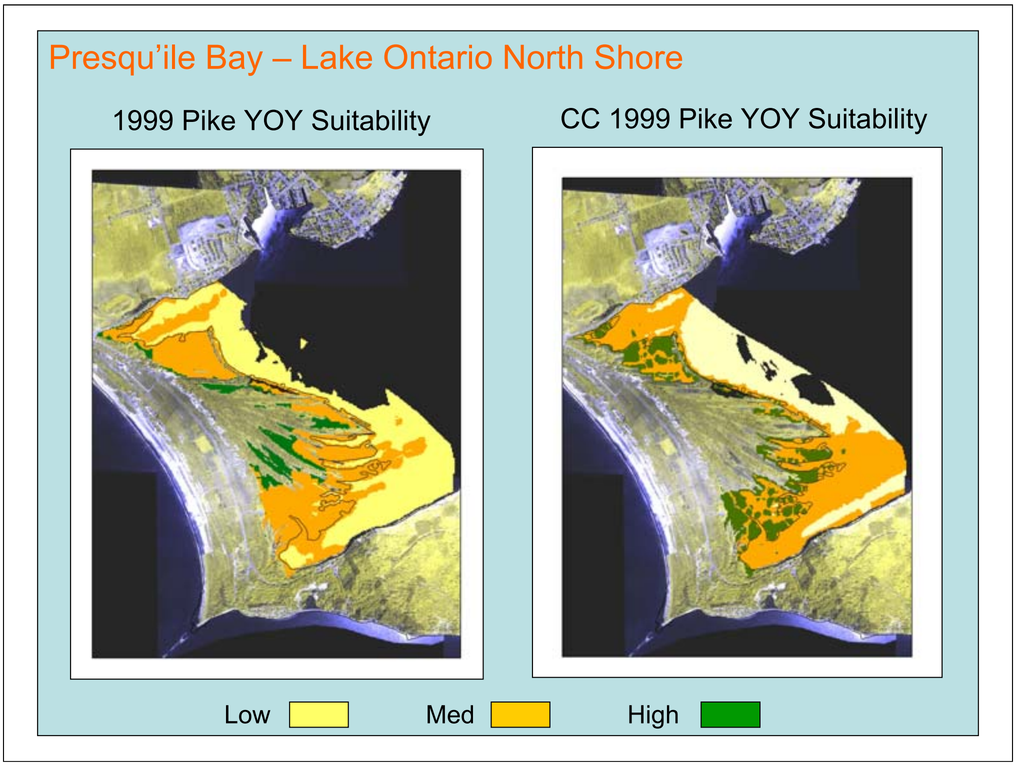
	Cold	Cool	Warm
Non-Piscivore (N)	troutperch	white sucker, banded killifish, brook silverside, greater redhorse, shorthead redhorse, golden shiner, pugnose shiner, emerald shiner, blackchin shiner, spottail shiner, yellow perch, logperch	rock bass, black bullhead, yellow bullhead, brown bullhead, freshwater drum, spotfin shiner, gizzard shad, channel catfish, green sunfish, pumpkinseed, bluegill, pugnose minnow, mimic shiner, tadpole madtom, white crappie, bluntnose minnow, fathead minnow, black crappie, central mudminnow
Piscivore (P)	Chinook salmon, brown trout	longnose gar, northern pike, spotted gar, walleye	bowfin, smallmouth bass, largemouth bass, white bass

Climate Change Scenario: Baseline is 2m, 100 ha wetland with mixed vegetation and fine substrates
Effect is 1m water level drop with same habitat (i.e. gradual change)

Spawning Habitat **YOY Habitat** **Adult Habitat**



In Climate Change scenario graphs, baseline is blue and effect (CC) is orange



NOTE: 1999 is a relatively low water level year

The CC suitability map is the predicted YOY pike habitat suitability given 0.5m drop in long term water levels

Summary (IJC & CCAF)

Tools and Information for clients that include Great Lakes management agencies

- International Joint Commission
- Fish Habitat Management
- Great Lakes Fishery Commission
- Ontario Ministry of Natural Resources
- US State and Federal agencies
- Conservation Authorities

Lessons

- GIS-based habitat inventories are invaluable
- Fish-habitat suitability databases for freshwater fishes in central Canada are available and can be updated
- Fish-habitat models are becoming increasingly sophisticated and useful
- Coarse resolution fish habitat classifications are useful to managers
- Effective and continuing communication between Science, Fish Habitat Management, and other management agencies is paramount
- Habitat Science Advisory Group is needed

Lake Winnipeg Science Workshop

Modelling as a Method of Data Integration

Scott Millard — Bay of Quinte Overview & Phosphorus Modelling

Marten Koops — Ecosystem Modelling Using Ecopath with Ecosim Software

Fisheries and Oceans Canada | Pêches et Océans Canada

Freshwater Institute Nov 29-30, 2004

"All models are wrong …but some are useful." – G.E.P. Box

Models are one tool by which research and monitoring data can be integrated to provide input to management.

Pros Cons of a Modelling Approach

Pros

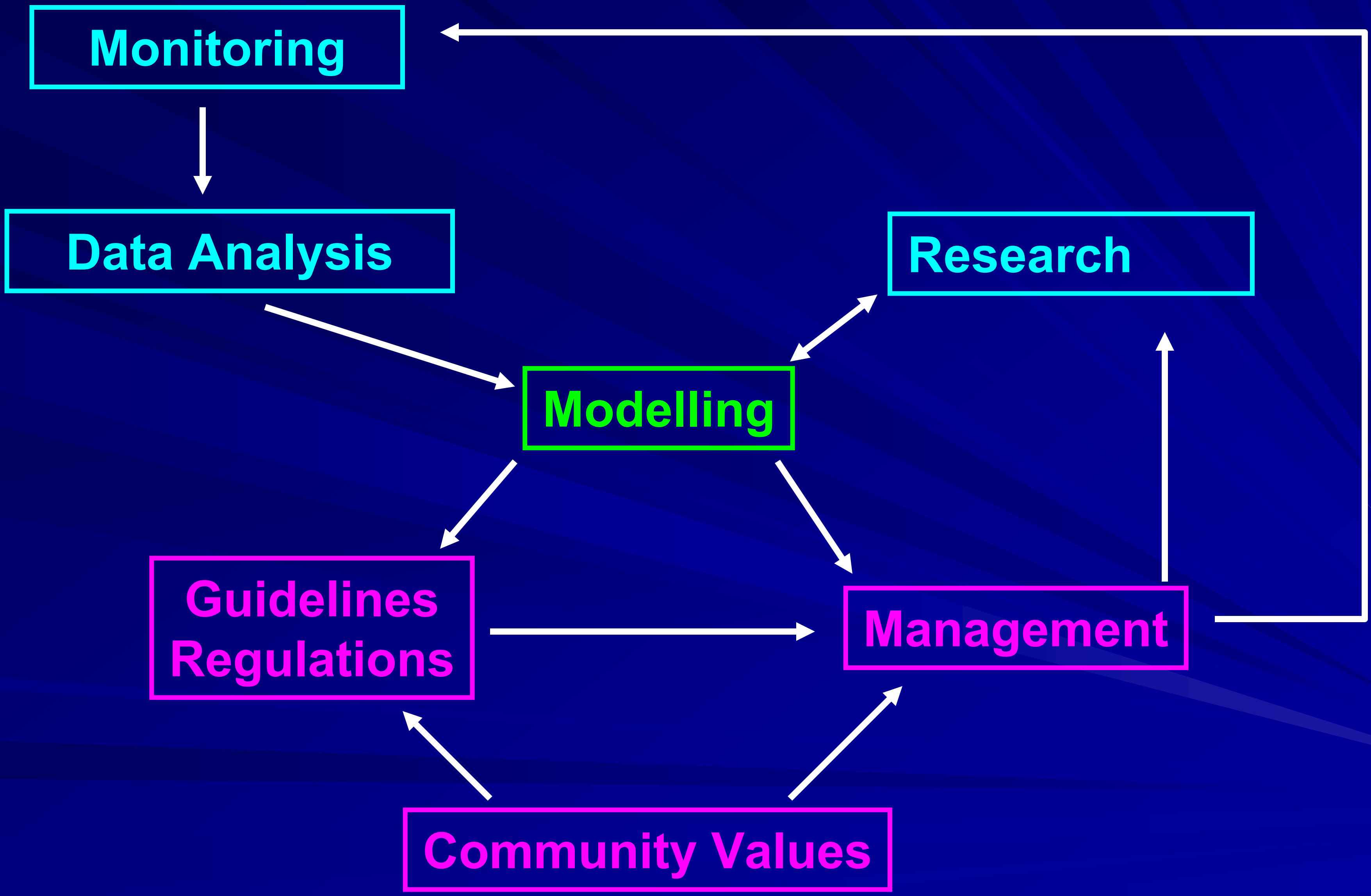
- ✓ Provides framework for understanding and developing management options.
- ✓ Provides a means to test hypotheses/management options integrating impacts of various stressors (e.g phosphorus, AIS, fisheries).
- ✓ Brings interdisciplanary expertise to the table to increase understanding of ecosystem function.
- ✓ Identifies and mobilizes more sources of data.
- ✓ Identifies gaps in understanding and data to help evaluate ongoing programs (e.g. Hamilton Harbour).

Pros and Cons of a Modelling Approach

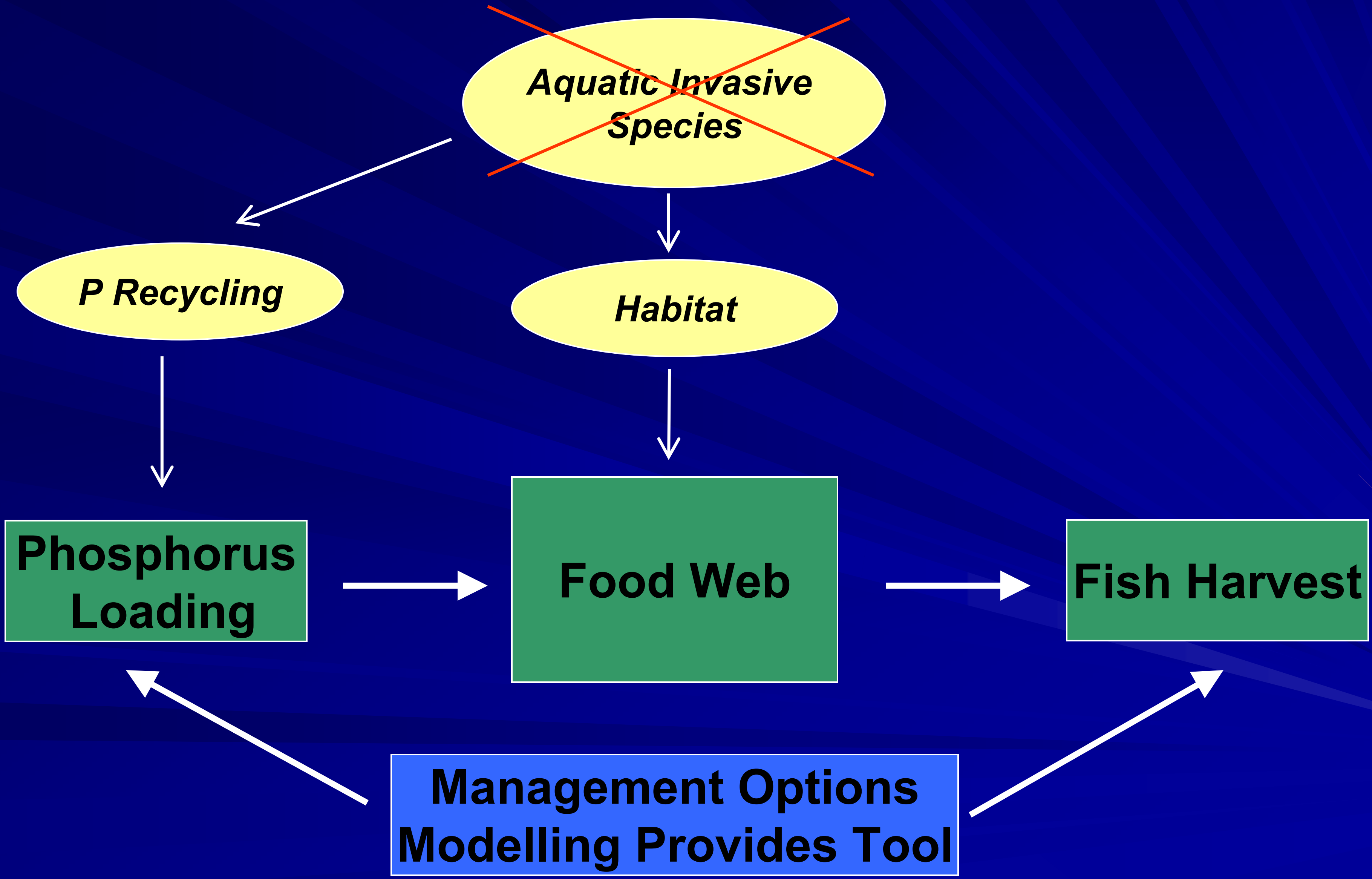
Cons

- ✓ Takes buy in from all parties.
- ✓ Need to overcome anti-modelling bias.
- ✓ Requires leadership with modelling expertise.
- ✓ Requires a critical mass of data to get started however,
  - ❖ conceptual framework requires no data
  - ❖ functional model often requires less data than perceived
- ✓ Start earlier rather than later.

Model for Integrating Science in Support of Management



Ecosystem Management



Phosphorus Modelling

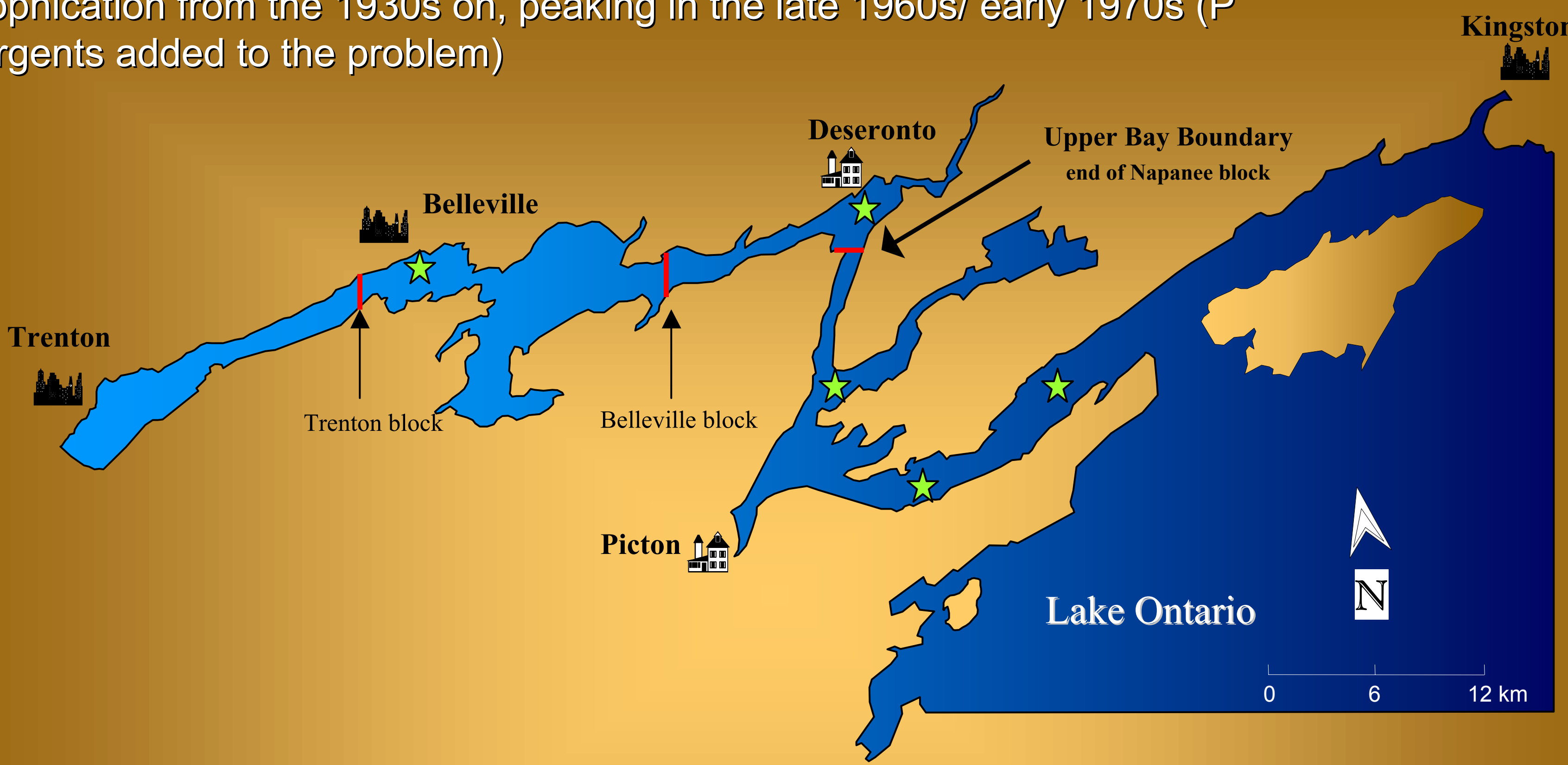
A Key Tool for Developing a P Management Strategy for the Bay of Quinte, Lake Ontario

Dr. Ken Minns and Jim Moore

Fisheries and Oceans Canada, Burlington

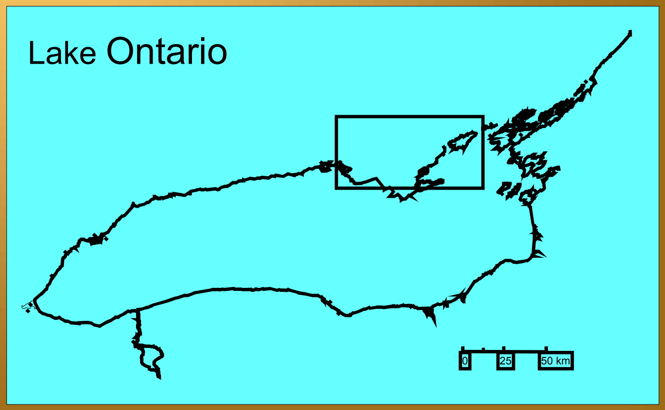
JEMSys Software, Dundas

Urban growth near the Bay coupled with collection of sewage waste led to eutrophication from the 1930s on, peaking in the late 1960s/ early 1970s (P detergents added to the problem)



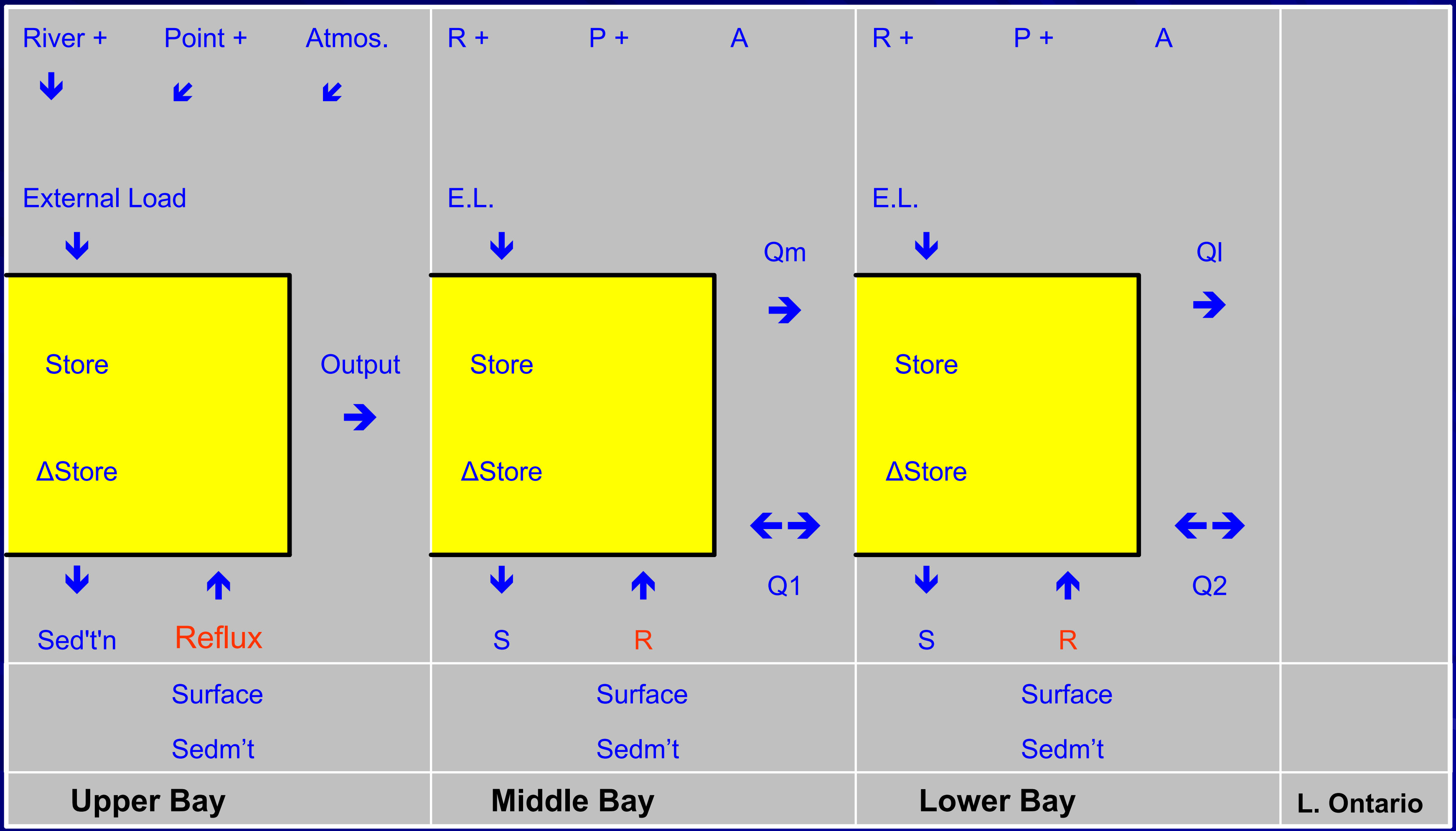
Bay of Quinte

Sampling Stns



Budget Framework

Snapshot for Predetermined Time Interval



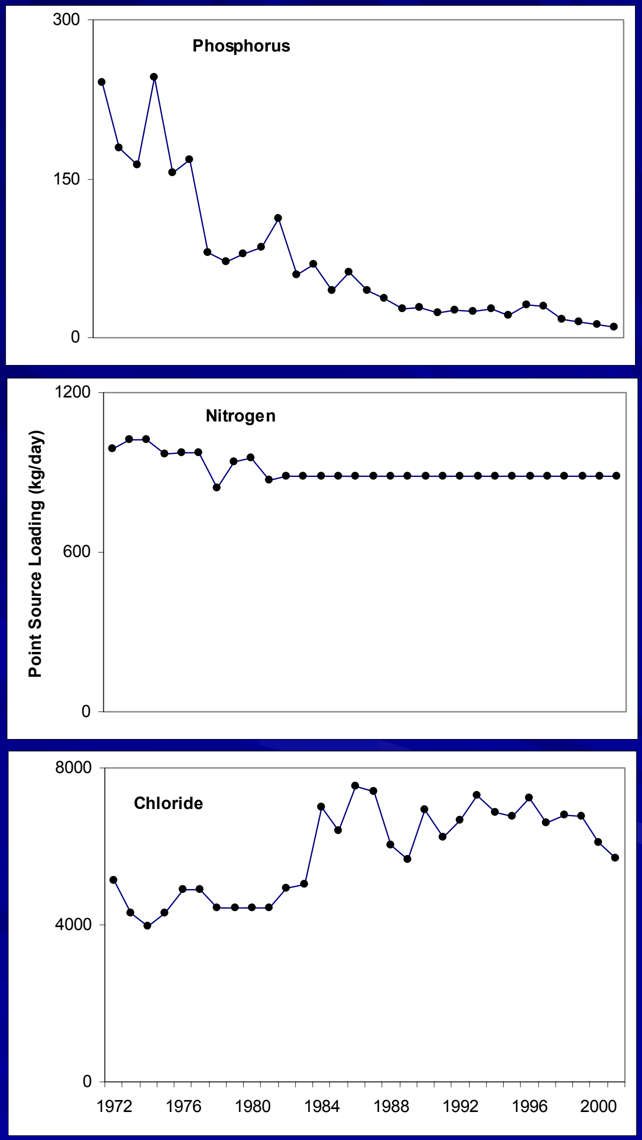
All inputs and outputs known, reflux rates used to balance the model

Hydrology
A Key Feature of Phosphorus Budget

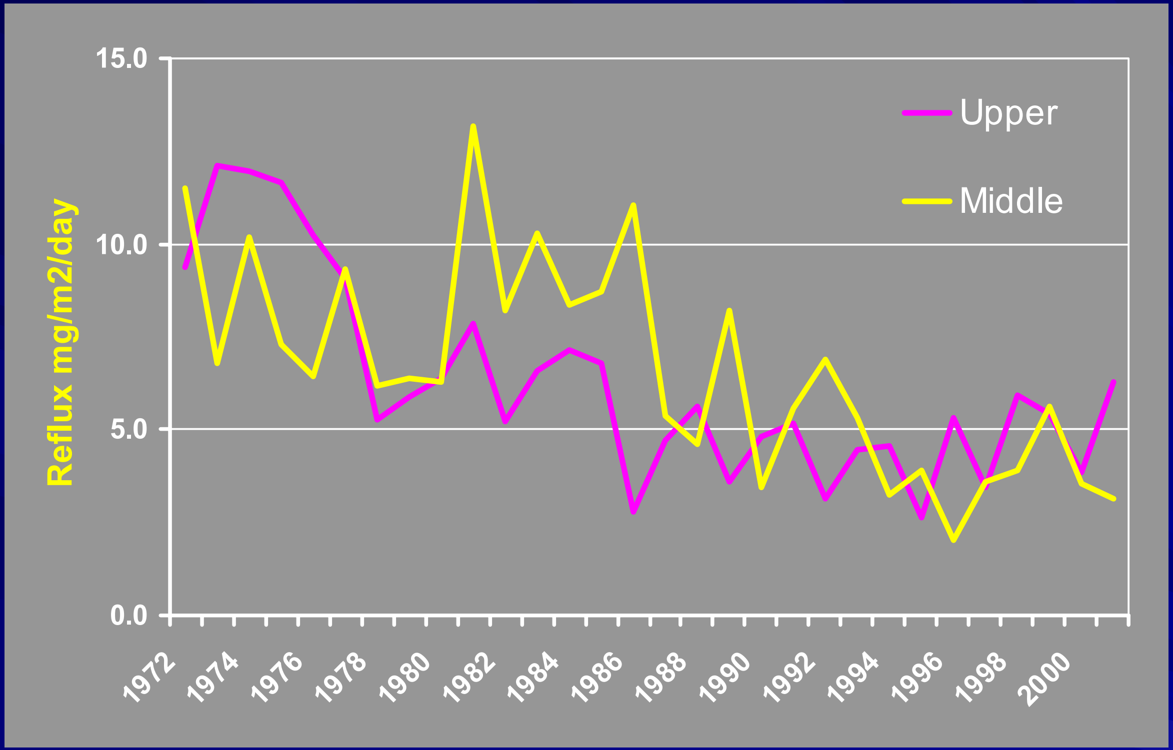
- River flow is a dominant feature in the upper Bay where Trent River provides 70% of total flow.
- Tributary flow has high seasonal variability.
- Exchanges flows between Lake Ontario and the lower/middle Bay are important and were included.
- Loads strongly related to river flows and promote flushing.
- Declines in trib P conc. minimal with no change in Trent R.

Point-Source Loadings

- Major decline in loadings since P control implemented.
- Seasonal hydrology must be taken into account when relative importance of trib vs. STP loads assessed.
- Point-sources are still the most effective way to control P inputs to the bay.



Summer Sediment P Reflux

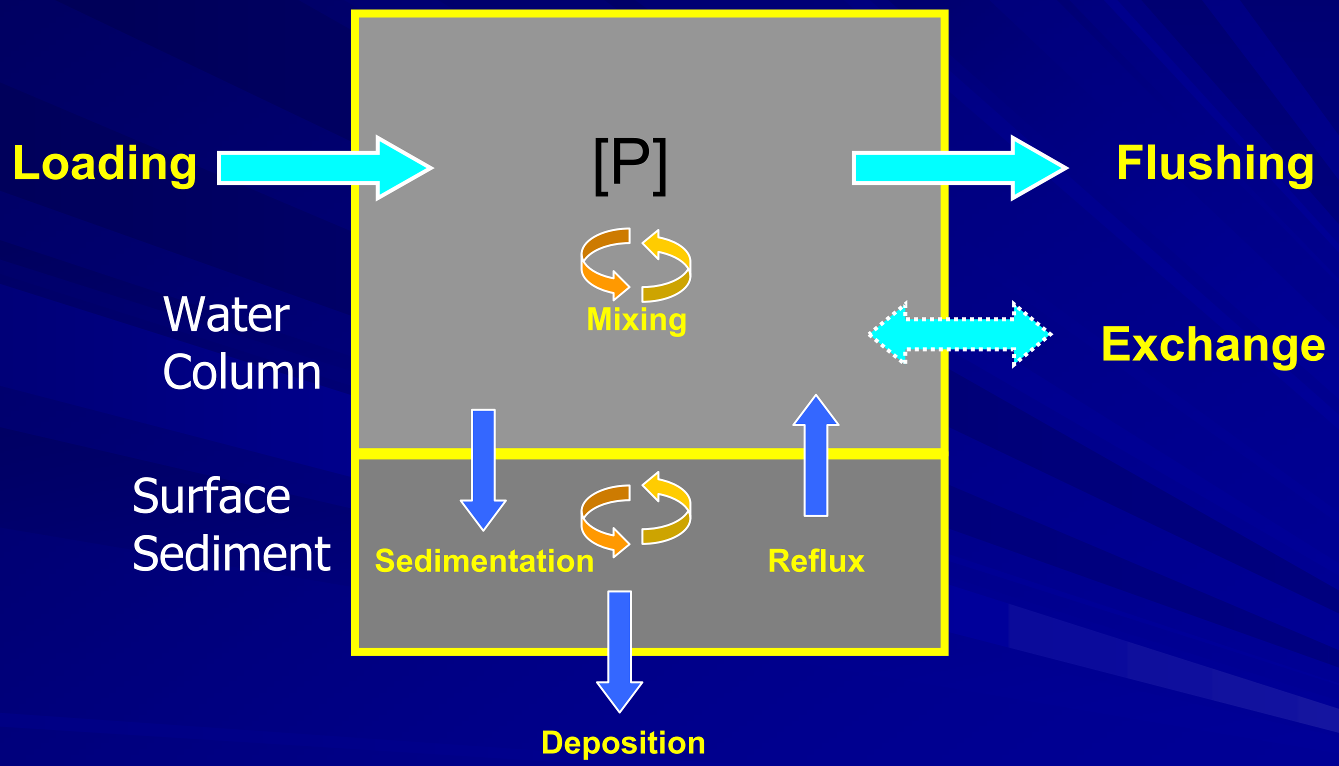


- Estimated reflux rates have declined
- Middle Bay response lagged behind Upper Bay as expected with slow turnover of surface sediments and movement down through the Bay and out over time

Implications of Budget Analysis

- **Point-source P control has been a major success**
- Negligible changes in tributary inputs.
- Water supply to bay has declined, possibly due to climate change; Water levels are also down
- Confirms earlier finding that upper Bay [P] results from the mixing of high volume tributary flows with low [P] and low volume point-source flows with high [P]
- Low river flows in the summer allow point source inputs to increase Bay [P], ie. eutrophication

Phosphorus Model

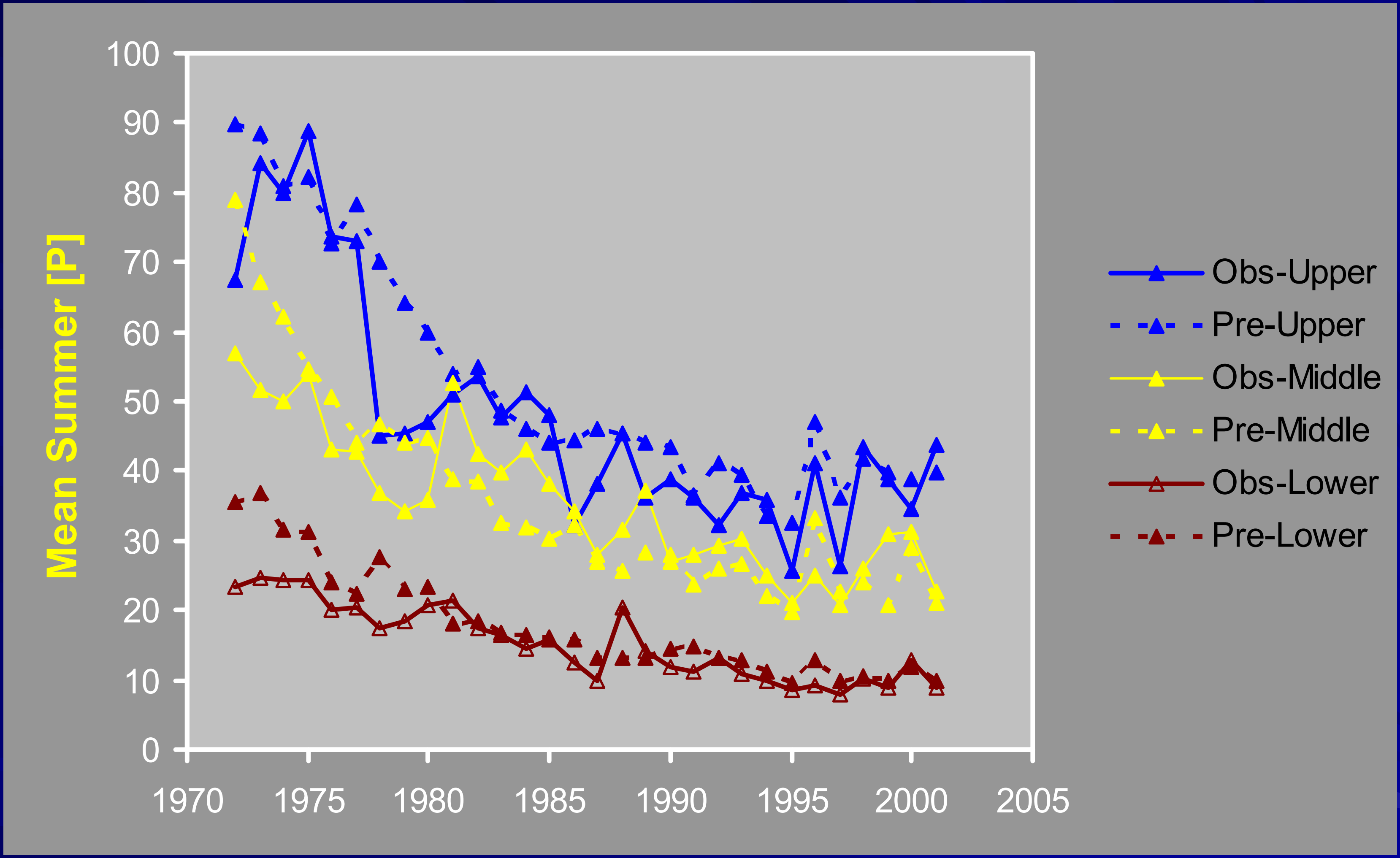


- dPw = Loading-Sedimentation-Flushing+Reflux (+/- Exchange)
- dPs = Sedimentation-Reflux - Deposition

P Model Components & Features

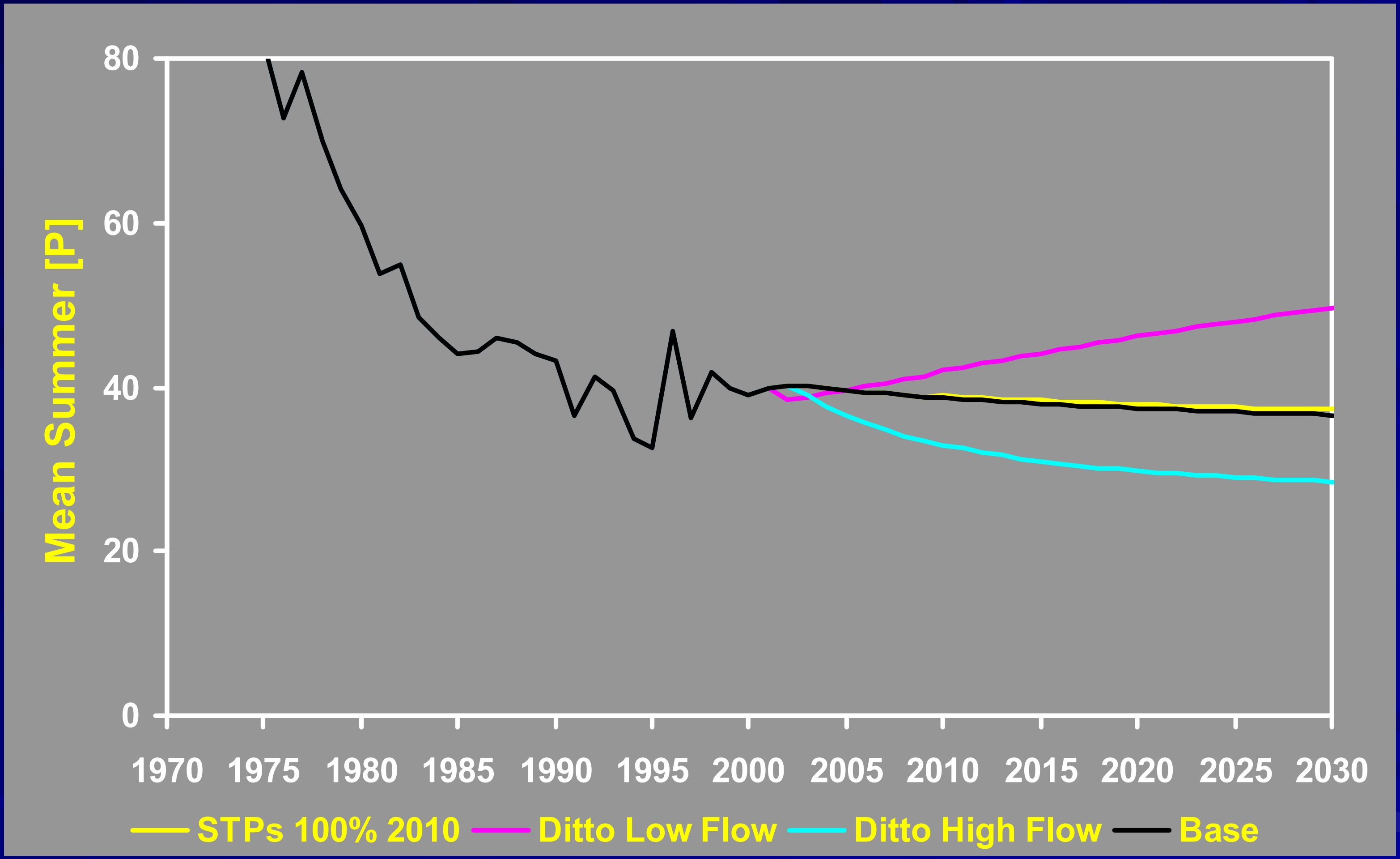
- Measured Inputs: Loading, Flushing, Exchange
- Estimated Inputs: Sedimentation, Deposition (literature and Quinte studies)
- Modelled Inputs: Sediment reflux. Rate function of [P] surface sediment gives best fit.
- Programmed in Stella with Excel for scenario input.
- Daily time step, input data smoothed from budget.
- Output is graphical display from past, to present (1972-2001) and predicted future (2002-2031).

Base Model Fit 1972-2001



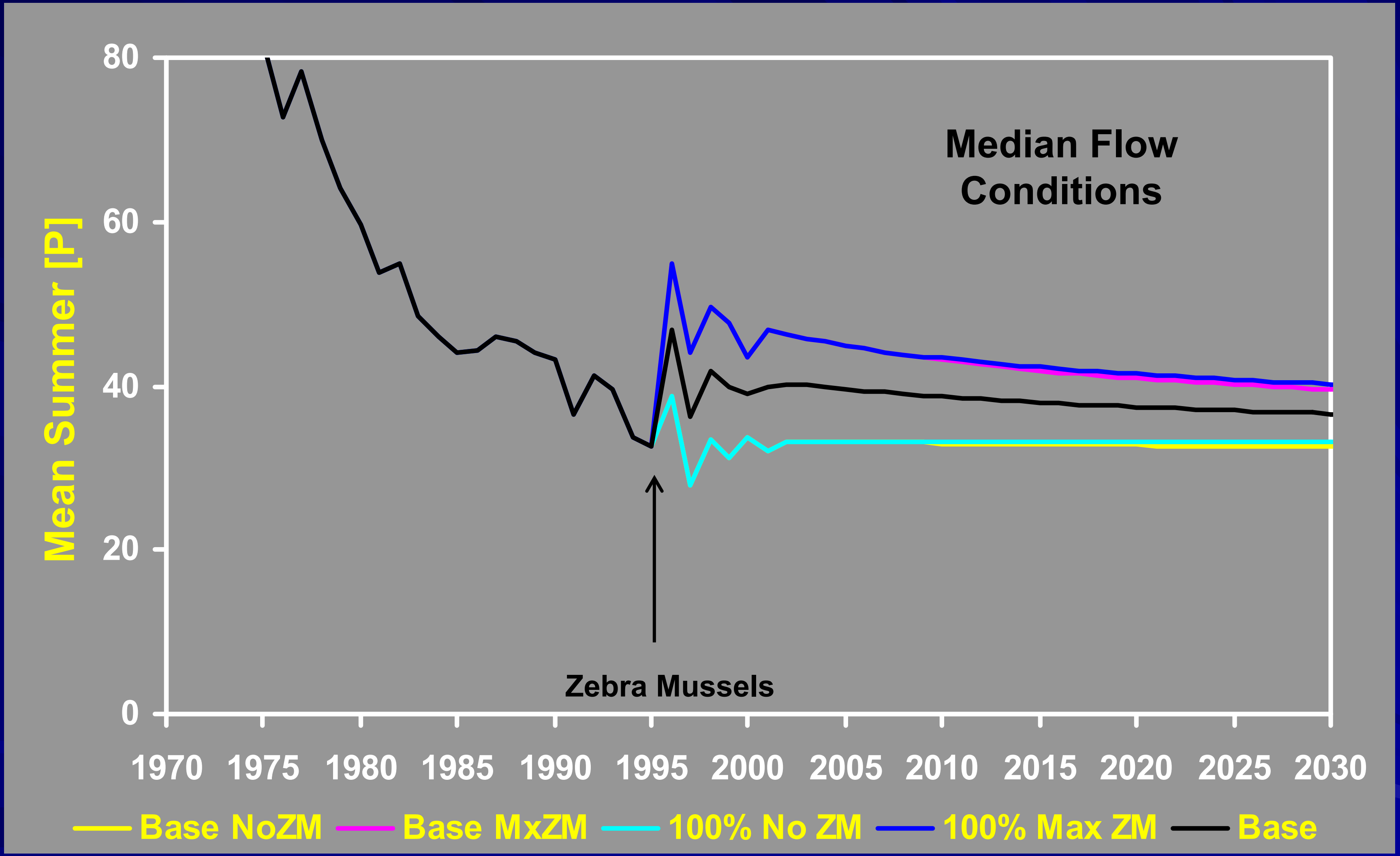
- Good agreement in all three sections
- Similar parameter values throughout

Scenario 1 STPs at 100% in 2010



- Three river flow levels (low flow may be more likely in the future).
- With zebra mussels present

Future ZM Effects



- ZM presence increases mean summer [P]
- Represents considerable uncertainty for future

Future Management Issues

- **Safe-guarding this success** will require eternal vigilance by means of P management plan and monitoring.

- **Future area human population growth** will increase STP flows and hence point-source loads (unless effluent [P]s are further reduced with new technologies or improved efficacy)

- **Lower runoff** (and potentially lower water levels), likely related to climate change, will increase the impact of point-source loads, especially in summer

Conclusions

- Using 100% point source P loads will not produce deleterious in-Bay impacts at average river flows
- Prolonged low river flows will lead to decreased water quality
- Zebra mussel effect is significant raising expected [P]
- Model has already been utilzed to rationalize small load allocation to local aboriginal community.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Canada

Ecosystem Modelling as a Tool for Integration and Management

Marten Koops

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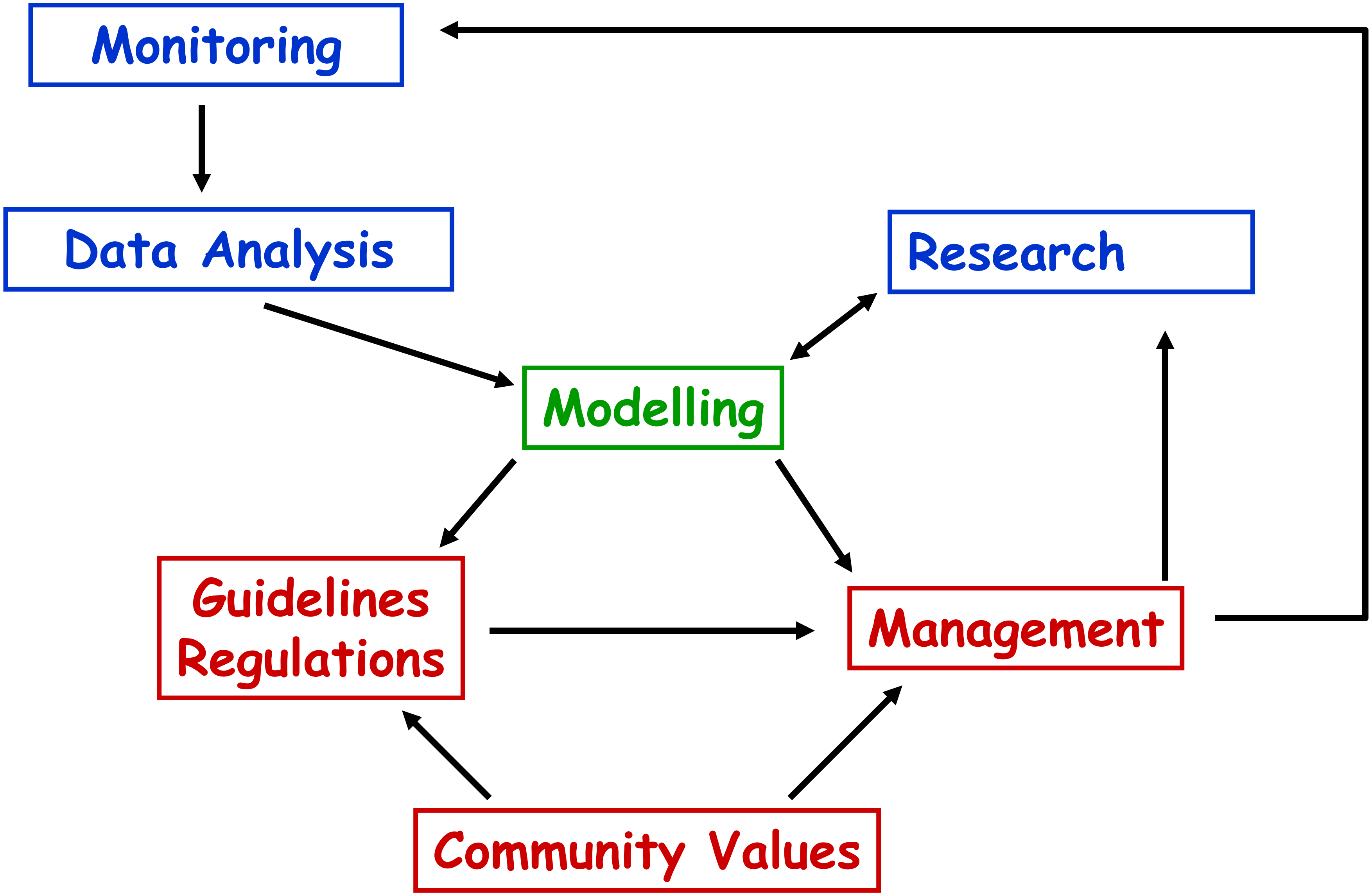
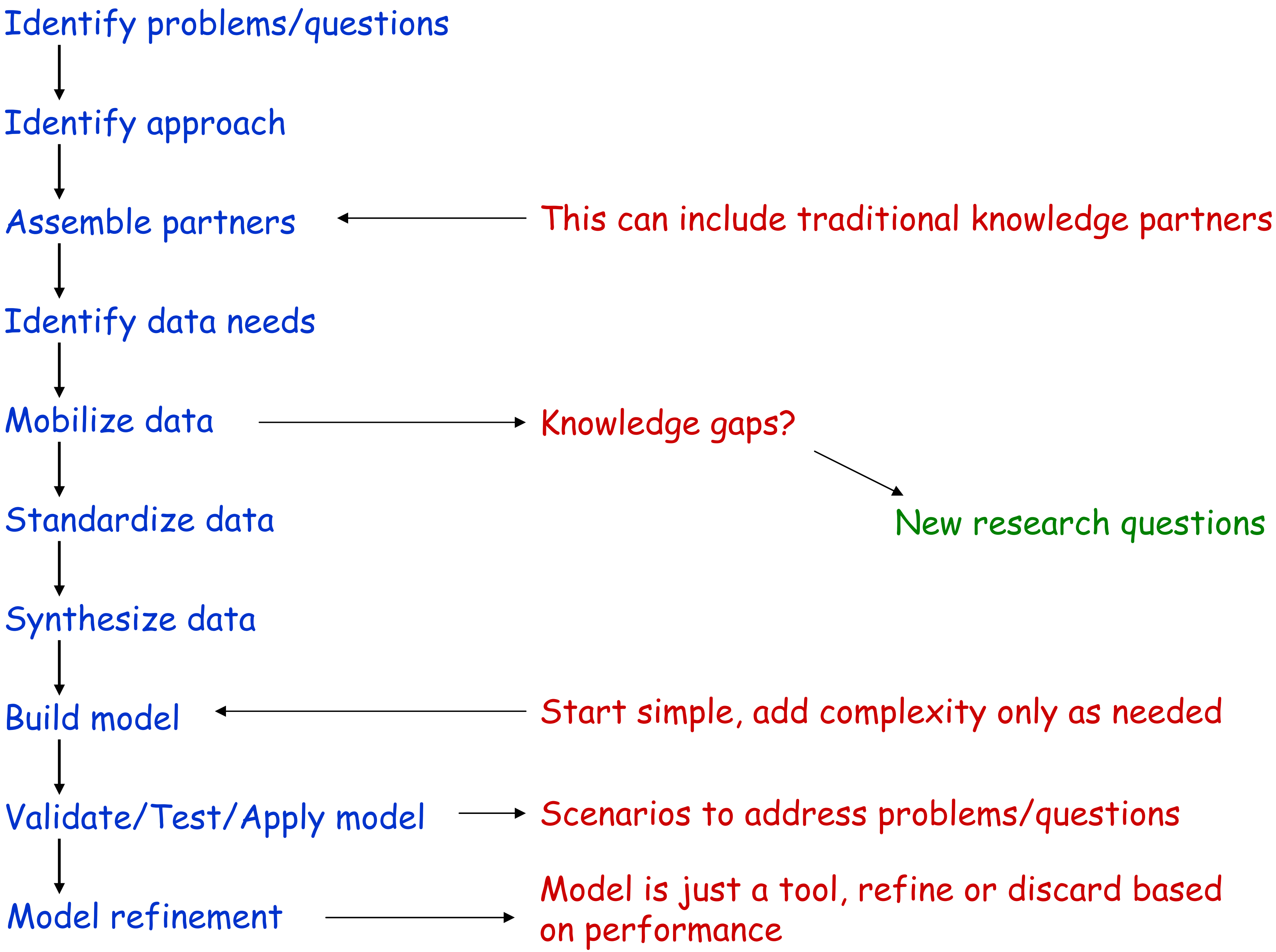
Burlington, Ontario

Fisheries and Oceans Canada Pêches et Océans Canada

Model for Integrating Science in Support of Management



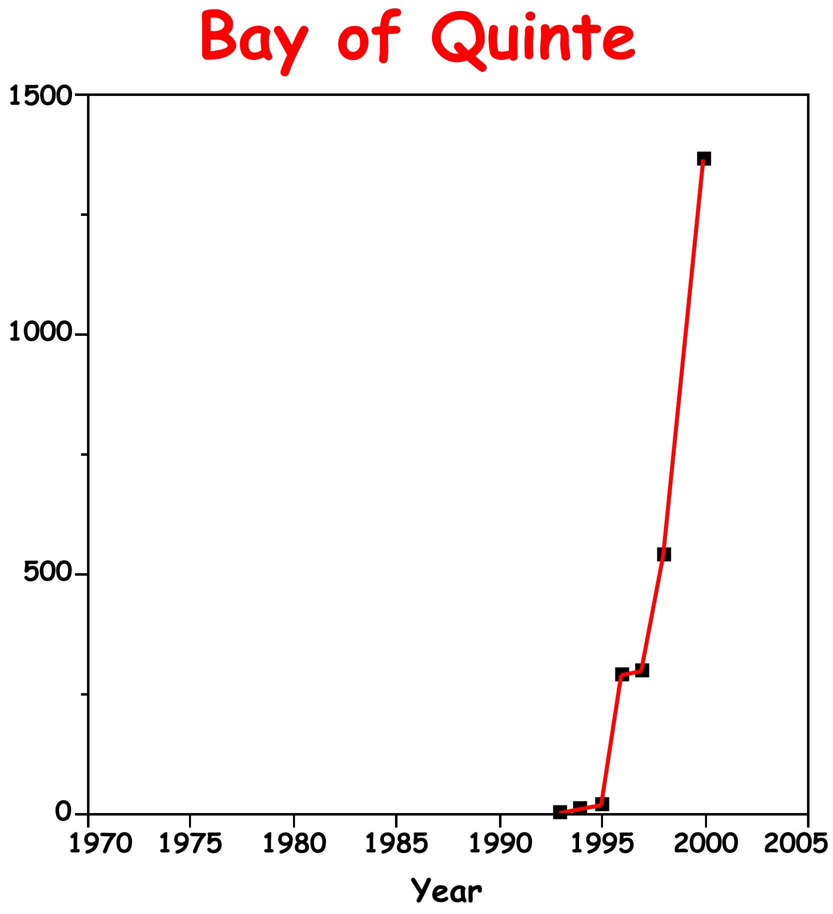


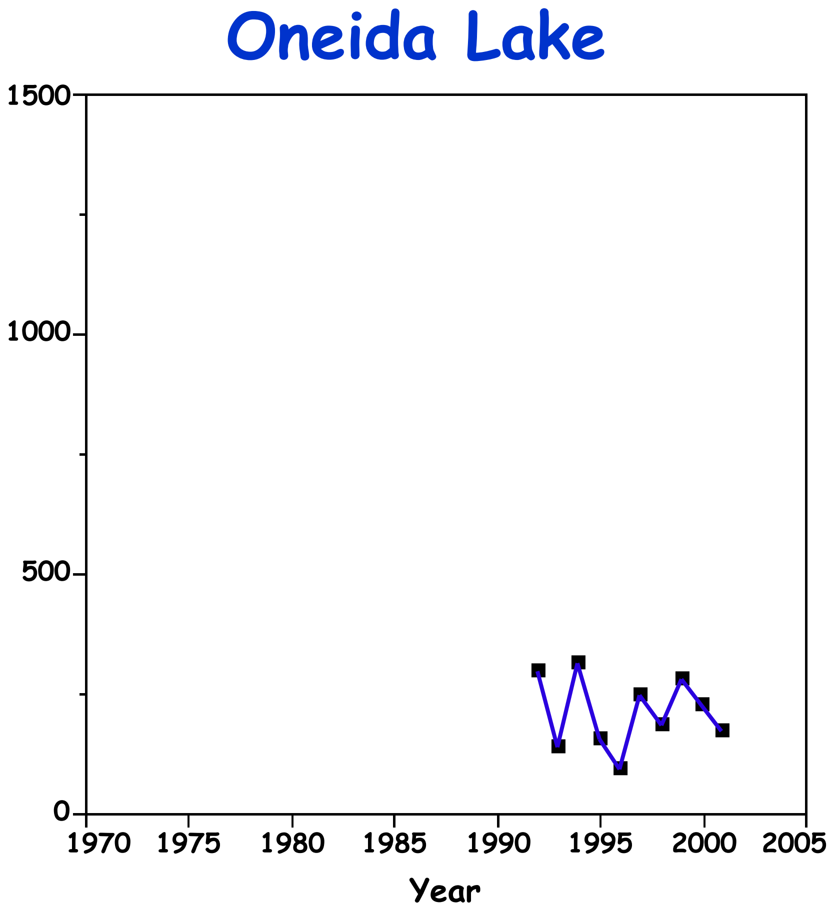
Identify problems/questions
Identify approach
Assemble partners
This can include traditional knowledge partners
Identify data needs
Mobilize data
Knowledge gaps?
New research questions
Standardize data
Synthesize data
Build model
Start simple, add complexity only as needed
Validate/Test/Apply model
Scenarios to address problems/questions
Model refinement
Model is just a tool, refine or discard based on performance

Bay of Quinte and Oneida Lake Milestones:

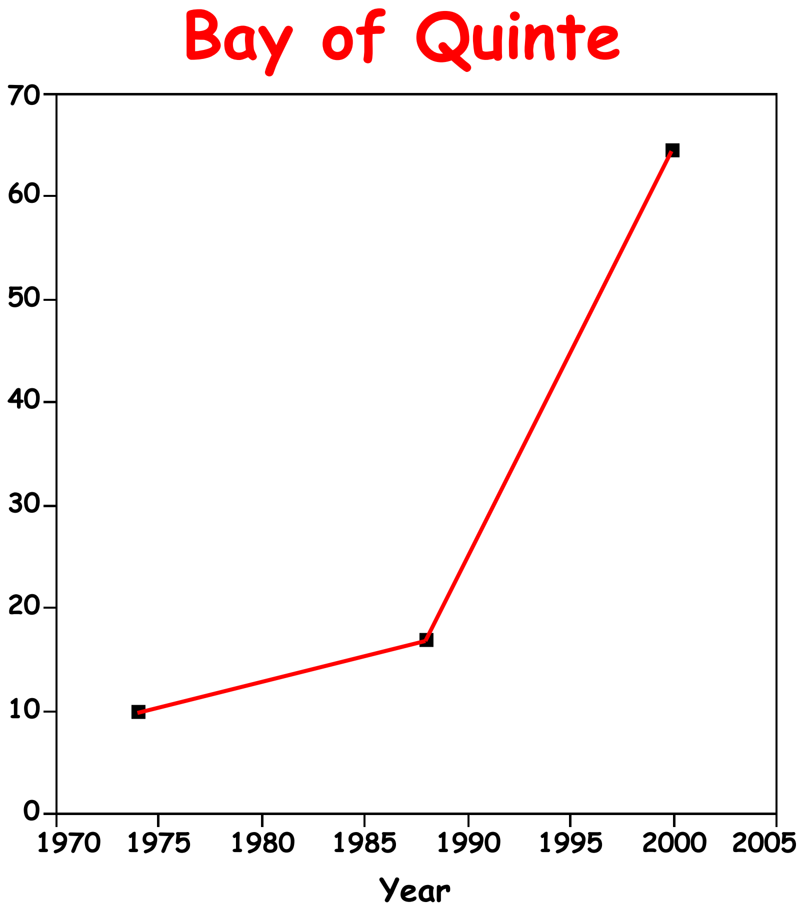
1950s-1970s	Phosphorus loadings Eutrophication
mid-late 1970s	Phosphorus control
1980s	Reduced phosphorus More macrophytes
early 1990s	Zebra mussel invasion Increased water clarity Benthification
thru 1990s	Increased cormorants Decreased walleye
late 1990s	Quinte invaded by: - *Cercopagis* - round goby

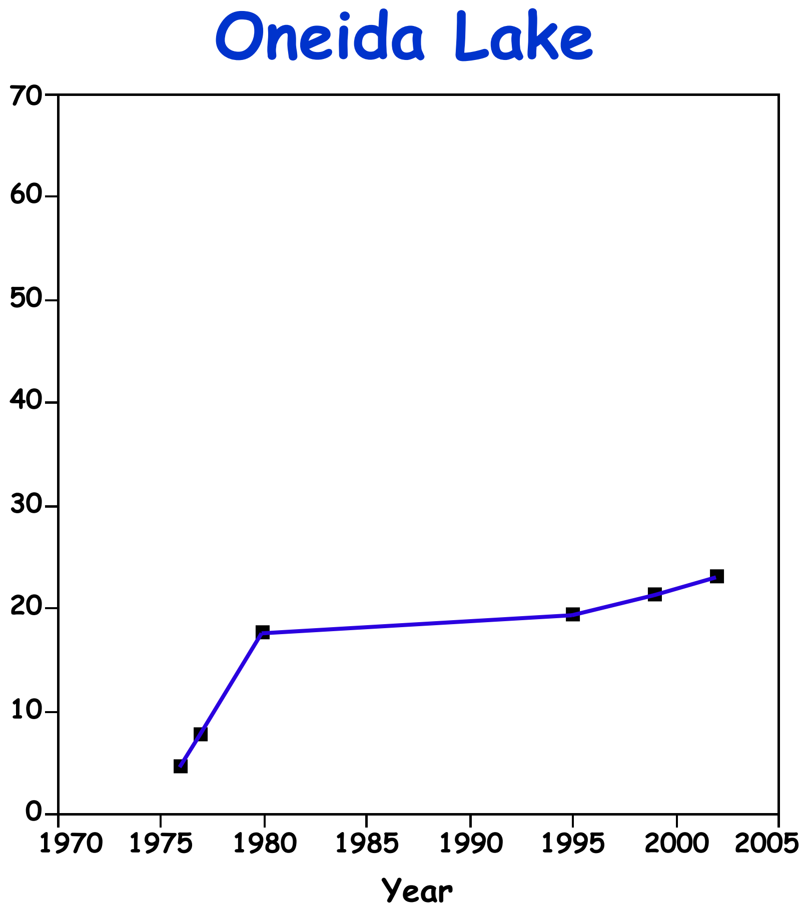
Dreissenid Biomass (t/km^2)



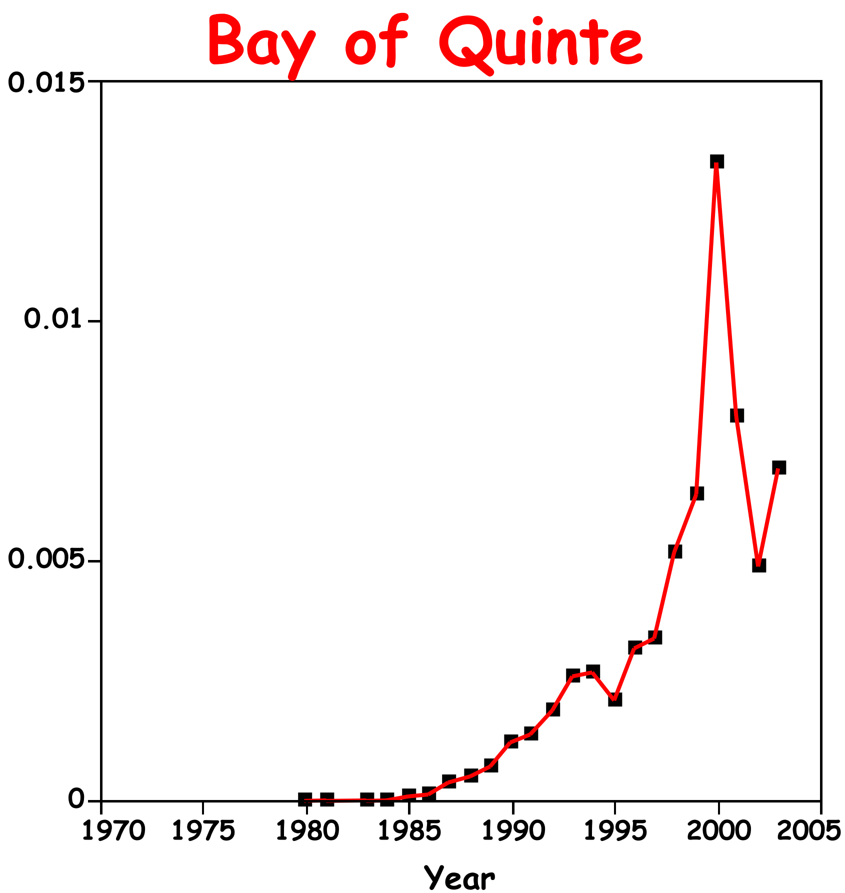


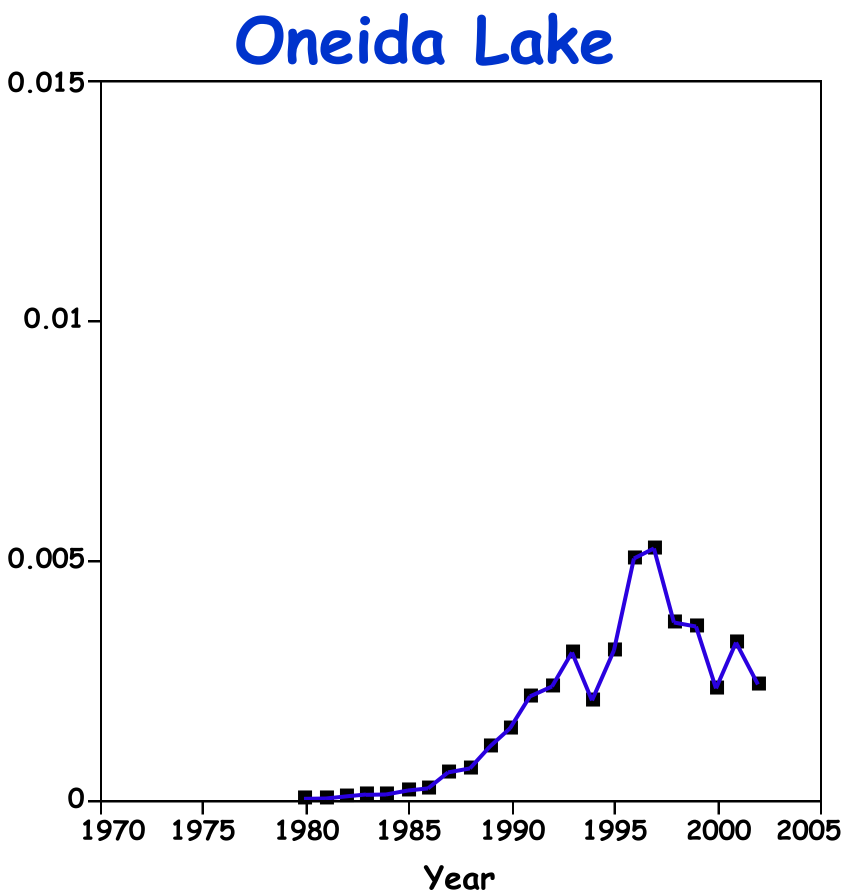
Macrophyte Biomass (t/km^2)



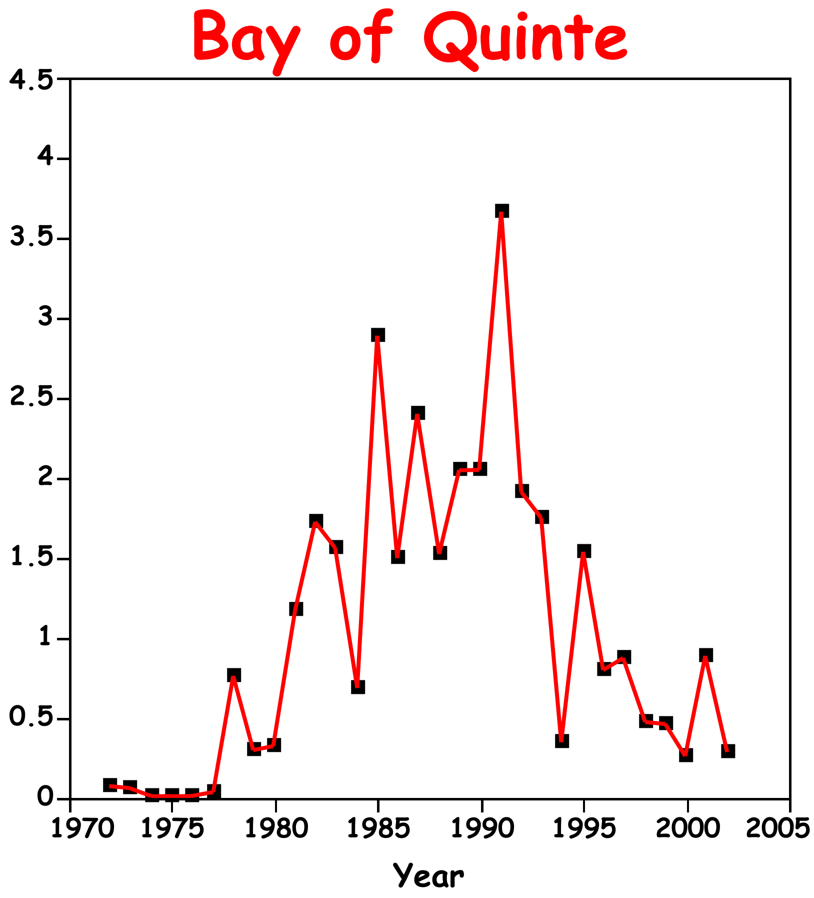


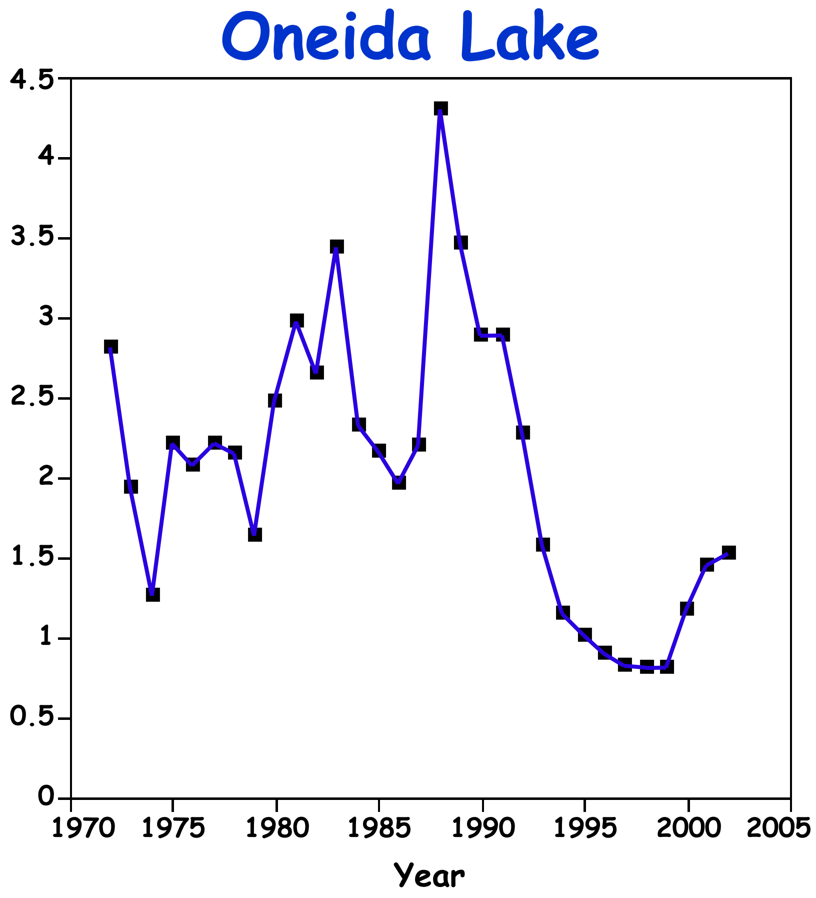
Cormorant Biomass (t/km^2)





Walleye Biomass (t/km²)





Hypotheses for Declining Walleye

Bay of Quinte:

- Decreased walleye habitat
- Increased refuge for juvenile walleye predators
- Over-harvesting

Oneida Lake:

- Increased larval walleye mortality
- Cormorant predation

The Quinte-Oneida Comparative Ecosystem Modelling Project Team

DFO - GLLFAS:
- Scott Millard (PI)
- Ken Minns
- Ora Johannsson
- Bob Randall
- Mohi Munawar
- Ron Dermott
- Kelly Bowen
- Christine Brousseau
- Marten Koops

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- Ed Mills (PI)
- Lars Rudstam
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- Dean Fitzgerald
- Randy Jackson
- Kristen Holeck
- Jeremy Coleman

OMNR – Glenora:
- Bruce Morrison
- Jim Hoyle
- John Casselman
- Tom Stewart
- Jason Dietrich

University of Toledo:
- Christine Mayer
- Bin Zhu

University of Waterloo:
- Jennifer Bowman
- Michael Power

ECOPATH
Mass Balance Model

Routines for entry of key data on the biology and exploitation of ecosystem groups and for establishing mass balance.

Ecopath mass balance is achieved by solving:

Production =

Predation Mortality

+ Fisheries Catches

+ Biomass Accumulation

+ Net Migration

+ Other Mortality

Ecopath Inputs

Mandatory User Inputs:

- DC = Diet Composition (proportions)
- BA = Biomass Accumulation ($t \cdot km^{-2}$)
- Y = Fishery Catches ($t \cdot km^{-2}$)
- E = Net Migration ($t \cdot km^{-2}$) = emigration - immigration

User Inputs 3 of 4:

- P/B = Production/Biomass (yr^{-1})
- Q/B = Consumption/Biomass (yr^{-1})
- B = Biomass ($t \cdot km^{-2}$)
- EE = Ecotrophic Efficiency (proportion)

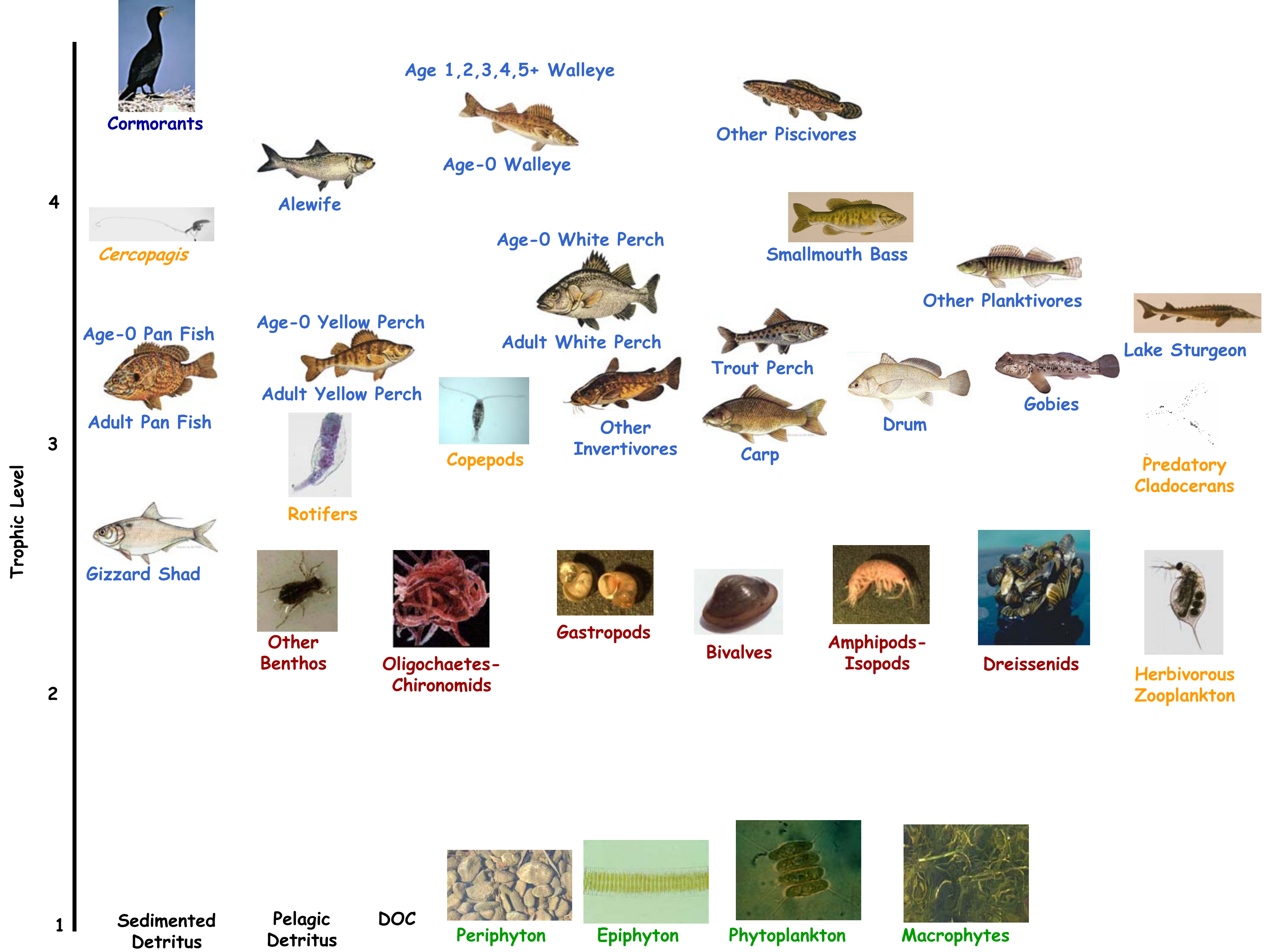
Challenges to Constructing Ecopath Models

• Productivity regime shifts (due to phosphorus control).

• Changes in food web structure (invading species): white perch, cormorants, zebra mussels, *Cercopagis*, gobies and probably others in future.

• Drastic increase in macrophyte biomass during the late 1990s. Stabilized?

• Lack of lengthy stable period to formulate the steady-state Ecopath base model.


Trophic Level
4
3
2
1
Cormorants
Age 1,2,3,4,5+ Walleye
Age-0 Walleye
Other Piscivores
Alewife
Cercopagis
Age-0 White Perch
Smallmouth Bass
Adult White Perch
Other Planktivores
Age-0 Pan Fish
Adult Pan Fish
Age-0 Yellow Perch
Adult Yellow Perch
Trout Perch
Lake Sturgeon
Copepods
Other Invertivores
Carp
Drum
Gobies
Predatory Cladocerans
Rotifers
Gizzard Shad
Other Benthos
Oligochaetes-Chironomids
Gastropods
Bivalves
Amphipods-Isopods
Dreissenids
Herbivorous Zooplankton
Sedimented Detritus
Pelagic Detritus
DOC
Periphyton
Epiphyton
Phytoplankton
Macrophytes

Ecopath System Statistics

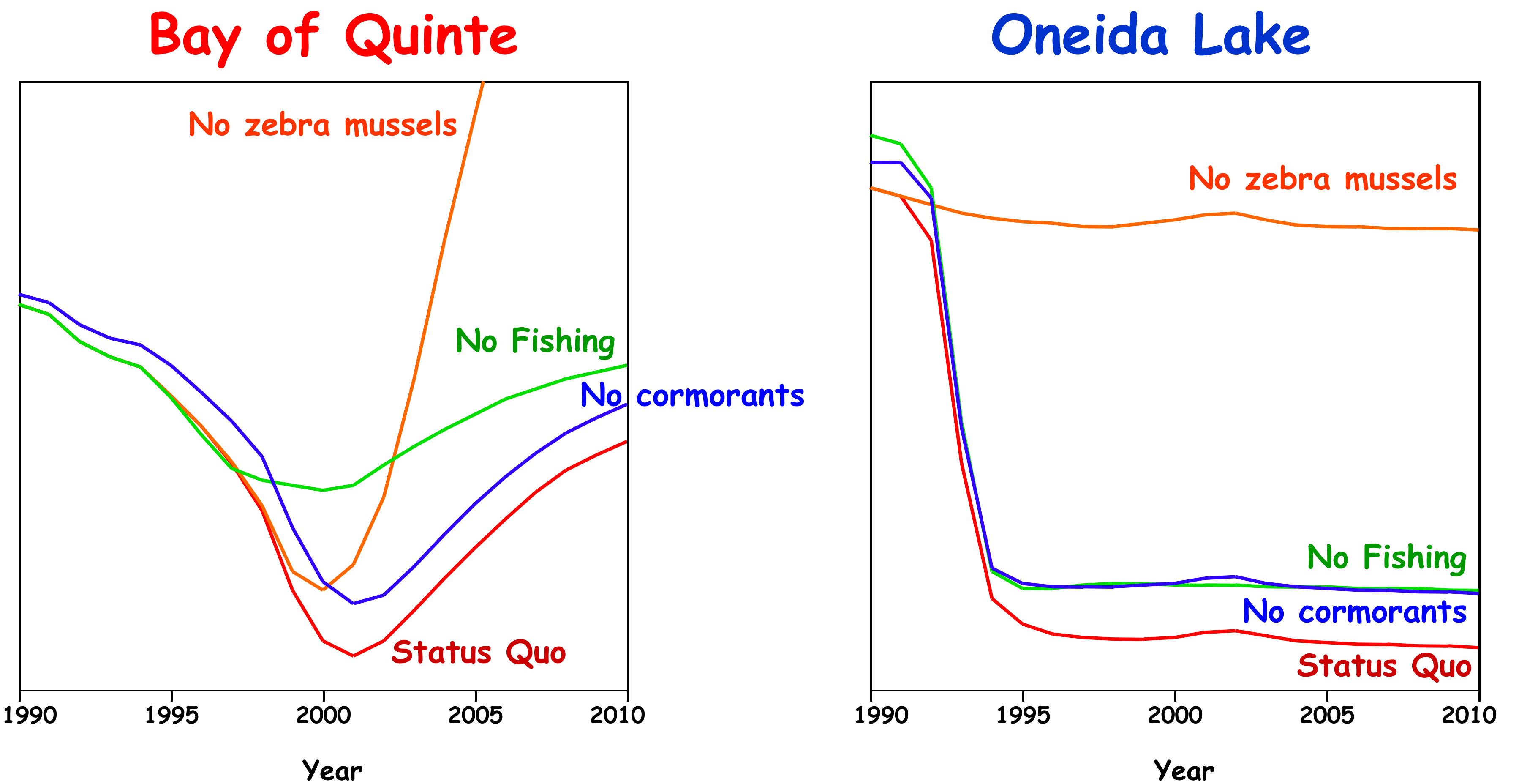
Parameter	Quinte	Oneida	Units
Total Biomass	281.9	271.9	t/km^2
Sum of all consumption	2,914	3,555	$t/km^2/yr$
Total system throughput	13,809	15,310 - 17,275	$t/km^2/yr$
Connectance index	0.191	0.220	
System omnivory index	0.152	0.141	
Sum of all production	4,561	4,782 - 5,867	$t/km^2/yr$
Calculated total net primary production	3,965	4,043 - 5,129	$t/km^2/yr$
Total catches	1.33	0.21	$t/km^2/yr$
Mean trophic level of catches	3.68	3.38	

Ecosim

Time Dynamic Model

Dynamic simulation of the effect changes in fishing and/or environmental regimes may have on fisheries catches and abundance of groups in the ecosystem.

Walleye Biomass - Ecosim Scenarios



Modelling as Part of Project Planning

- Think about models early in project development. Don't come to modelling at project completion.
- Persist.
- Consider models in the context of ecosystem management options.
- Use models to direct research toward management options.
- A model is just a tool. Refine or discard based on new information and performance.

"Models are not like religion – you can have more than one."

- Carl Walters

APPENDIX VIII Lake Winnipeg Science Workshop
November 29-30, 2004
Breakout Sessions 2 & 3

Water Quality and Nutrients

Fish Communities

Fish Habitat

Lake Winnipeg Science Workshop
November 29-30, 2004
Breakout Sessions 2 & 3

Water Quality and Nutrients

LWSW - Session 2

Development of Science Proposals

Water Quality and Nutrients

Session 2
Breakout - *Water Quality and Nutrients*

- Facilitator - Kevin Cash
- Rapporteur - Nicole Armstrong
- Participants - As assigned

Water Quality and Nutrients Issues - Session 2

- Bacterial levels at recreational beaches
- Carbon sequestration in relation to potential changes in nutrient management.
- Land use and impacts on nutrient loading of Lake Winnipeg.
- Water flow delivery to Lake Winnipeg.
- Uncertainty in management actions given current understandings of the precision of estimates of nutrient loadings.
- Use of an appropriate physical model of Lake Winnipeg for development of models of nutrients, algae, carbon, sediments to order to develop management objectives
- Use of science based ecological objectives for managing water quality in Lake Winnipeg

I think we had a good discussion in our group yesterday. We started off trying to nail down a little more precisely what the management issues were and we did struggle with that for a fair while.

I think there was consensus in the room as to what the issues were, but there was difficulty around articulating them properly.

So after going on that road for a little while, we decided we'd just plunge in and try to develop a little information around the science projects that we thought were of importance.

The above issues have been reformated from the sections following.

Ideas for *Water Quality* and Nutrients Science

- Water 1. Bacteria levels at recreational beaches

  Management Issue:

  Notification of bacterial levels at recreational beaches

  Description:

  - Identify unknown sources/reference bank
  - Study replication/survival of pathogens in sand/sediment
  - Determine exposure/risk?
  - Examine the relationship between wind/water and changing bacterial counts
  - What are the best management practices?

The first issue that we have here is bacterial levels at recreational beaches.

It may not be one of the single biggest issues for the lake itself, but it is of major concern to the people of Manitoba that use these beaches.

The management issue is simply the notification of bacterial levels at recreational beaches.

We would like to do this predictively and in a timely fashion. There's no point in notifying people two days after some kind of outbreak or elevated level, we'd like to do it preemptively.

We need to identify all known sources. Over a third, or 40 percent, of sources were currently avian. There's still a large unknown block, which may well be avian, but we need to work on those. We need a reference bank of DNA.

We need to look more at the ecology of these bacteria in the wet sand zone. We want to determine the exposure and the risk. E-coli as measured here is a surrogate for all of the pathogens and may not be necessarily indicative or representative of particular pathogens that we're interested in.

We want to examine the relationship between wind, water and changing bacterial counts and we want to use that understanding to develop a predictive model for bathing beaches and we want to use that model, along with other best management practices.

Ideas for *Water Quality* and Nutrients Science

- Water 1. Bacteria levels at recreational beaches

  Deliverable:

  Predictive model and best management practices

  Facilities and Researchers:

  - Existing laboratory support
  - MB Lead (Health and Water Stewardship)
  - Collaborators as required - Health Canada, EC, Agriculture, Universities, Other jurisdictions

The deliverable from this would be the predictive model.

The facility requirements are largely existing laboratory support with some offsite consultants, nationally and internationally.

We see Manitoba as leading that, particularly the departments of Health and Water Stewardship and then other collaborators as required, including Health Canada, Environment Canada, agriculture, universities and other jurisdictions.

Ideas for *Water Quality and Nutrients* Science

- Water 2. Carbon cycling/Carbon sequestering

  Management Issue:

  How will changing nutrient management relate to changes in carbon sequestration?

  Description:

  - Hypothesis is that decreased nutrient inputs will change carbon sequestration rates
  - What are sedimentation rates?
  - What are carbon fixation and respiration rates?
  - What is the C budget for Lake Wpg?
  - What is needed to determine deposition and suspension zones?

Project two is carbon cycling, carbon sequestration.

This is particularly important in light of Kyoto and ultimately carbon sequestration in this lake. If we start changing the nutrient balance of the lake, we may alter the rates of carbon sequestration.

The hypothesis is that decreased nutrient inputs will change carbon sequestration rates in the lake.

We need to identify the areas in the lake where carbon is being sequestered.

Ideas for *Water Quality and Nutrients* Science

- Water 2. Carbon cycling/Carbon sequestering

Deliverable:

Estimate of the relationship between nutrient loading and carbon deposition.

An economic evaluation of changes in carbon sequestration.

Carbon isotope analyses

Review satellite imagery

Direct measure of sedimentation rates (2 to 3 years)

Additional coring (1 year)

Analyze existing cores and data (2 years)

We need to estimate the relationship between nutrient loadings and carbon deposition.

We would like to do an economic evaluation of carbon sequestration.

We need tools, including carbon isotope analysis, satellite imagery, direct measures of sedimentation rates, coring and analysing the data that we have already.

Facilities and research required for this project include carbon with nutrient sampling; we need to engage universities and we need to better engage Federal and Provincial Government agencies.

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Ideas for *Water Quality and Nutrients* Science

- Water 2. Carbon cycling/Carbon sequestering

  Facilities and Researchers:

  – Include carbon with nutrient sampling
  – Universities
  – Federal/provincial government agencies

Facilities and research required for this project include carbon with nutrient sampling; we need to engage universities and we need to better engage Federal and Provincial Government agencies.

Ideas for *Water Quality* and Nutrients Science

- Water 3. Land Use: Lake Wpg Sustainability

Management Issue:

How does land use and landscapes impact on and impede loading to Lake Wpg?

What land use activities require priority attention?

How can land use be modified to reduce N and P loadings?

Description:

Hypothesis: Land use and soil type contributes to N and P enrichment of Lake Wpg

Project three is the first of three. One break-out group was given one project two and split it into three as they went along.

Really what they are is three projects that deal with the watershed level.

We recognize that in order to understand Lake Winnipeg we need to understand the watershed itself and within that understanding we've broken it down into three primary components for this exercise: we need to understand the hydrology of that system; we need to understand land use within that system; and we need to understand nutrients within that system.

So three largely out of lake projects, the first of which is this landscape.

So how does land use and landscape in the watershed impact loading to Lake Winnipeg; what land use activities require priority attention; and how can land use be modified to reduce loadings?

The hypothesis is that land use and soil type contribute to N and P enrichment of Lake Winnipeg.

Ideas for *Water Quality and Nutrients* Science

- Water 3. Land Use: Lake Wpg Sustainability

Deliverables:

Identify land use of greatest relevance to N and P reductions

Determine role of wetlands, riparian and other landscape uses

Develop a land use inventory and decision support model

Develop reach specific action plans

We want to identify the land use of greatest relevance to N and P reductions, and we're talking here again watershed levels, so it might be quite a ways away from the shores of the lake.

We want to determine the roles of wet lands for repairing and other landscape uses.

We had quite an interesting discussion around Netley Marsh, and I don't want to lose that in this overall presentation because we think that Netley and what's been happening to it and the role it may play in future management of the lake is really critical and deserving of special attention.

We want to develop a land use inventory, a support model and develop action plans where appropriate.

Ideas for *Water Quality and Nutrients* Science

- Water 3. Land Use: Lake Wpg Sustainability

  Facilities and Researchers:
  - GIS mapping facilities
  - Links to Red River flood mitigation
  - Access to other databases
  - DFO, international partnerships

The facilities and research required are, of course, GIS mapping facilities. We want to develop links to Red River flood mitigation, access to other databases. Some of the partners and people involved could be DFO and international partnerships.

As I'm sure you've all experienced in all of your groups, none of these lists are necessarily complete. We weren't given an awful lot of time. I don't think it's worth focussing too much on all the details here, it's the overall management issue and hypothesis, I think, that is of primary importance.

Ideas for *Water Quality and Nutrients* Science

- Water 4. Watershed Model - Reach Specific TMDLs, Seasonal Source Loads

Management Issue:

Understanding flow delivery to the lake

Description:

Quantity and timing of flow to Lake Winnipeg

Deliverables:

Hydrologic model for the watershed

This is the second of three watershed model levels and this is really looking at hydrology.

The issue is understanding flow delivery to the lake. We're interested in quantity and timing of the flow to Lake Winnipeg.

The deliverables associated with this would be a hydrologic model for the watershed, a hugely ambitious program but certainly a laudable goal.

We want specific TMDLs, for those of you who many not be familiar, that's "total maximum daily loads", seasonal source loads, facilities and research.

Model selection and adaptation, this is going to be a largely paper/computer exercise, very important computer and software.

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Ideas for *Water Quality and Nutrients* Science

- Water 4. Watershed Model - Reach Specific TMDLs, Seasonal Source Loads

  Facilities and Researchers:

  - Model selection and adaptation
  - Computer and software
  - NWRI, USGS, consultants, MB Water Stewardship, DFO, MOE, PFRA, Universities, North Dakota

The people involved in this potentially could be NWRI, USGS Consultants, Manitoba Water Stewardship, DFO, MOE, PFRA, University of North Dakota. There's a lot of expertise out there and a lot that can contribute to this exercise and we need to bring them together

Ideas for *Water Quality and Nutrients* Science

- Water 5. Nutrient Loading Estimates for the Lake Wpg Basin

Management Issue:

Are current understandings of nutrient loading precise enough to allow effective management?

Description:

Develop a nutrient budget with known precision and accuracy.

The third of these watershed issues is the nutrient loading estimates for the lake.

The management issue is our current understandings of nutrient loadings precise enough to allow for effective management of the lake itself.

The description is to develop a nutrient budget with known precision and accuracy. Mike Ell raised this point and I think it's a very important one. We're talking a lot about 10 percent reductions in current loadings.

It's really critical that, where possible, we refine our estimates so that we have confidence in them.

Ideas for *Water Quality and Nutrients* Science

- Water 5. Nutrient Loading Estimates for the Lake Wpg Basin

  Deliverables:

  10 year precise annual average with confidence limits

  Include monitoring design and interpretation of flow measurements and water quality sampling

  Mass balance model for DSS

  Facilities and Researchers:

  - Flow and sampling network
  - State, provincial and federal agencies

We're looking at a 10 percent reduction and in some cases the error around our measurement may be 10 percent or even more, so we need to, where possible, and in some cases it will never be possible to really get that much more precise, but in some cases it will be and we need to pursue that.

We need ten-year precise annual average with confidence limits, including monitoring design, interpretation of flow measurements and water quality sampling, mass balance models for decision support systems.

So again we're talking here about improved precision on both flow and loading and -- well, flow and concentration and loading.

Facilities and research, we need to develop and enhance our current flow and sampling network. We all know they've been cut back dramatically in the last 20 years. I think we have an opportunity to maybe reinvest in those and rebuild them, but we need to do it in a very strategic way to ensure that it's answering explicit questions and that the results of that program are being used to really manage this lake.

The people involved obviously would be state, provincial, federal agencies and, certainly from a research perspective in developing the program, maybe universities and other partners.

Ideas for *Water Quality and Nutrients* Science

- Water 6. Physical model for Lake Wpg

  Management Issue:

  Require an appropriate physical model of Lake Wpg to model nutrients, algae, carbon, sediments - key to developing objectives

  Description:

  How water moves within the lake? Consider wind velocity, temperature, bathymetry, currents, water velocity.

We need to understand the physics of the lake better, we need to understand the physical processes because they provide the context within which all of the chemical and biological dynamics of greater interest or of primary interest.

The management issue is acquire appropriate physical model of Lake Winnipeg to then model nutrients, algae, sediments, et cetera. It is key to developing the appropriate objectives.

The description is how water moves within the lake. We need to consider wind velocity, temperature of ethemitry, currents, water velocity and we could put a whole list of other physical variables here that need to be better measured and quantified.

Ideas for *Water Quality and Nutrients* Science

- Water 6. Physical model for Lake Wpg

  Deliverables:

  Physical model for Lake Wpg

  Facilities and Researchers:

  – Equipment - buoy network, optimize use of existing resources (ferries, fishermen, freighters, Namao)
  – Will require collaboration to fill in technical knowledge gaps
  – Government, Universities
  – Local/traditional knowledge regarding how water moves in the lake (calibration of computer models)

The deliverables will be a physical model for the lake.

The facilities and research would include a buoy network optimizing use of existing resources, ferries, fishermen, freighters and possibly the Namao. It would require collaboration to fill in technical knowledge gaps.

We don't have a lot of physical wind knowledge left anymore. As a science 20, 30 years ago we had a lot of that sort of expertise in both government and university and we've really lost it over the last while.

So we'll need to find that, in government and universities.

We also need to make use of local and traditional knowledge regarding how water moves in the lake. There is a lot of wisdom out there, a lot of experience and we owe it to ourselves to tap into it.

Ideas for *Water Quality and Nutrients* Science

- Water 7. Relating Nutrients and Biological Endpoints for Settling Ecological Objectives for Lake Winnipeg

  Management Issue:

  Development of science based ecological objectives for managing water quality in Lake Wpg

  Description:

  Are the biological endpoints a predictable function of N and P concentration? Biological endpoints - algae, benthic inverts, fish, etc.

The final project is sort of an overarching one and it's relating nutrients and biological end points for setting ecological objectives for Lake Winnipeg.

We saw that Manitoba wants to set a management objective that involves the reduction of nutrients by approximately 10 percent and then over time to replace that with a science-based objective that will preserve some desired state within the Lake Winnipeg ecosystem.

Two points: First of all, those of that state is really a societal/economic/political decision that should be informed by science, but falls outside the realm of science; and, secondly, we're not going to go back to some sort of pre European pristine condition, we just can't go back there.

So we need to have a good discussion about what we want this lake to look like and we need to have the science understanding in order to inform the decision makers as to what the consequences of a given amount of say N and P loading, what the effects will be on the ecology of that system.

So we won't set the objectives, but we'll provide them with scenarios, if you like, or the consequences of certain potential decisions they could take.

So we need to take all of those previous six projects, bring them together to do this kind of work.

Ideas for *Water Quality and Nutrients* Science

- Water 7. Relating Nutrients and Biological Endpoints for Settling Ecological Objectives for Lake Winnipeg

  Deliverables:

  Establish potential endpoints for objectives

  Determine relationship between nutrients and endpoints

  Facilities and Researchers:

  – Continue present monitoring and expand where appropriate

  – State, provincial and federal agencies, universities

We need development science based ecological objectives for managing water quality in the lake.

Some of the questions are; are the biological endpoints a predictable function of N and P concentration? The biological endpoints of primary concern are things like algae, benthic invertebrates, fish, et cetera.

The first question isn't trivial. I mean there are other things -- we tend to fall into this trap of thinking that primary productivity is influenced only by nutrients and there are others, temperatures, light, other things that do it as well.

The deliverables are to establish potential endpoints for objectives, to determine the relationship between nutrients and those endpoints.

The facilities and research involved include continuing present monitoring and expanding where appropriate. Again this goes back to rebuilding the monitoring system so that we have a good database.

Discussion - Session 2

- Best Management Practices Need to be Followed
- Contaminants Not Addressed

Bill Gummer - Environment Canada.

I guess what occurs to me is a discussion we had yesterday about best management practices and I don't think we incorporated that. But I really do believe that there is a need for science with respect to understanding how the existing activities actually contribute to increase nitrogen and phosphorus, landscape activities could even be point sources as well. What we can do about it? What are some new innovative, best management practices out there that we could actually be advocating? We need the science to be able to advocate and push those through our respective systems and I don't think we've reflected, in this particular working group, well yet on the best management practice side and I think we should.

DR. CASH: Yes, that's a fair point. The other issue that we talked about and didn't put into a project were contaminants, just as an issue from the water quality perspective. We felt that it might be dealt with by fish people, it turns out that they chose not to as well.

We didn't feel we necessarily had the expertise in the room to really scope the issue properly and decide what kind of science project should be built around contaminants so we agreed to kind of table it, but it's not something we want to get lost as the day proceeds.

LWSW - Session 3
Integration and Linkages to Other Proposals

Water Quality and Nutrients

We went through an exercise that was, for us, I think a little bit confusing and we kind of struggled with exactly where it was we were trying to go and we weren't really sure then whether or not we'd gotten there.

But we did attempt to link the seven water quality projects identified yesterday with fish and fish habitat projects identified by the other groups.

Ideas for *Water Quality and Nutrients* Science

- Water 1. Bacteria levels at recreational beaches
  - Internal linkages with Water 6 Physical Model

Our first program was the bacterial levels at recreational beaches and, as we said before, this is a bit of a one-off. It's certainly important to the citizens of this province and to the users of those beaches, but it doesn't -- it is, more than most of the others, kind of a standalone project.

It does have a strong link with water project 6, which is the physical modelling of the lake. And that kind of understanding is going to be essential to understanding how wind and wave action move up on the beach and impact that wet sand and make the bacterial cultures that exist in that sand available to the water column and, hence, to pose a risk to bathers.

There was some discussion about microbiology more generally in the lake and the work that's occurring there. We recognize that that's an important and interesting issue, but it may not be one that directly impacts the use of these beaches for recreational purposes, so that was sort of the only big connection there.

Ideas for *Water Quality and Nutrients Science* - Linkages

- Water 2. Carbon cycling/Carbon sequestering
  - Fish 4. Exotics and changes to grazing of phytoplankton
  - Any of the fish/habitat studies that look at food webs may link to carbon sequestering
  - Internal linkages with Water 4 Hydrology, 5 Nutrient Loading, and 6 Physical Model

Carbon cycling and sequestration, we recognize that fish project 4, exotics and changes to grazing of phytoplankton, we need to monitor, under any kind of change, nutrient regime, what the impacts on primary productivity and the resulting carbon sequestration is going to be.

The other things that could affect that certainly would be exotics, especially things like zooplankton changing phytoplankton communities, it could change the rates of primary productivity and ultimately carbon sequestration.

Any of the fish habitat studies that look at food webs may have a link to carbon sequestration.

There are internal linkages with water 4, which deals with hydrology at the watershed level.

Water group 5, which deals with nutrient loadings of course important to the carbon modelling and 6, the physical model of the lake to identify where these deposition zones may be, where sequestration may be occurring.

Ideas for *Water Quality and Nutrients Science* - Linkages

- Water 3. Land Use: Lake Wpg Sustainability
  - Habitat 2 DA 1 (Land Use) , Habitat 2 Inv 4 (Wetlands), Habitat 2 Inv 3 (Tributary Use),
  - Fish 2 – land use related mortality, Fish 4 – exotics (land based such as purple loosestrife)
  - Sewage discharges in spawning streams
  - Water 5 (Nutrient Loading), Water 4 Hydrology

Project 3 was land use in the watershed. We saw some very important linkages here. I won't try to go through the habitat 2(d)A1 protocol, I'm not sure of the logic underneath that, but I'll just refer to the abbreviated project titles, assuming that you're familiar with it.

We thought it would relate strongly to habitat projects including land use, wetlands and tributary use; we thought it would be important for fish related or land use related mortality in fish 2 study and for exotics in fish 4.

Sewage discharges in spawning streams, that was recognized earlier in the Fish Communities, as an important issue, although not explicitly captured in one of the projects, and we think we wanted to address it here.

Certainly the land use in the Lake Winnipeg watershed has important implications for two of our projects, nutrient loading and hydrology.

Ideas for *Water Quality and Nutrients Science* - Linkages

- Water 4. Watershed Model - Hydrology
  - Fish 3 (Spawning beds)
  - Habitat 2 Inv 4 (Decline in wetlands), Habitat 2 DA 2 (Define critical habitat)
  - Link to climate change
  - Internal linkage to Water 3 (Land Use), 5 (Nutrient Loading), 6 (Physical), 7 (Biological Endpoints)

Number 4 was the hydrology project. This project, the previous project and the one on physical modelling of the lake I think for us are really critical because a knowledge of hydrology, a knowledge of the physical model for the lake itself and a knowledge of land use patterns in the watershed are all going to be very, very important to understanding this lake, not only from a nutrient perspective, but also from a fish habitat and even fisheries perspective.

We see these as very, very critical first steps and I think that was reinforced this morning by some of the talks from the Great Lakes, which showed that hydrology was very important to their understanding of their fish communities.

So there's clear links to spawning bed studies proposed in fish 3; to declines in wetlands; to the definition of critical habitat in the lake. There are links to climate change. There are internal links to the land use, nutrient loading, physical model and biological endpoint projects under the water quality group.

Ideas for *Water Quality and Nutrients Science* - Linkages

- Water 5. Nutrient Loading Estimates for the Lake Wpg Basin

  - Habitat 2 DA 1 (Land Use), Habitat 2 Inv 4 (Wetlands)

  - Internal linkages to Water 3 (Land Use), 4 (Hydrology), and 7 (Biological Inputs)

Number 5 is the nutrient loading estimates for the lake. There's a strong connection to land use and to wetlands in the habitat group, as well as to land use, hydrology and biological inputs from the water quality group.

Ideas for *Water Quality and Nutrients Science* - Linkages

- Water 6. Physical model for Lake Wpg
  - Fish 2 (Mortality), Fish 5 (Traditional knowledge)
  - Habitat 2 Inv 2 (bathymetry), Habitat 2 Inv 1 (habitat classification), Habitat 2 Inv 4 (Netley Marsh impacted by water movement in Lake Wpg)
  - Internal linkages to Water 1, 2, 3, 4, 5, 7

Number 6 is the physical model for Lake Winnipeg, as I alluded to. This is one of our top priorities. We see it as important to the mortality study and the traditional knowledge study in the fish group, to the bathymetry, habitat classification and the Netley Marsh study, all mentioned in the habitat group, and certainly strong linkages to all of the other projects defined under the water criteria.

Ideas for *Water Quality and Nutrients Science* - Linkages

- Water 7. Relating Nutrients and Biological Endpoints for Settling Ecological Objectives for Lake Winnipeg

  - Habitat 2 Mon 1 (Zoobenthos), Habitat 2 DA 3 (nutrients, light, algae), Habitat 2 Mon 2 (exotics)
  - Fish 4 (exotics), 5 (traditional knowledge)
  - Internal linkages with Water 6 (Physical model)

Our final project was number 7, relating nutrients and biological endpoints for setting ecological objectives for Lake Winnipeg.

We see a strong relationship there to the zoobenthos, nutrients and exotic studies all under the habitat group, to the exotic studies under the fish group, as well as to traditional knowledge and to the physical model study, water 6 here.

We also see that one as very important to several of the other water quality ones. We'd like to know what the loadings are, but they don't -- that would be good information to have, but isn't really an impediment to understanding the biological relationship by themselves.

Several of these linkages here described we feel are going to result in the collapsing of some of the studies, especially between water quality and habitat, into one, because I think they can be subsumed or merged quite effectively.

Gaps for *Water Quality and Nutrients* Science

- Integrated watershed management
- Science to policy
- Climate change

A couple of gaps that were identified that we really should be looking at. Iintegrated watershed management, it's particularly important.

Much of the science that's necessary to do integrated watershed management has been captured in the other studies, but there's a separate exercise to integrate that effectively and it also requires politicians and social scientists and stakeholders and fishers and other people. We don't want to lose sight of its importance and we should sort of keep it in front of us at all times.

It was this morning about the need to not lose sight of best management practices and the science we're doing here should result in those kinds of practices. I agree. I think the issue is even broader, it's really a science to policy, science to action kind of issue because we also hope that our science here will influence regulations, in addition to BMP, and policy and frameworks in addition to simply regulations and BMP.

Thirdly, is an issue of climate change. It's going to be an overarching one. It's really a cross-cutting issue that's going to change the context of everything we're doing and should be at least, if not a specific project, at least recognized as something that's got to be addressed.

Discussion Session 3

- Best Management Practices.
  - Is there a need for another specific project proposal?
  - Need to address whole watershed.
  - Need to work with agriculture and forestry researchers to determine most cost effective means of reducing nutrient loadings.

Ray Hesslein - Department of Fisheries and Oceans

With respect to this best management practices. Is there an applied science issue with respect to evaluating management practices to determine which are best prqctices. For example, "We need to decrease runoff which is carrying high loads from particular areas. What are the management practices that will result in that effect?" Is there a toolbox ready to achieve that.

DR. CASH: I think what it points to is watershed management and that, in order to preserve the trophic integrity or the ecosystem integrity of Lake Winnipeg, we're going to have to consider what's happening on the uplands as well. There are a number of initiatives in the development of beneficial management practices specifically to develop environmental standards for agricultural practices.

We can bring to that discussion a better understanding of the consequences of different current and proposed practices with respect to hydrology and nutrient transport off the land and into the lake and what that means for the lake.

And with that knowledge, back it up to say, "Okay, a BMP that reduces your nutrients 20 percent is going to have no impact on Lake Winnipeg whatsoever and so the money that you spend on that is wasted". Alternatively we could be in situations where, for a small amount of money, 15 percent reduction has a big benefit.

But we are going to, at some point, have to do a cost/benefit analysis on those BMPs and the benefit side is the reduced impact on Lake Winnipeg.

Lake Winnipeg Science Workshop
November 29-30, 2004
Breakout Sessions 2 & 3

Fish Communities

LWSW - Session 2

Development of Science Proposals

Fish Communities

Session 2
Breakout - *Fish Communities*

- Facilitator – Drew Bodaly
- Rapporteur- Gary Swanson
- Participants – many and varied

We're the group on fish communities. I was facilitator, Gary Swanson was our rapporteur, we had many group members. We are very fortunate to have both Robert Kristjansen, a long-term fisherman on the lake, and Walt Lysack, the fish biologist for the province who deals with Lake Winnipeg, in our group.

Management Issues

- Fish Community
  - Exotics –
    - fish community stability
    - predator/prey interactions
    - impacts of algae/zooplankton
  - Partition Natural mortality – e.g. cormorants
  - Fish Stock
    - Assessment / stock dynamics
    - Stock differentiation
    - Life history – river vs lake spawning, indices of young of year
  - Productive Capacity
    - Sustainable yields

We basically divided into two main topics; fish community and the fishery.

And you can see some of the topics that we dealt with there is management issues, exotic species, both as affecting fish community stability, predator/prey interactions, impacts even of algae or zooplankton on fish communities.

An initiative that was brought up was the impact of natural agents, such as bird predation, toxic algae on larval fish as influencing mortality in fish populations.

Of course the fish stocks themselves are central to what we were talking about.

Assessment, stock dynamics, stock differentiation, that is the presence of genetic subpopulations in the lake was a key factor that we talked about quite a bit.

And there's a lot of information on life history that is not well-known for Lake Winnipeg. You would think that even for such a large and important commercial fishery, for such well-known species in Canada like lake whitefish and walleye, that we would have perfect knowledge of life history traits, while in fact we don't at all.

And a key issue, of course, in managing the fishery is what is the productive capacity of the lake and what sustainable yields are possible

Management Issues (Cont'd)

- Fishery
  - Fishing Mortality
    - Domestic fishing
    - Special Dealers Licences (FFMC) / Director's Authorizations (MB)
  - Effort
    - Fleet/gear efficiency
  - Management
    - Roe fishery impacts
    - 3 species quota's
    - season date
    - mesh size
  - Fish quality
    - Toxins, contaminants, "off flavour", temperature (season dates)

We talked about mortality, especially those factors of mortality which are outside the fishery.

Domestic or subsistence fishery, this source of mortality is completely unquantified, there are a number of special or unusual licences issued, there are unreported catches, we don't know very well what those are and we need to get a handle on them.

Effort, the issue that came up there was that there was a constant re-equipping of the fleet, both in terms of boats, of motors, of speeds of the boats, of the kind of gear that is used, the kind of mesh sizes, the kind of gill nets that are used.

The only long-term indication of effort, is the number of landings as kept by the Freshwater Fish Marketing Corporation, but so many other things of the fishery, especially gill net efficiency, that the indication of effort by the number of landings is not a very good indication of effort in the fishery.

Other issues included: specific impacts of the whitefish roe fishery, the fact that many of the quotas in many of the parts of the lake are done by combining total catches for three different species, seasons, mesh sizes. And fish quality issues, especially ones that are related to toxic chemicals, off-flavour, the impact the smelt invasion might have on palatability and flavour of fish like walleye, and how opening season dates relates to temperature on the lake.

Ideas for *Fish Communities* Science

- Fish 1 Community Index Sampling Programs
  - Monitoring and desk analyses
  - Long term standardized monitoring, sustainable yield estimation
- Fish 2 Partitioning sources of mortality, other than the commercial harvest
  - Inventory.
  - Estimation of mortality due to birds, domestic fishing, special permit fishing, toxic algae, unreported catches.
  - Essential for fishery allocation

Our flagship really is a community index sampling program.

We need an independent agency which would collect these kinds of data, which would report annually to the agencies which actually manage the fishery, that of course the data available in those management groups right now is essential and should be part of that, but we need an important major effort to start a standardized fish monitoring program. It should be intensive and not extensive. This is crucial to both the south end, primarily walleye fishery; and the north end, primarily whitefish fishery.

Our second project concentrates on those sources of fish mortality in the lake that are currently external to the fishery or not being captured by the standard monitoring done by the fishery.

It includes things like birds and toxic algae, unreported catches, special permit fishing, subsistence fishing.

Ideas for *Fish Communities* Science

- Fish 3 Subpopulation structure of commercial species (walleye, sauger, whitefish)
  - Inventory
  - Determine whether there are genetically distinct stocks of the three quota species.
  - Need for stock specific management ?
- Fish 4 Effects of exotic species on the Lake Winnipeg Ecosystem
  - Surveys, monitoring and desk analyses.
  - Assess the establishment and growth of exotic species
  - Improved understanding and ability to predict impacts to productive capacity.

There is some historical information on lake whitefish genetic stocks but there is no information on genetic stocks of walleye or sauger for the lake and we don't really know whether we should be managing these fisheries on a stock specific basis. The first step is: Are there genetically distinct stocks? What are their geographic extent? Where are they spawning? Where are they going? Where are they being caught? And this will provide the basis for determining whether we need to manage these fisheries on a stock specific basis.

Our fourth project concerned exotic species. Really we have a lake which is being invaded and probably will continue to be invaded. We don't have a very good handle on what is going on in the lake. The rainbow smelt is an obvious one, but a number have been invading before rainbow smelt, there will be more to come.

A lot of that might be university-based research and some of that could be experimental research that some experimental systems.

Ideas for *Fish Communities* Science

- Fish 5 Traditional and Local Knowledge
  - Inventory, applied research
  - To fully understand fish communities it is necessary to collect TEK.
  - Identify areas for scientific research.

We recognize that there is a huge inventory of local knowledge among First Nations, among fishermen on the lake, among people who have been on this system for sometimes decades who are observant and have a tremendous stock of knowledge; that the scientific way of looking at the lake can often be very restrictive; that the collection of traditional knowledge can be an excellent way to focus scientific studies, to provide ideas for scientific study, and we supported this as a method of gathering information on the lake.

This is also very cost-effective compared to many scientific studies, the information is there and important to go ahead and collect it.

Fish Communities Science Issues not dealt with

- Sedimentation
- Hydro regulation
- Conditions in spawning streams – sewage discharges

We did talk a little bit about sedimentation in the lake, it's possible effect on the lake ecosystem, productivity, fish spawning, habitat.

We decided that it would be taken care of by the fish and fish habitat group. I'm not sure whether it will be or not.

Hydro regulation we recognized as a potential issue. We again decided we had too much, so we would hope it was done by the fish and fish habitat group.

One issue that was brought up was that there was some concern for many of the spawning streams, especially in the south part of Lake Winnipeg, that there was a number of sewage discharges that potentially had a deleterious effect on runs of fish, I guess especially walleye going up these streams, and nobody seemed to be looking at it. There was some concern about it and maybe that was something that could be identified maybe in the toxic -- or in the water quality group this morning as a gap.

And the one that isn't on there that I should mention were just contaminants in general and that is another topic that we didn't tackle explicitly, we didn't develop a project about that, so that may also be a gap in discussions this morning.

Fish Communities Discussion

- Thompson. Sport Fishery? Where is it?
- Patterson. Factors affecting recruitment and growth? Eutophication, climate change etc.
- Wrona. Tainting issue.

Peter Thompson from DFO A glaring omission was the sport fishery, both in the lake and in some of the major tributary streams at particular times of year, and I just wondered whether that was an oversight or whether you excluded it on purpose?

DR. BODALY: We did talk about it. We didn't really have a consensus that it shouldn't be talked about, but we did skip over it, so that's a good point.

Mike Paterson from DFO. You addressed mortality issues, but didn't look at the other side of the population equation, that is factors affecting recruitment and growth of fish. And the potential importance of other things that might change the food web of Lake Winnipeg, like eutrophication, climate change and so forth and what their impacts might be on fish populations.

DR. BODALY: I think we implicitly defined our mandate a little more narrowly than that so I guess we were thinking that the issues of productivity, especially, would be dealt with by the water quality group.

Fred Wrona, Environment Canada. I've got a question regarding the taste and odour tainting issue. One of the key emerging issues on commercial fisheries in eutrophied system is basically dealing with tainting and the lack of commercial abilities because of the result of tainting

DR. BODALY: That is in the details of the exotic species part of our project. What we did talk about specifically was the idea or observation that rainbow smelt and feeding by walleye on rainbow smelt could be affecting the taste of the walleye and also could be affecting the fillet quality,

DR. WRONA: Well, the area that I'm thinking of is also related to the alteration of plankton community structure, particularly blue/greens and other die tenacious type of species that in fact invoke very strong taste and odour compounds, both in terms of the water quality, but also in terms of biological cascading.

LWSW - Session 3
Integration and Linkages to Other Proposals

Fish Communities

Session 3 Integration
Fish Communities

- A couple of comments
- Three new projects
- Overlaps

General comments

- Need for international point of view on many project – data need from both Canada and the US – esp. for Water Quality Projects such as Land Use, Watershed Model
- Possibility of a project on underutilized commercial species, e.g. yellow perch

One of the things we talked about, especially with our United States colleagues who were in the group with us, is a lot of these projects really need an international point of view.

The basin is not just in Canada, it's in two countries. Data will be needed from both countries. There probably will be a need for cooperative points of view and cooperative projects and certainly cooperating with our American colleagues.

Minister Ashton put it well this morning when he said that finger pointing isn't terribly useful and that's not what we want to get into here, but there is a need to recognize that it is an international basin and there are international implications to whatever we do.

There are especially a few projects, such as some of the ones that were identified by the water quality group, that will require that perspective and will require those kinds of data.

Another issue that came up in our group was that there's a need for some sort of study on trying to look at some of the under-utilized fish species related to Lake Winnipeg, especially things like yellow perch.

New Fish Project 1

- An ecosystem model to understand the impact of changes in the food web structure and function on fisheries productivity
  - Desk analysis, identification of known and unknown data
  - Will assess the combined and separate effects of various management strategies, e.g. nutrient loading, exotics
  - Important links to DFO Burlington for experience and expertise

The first camefrom a question this morning, about food chains and energy and from the presentations on ecosystem modelling.

The first new project we developed, is an ecosystem model to understand the impact of changes in the food web structure and function on fisheries productivity. The idea was to use the model in the way that Scott and Marten talked about this morning, especially to identify, in a combined way or in a separate way, the effect of various management strategies on outcomes in the lake. For example nutrient loading, exotics, productivity, food web structure and function, fisheries' productivity and fisheries' yield?

It would start with a desk analysis. This modelling exercise would help to identify data that's known, it would help to identify data that is not known and needs to be collected.

There is an important, interactive process in working with the models, developing them, identifying data that's needed, identifying what the models are sensitive to, collecting those data, refining the models and working that way, hand-in-hand.

We need some important links here to colleagues in DFO in Burlington and many others who are familiar with these kind of models.

New Fish Project 2

- CLIMATE
  - 2 main questions:
    1. What are the effects of climate and climate change on the biota, productivity and fish populations of L Wpg,
    2. What the potential climate change effects on runoff and nutrient and sediment supply from the watershed
  - Need for more complete temperature data collection on the lake (esp. depth profiles) and its tributaries
  - Need for remote sensing of surface temps
  - Deliverables – thermal habitat of L. Wpg, understanding of impacts

Our second new project is climate change.

The two main questions posed by this new project description are:

1. What are the effects of climate and climate change on the biota, productivity and fish populations of Lake Winnipeg?

2. Secondly, what are the potential climate change effects on runoff and nutrient and sediment supply from the watershed?

A lot of this will useexisting data, but there is an acute need for more complete temperature data on the lake, especially depth profiles, and the tributaries of the lake as well.

There is a really useful role here for remote sensing in determining surface temperatures and trying to improve our understanding and our data sets there.

The deliverable is a better definition of the thermal habitats that are present in Lake Winnipeg and understanding the impacts of changed climate.

New Fish Project 3

- CONTAMINANTS
  - No acute issues, but need for vigilance
  - Objectives – prevent impacts on resource users (proactive); ensure ecosystem protection from contaminants
  - Inventory of conc'ns of targetted contaminants in fish, water, sediments, food chain
  - Linkages to watershed model, land use and ecosystem model
  - Need to capture algal/tainting issue

The third new project is contaminants. We felt that there did not seem to be any particularly acute issues right now. The fishery is not closed due to mercury; nobody is screaming about PCBs or toxifine, but this is a potentially big topic and there is a need for vigilance related to the Lake Winnipeg ecosystem and its fisheries.

The objectives of this project are to prevent impacts on the resource users, in other words, to be proactive to ensure ecosystem protection from contaminants.

There is a need for an inventory of the concentrations of certain targeted contaminants in fish, in water, in sediments and in the food chain.

There are obvious linkages to the watershed model, the land use project, and the ecosystem model project.

And of course the issue of tainting that Fred Wrona brought up earlier.

OVERLAPS

- EXOTICS – combined the two proposals (from Fish Communities and Fish Habitat) into a single entity – were broadly overlapping
- TRADITIONAL KNOWLEDGE – Large number of links (11) with other projects

Just to briefly mention a couple of the broad areas that we saw as overlaps between existing projects and of course we picked on two of the projects that we, in the fish communities group, had developed yesterday.

Exotics. We looked at the two project proposals, one that had been developed by ourselves and the other by the other group and really they were very, very similar, many common elements, and what we did was we took the two proposals, the one from us and the one from fish habitat and combined them into a single entity.

TEK. The project we developed yesterday was an explicit project entitled, "Traditional local knowledge". There weren't other specific projects about traditional knowledge, but we just wanted to note that there were a huge number of links, we identify 11, without looking too hard, to other projects, so there's a lot of synergy or possibilities there between what was developed as a project focussed on traditional knowledge and other projects that were focussed on various subject areas, but could use traditional knowledge as part of the data and understanding gathering exercise related to those projects.

Lake Winnipeg Science Workshop
November 29-30, 2004
Breakout Sessions 2 & 3

Fish Habitat

LWSW - Session 2
Development of Science Proposals

Fish Habitat

Session 2
Breakout - *Fish Habitat*

- Facilitator – Peter Thompson
- Rapporteur - Joel Hunt / Laureen Janusz
- Participants – as assigned

Habitat Management Issues – Session 2

1. Lack of physical habitat inventory
    1a. Lakes and tributaries
        - shoreline, bathymetry, substrate classification,
        - riparian/upland, wetlands, fish habitat suitability index
    1b. Spawning streams and reefs
    1c. Critical habitat for SAR
2. Lack of Understanding of Watershed Impacts
    - forestry and agriculture (water quality and quantity), roads, water crossings,
    - recreational and urban development, dams, drainage, vegetation removal
3. Shoreline Development

We have nine proposals that we put together.

We had, I think, a very good discussion.

It was a pretty good consensus that not having a habitat inventory was a problem, was a big problem. We need the inventory both in the lake and in the tributaries and there's some more details there; spawning streams, tributaries and reefs and then critical habitat for species at risk.

The second issue that we looked at was the lack of understanding around watershed, watershed impacts. So again we've kind of gone through and listed those. We need to build up our understanding of those things.

Shoreline development came out as an issue and that was covered in Keith's presentation yesterday morning.

Habitat Management Issues (Cont'd)

4. Food web
   - hypoxia, warming, changes to algal community, trophic relationships,
   - zooplankton, inverts, exotic species invasion
5. Water regulation
   - fish passage at dams, wetland impacts
6. Water quality
   - sedimentation, nutrients, contaminants

- Ranking: 1, 2, 4, 3, 6, 5

The fourth one is around food web interactions. So we're talking about, as you can see, the anoxia and those things with the algae community and so on and so forth with benthos and exotic species invasions.

So I think part of this is having that basic understanding of how all these things are affecting the food web, so that we can go back and better understand what to do to deal with the watershed impacts.

Water regulation, primarily around, I think, wetland impacts, but there is some concern over fish passage and that might be more into the Saskatchewan River and downstream into the Nelson.

Finally, water quality was a management issue that we identified.

Ideas for *Fish Habitat* Science

- Habitat 1 Aerial inventory of north basin and channel areas
  - Aerial survey and geo-referenced digital photographic habitat record.
  - Linked to management issue #1.
- Habitat 2 Fish habitat classification for the south basin of Lake Winnipeg
  - Collect bathymetric, fetch, cover and habitat suitability data to build a productive capacity predictive model.
  - Linked to management issues #2 and #3

These are not prioritized, we've just put them up on the board, so to speak, at this point.

So the first one was having an aerial inventory of north basin and channel areas. As you can see there, it's to be georeferenced with digital photographs.

This was linked to our management issue number one, which was the inventory.

The second project that was identified was habitat classification for the south basin and the description here was to collect the symmetric, fetch, cover, habitat suitability data to build a productive capacity predictive model and it's linked to issues number two and number three that we identified.

Ideas for *Fish Habitat* Science

- Habitat 3 Assessment of tributaries and reefs by Lake Winnipeg fishes
  - An inventory of tributaries and reefs used by fish for spawning, rearing and growth.
  - Linked to management issue #1b.
- Habitat 4 Decline in wetland habitat
  - Assess wetland productivity relative to water regulation.
  - Linked to management issues #5

The third project was an assessment of the tributaries and reefs used by Lake Winnipeg fishes. This is an inventory of those areas and it's linked to our issue number one.

The fourth project, to assess declines in wetland habitat, the notion here being to assess the wetland productivity relative to water regulation, so the fish community group, we did pick up on this, at least part of it.

The fifth project that we have here is correlation of land use to watershed nutrient databases. We understand that there is an existing inventory of land use and nutrient loading information within Manitoba and within the basin, and the notion here is to try and bring those two databases together so we can start to see where the -- what land use activities are contributing significant nutrient loading to the lake and to the watershed.

Again, it's linked to our management issue number two.

Ideas for *Fish Habitat* Science

- Habitat 5 Correlation of land use and watershed nutrient databases
  - Assemble existing land use and nutrient loading information into an integrated GIS database
  - Linked to management issue #2.
- Habitat 6 Define and describe critical habitats of species at risk
  - Linked to management issues #1c.

The fifth project that we have here is correlation of land use to watershed nutrient databases. We understand that there is an existing inventory of land use and nutrient loading information within Manitoba and within the basin, and the notion here is to try and bring those two databases together so we can start to see where the -- what land use activities are contributing significant nutrient loading to the lake and to the watershed.

Again, it's linked to our management issue number two.

The sixth project that we outline is to define and describe critical habitat for species at risk. Right now there are a number of species, there are a couple of species at risk that are currently being assessed, I think it's the -- snail and the short-jawed cisco and ultimately I guess the biggy will be, in Lake Winnipeg and its watershed, sturgeon, if we understand where Cosovec (ph) is going with their assessments.

Ideas for *Fish Habitat* Science

- Habitat 7 Improve the understanding of nutrients, light and temperature to the algal community
  - Sufficient funding to complete analysis of existing data
  - Linked to management issue #4.
- Habitat 8 Causes and consequences of the decline in zoobenthos communities
  - Assess potential causes of zoobenthos decline and their importance to the fish community
  - Linked to management issues #4.

The seventh project that we identified was to improve our understandings of nutrients, light and temperature to the algae community.

Again we understand that over the past three to four years there's been large amounts of data collected on Lake Winnipeg, and the current situation is that the researchers who have this data have not had the funding to analyse and to publish this data and we felt that this was an important step to move the yardsticks.

The eighth project that we identified was identifying the causes and consequences of decline of zoobenthos communities.

The description is to assess the potential causes of the decline and identify their importance to the fish community.

Again you can see what manage issue it was linked to

Ideas for *Fish Habitat* Science

- Habitat 9 Invasion of exotics and consequences to the fish community
  - Develop a risk assessment model
  - Linked to management issue #4.

Finally, the last project was the invasion of exotics and the consequences to the fish community and the description of the project was to develop a risk assessment model, and again this was linked to management issue number four

LWSW - Session 3
Integration and Linkages to Other Proposals

Fish Habitat

Ideas for *Fish Habitat* Science

- Habitat 1 Aerial inventory of north basin and channel areas
  - No linkages to other projects (Note pointed out by G. McCullough that there are links to many of the other projects see Discussion)
  - Suggested that this is one of a subset of inventory projects (Habitat classification, tribs and reefs, and wetlands)
- Habitat 2 Fish habitat classification for the south basin of Lake Winnipeg
  - Fish 3 – Subpopulation structure
  - Water 6 – Physical model
  - Habitat classification, tribs and reefs, and wetlands

1. With Number 1 the aerial inventory, there were not specific linkages to other projects, however, in the discussion, and I think this kind of comes through in sort of our classification and inventory projects and that kind of classification system we used.

We actually had a number of inventory kind of subjects and the suggestion was that we really had one big inventory project with a number of sub-projects underneath it and it would benefit from putting them together and making sure the appropriate linkages were there.

2. Second, with the habitat classification of the south basin, this was a link to fish 3 population structure and to the water 6, the physical model.

Ideas for *Fish Habitat* Science

- Habitat 3 Assessment of tributaries and reefs by Lake Winnipeg fishes
  - Fish 1 – Community Index sampling
  - Fish 3 – Subpopulation structure
  - Fish 5 – TEK
- Habitat 4 Decline in wetland habitat
  - Fish 4 – Effects of exotics (carp)
  - Habitat – Invasion of exotics

3. The third project was the assessment of tributaries and reefs, it was linked with the three fish community project; community index sampling, sub population structure and traditional ecological knowledge.

The discussion was around the need to have a specific project around the collection of traditional knowledge. That it's not an easy thing to do, it takes a fair bit of effort and, you know, you have to engage the people that have the knowledge and do it in a way that the knowledge will be forthcoming and so it's not as easy as it seems. So if you're really interested in bringing this kind of information forward, you have to dedicate a fairly significant amount of resources to doing it and then relating it back to the projects where you're going to use it.

4. The fourth project we had was the decline in wetland habitat and we again noted there were some linkages to fish 4 exotics and our own project on exotics.

Ideas for *Fish Habitat* Science

- Habitat 5 Correlation of land use and watershed nutrient databases
  - Water 3 – Sustainable land use
  - Water 4 – Watershed modeling
- Habitat 6 Define and describe critical habitats of species at risk
  - Fish 1 – Community index sampling

Habitat 5, the correlation of land use and watershed nutrient databases. We noted that there were links to sustainable land use in the water and the watershed modelling.

Habitat 6, describing critical habitats. Again linkages to the fish community index sampling.

Ideas for *Fish Habitat* Science

- Habitat 7 Improve the understanding of nutrients, light and temperature to the algal community
  - Fish 3 – Subpopulation structure
  - Water 3 – Sustainable land use
  - Water 4 – Watershed modeling
  - Water 6 – Physical model
  - Water 7 – Relating nutrients and biological endpoints
  - Habitat – Zoobenthic declines, tribs and reefs, and habitat classification

Habitat 7, improving our understanding of nutrients, light, temperature to the algae community. A large number of linkages here: fish 3, sub-population structure; water 3, sustainable land use; water 4, watershed modelling; water 6, physical model; and, water 7, relating to nutrients and the biological endpoints.

Particularly to the modelling, it only makes sense that this is food for the models.

Project 8, causes and consequences of declines of benthos communities. Again linked to the watershed modelling and to the water nutrients and biological endpoints project.

Ideas for *Fish Habitat* Science

- Habitat 8 Causes and consequences of the decline in zoobenthos communities
  - Water 4 – Watershed modeling
  - Water 7 – Nutrients and biological endpoints

- Habitat 9 Invasion of exotics and consequences to the fish community
  - Fish 1 – Fish community index sampling
  - Fish 4 – Effects of exotics
  - Water 7 – Nutrients and biological endpoints

Habitat 9 Exotics and consequences, linking to fish 1 and fish 4 and again to the water 7

Gaps for *Fish Habitat* Science

- Toxins - effect of toxins in sediment runoff as a result of drain construction or maintenance on successful reproduction. Partially reflected in H2 (Hab 2 Mon 1) and this one.
- TEK incorporate across the board
- Data management - compile all data that is available on the lake itself (catalogue what is available and where), including management data (database manager and method to collect it) and ability to collect and analyse the huge inventory of samples that exist. Quality control caveats need to be established.
- Science of habitat restoration / enhancement needs (has there been a Net Gain in productive capacity) and BMP's.

We're talking about contaminants in number 1, the effects of toxicants, you can read it.

I already talked about the traditional knowledge.

Data management, in this kind of integrated approach an overall data management project, I think, is going to be required because we've got, you know, a need for compiling data from many, many sources and trying to link them together, so the group thought it was important that we think early on about how we were going to do the data management around this.

The fourth point there was around doing applied science around habitat restoration and enhancement needs.

Gaps for *Fish Habitat* Science

- Wetlands and tributaries - need to look at other factors: dredging, culverts, drainage etc.
- Include wetlands connectivity to tributary drains.
- Native and indigenous biodiversity
- Expand to more of an ecosystem approach and include species like mayflies
- identify source of contaminants from habitat perspective and food web effects (confirm there is adequate monitoring)

We recognize that this was a much larger habitat issue than just Lake Winnipeg and Lake Winnipeg watershed. If we're going to start restoring or doing enhancement work, is it really contributing to net gain.

More gaps around wetlands and tributaries. We thought that there was a need to look at other factors that are impacting on those, dredging culverts and this was partly sort of the other things that are occurring in the wetlands and in the tributaries, over and above what the water regulation was causing, because there's an interrelationship there.

There was some discussion that we hadn't really captured native and indigenous biodiversity in some of our projects.

I think the fourth point is in keeping with the fish communities, one of their new projects. It's bringing in a broader ecosystem modelling than what was described in the projects.

The final one here is identify source contaminants from a habitat perspective and food effects, confirm that there's adequate monitoring.

These initiatives were of lower priority than the projects described in detail.

Greg McCullough - University of Manitoba

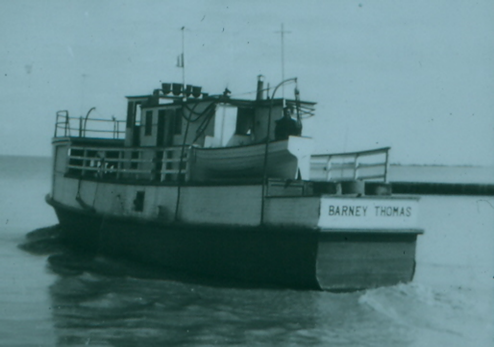
Habitat 1 has many links e.g. spawning habitat, tributaries and reef. When you do an inventory of shorelines you will, among other things, probably see where there are shoals, if you don't see them, and you'll certainly see the configuration of inlets to the streams. Wetland habitat is going to be impacted by water level regulation.

Soil erosion. The north end of Lake Winnipeg is eroding at a considerable rate and people have been talking almost exclusively of the Red River, when they talk about sediment supply to Lake Winnipeg. It isnot the only source of supply.

If you look at the north basin, most of the sediment that you see in the water column there is related either to near shore bottom resuspension or directly to shore erosion. From Warren's Landing over to Limestone Point there is a shore composed of glacier lake clays mostly, in permafrost, that has been receding probably at a metre per year ad infinitum. It produces a tremendous amount of sediment and a tremendous amount of organic matter.

I don't think the bathymetry regionally has changed all that much even in 100 years, but locally it's probably important and aside from whether it's regionally changed or not, there are very large areas of that lake that have no bathymetry.


LAKE WINNIPEG FISHERIES
1905 TO 1955
ORIGINAL PHOTOS
MANITOBA ARCHIVES &
OLI JOSEPHSON


BARNEY THOMAS


COLDFIELD


A
SOMERVILLE
Product

Sailboats at Horse Island, 1920's.


Foote

ING FLEET AT WARREN LANDING, LAKE WINNIPEG, 1ST. AUGUST 1920.