Technical Assessment of the Status, Health and Sustainable Harvest Levels of the Lake Winnipeg Fisheries Resource

Prepared for:
Manitoba Minister of Water Stewardship

Prepared by:
Lake Winnipeg Quota Review Task Force

Date Submitted:
January 11, 2011

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FOREWORD AND ACKNOWLEDGEMENTS

The Lake Winnipeg Quota Review Task Force was established by the Minister of Water Stewardship in November 2008. The Task Force was conceived by the Minister as the initial phase of a more comprehensive review of the Lake Winnipeg fishery quota management system to be undertaken upon the establishment of a new Lake Winnipeg Fishery Resource Management Board. The Task Force was established as a co-management group of three Lake Winnipeg fishers, Ken Campbell, Norm Traverse and Langford Saunders (August 2009), three scientists, Darren Gillis, Karen Scott and Ross Tallman and an independent chair, Burton Ayles. The Task Force was charged with reporting on productivity and assessment of the fish stocks of Lake Winnipeg**, not on how access to those stocks is allocated to fishers**.

Fishers and the industry in recent years have observed that the stock of the three quota species, walleye, sauger and whitefish, were healthy and there were calls from some fishers for increases to the allowable harvests or increases to the number of licence holders. Provincial officials were hesitant to allow increased harvests because data from the fishery and from the limited provincial monitoring programs were equivocal and officials were concerned for the long-term health of the fishery. Also other agencies, such as the Lake Winnipeg Research Consortium, indicated that the Lake Winnipeg ecosystem was changing, possibly to an unstable state.

Task Force members saw this initiative as a unique opportunity that gathered fishers and scientists into a single independent forum to discuss health of the fish stocks and to make recommendations for the future.

The Task Force met in full meetings in different geographical locations to interact with fishers, biologists, scientists, students and managers from various organizations and learn how their knowledge, information and data could contribute to an understanding of the task at hand. We reviewed the monitoring data presented to us by the Manitoba Fisheries Branch and the commercial data provided by the Freshwater Fish Marketing Corporation. We also extensively reviewed the scientific and management literature on topics related to our task. We did not carry out extensive data collection or analyses of our own.

The work of the Task Force was supported by many individuals. In Appendix II we identify our many contacts, their expertise and the information and knowledge they provided. We also acknowledge and thank the staff of the Manitoba Fisheries Branch for their administrative and technical support and for their knowledge of the Lake Winnipeg fishery. We would also like to thank the many Lake Winnipeg fishers who participated in the fishers' survey without which we would have had no systematic assessment of fishers' knowledge and opinions of the fishery. The Freshwater Institute, Freshwater Fish Marketing Corporation, Manitoba Fisheries Branch and the Southern Chiefs Organization provided facilities and equipment for our meetings.

The Task Force would especially like to acknowledge the thoughtful counsel and critiques from four scientists who provided an external peer review of a penultimate draft of the report: Peter Colby, Mark Ebener, Mike Hansen, Robert Young (see Appendix VI.) and the editorial assistance of David Rosenberg and Donna Laroque.

EXECUTIVE SUMMARY

Lake Winnipeg supports the second largest commercial inland fishery in North America. Walleye commercial production is currently stronger than it has ever been; however, the Provincial Government has proceeded cautiously in addressing quota increases because of uncertainty in the available fisheries data and the long-term sustainability of the fishery. The Lake Winnipeg Quota Review Task Force (Task Force), consisting of three Lake Winnipeg fishers, three scientific experts and a chairperson, was established by the Minister of Water Stewardship to evaluate the biological sustainability of the fishery and to help inform decisions about quota adjustments by the Department of Water Stewardship, or by the new Lake Winnipeg Co-Management Board when that Board has been fully established. The focus of this report is the biological productivity and assessment of fish stocks, **not on how access to those stocks is allocated to fishers**.

The fisheries of Lake Winnipeg are governed by numerous federal and provincial acts and regulations, but the Minister of Water Stewardship has primary legislative authority and the Manitoba Fisheries Branch (MFB) has the major operational responsibility for the fishery. In any future co-management arrangement, both fishers and the Freshwater Fish Marketing Corporation (FFMC) will also have important obligations, roles and responsibilities for management of the Lake Winnipeg fisheries. For this reason, our conclusions and recommendations are directed at fishers, the FFMC and government because all parties must be involved if our recommendations are to be implemented successfully. This work is the initial phase of a more comprehensive review of the Lake Winnipeg fishery quota management system to be undertaken upon the establishment of a new Lake Winnipeg Fishery Resource Co-Management Board.

Task Force Conclusions

The biological assessment of fisheries has been a topic of scientific interest for over a century and data are the foundation of any such assessment. We have found significant uncertainty in the fishery data of Lake Winnipeg, and as a result, absolute estimates of current or past biological productivity, proper application of Maximum Sustainable Yield (MSY) methods, and determination of reference points are not possible with the data that are currently available. Moreover, the uncertainty in the fishery data of Lake Winnipeg is exacerbated by environmental uncertainty from factors such as exotic species, nutrient loading and climate change. Thus, the basis of our conclusions is limited to considerations of relative productivity and stock health based primarily on catch rates in the index-net survey and commercial fishery, limited analyses of biological variables of quota species and input from fishers.

Catch rates of walleye in the commercial fishery are currently at an unprecedented high, and the index-net series suggests that walleye are abundant and healthy. However, the age structure of walleye shows that this abundance is mostly caused by a single age class: fish hatched in 2001. This age class can be expected to sustain the fishery in the immediate future but eventually the fishery will depend on the upcoming year classes, which do not appear as abundant, according to the available data. There is not enough information currently available to state exactly what this situation means to future commercial production.

The position of sauger is more tentative. Its decline in commercial catches has continued consistently since the late 1980s. Its presence in survey catches also declined in the late 1980s and remained low, albeit stable, through the 1990s and into the 21st century. Low sample sizes and a lack of data leave trends in the most recent years unclear, although the most recent age data suggest that there were two years of good recruitment in the population. The fishers on the Task Force observed that sauger harvests are influenced by walleye prices and abundance and do not necessarily accurately reflect the actual abundance of sauger in the Lake.

Whitefish harvests have remained stable over the past two decades, i.e. they have varied but without trending up or down. However, information on lower-valued species within a multi-species quota can be poor because of unreported discarding (“bushing”). Given the low catch rates, questionable changes in catch rate and other indicators of population health, whitefish should continue to be followed closely. Sampling independent of the regular commercial catch is especially important in cases like this.

The Task Force has reached three major conclusions as a result of its work:

1. The available fisheries information and analysis from sources consulted are inadequate to determine absolute estimates of current or past biological productivity for Lake Winnipeg, and the proper application of standard stock assessment methods based on biomass or indices is not possible with the data at hand.
2. Because of the lack of data, the Task Force is unable to recommend either increases or decreases in a total Recommended Allowable Harvest (RAH) of 6.52 million kg for the Lake.
3. The uncertainty and lack of adequate information needed to make informed decisions about possible changes in RAHs will continue unless there are changes made to data collection by the MFB, FFMC, and fishers, and additional research is done to enhance our understanding of the fishery, the fish and the broader ecosystem.

Task Force Recommendations

Our recommendations are presented as a series of sequential actions, which include: 1 and 2) the development of separate RAHs for each species; 3) the development of reference indicators that can be used to provide more objective and timely advice on increasing or decreasing quotas in the future; 4) adequate surveys and monitoring to provide the necessary data to support the reference-indicator system; 5) supporting research projects; 6) proper data management to improve the monitoring and decision-making processes; and 7) implementation of an open and transparent adaptive co-management process for future stock assessment recommendations.

The Task Force proposes the following recommendations to the Minister of Water Stewardship or the new Lake Winnipeg Co-Management Board if that Board becomes fully established.

1. Recommended Allowable Harvests (RAHs) For Sauger, Walleye and Lake Whitefish. *The Task Force recommends that the current multi-species quota of 6.52 million kg for sauger, walleye and lake whitefish be partitioned into three separate RAHs for the three species in a ratio of 19% for sauger (1.24 million kg), 56% for walleye (3.65 million kg) and 25% for lake whitefish (1.63 million kg).*

In general the scientific assessment is that a multi-species quota does not meet the Precautionary Principle for fisheries management of these three species. Whitefish, walleye and sauger have very different life histories, prices between the three species can vary significantly and fishers can selectively harvest the more desirable species (see details in the Assessment Section). There is a significant capacity to over-harvest one species while under-harvesting the others.

The Task force urges extreme caution in relying on this partitioning for long-term management. The whitefish portion is based on commercial harvesting that has an overall tendency to select for walleye and sauger, so it may be an underestimate. Anecdotal reports of bushing of whitefish by fishers indicates that the actual harvest is probably higher. The partitioning between walleye and sauger is based on very few years of data and very few nets, and the results differ considerably from results of the commercial fishery. We know that fishers are selecting walleye but the extent is unknown. Our conclusions above regarding the health of the stocks of the three fish species are also relevant. We know a bit about the harvest but not much about the populations.

The Task Force assumes that RAHs will be adjusted in the future following the other recommendations in this report.

2. RAHs for a Lake Whitefish/Percid Option for Establishment of Quotas. *The Task Force recognizes that the overall authority for the fishery (i.e. either the Minister of Water Stewardship, or a new Lake Winnipeg Co-Management Board) may choose not to separate the current multi-species quota into species quotas but may retain a combined percid quota. In this event RAHs should still be established for all three species and future management decisions on increases or decreases of a combined percid quota should be on the basis of the species whose stock status is rated in the Cautious Zone or Critical Zone even if the other species is rated in the Healthy Zone. This recommendation follows the Precautionary Principle and assumes that the recommendations below for reference indicators and a new assessment process are fully implemented.*

Scientifically a multi-species quota does not meet the Precautionary Principle for fisheries management of these three species. However, the fishers on the Task Force have emphasized that there are strong practical, operational reasons for establishing a common percid quota for sauger and walleye and that sustainability of the Lake Winnipeg fishery depends upon social and economic considerations as well as biological considerations.

They also emphasized that the fishery has remained successful under the current management regime for the past 40 years.

The Task Force recognizes that this is to be an adaptive co-management process and has considered how a percid quota might be achieved within a precautionary approach. Technical advice must still be provided in terms of a RAH for each species. The biological assessment process must be maintained and monitoring enhanced as described in the following recommendations. As well as closure of the fishery when the quota for the most vulnerable species is reached, management factors that need to be considered for co-management of the fishery and protection of a vulnerable stock from over-harvesting include the following: 1) FFMC pricing; 2) different mesh sizes for nets; 3) changes in fishers' behaviour; 4) modified use of tolerances; 5) changes in seasonal openings and closings; 6) changes in regulatory areas; and 7) additional protected areas. These options must be discussed and agreed upon before problems arise with the fish stocks.

3. Reference Indicators for the Future. *The Task Force recommends that the Minister of Water Stewardship, or a new Lake Winnipeg Co-Management Board, implement a biological reference indicator process for annually assessing the status of lake whitefish, sauger and walleye stocks of Lake Winnipeg and determining whether changes to the RAH are necessary.*

The United Nations FAO Code of Conduct for Responsible Fishing states that implementation of a reference-indicator process for management decision-making is essential. The Task Force has outlined a "traffic-light" approach to the assessment of a series of reference indicators. Changes in the RAH would be based on the overall status of those assessments. Individual indicators would be assessed as Healthy (RAH up), Cautious (RAH remain) or Critical (RAH down). Changes in the RAH would be based on the number of indicators that were in a high risk (red light), medium risk (yellow light) or low risk (green light) zone. Allowable changes to the RAH would be limited to plus or minus a 10% change from current levels. Further details are in the Recommendations section.

4. Monitoring and Surveys. *The Task Force recommends that the Department of Water Stewardship do, or arrange for other agencies to do, an integrated series of monitoring programs and surveys in support of the reference indicator system recommended above and the management-decision process described in the final recommendation below.*

Specific recommendations in terms of monitoring programs are as follows:

4a. Commercial fisheries harvest and effort monitoring program – FFMC, fishers and MFB should modify the current FFMC harvest delivery program to include better effort data for each delivery. At a minimum the number of nets, length of nets, mesh sizes of nets and nights set for each delivery should also be reported. This information would be used to establish commercial fisheries catch per unit effort (CPUE) for each species;

4b. Index gill netting monitoring program – Modify the current program to increase the coverage of the current MFB index-survey program to a number that would provide statistically valid data. Fisher participation in some areas is also recommended. The percid program and Mossy Bay lake whitefish program should be integrated with appropriate stratification to ensure adequate sampling of all relevant habitats;

***4c. Commercial catch sampling program* –** Review and revise the current program to overcome issues related to proxy weights calculated from the index-netting program, to gain independence from that program and improve future reference indicators derived from the commercial catch sampling, and to include more than just age data;

***4d. Sentinel fishers monitoring program or fishers' logbook program* –** Establish a new program to aid in the development of a reliable commercial index of abundance of the walleye, sauger and whitefish stocks and of non-target species;

***4e. Offshore small fish trawling program* –** Continuation of the current program to better predict future walleye recruitment into the commercial fishery and to estimate the abundance of forage fishes including exotic species such as rainbow smelt;

***4f. Recreational sport fishing survey* –** Modify the national survey to include sauger as well as walleye and develop a specific survey to determine recreational harvests of walleye and sauger and recreational CPUE on a regular basis for Lake Winnipeg and its major tributaries; and

***4g. Comprehensive domestic (subsistence) survey* –** Conduct a new survey to determine the harvest and consumption by First Nations communities of fish from Lake Winnipeg.

<u>**5. Areas of Needed Biological Research for Lake Winnipeg Fisheries.**</u> *The Task Force recommends that The Minister of Water Stewardship seek the involvement of Fisheries and Oceans Canada, university researchers, Manitoba Hydro, the Lake Winnipeg Research Consortium, Lake Winnipeg fishers and the Centre for Indigenous Environmental Resources, amongst others, to support research initiatives related to the fish and fish habitat of Lake Winnipeg.*

The Task Force has identified the following needed areas of research or investigation:

***5a. Research in support of the monitoring programs we have recommended* –** to ensure, for example, their statistical validity;

***5b. Diets of lake whitefish, walleye and sauger* –** to evaluate the quality of and changes in diet and productivity. The diets of the three quota species, especially in comparison to historical evidence, need to be investigated;

***5c. Genetic stock structure* –** to effectively manage and protect stocks;

***5d. Seasonal migrations of walleye, sauger and whitefish* –** to gain a fuller understanding of the importance of these movements. Studies would include a fishers' knowledge study, combined with scientific tagging and genetic studies;

***5e. Incorporate fishers' knowledge into research priorities and management decisions* –** to incorporate a formal mechanism for including fishers' questions as a way to facilitate priority setting for the scientific community. This recommendation would be achieved through data collection and surveys of locally specific information;

***5f. Ecological model for Lake Winnipeg* –** to aid in understanding the impact of changes in foodweb structure on fisheries productivity, and in understanding the impact of changes in fisheries management procedures on fish stocks;

***5g. Information on critical habitats and habitat components* –** to establish baseline information on critical habitats. Methods used would include: aerial inventories of habitats in the North Basin and channel areas, a fish habitat classification system, and assessment of the use of streams and reefs for fish spawning. In addition, the Task Force recommends an assessment of artificial changes in the water flow regime and ongoing monitoring of the chemical, biological and physical variables of the Lake ecosystem of both the pelagic and nearshore areas to support development of a whole-ecosystem model and to gain a better understanding of trophic dynamics as impacted by eutrophication, climate change, exotic species and other stressors to the ecosystem; and

***5h Management changes should be the subject of systematic evaluation* –** *to* learn from the success or failure of management actions.

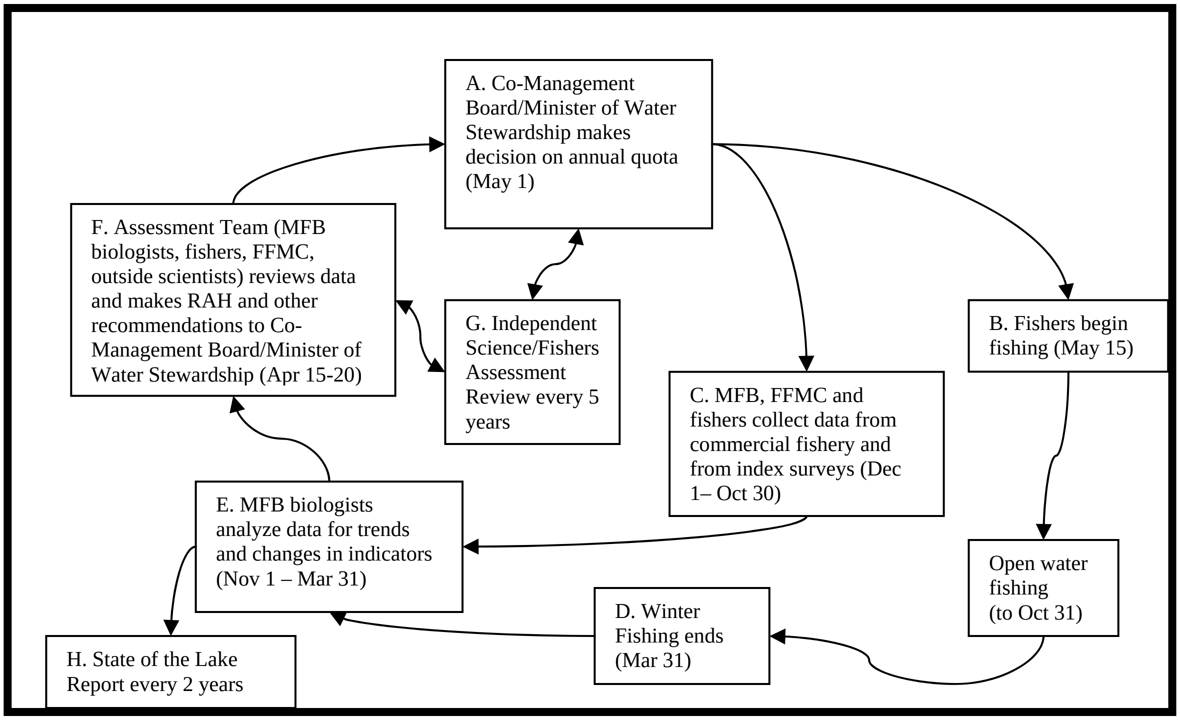
6. Data Stewardship and Management. *The Task Force recommends that an integrated data management system that includes all relevant data be developed for the Lake Winnipeg fishery.*

Currently, there is no organized data-management system other than that maintained by the FFMC. In order to efficiently analyze fisheries, the data need to be organized with consistent fields and formats and maintained over time. Data need to be readily accessible. This is not a trivial task, and will require additional resources and new levels of coordination between agencies and stakeholders.

7. Adaptive co-management assessment process. *The Task Force recommends that the Minister of Water Stewardship, or the new Lake Winnipeg Co-Management Board, implement an adaptive co-management process for the annual assessment of lake whitefish, walleye and sauger for Lake Winnipeg.*

Management decisions will be more trusted and have greater acceptance by fishers, government and FFMC personnel, community leaders and the general public if the decisions occur within an open and transparent process subject to appropriate levels of examination and scrutiny. Adaptive co-management is a management structure that permits stakeholders to share management responsibility within a specific system of natural resources and to learn from their actions. For Lake Winnipeg the cyclical process we propose would involve fishers, government biologists, FFMC managers and others and would be critical to sound decision-making by the proposed new Lake Winnipeg Co-Management Board.

The following is a schematic diagram of how such a cyclical process might operate. Further details are in the Recommendations section.



The Task Force emphasizes that the fisheries of Lake Winnipeg are generally in a healthy state and given proper management the resource will be biologically, economically and socially stable in the future. The Task Force is confident that implementation of its recommendations will assist the government, fishers and industry to ensure that the fishery remains sustainable.

The Task Force also emphasizes that the fishery will be at risk without implementation of the recommendations. The fishery is at an historic high but natural systems are subject to significant fluctuations. The history of Lake Winnipeg fish stocks has been one of significant variability and it is relevant for us all to remember that in the early 1940s sauger harvests were as high as walleye harvests are at present. We have seen other systems, such as Lake Erie and Lake Winnipegosis, experience extremely high catches for a number of years followed by dramatic collapses.

I. INTRODUCTION

Lake Winnipeg has supported a remarkable fishery since 1883 (Figure I.1, Appendix III.b.)—a fishery that is the second largest commercial inland fishery in North America next to Lake Erie. In the first 10 years of the 21st century some 850–900 fishermen harvested an average of 6.19 million kg of fish from Lake Winnipeg with an average landed value of $16.4 million (pers. comm. Dave Bergunder[1]). The production of the three major species, lake whitefish (*Coregonus clupeaformis*), sauger (*Sander canadense*) and walleye or yellow pickerel (*Sander vitreum*), averaged 5.78 million kg, 93% of the total landed weight and 98% of the total landed value of all fish harvested.

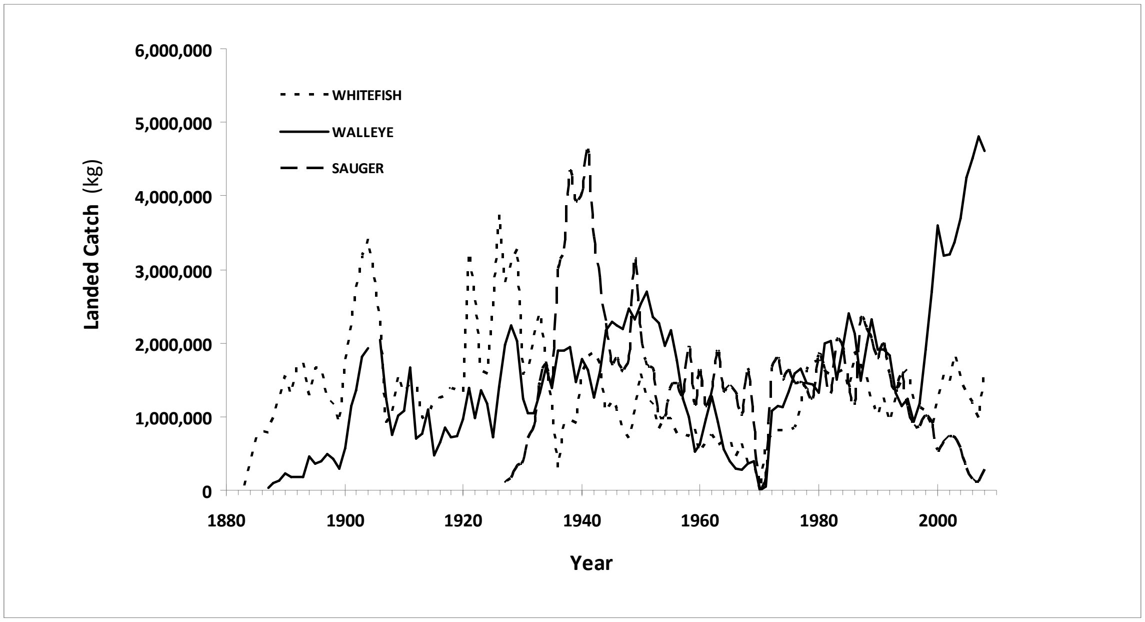


Figure I.1. Landed commercial catch (kg) for lake whitefish, walleye and sauger from Lake Winnipeg from 1883 to 2009.

The fisheries of Lake Winnipeg are managed under the Canada *Fisheries Act* and the Manitoba *Fisheries Act* by the Manitoba Fisheries Branch (MFB)[2] of the Manitoba Department of Water Stewardship. Since 1972, the three major species have been managed under an evolving quota-management system. The initial individual quota system provided non-transferable quotas and a total combined quota for the three species of 3.2 million kg. Major changes occurred in 1985 with an increase in the total quota to 6.4 million kg and in 1986 with the introduction of an Individual Transferable Quota (ITQ) system, termed Quota Entitlement (QE), for Lake Winnipeg, which provided for the transfer (sale) of quotas but with certain restrictions (Scaife 1991). Some previously temporary changes were made permanent in the 2000s and the total quota as of March 2009 is 6.52 million kg (pers. comm. W. Galbraith).

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[1] See Appendix II for contact information for references to personal communications.
[2] See Appendix I for acronyms and glossary.

The Lake Winnipeg Quota Review Task Force (Task Force) was established by the Minister of Water Stewardship and announced in letters to all Lake Winnipeg fishers dated November 20, 2008 (see Appendix II for Terms of Reference). The Task Force… *"consisting of Lake Winnipeg fishers and scientific experts, will be conducting a biological review of the fishery to determine sustainable harvest levels which would be used to inform decisions about quota adjustments"*.

The Task Force is composed of three Lake Winnipeg fishers, three scientific experts and a chair. The focus of the report of the Task Force is on the biological productivity and assessment of fish stocks, **not on how access to those stocks is allocated to fishers**. This report is the initial phase of a more comprehensive review of the Lake Winnipeg fishery quota management system to be undertaken upon the establishment of a new Lake Winnipeg Fishery Resource Co-Management Board. The subject of this report is the health of the three stocks managed under the QE system, not the QE system itself, except where the QE system impacts the health of stocks or determination of the health of stocks. The Task Force report provides advice in the form of a Recommended Allowable Harvest (RAH), which is biological advice that would go to the Minister or Co-Management Board for management and allocation decisions on the total quota or individual QEs on the basis of economic, social and biological factors.

The specific objectives of this report were to:

- Review the status of the Lake Winnipeg fishery following the key principles of biological sustainability and the precautionary approach when uncertain over impacts;
- Evaluate available fisheries information and analyses to determine stock status;
- Identify informational gaps and challenges;
- Provide advice on monitoring and assessment programs; and
- Provide recommendations to government on the health of fish stocks, sustainable harvest levels and factors that should be considered in future quota-adjustment decisions.

As one of the Great Lakes of Canada Lake Winnipeg has received comparatively little scientific attention. Fewer than 200 fisheries, environmental sciences and pollution-management publications for Lake Winnipeg are available in the peer-reviewed literature, whereas each of the Laurentian Great Lakes has over 1500 and as many as 4000. Only Great Slave and Great Bear lakes have as few research publications as Lake Winnipeg (Ayles and Rosenberg 2004) (for a recent summary of walleye studies see Roseman et al. 2010). Bajkov (1930) did the first comprehensive limnological survey of Lake Winnipeg in the late 1920s. Forty years elapsed before the next comprehensive survey was done in 1969 (Brunskill *et al.* 1980). Additional limnological surveys limited to the summer in the North Basin were undertaken in 1963–1964 (Rybicki 1966) and 1974 (Kristofferson *et al.* 1975), and to mid-summer for the whole lake in 1994, 1996 and 1999 (www.lakewinnipegresearch.org - accessed March 2009). However, the next multi-season, whole-lake limnological survey was not done until 2002 with the establishment of the Lake Winnipeg Research Consortium (LWRC). Data on the commercial fisheries have been collected for many years, as have data on research and monitoring of commercially valuable stocks.

This report consolidates available fisheries information, knowledge and understanding from government, universities, fishers, the Freshwater Fish Marketing Corporation (FFMC) and others, and uses the expertise and knowledge of the Task Force fishers and scientists. Chapters I and II introduce the report and describe how we did our work. Chapter III addresses the current state of the environment of Lake Winnipeg; the biology and use of the three quota species; current management tools used on Lake Winnipeg; and stock assessment methods used for other fisheries around the world but particularly for similar fisheries in North America. Chapter IV provides our evaluation and analysis of the status of sauger, walleye and lake whitefish of Lake Winnipeg; the present management of the fishery including the QE system and current data-collection systems; and other factors as they relate to health of the stocks and future needs. Chapter V provides recommendations for future decisions by the Minister of Water Stewardship or the new Lake Winnipeg Co-Management Board, when that Board has been fully established.

II. METHODS FOR THE REVIEW

The work of the Task Force took place over 18 months, from November 2008 to November 2010. The original request from the Minister was for a report by April 1, 2009 but it soon became apparent to Task Force members that the scope of the study and other commitments of the members (fishing, teaching and researching) meant that this deadline was unachievable. The Task Force met with the Deputy Minister of Water Stewardship, who agreed with our assessment but emphasized the importance of our work for the future Co-Management Board that was under discussion with fishers. The Deputy Minister also agreed that we should expand our work to include a special initiative to acquire fishers' knowledge of the health of the fish stocks. Our activities were also delayed and then restarted in the summer of 2009 at the request of representatives of the Community Licencing Areas (CLAs).

Operating Principles of the Task Force

Task Force members saw this initiative as a unique opportunity that brought together fishers and scientists into a single, independent forum to discuss the health of fish stocks and to make recommendations for the future. Therefore, the way the Task Force operated was an important part of what it was going to achieve. The following points are the working assumptions of the Task Force:

- First, we considered that what we are doing is a type of "co-science" in which the fisheries of Lake Winnipeg will be examined through the eyes and minds of fishers and scientists, both experts within their own fields. Each perspective is assumed valid within its own set of rules, and neither replaces the other. In applying both perspectives, we must attempt to find inherent value and common links, and accept the different assumptions and goals of fishers' local knowledge and Western science[3];
- Second, we did not feel beholden to anybody or any group beyond our Terms of Reference. We were not prepared to be directed by any government official or pressure group;
- Third, we agreed that we were a working task force, not a public advisory group. We would not have meetings where individual members could just come, listen and comment, based on quick judgements, and then go home. Each meeting would require each member to prepare beforehand and do follow-ups afterwards;
- Fourth, we preferred to operate as informally as possible. We would be non-voting and would make decisions by consensus (i.e. individuals would not have

[3] This parallel between fishers' knowledge and Western science is described by Carmack and Macdonald (2008). Scientists employ formal experimentation and quantitative methods to test their ideas and shape their views of the world; knowledge is passed from scientist to scientist via written scientific publications. Fishers behave similarly, examining what works for catching fish in certain areas or conditions and what doesn't work; their knowledge is passed from generation to generation and from fisher to fisher. Indeed, the success of fishers' knowledge over changing fish populations is founded on trial, innovation and adaptation. In the presence of natural change in a fishery, the fisher will know its visible signs and value to his survival, whereas the Western scientist will use analytical methods to examine these changes and have access to a broad literature to compare to the local patterns being examined.

to totally agree with everything but for the sake of the Task Force would agree to support Task Force decisions); and

- Last, we recognized the importance of communication, respect and trust both within the Task Force and with the government, fishers and others outside the Task Force. Co-management depends on these three factors and so our success—and acceptance of our report—depended on them.

Task Force Operations

The full Task Force met 21 times in different geographical locations to interact with individuals from various organizations and learn how their knowledge, information and data could contribute to the understanding of our task. Our meetings involved presentations from provincial fisheries biologists, FFMC officials, University of Manitoba scientists and students, and other outside specialists. Individual Task Force members also met and/or talked with fishers, provincial biologists and managers; with scientists, biologists and officials from other fisheries agencies; made short-term visits to winter and summer fishing operations; visited the FFMC plant; and participated on the LWRC's research vessel MV *Namao* (see Appendix II for information on contacts).

We assigned lead responsibilities for components of our tasks among members, who reviewed reports and scientific literature from Lake Winnipeg and other lakes between meetings and prepared summaries for further discussion at full meetings. Individual members would lead discussion of their assigned responsibility so we could better understand the issues and potential solutions (e.g. QE system, water quality and ecosystem changes, stock assessment models, use of fishers' knowledge, etc.). We also asked provincial biologists and FFMC managers to provide us with additional analyses, which we incorporated into our discussions. Fisher members had a special responsibility to maintain contact with Lake Winnipeg fishers and explain the functions and responsibilities of the Task Force.

Our recommendations were discussed in several different stages: 1) as an idea list; 2) as priority topics; 3) as written recommendations; and 4) finally as revised recommendations with rationales or explanations. Following the principles above, our final recommendations are a consensus supported by the individual members.

Peer review is a critical component of the scientific method, so the Task Force asked four outside specialists (see Appendix II.c.) to review a draft of the report. Their assessments were considered by Task Force members and incorporated into the final report or addressed separately as appropriate.

Fishers' Survey

Although limited, scientific papers on Lake Winnipeg and the three quota species are accessible in the published literature. The knowledge of the Lake and fishery that is held by fishers, however, is not as readily accessible because it is typically not recorded in a written format. Acquiring new information was originally not part of our responsibilities; nevertheless, members considered fishers' knowledge an essential part of the overall assessment of the health of the stocks, and consensus amongst members was that a complete assessment was impossible without this knowledge.

The Fishers' Survey was designed to gain additional knowledge about the status and health of the fish stocks; changes in fishing behaviour; changes in water quality; observations regarding exotic species; changes in by-catch; climate; spawning grounds and fish habitat; and views regarding quota adjustments. Additional comments were also requested. The Task Force recognizes the limitations of such an approach but believes that, over time, a more formal and structured survey should be developed and implemented to consistently engage fishers in sharing knowledge.

All fishers received letters outlining the purpose of the survey, the information being sought and the meeting dates and locations at which the survey would be distributed (Appendix V: Fishers' Survey, Tables 1 and 2). Fisher members of the Task Force provided information locally to inform fishers of upcoming meetings.

Meetings were held after the autumn fishing season, during the last week of October and the first week in December, 2009. Each community meeting had one fisher member and one scientist member in attendance. At each meeting, the role of the Task Force was described, the rationale for the survey was explained and questions were answered. Fishers then filled out the surveys, which were collected at the end of the meeting. Some deviations from this approach occurred: Norway House fishers requested that the survey be competed together as well as individually, and one fisher from Berens River requested that the survey be reviewed together with the scientist member of the Task Force. Blank surveys were left in the community to be filled out and returned to the Task Force by those not able to attend the meeting. However, no surveys were returned. The survey responses were collated, summarized and used where appropriate in the report.

III. BACKGROUND

In this Chapter we describe the environment of Lake Winnipeg and discuss the biology of the three quota species and their use particularly as it relates to management and fishing patterns. We conclude with a brief reference to the Code of Conduct for Responsible Fishing of the Food and Agriculture Organization of the United Nations (FAO) and a discussion of ways to manage a data-deficient fishery such as exists for Lake Winnipeg.

Lake Winnipeg Environment

Lake Winnipeg is among the largest lakes, by area, in the world. At 23,750 km^2, it is the sixth largest lake in Canada, after Lake Erie, and covers nearly 4% of the province of Manitoba. Lake Winnipeg receives its water from three major river systems, the Saskatchewan, Red, and Winnipeg, which drain an enormous watershed of 953,000 km^2. This watershed, known as the Nelson River Basin, is the second largest in North America, extending from the Canadian Rockies to within 20 km of Lake Superior (see Rosenberg *et al.* 2005 for detailed information on the Nelson River watershed). The watershed is 40 times larger than the surface area of Lake Winnipeg (Brunskill *et al.* 1980), in contrast to the watershed to lake surface area ratios of the Laurentian Great Lakes, which range from 1.6 (Lake Superior) to 3.2 (Lake Ontario) (Beeton *et al.* 1999). Lake Winnipeg is also the third largest hydroelectric reservoir in the world, providing Manitoba Hydro with 50% of its storage for 75% of its generating capacity (LWSB 2006). There is one controlled outflow to Lake Winnipeg, the Nelson River, which flows into southwest Hudson Bay.

The total length of Lake Winnipeg is 430 km spanning 3^o 30’ of latitude. A river-like area, known as the narrows or channel, separates two distinct basins, the North Basin and South Basin (Figure III.1). The North Basin reaches 100 km wide and comprises nearly 75% of the entire Lake’s area. The lake bottom in this Basin is generally flat with the exception of the eastern shore, which has a rugged bathymetry (Todd *et al.* 1996). The South Basin is 46 km wide making up roughly 11% of the total area of the Lake. Its lake bottom is also generally flat. The narrows are characterized by numerous islands and constricted passages only a few km wide, and by an irregular lake-floor bathymetry (Todd *et al.* 1996). Similar to the other inland Great Lakes, the boundary between two distinct geologic features, the Interior Plains and the Canadian Shield, runs down the centre of the Lake Winnipeg (Todd *et al.* 1996). The eastern and northern shores are underlain by Precambrian rock consisting mostly of granite, greenstone belts and gneisses, and the western and southern shores are composed of much younger Palaeozoic carbonate rock and sandstone (Todd *et al.* 1996).

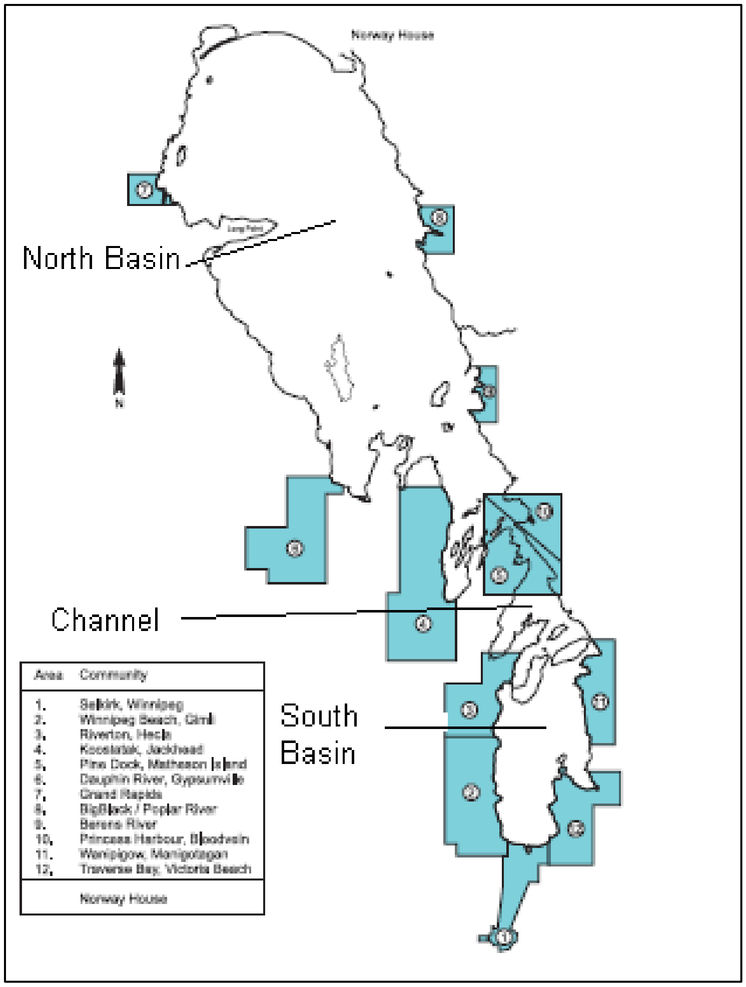

Figure III.1 Map of Lake Winnipeg showing the North and South Basins, the channel area and the Community Licensing Areas (map courtesy of MFB).

Both Lake Winnipeg and Lake Erie are unusual among the Great Lakes in being so shallow. The mean depths of the North Basin, South Basin and narrows are 13.3 m, 9.7 m and 7.2 m, respectively (Table 1), and the mean depth of the entire lake is only 12 m (Brunskill *et al.* 1980). Thus, despite its size, the shallow depth of Lake Winnipeg results in a total volume of only 284 km^3, most of which is held in the North Basin.

The thermal regimes of the North and South Basins are notably different, due largely to the volume and depth differences between them, but also because of the influence of tributaries (Brunskill *et al.* 1980) and latitude. This difference, however, diminishes as the open-water season progresses. The spring ice-melt and break-up period is typically shorter in the South Basin, lasting one to two weeks versus two to three weeks in the North Basin (McCullough 2005). Further, Brunskill *et al.* (1979a) found that water in the South Basin warmed more quickly, with June temperatures being 4^oC higher than the North Basin; by summer this difference was reduced to about 2^oC. In the autumn, temperature differences between basins are further reduced as the North Basin cools more slowly because of its much larger volume of water and storage of heat (Brunskill *et al.*

1980). Freeze-up in the North Basin occurs within a few days of the South Basin (McCullough 2005).

Table III.1. Morphometry and lake renewal time of Lake Winnipeg by basin and of Lake Erie (from Brunskill *et al.* 1980; Lake Erie data from Beeton *et al.* 1999; [a] from Pielou 1998).

Variable	North Basin	Narrows	South Basin	Whole Lake	Lake Erie
Surface area (km^2)	17,520	3450	2780	23,750	25,700
Volume (km^3)	232.4	24.6	27	284	488
Mean depth (m)	13.3	7.2	9.7	12	19
Max depth (m)	19	36	14	36	64
Max length (km)	232	143	93	436	388
Max breadth (km)	111	30	46	111	92
Shoreline (km)	761	640	349	1750	1402
Renewal (yr)			0.43–0.83	2.9–4.3	2.5 [a]

The North and South Basins of Lake Winnipeg are also optically distinct. The shallow South Basin is generally highly turbid with Secchi-disk depths less than 1 m, and as low as 0.25 m at the mouth of the Red River where suspended sediment levels are often high. The North Basin is comparatively clear, with Secchi-disk depths of 2–3 metres (Brunskill *et al.* 1979b) with the exception of some episodic shoreline erosion, which contributes to greater turbidity at increasing distances off-shore, especially during a strong south wind (Appendix V). Rivers draining the Precambrian Shield on the east side of the Lake are another factor influencing the optical properties of the Lake. This river water is visibly darker because of its high levels of dissolved organic carbon, which originates from organic soils and wetlands of the Shield.

Water renewal time for Lake Winnipeg was estimated by Brunskill *et al.* (1980) to be between 2.9 and 4.3 years, based on data from the period 1969 to 1974 . However, water renewal is not constant and depends on the amount of precipitation and evaporation, so this estimate could vary by at least 20% (Brunskill *et al.* 1980). Regulation by Manitoba Hydro also affects the water renewal time because minimum lake levels need to be maintained (Department of Mines, Resources and Environmental Management 1972). Nevertheless, the water renewal time for Lake Winnipeg is short, and as a result, the Lake responds fairly quickly to the quantity and quality of water entering from its inflowing rivers.

Lake Winnipeg is strongly influenced by the geology, land use and discharge patterns of the drainage basins of its inflowing rivers. The Winnipeg River, the Saskatchewan River and the Red River are the major inflowing rivers that provide most of the water and nutrients to Lake Winnipeg (Figure III.2). There are roughly 60 smaller rivers that also flow into Lake Winnipeg (e.g. the Pigeon, Poplar, Berens, Bloodvein, Wanipigow, Manigotogan, Brokenhead, Icelandic, Fisher and Dauphin rivers). The Dauphin River receives water from Lake Manitoba and Lake Winnipegosis, which first flow into the Fairford River and Lake St. Martin.

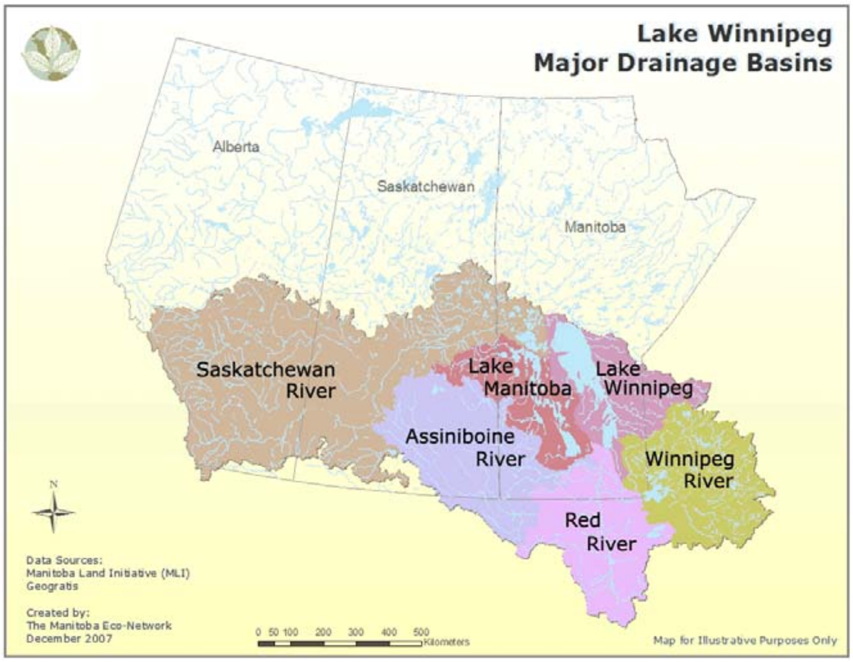

Figure III.2. Lake Winnipeg watershed and its major drainage basins (Manitoba Eco-Network 2007).

Nearly half of the water in Lake Winnipeg comes from the Winnipeg River (Table III.2), which drains over 137,000 km^2 in predominantly igneous and metamorphic bedrock of the Precambrian Shield. The Saskatchewan River is second in volume and contributes about a quarter of the water entering the lake (Table III.2). The Saskatchewan River system drains 416,000 km^2 that extend from the Rocky Mountains in Alberta to the North Basin of Lake Winnipeg; less than 5% of this area is located in Manitoba. The Saskatchewan River has a number of reservoirs along its course, but only one in Manitoba, Cedar Lake, upstream of the Grand Rapids dam. Cedar Lake retains considerable sediment from the Saskatchewan River before it enters Lake Winnipeg. Brunskill *et al.* (1980) estimated that less than 1% of the suspended sediment load at The Pas reaches Lake Winnipeg. The Red River contributes only about 11% of the water entering Lake Winnipeg (Table III.2). It drains about 127,000 km^2 (not including the drainage area of the Assiniboine River, a tributary of the Red), crosses the International Border with the U.S. and includes North Dakota, Minnesota and a small part of South Dakota. Only 26,000 km^2 (20%) is located in Manitoba, with the rest in the northern U.S. states.

Table III.2. Drainage and flow characteristics of major inflowing rivers to Lake Winnipeg (Flow data from LWSB 2006; drainage data from Jones and Armstrong 2001).

River	Mean Monthly Flow (m^3/sec)	% of Total Flow	Drainage Area (km^2)	% of Total Drainage Area
Winnipeg	999	45	137,000	14.4
Saskatchewan	567	26	416,000	43.6
Red	252	11	127,000	13.3 (MB 2.7%, U.S. 10.6%)
Assiniboine			154,300	16.2
Other (not precip.)	400	18	118,950	28.7
Total	2218	100	932,250	100

Inflowing rivers and precipitation contributed an estimated 96,000 tonnes/yr nitrogen and 7900 tonnes/yr phosphorus to Lake Winnipeg between the period 1994 to 2001 (Bourne *et al.* 2002). Despite the comparatively minor contribution of water (about 11%), the Red River was the largest contributor of nutrients with over half (54%) of the total phosphorus load and 30% of the total nitrogen load (Figure III.3). Furthermore, the Red River contributes most of its nutrients to Lake Winnipeg as a pulse in the spring during the melt period (Brunskill *et al.* 1980). The Winnipeg River contributes one fifth of the phosphorus load of the Red River yet has a five-fold greater discharge; thus, lower concentrations are delivered in a larger volume of water over a longer discharge period (Brunskill *et al.* 1980). Much of the nitrogen and phosphorus delivered by both the Winnipeg and Red rivers is in a form that is biologically available. Brigham *et al.* (1996) found, from1975 to 1988, dissolved phosphorus (mostly bioavailable orthophosphate) accounted for about half of the total phosphorus load in both rivers. Furthermore, about half of the suspended phosphorus in the Red River was in bioavailable forms. The Saskatchewan River is a comparatively minor contributor of both nitrogen and phosphorus (Figure III.3) because of the presence of large lakes and reservoirs on this river, which act as settling basins (Brunskill *et al.* 1980).

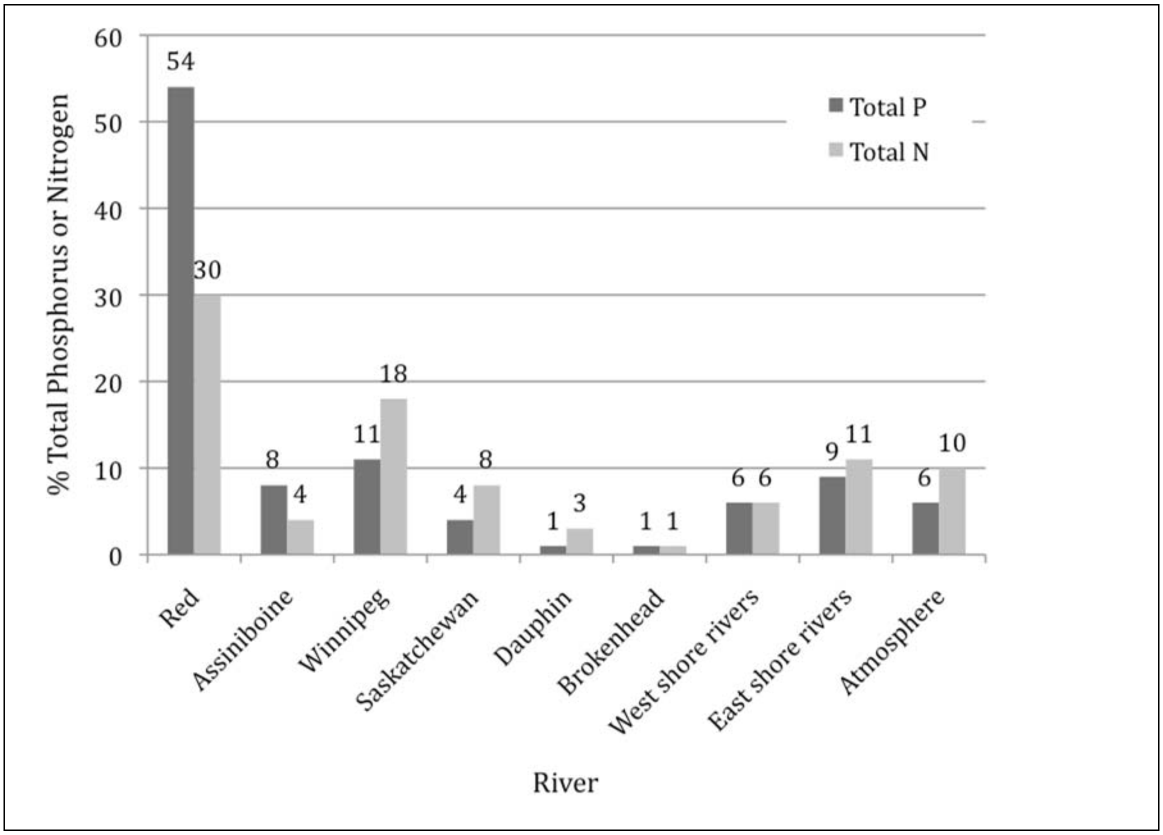

Figure III.3. Percent total nitrogen and total phosphorus loading to Lake Winnipeg, 1994 to 2001 (modified from LWSB 2006).

The South Basin receives over three quarters of the phosphorus entering Lake Winnipeg from the Red and Winnipeg rivers, much of which is delivered in the spring. Movement of nutrients from the South Basin to the North Basin is gradual, resulting in a south-to-north declining nutrient-concentration gradient (Figure III.4) that is typically maintained through at least the open-water season (McCullough 2001).

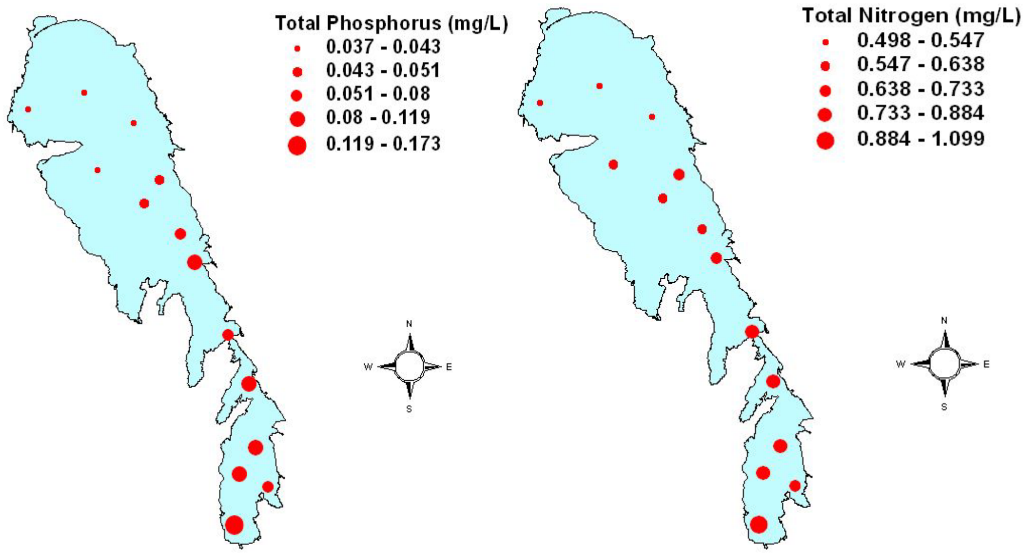

Figure III.4. Station average concentrations of total nitrogen and total phosphorus, 1999 to 2007 (Manitoba Water Stewardship) (E. Page, MWS, unpublished data).

Increasing nutrient loading to Lake Winnipeg has resulted in important changes in the ecosystem. These changes, as well as other stressors that are being imposed on the Lake, are discussed in Chapter IV.

Biological Descriptions and Human Use of Sauger, Walleye and Lake Whitefish

The three quota species of Lake Winnipeg, lake whitefish, walleye and sauger, differ in geographic distribution, habitat requirements, basic biology and importance to people. Lake whitefish is most different from the other two species, but sauger and walleye also differ in important ways, despite belonging to the same genus (i.e. they are close cousins). The summary information in this section is based on the knowledge of the fisher experts on the Task Force and a variety of published sources (especially Scott and Crossman 1973, Carlander *et al.* 1978, Colby *et al.* 1979, Franzin *et al.* 2003, and Stewart and Watkinson 2004), which are in turn synopses of a great number of scientific publications. Specific information for Lake Winnipeg is referenced directly.

Distribution and lake habitats

Lake whitefish are more tolerant of cool to cold water than warm water, whereas walleye and sauger are the opposite. These differences are reflected in differences in geographic distributions and habitats of these fishes in lakes. Lake whitefish occur much further north than walleye and sauger, extending through Alaska, the Northwest Territories and Nunavut as far as Labrador, with northern limits on Victoria and Banks Island. The southern limits of lake whitefish are in Lake Michigan and Lake Erie (MacPhail and Lindsey 1970, Nelson and Paetz 1992). Lake whitefish are typically found in lakes but may also be found in large rivers and even in brackish waters. Young whitefish occur in shallow water but they move to deeper, colder water as they grow older.

In Manitoba walleye are found in lakes and rivers throughout the province as far north as the Seal River watershed (Stewart and Watkinson 2004). In Canada, they are found as far north as the Mackenzie River system almost to the Mackenzie Delta but in only the southwest portion of Nunavut (MacPhail and Lindsey 1970, Richardson *et al.* 2001). They are found throughout the prairie provinces and east across Ontario to southern Quebec (Scott and Crossman 1973). In the United States walleye are native to the north–central states and occur to the south as far as the Gulf coast of Alabama. They have been widely introduced along the eastern seaboard and west of their natural range.

Sauger distribution overlaps that of walleye but over a smaller geographic range and not as far north. In Manitoba their northern limit is the Churchill River system. They occur in both large and small lakes and rivers in Manitoba and Ontario, but only in rivers in Alberta (Nelson and Paetz 1992). In the U.S. Midwest, Plains and Gulf states, they are found primarily in rivers and small impoundments (Carlander *et al.* 1978), with their native range extending as far south as Louisiana and Oklahoma.

The eyes of sauger and walleye have special light-sensitive retinas, which make them well adapted to turbid water. Sauger are less light tolerant than walleye and are more numerous in sediment-laden Manitoba rivers (Stewart and Watkinson 2004), whereas walleye are typically found in less-turbid waters. Young sauger and walleye are generally found in shallow water moving to deeper water as they age. MFB trawl surveys in Lake Winnipeg between 1976 and 1983 showed that young-of-the-year, yearling and two-year-old sauger occurred deeper in the water than walleye (Kristofferson 1985). In Lake Winnipeg lake whitefish are found in the North Basin and north-channel areas, whereas walleye and sauger occur primarily in the South Basin and channel areas and in specific areas along the north-eastern and north-western shores (Lysack 1986a).

Spawning

Whitefish spawn in the autumn usually earlier in northern lakes than southern lakes but even in the same lake the exact date of spawning varies from year to year. Whitefish most frequently spawn over gravel, boulder, rubble and cobble bottoms but also over sand (Richardson *et al.* 2001). In the area of Poplar River on the east side of Lake Winnipeg, whitefish spawned in the last two weeks of October in 1–3 m of water over mud or clay and detritus (Green and Derksen 1987) but this habitat is not preferred in most systems. The eggs incubate on the bottom for several months, hatching the following spring. Cool waters are required for normal egg development and the eggs will suffer extreme mortalities if temperatures exceed 10ºC.

Walleye and sauger spawn in the spring, from mid- to late-April to mid-May. Spawning is in lakes and streams generally over rocks, rubble and gravel in water 0.1–4.6 m deep (Craig 1987, Richardson *et al.* 2001). In Lake Winnipeg sauger spawn one to two weeks later than walleye and appear to have a higher fecundity with smaller eggs containing higher lipid content (Johnston *et al.* 2010). Stocks in the North Basin of Lake Winnipeg spawn later than those in the South Basin. Incubation time of the eggs depends on temperature, ranging from about 25 days at 8ºC to 15 days at 12ºC. Water temperatures that are too high or too low will affect viability of the eggs (Craig 1987).

Growth, feeding and ecological niches

Growth of lake whitefish, walleye and sauger varies from lake to lake but is generally fairly rapid in the first year. At the end of the first year whitefish larvae are larger than the other two species because of their larger eggs and hence larger size at hatching. However, walleye are larger by age three and continue to be larger at a given age, whereas sauger grow more slowly after the first year. Walleye consistently grew faster than sauger in all three regions of Lake Winnipeg (Johnston *et al.* 2010). In a study conducted between 1976 and 1983, the mean length of yearling walleye caught in trawls ranged from 150 mm to 190 mm, whereas the mean size of yearling sauger only ranged from 120 mm to 160 mm (Kristofferson 1985). Lysack (2005)compared growth of the three species from 1979 to 2003: mean fork lengths of six-year-old female walleye, whitefish and sauger were 440 mm, 385 mm and 350 mm, respectively; comparable lengths for males were 390 mm, 385 mm and 325 mm. Interestingly, walleye show a bimodal growth pattern of “normal” and “dwarf” growth that is most prominent in females aged five to seven years in the South Basin and in seven-year-old females in the channel area of Lake Winnipeg. There is no evidence of this growth pattern in North Basin walleye, and it does not appear to occur in sauger in any region of the Lake (Johnston *et al.* 2010). Experimental trawl studies found that the density of young walleye was higher in the South Basin than in the North; density in the channel was intermediate (Lumb *et al.* 2010).

The three species use different areas of the Lake and have different roles in the ecosystem (see Franzin *et al.* 2003 for schematic representations of major foodweb interactions in the Lake Winnipeg fish community). Lake whitefish feed mainly on benthic organisms (e.g. snails, clams and chironomid larvae), copepods, *Daphnia* (Davis and Todd 1998) and some small fishes, including rainbow smelt (*Osmerus mordax*) (Appendix V). Lake whitefish are adaptable, feeding on a range of prey, but unlike walleye and sauger, fish do not make up a major part of their diet. Major predators of whitefish are northern pike, burbot and walleye.

The larvae of sauger and walleye are opportunistic feeders on small plankton. As they increase in length these larvae consume larger prey; they actively feed on young larvae of other fish species by mid-summer of their first year. Juvenile and adult walleye and sauger consume a wide range of fish species depending on what is available. Adults may eat other items, but they are primarily piscivores. The invasive rainbow smelt has become an increasingly important prey species for sauger and walleye in Lake Winnipeg, (pers. comm. A. Derksen 2002, reported in Stewart and Watkinson 2004). Fishers’ on the Task Force personally observed that cisco (“lake herring”: *Coregonus* sp.) predominated in walleye stomachs in the North Basin prior to the 1990s. Remnant (1991), reporting when smelt were first appearing in Lake Winnipeg, found that lake herring and “shiners” (*Notropis* sp.) were the primary items in stomachs of walleye harvested in the spring commercial fishery. Only one smelt was found in the stomachs of 509 walleye. Two decades later Sheppard *et al.* (2010) found that smelt comprised 100% of the diets of walleye larger than 181 mm fork length in the North Basin of Lake Winnipeg. Fishers reported that smelt predominated in the diets of walleye in the North Basin but not in the

South Basin (Appendix V). Offshore mid-water trawl studies in this decade have shown that the greatest number of species and greatest biomass of forage fish are from the South Basin. The offshore forage fish assemblage includes emerald shiner, rainbow smelt (an exotic species), cisco, white bass (an exotic species), yellow perch and walleye. The greatest biomass of emerald shiner and cisco occurs in the South Basin and channel, whereas the greatest biomass of rainbow smelt occurs in the North Basin. (Lumb *et al.* 2010).

Use

Fishing has been an important activity for people of the boreal forest for at least 3000 years (MacDonald 1993), and fish are regarded as the boreal people's most predictable food resource (Graham 2005). The earliest fishing methods were probably spearing, angling and weirs. Gillnets and seine nets came later, as early as 2000 years ago in the upper Great Lakes (Cleland 1982). The Laurel people in southern Manitoba (200 BC–1000 AD) consumed pike (Esocidae), sturgeon (*Acipenser fulvescens*), sucker (Catostomidae), walleye and bass (Centrarchidae) (MacDonald 1993), probably concentrating on spawning aggregations when fishing would have been most efficient. In northwestern Ontario whitefish were predominant at sites where autumn fishing was important (Cleland 1982). 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). When Europeans arrived with the advent of the fur trade, fish was an important source of food for the traders around Lake Winnipeg.

In Canada the use of fish is categorized as follows: 1) domestic or subsistence use of First Nations and Inuit people; 2) sport or recreation; and 3) commercial harvest. After conservation, domestic or subsistence use is always accorded first priority for allocation of harvests. Recreational or commercial harvests are accorded the next priority depending on the jurisdiction, species and area. In Manitoba the first priority for allocation of fish beyond conservation is for the constitutionally protected aboriginal domestic harvest, second is for resident recreational angling opportunity and third is for commercial net harvests, commercial tourism operations, bait fishing and fish farming (Manitoba Water Stewardship 2006, 2010).

Comparisons between subsistence, recreational and commercial fisheries are problematic because of their diversity. In general walleye are a preferred fish for both recreational and commercial fisheries in many systems. Sauger are important commercially only in Lake Winnipeg but are important recreationally in many rivers and reservoirs, especially in the U.S. Whitefish are rarely harvested recreationally but are the most commonly harvested inland commercial species. All three types of fisheries are carried out in Lake Winnipeg but the commercial harvests of the three quota species dominate the domestic and recreational harvests. Data on domestic or subsistence harvests of fish from Lake Winnipeg are generally unavailable, and there are no estimates of the harvests of the three quota species. Recreational harvests are similarly under-studied; only in the most recent national survey was there an attempt to determine walleye recreational harvest rates from Lake Winnipeg (DFO 2007). The paucity of data for domestic and recreational harvests from Lake Winnipeg is treated further in Chapter IV and in the recommendations of this report.

Management of Lake Winnipeg Fisheries

The fisheries of Lake Winnipeg are governed by a number of different federal and provincial acts and regulations (Manitoba Water Stewardship 2010). The Task Force did not do an in-depth review of management rules and regulations but recognizes the many players who can have an impact on fisheries management, and directly and indirectly, on the health of fish stocks. The following legislation is of primary importance:

- The *Constitution Act* (Canada) assigns responsibilities for sea coast and inland fisheries to the federal government, and management of lands and resources to the provincial government, and protects treaty and aboriginal rights relating to fishing;
- The *Fisheries Act* (Canada) and associated regulations under the Act provide for control of fishing through quotas, seasons, gear, etc. and the protection of fish habitat;
- The *Fisheries Act* (Manitoba) and associated regulations provide for licencing, control of records, transportation, loans, etc;
- The *Fish Inspection Act* (Canada) and associated regulations provide for the safety and quality of fish, including processing, storing, grading, marketing, transporting and inspecting;
- The *Freshwater Fish Marketing Act* (Canada) regulates interprovincial and export trade in freshwater fish; and
- The *Species at Risk Act* (Canada) provides for special protection of species that may be threatened or endangered.

Many different agencies are involved but the MFB of the Department of Water Stewardship is charged with the major responsibilities for day-to-day management of Lake Winnipeg fisheries. The priority for resource allocation among uses and user groups is: 1) conservation; 2) constitutionally protected aboriginal domestic harvest; 3) resident recreational angling opportunity; and 4) commercial net harvest (Manitoba Water Stewardship 2010). Sustaining biological viability or conservation is the basic assumption on which restrictions on the other three uses, and user groups, is based. Aboriginal domestic harvests, are not managed proactively in Manitoba (Manitoba Water Stewardship 2010). Manitoba recreational fisheries are managed by seasonal closures, gear, size and possession limits but there are no specific regulations for Lake Winnipeg sauger, walleye or whitefish except for possession limits on the lower reaches of the Winnipeg River (Manitoba Water Stewardship 2009a). In contrast the commercial net fishery of Lake Winnipeg is actively managed.

Fisheries management systems are important because they can affect sustainability of the fisheries. The primary tools used by MFB for the management and control of commercial fisheries in Lake Winnipeg are:

- The QE system, which was introduced in 1972 and modified in 1986 to allow transfer of individual quotas. This system comprises a total lake quota for sauger, walleye and lake whitefish combined. It also includes individual fisher quotas within specific CLAs, which include 12 CLAs plus Norway House, the whitefish fleet, and within-season limits (Scaife 1991, Manitoba Water Stewardship 2007). There are limits on transfers of QEs between different CLAs;

- The "Community Enterprises" ownership of QEs established within CLAs allows community control of quota entitlements for the community skiff fleet and for the whitefish fleet. It also allows sub-allocations to existing fishers and trainees (Lake Winnipeg Quota Entitlement Administrative Procedure 17, Manitoba Water Stewardship 2007);
- Lake Winnipeg Commercial Fishing Areas are defined under the Manitoba Fisheries Regulations and they are different from CLAs. They also differ among the summer, fall and winter seasons;
- Gill net mesh-size restrictions, which control minimum mesh sizes, are defined in the regulations. There are variations that are important to individual communities, but in general, the South Basin and channel fisheries can use nets as small as 3 inches throughout the year. Inshore areas of the North Basin, referred to as "pickerel pockets", can use no smaller than 3¾ inches in the summer and fall and 4¼ inches in the winter. The whitefish fleet is restricted to the central part of the North Basin and must use 4¼ inch mesh nets or larger;
- The timings of seasonal openings and closings are defined in the regulations. Spring opening for the South Basin is set according to the completion of 80% of walleye spawning there (approximately the 3rd to 4th week of May), whereas other areas are opened about five to seven days later. The central part of the North Basin is closed to fishing in the autumn to protect whitefish spawning;
- There are protected areas or sanctuaries that restrict fishing near river and creek mouths; and
- There are "tolerances", which are the allowable harvest levels of walleye and sauger for certain sectors and seasons, as follows: 20% of the QE for the whitefish fleet and 20% for any North Basin winter QEs fished during the open-water season.

Harvest management tools used by other agencies also can have an effect on harvest levels, and thus on biological viability, and include the following:

- Prices offered by the FFMC;
- Delivery service points provided by FFMC and their local agencies;
- Rules established by fisheries cooperatives through the Community Enterprises community fishing rules; and
- Self-regulation amongst fishers (see Pinkerton 1989, Notzke 1994 and Pomeroy and Rivera-Guieb 2006 for discussions on self-regulation of resources by communities and harvesters).

The Lake Winnipeg fishery is often referred to as a "QE system" or an "ITQ system" but it should be clear from the above that it is much more than that. Although the QE system may be paramount, other management tools are also critical for ensuring sustainability of the fishery. How these other tools are implemented is important if management of a fishery is to evolve effectively. Adaptive management (Walters 1986, Hilborn 1992) is a cyclical process of identifying management alternatives or options, development of key indicators, designing an effective monitoring system and then modifying the management actions as appropriate. Adaptive management allows managers to learn from their successes and failures, and recognition is growing of its usefulness in fisheries management around the world (Berkes *et al.* 2001)[4].

<u>Methods for Fisheries Assessment</u>

The assessment of fisheries has been a topic of scientific interest for over a century. Through that time the science of assessment has become more quantitative and complex, incorporating mathematical and technological developments as well as advances in the biological understanding of aquatic systems. However, the basic underlying rationale of fisheries assessment remains fairly straightforward, as described by Walters and Pearse (1996):

> *"There are two basic approaches to assessment of the abundance of fish stocks. One is direct survey counts, using echo-sounding and other fish-counting technologies. Hitherto, these technologies have usually been regarded as incapable of providing measures of absolute abundance; they are used mainly to provide indices of relative abundance. The other, far more widely used approach combines indices of relative abundance with information about absolute catches, using in essence a simple depletion argument (e.g. if 100 tonnes were caught and relative abundance declined 50 per cent, there must have been 200 tonnes to begin with). Multi-year elaborations of this calculation enable reconstruction of the stock size and its change over time."*

The quantitative details of the myriad of methods available today have been developed to answer various technical and quantitative issues in the application of this rationale, including the incorporation of age structure, biological production in the form of growth and reproduction, and mathematical issues that arise due to the nature of the available information.

Data are the foundation of any biological assessment. The methods used will be limited, and sometimes determined, by the type and quantity of data that are available. For example, without information on fish ages, current methods such as virtual population analysis, statistical catch-at-age and even simple catch curves are not available (Hilborn and Walters 1992). Without reliable effort data surplus production methods and even simple catch-rate time series area also unreliable. Therefore, an overview of assessment methods, as they relate to the current state of Lake Winnipeg, is best developed in terms of the available data sources.

Commercial data in fishery assessment

Information on the number of fish caught is the first data collected from any fishery. However, it was recognized in the early 20th century that this information was a poor

[4] For example North Basin fishers questioned the rationale for smaller nets in the South Basin. In an adaptive management approach the rationale and expectations for proposed changes to mesh sizes would be explicitly stated, decision points for success or failure of the new approach defined, results monitored and the changes reversed or accepted for future fishing.

indicator of underlying fish abundance (Cushing 1988). Such catches had to be corrected by the amount of effort expended or fishing activity required to catch the fish because scarcer fish would require more fishing to capture the same number. Thus, catch per unit effort, or CPUE, has been a standard fishery statistic for the last century. Its simplest use is as a direct index of abundance, but it is also used to estimate Maximum Sustainable Yield (MSY) as simple biomass or to adjust more intricate estimates of abundance based on the distribution of ages in the catch (see Hilborn and Walters 1992 for an overview of methods).

The potential pitfalls of CPUE use can be seen in its use as an abundance index, although the following caveats also extend to more complex applications. Primarily, the validity of the calculations depends on the quality of the data collected. Misreported catches, unreported discarding of catches and other fishing mortality that is not included in the final tally of catches has the potential to generate a biased analysis. In addition, the effort value used must capture the impact of fishing on the fish population. For example, in Lake Winnipeg, effort is currently reported as “deliveries” to the FFMC. However, it is unclear how long the nets were in the water, how many nets were in the water or the nature of those nets. Thus, two single deliveries could represent very different intensities of fishing. As such, deliveries are a poor effort measure for calculation of CPUE index series, more complex calculations of MSY or estimates of absolute population abundance.

Detailed and comprehensive catch and effort data alone are not enough to generate a meaningfully CPUE index series. The dynamics of the relationship between catch rate and abundance must also be considered. This relationship is profoundly affected by the behaviour of both fish and fishers. The tendency of fish to aggregate and school is well known, but its implications to the interpretation of CPUE are easily overlooked. For CPUE to track abundance, both values must be proportional to each other. Thus, if abundance decreases by half, we expect CPUE also to be reduced by half. However, this relationship is often not what is observed in fisheries (Harley *et al.* 2001). Instead, as abundance declines, the remaining fish often concentrate in the best locations at densities similar to those present under high abundance. Fish harvesters know these locations and prefer to set their gear there. Thus, commercial catch rates can remain similar as abundance declines. There is a limit to this situation, of course, and eventually fish will appear to “crash” even though the decline has been occurring for some time. This pattern in catch rates is known as **hyperstability** (Hilborn and Walters 1992). Alternatively, when fishing occurs away from the areas that fish prefer, numbers may appear to decline in commercial catch rates even though most of the population remains unfished, a pattern referred to as **hyperdepletion.** Hyperstability is more likely to occur in a fishery where fishers are able to relocate gear in response to fish movements, but either phenomenon will disrupt a proportional relationship between commercial catch rate and abundance. Little can be deduced about the state of a particular fishery from catch rates alone. However, the addition of abundance data collected independently from the fishery and detailed spatial information on fishing effort would make it possible to define these relationships and incorporate them into the interpretation of changes in catch rate over time.

In addition to catch and effort data, information on biological characteristics of the commercial catches is often collected, including the size, age and sex of fish being caught. This information, in conjunction with CPUE, can be used to reconstruct populations that have already passed through the fishery and to estimate what is currently present (Hart and Reynolds 2002). For Lake Winnipeg, however, such methods will require more intense data collection from the commercial fishery than is currently undertaken. Statistical power analyses can assist in determining the intensity of data collection that will be necessary to improve the validity of the results (Walters 1986, Peterman 1990).

Research survey data in fishery assessment

Most of the problems in the use and interpretation of commercial fishery data originate from the fact that fishers direct all their efforts at catching fish. This obvious fact has easily overlooked implications to the interpretation of CPUE trends. The problem is not with fishers, but rather with those people who interpret information from fisheries without considering the biases discussed above. It is critical to have a sound biological survey that is independent of commercial fishing activities. Commercial fishers can be involved, but if they are part of the survey, they must fish as directed by the biologist rather than in their usual manner; they are now fishing for information rather than for the fish themselves.

Abundance surveys often use the same or similar gear to what is used in the commercial fishery. The key difference is that the deployment of this gear is based on a pattern of time and area designed to provide a representative catch of the species being studied *in proportion to their abundance*. The principles of statistical design such as stratification, replication and *a priori* power analysis are used (Quinn and Keough 2002) to improve the precision of the resulting catch-rate index. However, the fundamental goal remains to create an index that is representative of the entire fish population and one that changes in proportion to population abundance.

A representative survey will collect fish in areas that are not favoured by commercial fishing, which avoids the introduction of hyperdepletion, as described above, into the sampling design. In these areas, the “null catches”, or sets that have no fish of particular species, still provide valuable information about those species. Catch rates based on survey data that ignore the null catches are no longer representative. In fact, the frequency of “zeros” itself can be a valuable index from a survey (Bannerot and Austin 1983) and can be expected to increase with declines in fish abundance. The proper treatment of zeros is an area of much debate in fisheries, but deleting them is a poor option that will likely bias the resulting trends (Maunder and Punt 2004).

The precision of the abundance index should be considered in addition to bias. Imprecise estimates will introduce random noise into the resulting indices that may be mistaken for actual changes in underlying fish abundance. Precision can be improved through the introduction of stratification and an increased number of nets deployed. Developing these details requires professional statistical advice, but understanding the consequences of disregarding them does not. Much time can be wasted debating changes that may or may not be random when estimates are imprecise, which can result in reaction to non-existent trends or a failure to detect deteriorating conditions in timely fashion.

Bias and precision are also concerns in the analysis of commercial data. However, due to usually limited resources, their consideration is even more critical in survey sampling, such as the index-net survey on Lake Winnipeg. The coverage of areas typically unfished means that with proper sample sizes and stratification, these surveys will be more sensitive to abundance changes than commercial catch rates, providing a critical indicator for management. Additional age and size data collected during these surveys will allow the examination of changes in age structure and may identify upcoming year classes. Combined with mortality estimates and growth rates, the knowledge of age and size structure can allow predictions of expected fish availability in future years. However, the number and representative nature of the samples still remain considerations. At the very least, these additional factors provide alternate indicators of the changing state of fish populations.

The role of MSY in fishery assessment

In Lake Winnipeg, as in other fisheries, the goal of management is stated to be the MSY[5], the concept of which is based on determining a level of harvest that provides the greatest yield from the fishery in all years. The MSY value can be calculated from commercial fisheries data when accurate information is available for both landings (catch) and fishing activities (effort). Perhaps the greatest contribution of MSY to fisheries was the formal recognition of natural limits to the level of exploitation desired in a fishery, in contrast to the perspective of the 19th century stated by T.H. Huxley (Inaugural Address Fisheries Exhibition, London, 1883) regarding marine fisheries:

> *"I believe that it may be affirmed with confidence that, in relation to our present modes of fishing, a number of the most important sea fisheries, such as the cod fishery, the herring fishery, and the mackerel fishery, are inexhaustible."*

After this address modes of fishing continued to develop and limits to fisheries became more apparent. By the end of the 1970s it became obvious that fisheries could be exhausted and the even more restrictive MSY approach was insufficient to avoid collapse in the presence of highly variable biological fish production.

The classic example of MSY failure is the 1972 collapse of the Peruvian anchovy fishery, in which the best available science was used to set MSY based quotas. Unfortunately, the MSY model did not account for fluctuations in biological fish production associated with El Niño or biases expected in developing fisheries (Pitcher and Hart 1982). As a result overharvest closed what had been one of the largest fisheries in the world. Because of this event and the controversy that it inspired, fisheries scientists now recognize that a single,

[5] The stated MFB guideline for managing commercial net fisheries is *"Quotas beyond the estimated MSY should not be considered"*. However MFB recognizes that this is not optimal, that the approach does not account for year-to-year variation in year-class strength nor does it protect a specific amount of spawning stock.

unchanging total harvest that is not adjusted during poor conditions is a high-risk management strategy that will eventually lead to fishery collapse. Delays in the recognition of poor conditions only exaggerate the risk, emphasizing the need for accurate fisheries assessments and their incorporation into regulatory regimes (Saetersdal 1980).

Today MSY remains an important concept within fisheries management, but now it is considered as a reference point with the understanding that calculated MSY values will usually be overly optimistic and not truly sustainable (Mace 2001). Current applications of MSY strive to set harvests at a level below calculated MSY levels: MSY has become a high-risk, upper limit to allowable harvests (Mace 2001). The goal in setting limits below the calculated MSY is to allow for uncertainty in the biological productivity and to place a buffer of biomass between harvests and conditions that would lead to collapse. MSY can be calculated from commercial fisheries when reliable catches and records of fishing effort are available (see Hilborn and Walters 1992 for a review of methods). However, inaccuracies and biases in these data translate into less-reliable MSY estimates and inappropriate harvest levels. Logically the less faith we have in the MSY estimate the greater the "buffer of biomass" should be to account for it. However, this discussion is premature for our report. True MSY management requires estimates that are not scientifically defensible with the data currently available for Lake Winnipeg.

The Precautionary Principle and Precautionary Approach

Ecosystems, especially large systems like Lake Winnipeg, are complex and decisions on harvest will always carry a degree of uncertainty. As noted above, more organized data-collection systems can reduce uncertainty in decisions; however, there will always be a degree of uncertainty. To deal with the problem of making difficult decisions, organizations tasked with managing natural resources have used the Precautionary Principle and precautionary approach.

> *Precautionary Principle: a general philosophy to managing threats of serious or irreversible harm where there is scientific uncertainty.*

Good risk management compels us to use caution and to take uncertainty into account when making decisions. Application of the Precautionary Principle requires increased risk avoidance where there is risk of serious harm and uncertainty is great. The Precautionary Principle applies widely to conservation, management and exploitation of living aquatic resources to protect them and preserve the aquatic environment. The absence of adequate scientific information should not be used as a reason for postponing or failing to take conservation and management measures. The Principle is applicable to all fishery management strategies.

> *Precautionary approach to fishery management: the practical application of the Principle in terms of tactical decisions for quota setting.*

One might ask: What are the minimal elements a harvest strategy must have to comply with a precautionary approach? The Canadian Federal Government Precautionary Approach Framework as applied to fisheries prescribes three stock status zones (Figure III.5) (DFO 2010).

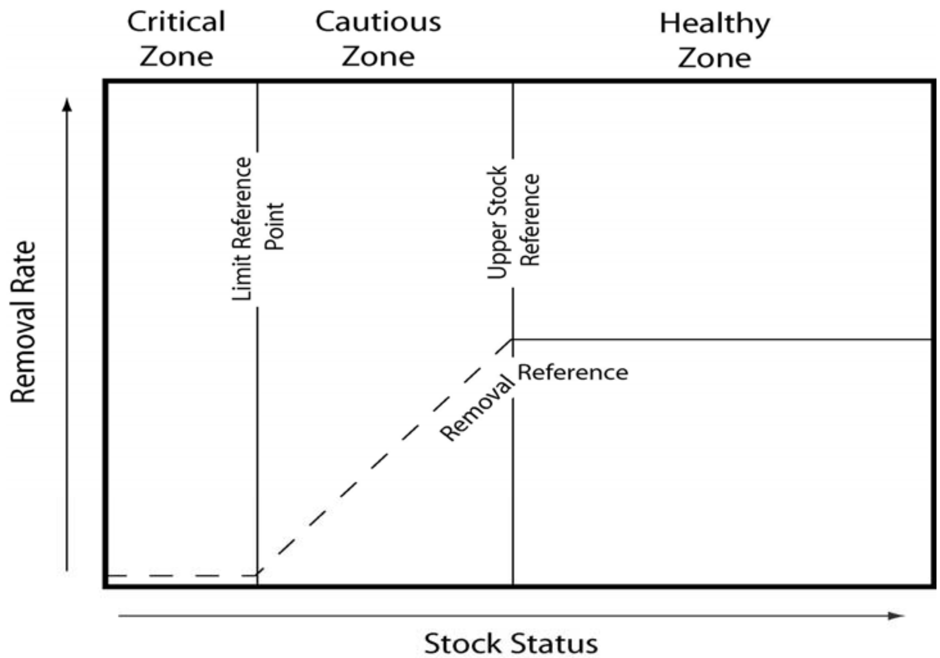

Figure III.5. The Precautionary Approach Framework

Key elements of the Framework are as follows:

- The *Limit Reference Point* is the stock level below which productivity is sufficiently impaired to cause serious harm. The zone below the Limit reference point is called the *Critical* zone;
- The *Upper Stock Reference Point* is the stock level threshold below which the removal rate is reduced. The stock status zone above the Limit reference point but below the Upper stock reference is called the *Cautious* zone. The stock status zone above the Upper stock reference is called the *Healthy* zone;
- *The Removal Reference* is the maximum acceptable removal rate;
- In the *Healthy Zone* the removal rate should not exceed the Removal reference;
- In the *Cautious Zone* fisheries management actions should promote stock rebuilding towards the Healthy zone. The removal rate should not exceed the Removal reference; and
- In the *Critical Zone* fishery management actions *must* promote stock growth. Removals by all human sources must be kept to the lowest possible level.

In a general sense the Precautionary Principle ensures that uncertainty does not inhibit prudent steps toward resource conservation. It is understood that ecosystems are fragile, so that decisions are made on conservation before a point of no return. Typically international organizations have set specific targets for calculation of the key reference points and Removal reference, such as biomass and fishing mortality at MSY. However, there are many practical proxies used for these values, i.e. metrics that are easily measured and that are deemed to track overall stock status. The key to the approach is that all partners in management should agree, in advance, on the measures taken to ensure sustainability of the fishery. These measures are best established when the fishery is in or near the Healthy zone.

In the following section we discuss a practical use of reference indicators within the Precautionary Principle.

Use of Reference Indicators for Lake Winnipeg Sauger, Walleye and Lake Whitefish Stocks Within a Precautionary Approach

The variables discussed in the section above on methods for fisheries assessment (e.g. CPUE, MSY, and other biological characters of a stock such as growth rates, mean age etc.) are examples of reference indicators. Reference indicators are simple measures that tell us what is happening to fish stocks. They should be statistics that are scientifically credible and representative and can help track trends in the state of a fish stock (Environment Canada 2008).

In 1995 the FAO of the United Nations produced a Code of Conduct for Responsible Fishing—a guide and an initiative to improve fisheries management (FAO 1995). An evaluation of how well countries have lived up to the code revealed very poor compliance (Pitcher *et al.* 2008, 2009). A fundamental principle of the Code is that government agencies need to establish reference indicators and target and limit reference points, and determine actions to be taken if those points or indicators are exceeded (FAO 1995). Target reference points may be viewed as a condition of the fishery to be achieved or striven for, whereas limit reference points may be viewed as conditions of the fishery at which significant actions must be taken to avoid unwanted results such as stock collapse (Pitcher *et al.* 2008, 2009). For example, if an indicator is the number of fish in a population, a target reference point would be the desired population size, whereas a limit reference point would be a low population number that would trigger some action such as restrictions on the fishery. Over half the countries had failing grades for compliance with respect to this basic prerequisite for effective fisheries management (Pitcher *et al.* 2008).

No clear reference indicators have been established for Lake Winnipeg fisheries, although MFB has identified the following stock-monitoring criteria:

- Presence of 3 year classes at >15% each;
- Stable or increasing mean age; and
- Mean age of maturity < mean age of the catch.

There are advantages in setting up a management system that does not depend on a single limit reference point especially when that point can only be measured with low precision. When limited data are available or when data collection is expensive, a multiple-indicator approach, based on a range of suitable indicators, will provide an ideal management tool (Kelly *et al.* 2006). Examples of indicators that have been considered for other fisheries include:

- Raw catch or CPUE;

- Mean age/length/weight of population samples;
- Age structure of population samples;
- Area distribution; and
- Interview information and other subjective sources.

Caddy (1998) proposed using a suite of reference points that could form a component of a management system as long as management and industry work together. Caddy (1998) outlined a “traffic-light” approach to the use of limit reference points to provide advice to management on the status of fish stocks. Management responses are expected to be progressively more severe as the reference points pass from green to orange to red. Mohr and Ebener (2005) described a similar system for Lake Huron lake whitefish using a minimum of six and as many as 18 indicators to determine the status of stocks in 17 quota-management areas.

Three points should be emphasized. First this approach must have the full support and cooperation of fishers, the management agency and the industry. Second clear limit reference points (i.e. decision points) and clear management guidelines for action must be established in advance, not after the fact in an *ad hoc* manner. Third the process must be evolving to allow new information and approaches to be incorporated as conditions change. These three points are key to an approach to resource management called “adaptive co-management”, a process that permits stakeholders to share management responsibility and to learn from their actions through multi-level feedback. Adaptive co-management includes a shared common focus, a high degree of interaction, multiple levels of shared responsibility, some autonomy at different levels, generation and sharing of knowledge at all levels, flexible learning, and recognition of uncertainty. It combines shared decision-making between governments and resource users, the mark of co-management (Pinkerton 1989, Berkes *et al*. 2005, Pomeroy and Rivera-Guieb 2006), with the cyclical process of identifying management alternatives or options, development of key indicators and designing an effective monitoring system of adaptive management (Walters 1986, Hilborn 1992).

The fishery of Lake Winnipeg is data deficient (see Chapter IV), and the approaches espoused by Caddy (1998), Mohr and Ebener (2005) and Kelly *et al.* (2006) can provide lessons for this fishery. The choice of indicators to use will depend on factors, such as data availability, cost of data collection and variability of the indicator. In Appendix IV, we provide the Task Force assessment of potential reference indicators for Lake Winnipeg. Use of reference indicators and adaptive co-management should be critical for future decision-making on any changes to allowable fish harvests for Lake Winnipeg (see Chapter V).

IV. EVALUATION AND ANALYSES

In this Chapter we provide our analysis of the current state of health of the lake whitefish, sauger and walleye stocks of Lake Winnipeg. First we summarize information on the commercial harvests of quota species, and harvest-management tools used on the Lake and their relation to the long-term health of the fish stocks. Then we provide our evaluation of data available for assessing the stocks and what those data can tell us. Last we describe the minimal elements required in a harvest strategy to comply with a precautionary approach and our assessment of the health of the fish stocks within the context of a precautionary approach. In the second part of the Chapter we address some of the unknowns or uncertainties that need to be considered, including: 1) the probability of the existence of discreet stocks of the three quota species in different geographic areas of the Lake; 2) the currently unknown harvests from the domestic and recreational fisheries; and 3) and environmental changes that have occurred and are occurring in the Lake.

QUOTA SPECIES

Overview of Harvests of Sauger, Walleye and Lake Whitefish in Lake Winnipeg

Whitefish and walleye contribute over 20% of the commercial landed catch of freshwater fishes in Canada with walleye being by far the most valuable fish, especially in Manitoba (Table IV.1). Over 99% of the sauger harvested in Canada is taken in Manitoba

Table IV.1. Mean commercial production (thousands of kg) and landed value (thousands of $) for sauger, whitefish and walleye between 1997 and 2006 for Manitoba and Canada (from www.dfo-mpo.gc.ca, accessed August 15, 2009).

Species	Manitoba		Canada	
	Quantity x 1000 (kg)	**Value x 1000 ($)**	**Quantity x 1000 (kg)**	**Value x 1000 ($)**
Sauger	708 (5.4%)	2339 (9.2%)	709 (1.9%)	2344 (3.1%)
Whitefish	2391 (18.3%)	2629 (10.3%)	8506 (22.6%)	12,369 (16.4%)
Walleye	4417 (33.8%)	14,983 (58.7%)	8125 (21.6%)	32,511 (43.2%)
Total	13,057	25,538	37,602	75,216

Commercial harvests for Lake Winnipeg have been well-documented. Heuring (1993) and Franzin *et al,* (2003) summarized the fishery of the Lake, including landed commercial catch from 1883 to 1991. (Readers are directed to those reports for detailed descriptions that are beyond the scope of this current review.) Lake Winnipeg commercial fish harvests from 1883 to 2008 are summarized in Appendix III. Table IV.2 shows decadal means of quota species and total marketed harvests of all species from the 1940s to the present, but our review focused primarily on the most-recent decade rather than the historical harvest.

Table. IV.2. Mean commercial harvest (thousands of kg) by decade of Lake Winnipeg quota species from the 1940s to 2000s (i.e. 2008) (see Appendix III for details).

Decade	Whitefish (kg x 1000)	Walleye (kg x 1000)	Sauger (kg x 1000)	Total (Quota spp.)	Other Species (kg x 1000)	Total Harvest	Quota Species (% of total)
1940s	1299	1998	2737	6034	1688	7722	78
1950s	991	1854	1479	4324	1578	5901	73
1960s	567	603	1374	2543	915	3458	74
1970s	1028	1205	1370	3603	662	4265	84
1980s	1591	1911	1795	5298	459	5757	92
1990s	1089	1608	1316	4014	784	4798	84
2000s	1420	3914	450	5784	409	6193	93

The decadal mean summaries eliminate year-to-year variability due to seasonal fluctuations in fishing conditions, so it is clear that over time there have been major biological changes in the lake. Walleye and sauger show six-fold differences in commercial harvests from the lowest decade of production to the highest, whereas lake whitefish catches are less variable. Other species have never contributed more than 30% to the total harvest, and closer to 10% in the past three decades. Harvest levels are considered further in subsequent sections of this Chapter.

Analysis of Harvest Management Tools and the Suitability of Multi-species Quotas

In this section we consider the suitability of the harvest tools currently used in Lake Winnipeg, particularly the multi-species quota, from the biological perspective of the health of the fishery.

The Lake Winnipeg sauger, walleye and lake whitefish fisheries are managed under a multi-species quota of 6.52 million kg. The quota system was introduced in 1972 with individual, non-transferable quotas. The present QE system, which allows transfer of quota between fishers, was implemented in 1986. Supplementary management tools include restrictions on licencing areas within which fishers can exercise their QEs, gill net mesh-size restrictions, timing of seasonal openings, tolerance levels, season opening and closing dates, and protected areas (see Chapter III: Management of Lake Winnipeg Fisheries).

The Task Force was charged with advising best practices with respect to fish-stock management. Multi-species fisheries are notoriously difficult to manage. Other strategies are possible (e.g. effort quotas and protected areas: Walters and Bonfil 1999), but ITQ systems are widely recognized as an effective tool for most multi-species fisheries if implemented with full consideration of potential problems in enforcement and in fishers' operations (Morgan 1997, Sanchirico *et al.* 2006). Applying ITQs to multi-species fisheries is difficult because of complex multi-species interactions, substantial mingling of stocks and limited ability of fishers to target specific species, resulting in quota overages and discards. Nevertheless Grafton *et al.* (2005) reviewed the British Columbia multi-species ground-fish trawl fishery and argued that an ITQ system can be effectively implemented in a multi-species fishery that includes over 55 distinct quotas while still addressing the discarding issue, equity issues, economic issues and sustainability. According to Sanchirico *et al.* (2006) there are over 170 species around the world currently managed with ITQs. The Lake Winnipeg fishery is a complex multi-species fishery, but based on our review of the fisheries literature, our assessment is that an ITQ system is probably the most effective means of its ensuring its long-term economic, social and biological sustainability.

An ITQ system, in general, may be an effective means of ensuring biological sustainability for the Lake Winnipeg fishery, but we do not have the same degree of confidence in the current system of combining three species into a single lake quota and into individual fisher's quotas. Although fisheries management may be simplified if species are aggregated into a single total allowable catch (TAC), it is questionable, based on biological criteria, whether species should be managed as a multi-species quota even if they are closely related species. An aggregate quota would be appropriate biologically only if there were no substantial differences in age structure, recruitment, growth rates and year-class strengths of the different species, and the species were routinely caught in the same ratio (i.e. fishers could not target individual species) (Squires *et al.* 1998).

The issue of a common quota for Lake Winnipeg sauger, walleye and whitefish has been commented on by others:

- Symbion Consultants (1996, p. 2) report of the Lake Winnipeg fishery, based on discussions with fisher and MFB managers, concluded that *"The use of the multi-species quota to manage the harvest of three species (pickerel, sauger and whitefish) ... compromises effective fisheries management."*;
- Gislason's (1999, p. 125) report on the Lake Winnipeg fishery at a UN FAO conference on the use of property rights in fisheries management also called into question *"… the wisdom of an aggregate quota when the biology of the three species is different and the price of walleye and sauger is much higher than for whitefish."*;
- Tavel Certification Inc.'s (2008, p. 42) report prepared as a pre-assessment for potential accreditation of the Lake Winnipeg fishery by the Marine Stewardship Council stated: *"Management of the fishery against a single quota for the three target species is fundamentally an unsustainable practice."*; and
- Our survey of Lake Winnipeg fishers (Appendix V) indicated that 45% of participants in the survey would like the Lake quota changed and 8% would like it changed under certain conditions. Among the comments from these respondents were suggestions to separate whitefish from walleye and sauger, and open up whitefish by taking it off the quota altogether.

It is possible that, for some fisheries, fishers' operations and management may be simplified if species are aggregated into a single multi-species quota. The fisher members of the Task Force emphasized the commonalities related to fishing for sauger and walleye and the differences in fishing lake whitefish vs. percids. However, from a stock-health perspective, a multi-species quota could have negative consequences because the biology of the three species is different and the prices offered for the three species can also differ significantly. As described in Chapter III key differences in biological variables, including preferred habitats, fecundity, time and area of spawning, growth rates, size and age at maturity, and behaviour patterns (including migration and response to light) mean that harvesting different species at the same level would certainly interact with the biology of the species and result in different impacts on each species. For example harvesting with large mesh nets will result in higher impacts on walleye and whitefish than on sauger, which mature at a smaller size. The ability of fishers to target particular species in response to price changes is especially critical.

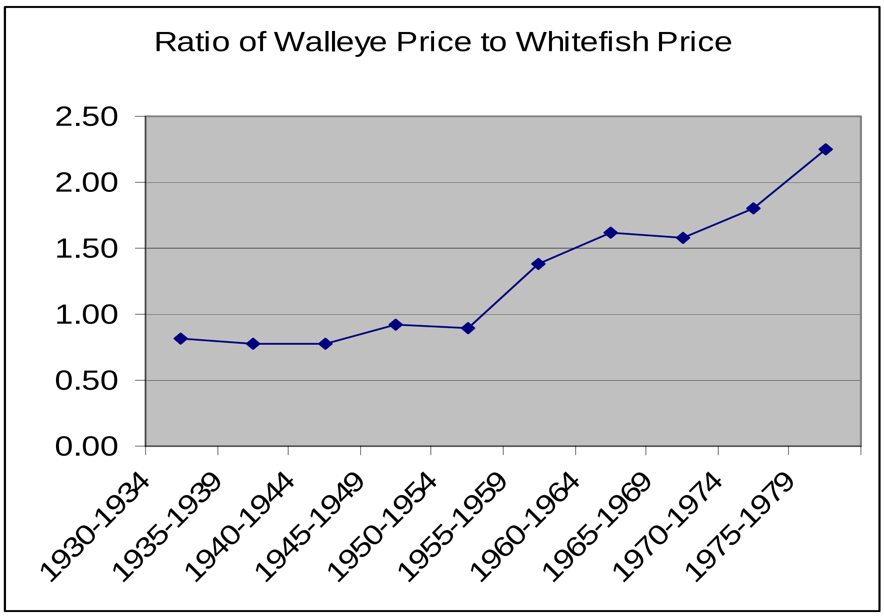

Figure IV.1. Ratio of walleye prices to whitefish prices for Manitoba fisheries from 1930 to 1980 (redrawn from Ayles 1985, figure 7).

In the early decades of the Lake Winnipeg fishery, whitefish had a higher value than walleye (Figure IV.1). Walleye became more desirable as transportation and processing improved and markets changed. The ratio was almost two to one by the time the initial multi-species quotas were implemented in the 1970s. The ratio has fluctuated between three and four to one in recent years (Figure IV.2). Sauger also commands a significant premium over whitefish but is not usually as valuable as walleye, although sauger prices have varied between 75% and parity with walleye in the past decade. We emphasize that recent figures are year-end prices and that there are also significant differences between seasons and for different sizes of each species, but we are confident that the overall trend remains the same. If fishers could not selectively target the three species, price changes would be irrelevant; however, they can target species through area fished, size of mesh, depth of set and other factors[6]. FFMC managers also indicated that changing the prices offered for walleye and sauger and for different sizes of the two species is reflected in deliveries of harvested fish (pers. comm. D. Bergunder). With a single multi-species quota, and a goal of MSY, price differences between species could lead to overharvesting of the more-profitable species and underharvesting of the less-profitable species.

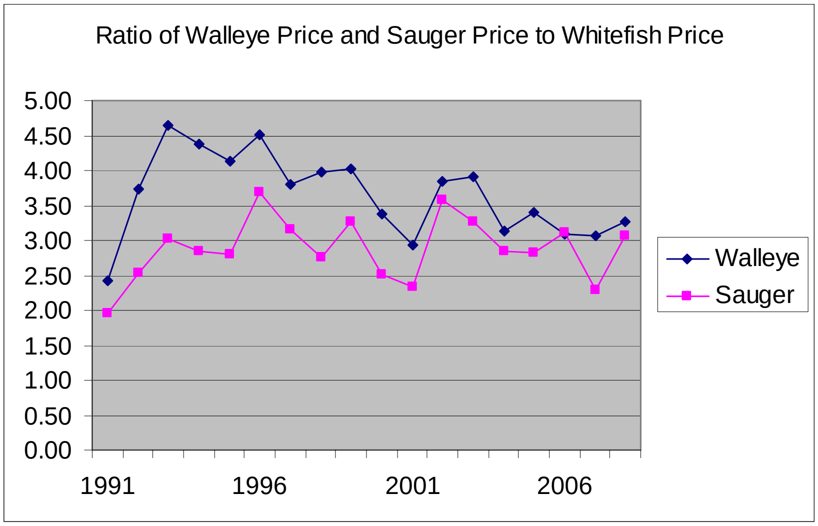

Figure IV.2. Ratio of walleye and sauger prices to whitefish prices based on annual final FFMC prices (FFMC data from D. Bergunder, February 2009).

Our assessment of the suitability of multi-species quotas also included a review of management practices for commercial fisheries in adjacent provinces and territories. We wanted to determine the extent of multi-species fisheries under conditions where the species are similar and the buyer of fish, the FFMC, is the same and so prices offered to the fishers are comparable.

The fisheries of the Northwest Territories (NWT) are managed via quota, gill-net mesh size and season closures (pers. comm. Peter Thompson). There are over 400 lakes for which a quota has been established. Many of those lakes have two species quotas for lake whitefish and lake trout but there are no lakes with multi-species quotas that include walleye (DFO 2009a). Most of these lakes are very small with quotas between 1000 and 5000 kg. Although there are two species quotas actual harvests consist primarily of whitefish. From 2000 to 2006 total whitefish production averaged 786,000 kg, approximately 16 times the lake trout production (DFO 2009b). The difference in production may be a reflection of FFMC prices—the value of lake trout is only about half of that for whitefish. However, walleye prices are 2.5 times the price of whitefish, but whitefish production is over 22 times that of walleye (DFO 2009b). Great Slave Lake is the only large system in the NWT similar in complexity to Lake Winnipeg . Great Slave Lake has a total quota of 1.95 million kg. It is an open fishery and individual fishers'

[6] The fishers on the Task Force described how experienced fishers could target different species.

quotas do not exist as for Lake Winnipeg (Reist *et al.* 2010). Five of the six regions of Great Slave Lake are fished commercially, whereas the sixth, the deep and complex East Arm, is managed for lake trout sport fishing. The Lake was previously formally managed under a two-species quota. Four of the regions now have regional whitefish quotas, whereas the fifth, adjacent to the East Arm, has a combined whitefish/lake trout quota of 363,000 kg. This fifth region is far from the commercial delivery points, so it is only lightly fished (pers. comm. Larry Dow).

The commercial gill-net fisheries of Saskatchewan are managed by area, mesh size, season, number of nets and individual species quotas (Saskatchewan Environment 2009a,b,c and pers. comm. Peter Ashcroft). Some 1190 lakes have quotas established but less than 300 are fished in a typical year for an annual total harvest in excess of 3 million kg in the present decade (Saskatchewan Environment 2009b). In the past Saskatchewan used to have multi-species total quotas on many northern lakes, but that began to change in the 1970s and early 1980s (pers. comm. Peter Ashcroft). Some very small remote lakes continue to have a combined quota, e.g. Ballentyne Lake has a combined quota of 500 kg for lake trout, pike, walleye and whitefish. Initially the province moved to a system of total quotas with game fish tolerances (pike trout and walleye) that ranged from 10 to 25% (i.e. a commercial fisher could catch that many game fish.). The management system then moved to an individual-species quota system for each lake. For example Lake Athabasca, almost as large as Lake Winnipeg, has individual species quotas of 340,000 kg of whitefish, 150,000 kg of lake trout, 68,000 kg of walleye and 68,000 kg of northern pike. In practice, because prices for walleye are much higher than for the other species, in many lakes fishers concentrate first on walleye. When the walleye quota is reached then all fishing stops (pers. comm. Peter Ashcroft). There are no individual fisher quotas in Saskatchewan.

Commercial fisheries in Ontario are in the Great Lakes, other large lakes (e.g. Lake Nipigon and Lake of the Woods) and smaller lakes primarily in the north. Most smaller lakes in southern Ontario are restricted to subsistence and recreational use. The fisheries of Ontario are very diverse and management differs significantly between lakes. However, the quota management system introduced across the province in 1984, as part of a provincial initiative called “Modernization of the Commercial Fishery”, is the most important system (OCFA 2009). Fishers’ licences, commonly referred to as ITQs, authorize harvests of specific amounts of individual quota species. For example, in Lake of the Woods individual species quotas are established for walleye, perch, lake whitefish, pike, sauger, black crappie and lake sturgeon and each fisher holds a portion of the overall quota. Multi-species quotas are not used in Ontario (pers. comm. Tom Mosindy).

In summary, although there are two species quotas in the NWT, except for one region of Great Slave Lake, they are *defacto* single species quotas for lake whitefish because lake trout harvests are incidental to whitefish. Thus, management regimes in the NWT are dissimilar to those for Lake Winnipeg. Saskatchewan and Ontario are also dissimilar to Lake Winnipeg because their management systems have generally moved to individual species quotas, with Ontario moving even further to a more general system of ITQs for each species.

The Task Force assessment is that the combined sauger, walleye and lake whitefish multi-species quota for Lake Winnipeg is not sound biological practice. Other nearby jurisdictions operating under similar conditions no longer apply such a system, and from a biological perspective, for the conditions that exist in Lake Winnipeg, the scientific literature also does not support such a system.

However, we must point out that the Lake Winnipeg fishery is not managed solely by ITQs. As indicated in Chapter III there are several other harvest-management tools currently used in the fishery, and they can be used to direct harvests from one species, or even a size class within a species, to another within a common quota. These management tools include:

- Area restrictions prevent mass concentration of fishers on single segments or stocks, and thus may provide effective sanctuaries in areas less heavily fished;
- Delaying the opening date in the spring could conceivably protect spawning concentrations of sauger, which spawn later than walleye;
- Increasing the minimum mesh sizes in certain areas of the Lake would protect the smaller sauger;
- Restricting transfer of winter quotas to summer quotas would change the mix of fish harvested; and
- Changes in delivery price of different species and sizes would lead to changes in fishers' behaviour with respect to depth of water fished, area fished and mesh size, thus leading to changes in harvest rates.

The fisher members of the Task Force emphasized the commonalities related to fishing for sauger and walleye and pointed out that changes in some of these harvest management tools might also serve to adequately focus harvests on different species, even for sauger and walleye fishers. For example fishers can shift fishing emphasis, but not exclusively, from sauger to walleye (or vice versa) by using larger mesh sizes to focus on the faster-growing walleye; by fishing at the surface because sauger are more negatively phototropic and prefer deeper and darker waters; by fishing in different areas; and by fishing in different seasons (pers. comm. Ken Campbell, Langford Saunders, Norm Traverse).

The Task Force did not address such options specifically because there is no quantitative information on the effect that changes of any of the above tools would have on harvest levels. Changes in these supplementary management tools would be particularly amenable to an adaptive co-management approach in which specific proposals are proposed/predicted by fishers and government biologists, applied in the fishery and then jointly evaluated for effectiveness at achieving the desired aims.

Partitioning a Multi-species Quota into Individual Species Quotas

Our conclusion from the previous section that a combined whitefish, walleye and sauger quota is unsustainable from a biological perspective, raises the question of how the current three-species quota might be subdivided to provide an initial RAH and potentially separate species quotas. In this section we consider experiences from other nearby jurisdictions faced with similar circumstances and the past history of harvests on Lake Winnipeg to determine a percentage allocation between the three species.

Individual quotas for most lakes in the NWT were originally established on the basis of a standard "rule of thumb" of one-half pound of the quota species per surface acre of the lake. Quotas are adjusted downward if problems are observed in the fish harvests but there are no clearly established protocols for any changes (pers. comm. Larry Dow). For Great Slave Lake, the original total Lake quota established in 1947 (1360.9 to 2268.3 tonnes) was based on sustainable fisheries on the upper Great Lakes and Lake Nipigon (pers. comm. George Low). This quota was gradually reduced over the decades as biologists, managers and fishers recognized that the initial total quota was much higher than the system could sustain (Reist *et al.* 2010).

Initial individual species quotas for Saskatchewan lakes were set primarily on the basis of historical information and trend analysis of the fishery, although for some lakes biological variables of the primary species were used. Formal methods have not been established for modifying the species quotas. Quotas may be reduced, if problems are observed in the commercial harvests, on the basis of local knowledge, local indicators, test netting and negotiations with fishers (pers. comm. Peter Ashcroft).

Quota management systems established for lakes in Ontario used different approaches, depending on the amount of information available from the fisheries and from the fish stocks. We looked specifically at the experiences for Lake Erie, Lake of the Woods and Lake Superior. In Lake Erie international walleye quotas were established in 1976 following a fishing moratorium in 1970 due to high levels of mercury and subsequent limited harvest after 1972. The initial TAC was based on ½(B)(M) where B is the total estimated biomass at carrying capacity and M is the natural mortality at carrying capacity. These variables were estimated from catch–age analyses, inter-agency sampling and commercial harvest data. The models have increased in complexity over time as understanding and data availability increased (Lake Erie Committee 2005, Roseman *et al.* 2010). For Lake of the Woods total quotas were based on Ryder's morphoedaphic index (MEI) (Ryder 1965) partitioned by species, following provincial guidelines. Roughly 33% of Ryder's index was allocated to percids (walleye, sauger and perch), and roughly 10–20% to whitefish. The walleye allocation was based on Adams and Olver's (1977) study on yield and structure of percid communities. The whitefish allocations, along with those for most other species, were calibrated to a specific sector of the Lake based on assessment netting results (pers. comm. Tom Mosindy)[7]. For Lake Superior there was little biological data on fish other than lake trout (lake trout populations were significantly reduced as a result of sea lamprey [*Petromyzon marinus*] predation and over-harvesting). Commercial fishers were required to submit reports on fish catches (primarily cisco or lake herring [*Coregonus artedii*]) and effort, so in theory it was possible to calculate CPUE abundance estimates. In practice, however, commercial

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[7] Although not a subject for consideration by the Task Force the total Lake of the Woods quota for each species was allocated to individual fishers based on the productivity of each local area and past production of the fishers.

fishers did not accurately report catch/effort data and any biological assessment was problematic. Ultimately quotas for lake trout were set mainly based on sampling requirements for monitoring lake trout restoration, and cisco quotas were set mainly based on past catches and on previously established catches for certain areas. The quotas for deep-water ciscos (*Coregonus hoyi, C. artedi, C. kiyi and C. zenithicus*) were based on experimental fishing and the establishment of a total quota of 0.25 kg/ha for waters from approximately 50–100 fathoms (pers. comm. Wayne MacCallum).

The Task Force concluded that circumstances in other jurisdictions do not have a lot to tell us about species-specific productivity of Lake Winnipeg. However, the general approach of using past catches of the species in question offers a reasonable and understandable approach to deciding how a total quota might be divided amongst the three species. We considered two sets of catch data: commercial yield data from FFMC deliveries, and 2) the current index gill-net surveys (Appendix III). The strengths and weaknesses of the two data sets are discussed in the following section. In general the shortcoming of commercial harvest data is that the fishers can selectively fish for whitefish, walleye and sauger, and they do so depending on many factors but primarily price and catchability (sauger are smaller so they require more handling per kg of production). Thus actual reported harvests do not reflect the availability of the species in the Lake and are biased to an unknown degree. The shortcomings of the index gill-net surveys are in the limited number of years the survey has been in place and the limited coverage (i.e. the total number of nets and areas fished each year are very small compared to the size of the Lake and diversity of fish habitats).

Commercial harvests are discussed in the second section of this chapter and presented in detail in Appendix III. There is significant year-to-year variability so we used decadal mean harvests for our assessment (Table IV.2 and Figure IV.3).

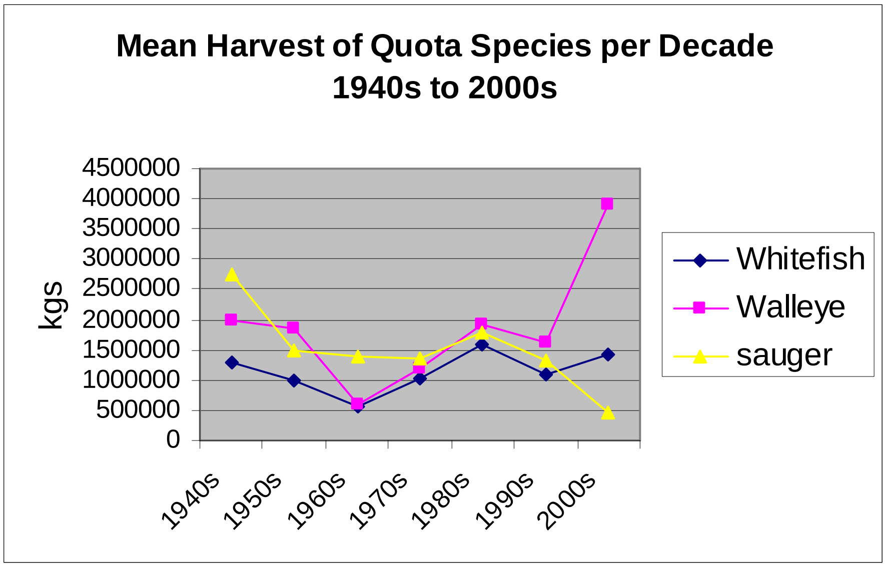

Figure IV.3. Mean commercial harvest of whitefish, walleye and sauger from Lake Winnipeg per decade from the 1940s to 2000s.

Total harvests have varied significantly over the past 70 years, especially for walleye and sauger, but the stability of whitefish harvests is striking (Table IV.2). Except for the low harvests of the 1960s the decadal mean whitefish harvest has stayed between 1.0 million and 1.6 million kg. This stability is particularly obvious if we examine whitefish harvests as a percentage of the total harvest of quota species (Table IV.3). This stability of whitefish harvests is also supported by the limited CPUE data based on whitefish harvests and total FFMC deliveries over the last four decades (see Figure IV.17). In contrast the walleye and sauger percentages have varied considerably (Table IV.3). The harvest of sauger fell to only about 8% of the total harvest of the quota species from the 1990s to the 2000s. The commercial harvest CPUE data also show a significant change in the most recent decade (see Figure IV.6 and Figure IV.9).

Table IV.3. Commercial harvests of whitefish, walleye and sauger as a percentage of the total harvest of quota species for decades from the 1940s to 2000s.

Decade	Whitefish	Walleye	Sauger
1940s	22%	33%	45%
1950s	23%	43%	34%
1960s	22%	24%	54%
1970s	29%	33%	38%
1980s	30%	36%	34%
1990s	27%	40%	33%
2000s	25%	68%	8%

The Task Force considered that if a total quota was to be partitioned on the basis of past harvests then the whitefish portion should be between 22% and 30%. Because the harvests of walleye and sauger show such a dramatic change in the 2000s we felt a more precautionary approach for those species would be to disregard the harvests prior to the 2000s. This approach of only using commercial harvests of the 2000s would result in partitioning as follows: whitefish 25%; walleye 68% and sauger 8% of the total quota allocation.

Index-netting should provide an estimate of relative abundance of a species over a number of years, unbiased by commercial fish prices, assuming that the program is properly done over an extended period of time. The current index-netting program does not provide information on whitefish, but does provide indices of walleye and sauger for a very limited period from 2005 to 2009 (Table IV.4, see also the following section and Appendix III.a for further descriptions of the index-netting program). Except for 2005, which was the first year of the program and was in essence a pilot project to fully develop procedures (pers. comm. Derek Kroeker), index netting shows a fairly stable[8] ratio of walleye to sauger and no apparent trend in either number or weight of either species caught per night. Note that sauger do not grow as large as walleye so they are only fully susceptible to the smaller net panels in the survey gangs, whereas walleye are susceptible to a larger range of the panels (pers. comm. Derek Kroeker). Therefore the walleye to sauger ratio in the Lake is probably not as high as shown in the index- netting data.

Table IV.4. Catch Per Unit Effort, number and weight (kg) of walleye and sauger caught per net per night and percentages for each species in the MFB index-netting program from 2005 to 2009.

Year	No. of Nets	Walleye				Sauger			
		Number of fish per net		Wt (kg) per net		Number of fish per net		Wt (kg) per net	
2005	35	9.2	88%	4.6	92%	1.3	12%	0.4	8%
2006	55	12.0	54%	6.7	73%	10.0	46%	2.5	27%
2007	58	17.2	49%	12.7	71%	17.8	51%	5.1	29%
2008	73	19.6	58%	15.4	79%	14.4	42%	4.1	21%
2009	58	19.2	48%	12.7	72%	20.9	52%	5.0	28%
Mean			59%		77%		41%		23%
Mean 2006–2009			52%		74%		48%		26%

The MFB index netting does not sample whitefish so we used the whitefish percentage from the commercial fishery, as described above (i.e. 25%) and the mean walleye and sauger percentages by weight from the index netting. This approach of using commercial harvests of the 2000s for whitefish combined with index netting for the other two species would result in partitioning as follows: whitefish 25%; walleye 56% and sauger 19% of the total quota allocation.

In the following sections we turn to our assessment of the harvest and monitoring data from the Lake Winnipeg fishery and what those data can tell us about the health of the three quota species.

[8] In this report we use “stable” to mean “varying without trend”. It does not mean that variability is negligible).

Assessment of Lake Winnipeg Sauger, Walleye and Lake Whitefish

Empirical estimates

The 2008–2009 Manitoba Water Stewardship's Annual Report (Manitoba Water Stewardship 2009b, p. 85) illustrates three different MSY estimates for Lake Winnipeg (Figure IV.4). One is based upon a rule of thumb of 1 kg of walleye per ha (source not documented). A second method is identified as "Colby's Method" and refers to an observed relationship between lake area and walleye commercial harvest in 167 North American lakes (Baccante and Colby 1996). Both of these methods provide an indication of expected productivity, but do not allow this estimate to change through time. Empirical methods such as these are based upon past observations of similar situations rather than explicit models of underlying biological processes. The two methods can be quickly calculated and provide a rapid assessment tool in novel or data-limited situations. However, their precision is limited by variability in the reference data (here, the other lakes) used to define the relationship.

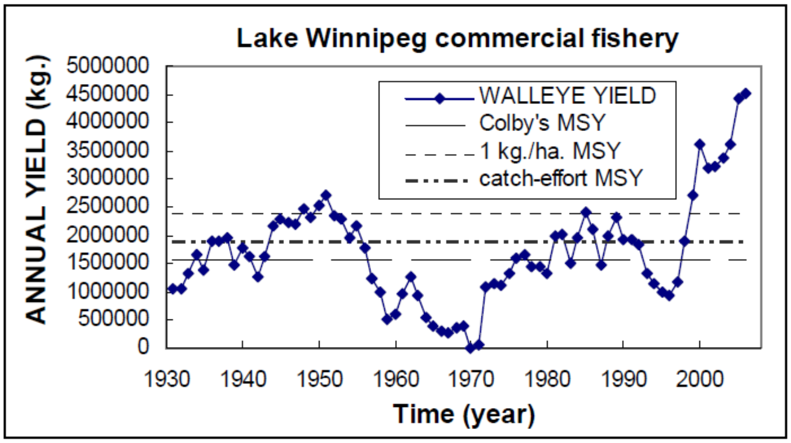

Figure IV.4. Annual yield for the Lake Winnipeg commercial fishery (Manitoba Water Stewardship 2009b, p. 85).

The strengths and weakness of the empirical approach are illustrated by the application of Ryder's MEI (Ryder 1965) to predict the expected harvest of fish in Lake Winnipeg. The MEI requires only two common lake variables to be estimated: total dissolved solids (TDS in ppm) and mean depth (D in ft). Ryder developed a simple formula to predict fish harvest, based upon the observed fisheries in 23 Canadian lakes: Yield (Y) = $2.094*MEI^{0.44610}$, where Y is in lb. However, this relationship is not perfect and results in large ranges in its predictions (Appendix IV), corresponding to variation in the range of lakes used to define it. For Lake Winnipeg with a mean depth of 12 m (39.4 ft) and a TDS of 164 mg/L (COSEWIC 2002), Ryder's relationship predicts that the appropriate yield should be between 6 and 26 million pounds (2.7–11.8 million kg) for all fish species combined. Because of the range of this estimate the method and subsequent improvements upon it (Rempel and Colby 1991) provide limited information for setting a lake-wide harvest limit, although it is a start.

An empirical estimate based upon lake area alone (Baccante and Colby 1996) suffers from similar issues. Through correspondence with the Task Force D.A. Baccante provided a reanalysis of his 1996 data set that illustrates the prediction interval for the relationship (Figure IV.5). Superimposing Lake Winnipeg on this figure (area = 2,375,000 ha) predicts that the sustainable walleye yield is somewhere between 100,000 kg and greater than 10 million kg. Thus current harvests could be well below the sustainable level or they could already be far beyond it. In fact Figure IV.5 shows that the current harvest (yellow square) is already beyond the single most likely predicted sustainable yield of this model (1.6 million kg, yellow circle). The figure also shows that Lake Winnipeg is larger than any of the lakes used to define the relationship. Extrapolating beyond a reference data set should always be treated with caution because extrapolation is based on the assumption that the relationship continues beyond the observed range of data. A final shortcoming is the sustainable-yield estimate is based on the surface area of the lake, which is not expected to change substantially through time. The model does not account for other factors that may influence yield, such as natural fluctuations of the population biomass due to variation in recruitment, growth and survivorship, and other factors such as nutrient loading, climate or introduced species. Other factors may change in a manner that influences abundance, and consequently, harvests. Once again the empirical model provides a broad range of expected values, but does not clearly define a harvest limit.

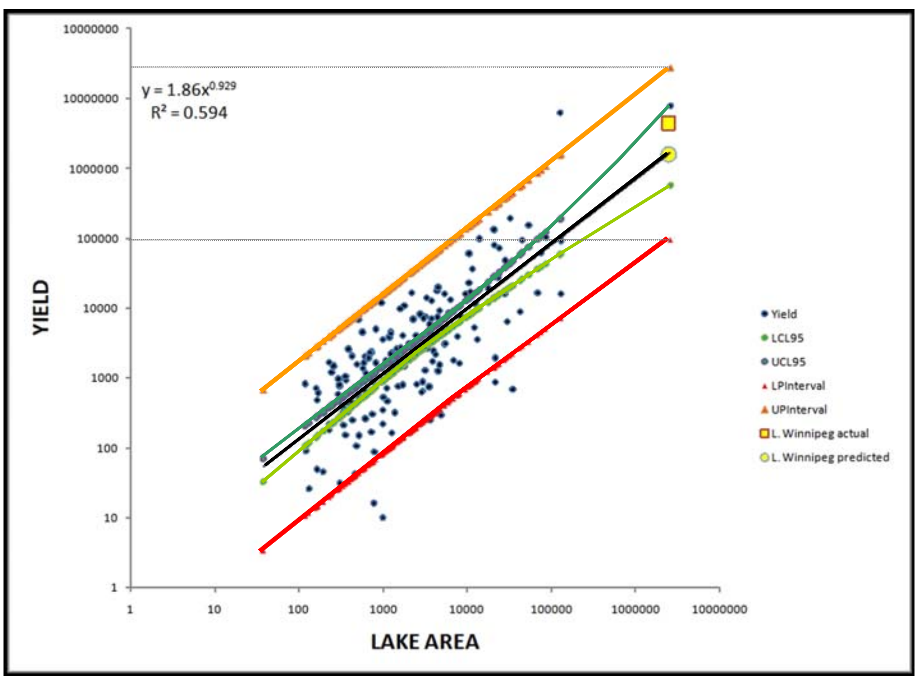

Figure IV.5. Baccante and Colby's (1996) empirical model of fish production with confidence intervals[9].

[9] Analysis with prediction intervals provided by D.A. Baccante (pers comm.). The two lines that are furthest apart (orange and red) define the 95% prediction interval, where most observations for individual lakes are expected to occur. The inner lines (curved dark green and green) are 95% confidence intervals for the line itself (blue).

A more complex empirical relationship predicting walleye yield, used in Ontario, is based upon several physical variables directly related to the quality of walleye habitat (Lester *et al.* 2004), including TDS, D and lake area as in the previous models. Lester *et al.* (2004) also incorporate temperature (as degree-days), water clarity (Secchi depth), maximum depth and thermocline depth. Other models of total fish production have been based on total phosphorus (Hanson and Leggett 1982), phytoplankton production (Downing *et al.* 1998) and chlorophyll (Ogelsby *et al.* 1987). These alternate models could be explored when the required data on Lake Winnipeg become available in the published literature, but the applicability of the reference lakes defining the relationships and the precision of the predictions should be carefully considered before applying the results in a management setting. The South Basin of Lake Winnipeg is very turbid, and although primary productivity is generally light-limited, fish yield is high. Consequently independent variables such as chlorophyll may not be suitable for this basin. Generally these methods represent a broad, first approximation of expected fish production but are not the basis for management that responds to rapidly changing biotic and abiotic conditions.

Estimates based upon survey data

Scientific surveys based upon statistically sound sampling designs provide a more direct method to determine the status of fish populations of Lake Winnipeg. Such methods can detect changes in fish abundance among lake habitats and between years—the critical information required to manage the Lake's fishery. Index-net surveys in Lake Winnipeg provide CPUE information that does not estimate the absolute abundance of fishes in the Lake, but rather their relative abundance among sites or between years. These data are typical of gill-net surveys and allow biologists to follow increases and decreases in fish stocks, and to obtain information about other biological characteristics of the population such as age composition and average growth.

Since the 1980s there have been three distinct periods in the index-net data series of Lake Winnipeg. From 1979 to 2003 index-nets were set at between 10 and 40 locations to gather biological data focusing on the three quota species. Index netting was not done in 2004 because of retirements and staff vacancies. It resumed in 2005 with the hiring of new staff. The new index-net survey is more broadly focused on community structure within the Lake, and samples a variety of habitat types based on established access points. From 2005 to 2009 samples of quota and non-quota species were collected using between 35 and 73 gill-net sets (see Table IV.4, above). During this most recent period 2005 was essentially a training year, and additional, smaller meshes were added in 2008 to the gangs. Thus the most recent years represent a sampling program that is still in development. In the early years of the survey the unit of fishing effort for all species was the 24-hour set of a gang of eight 91.5 m gill-net panels that were each 5.2 m in depth. The mesh size of these panels was 76, 83, 89, 95, 102, 108, 127 and 133 mm (from 3 to 5¼ inches). The years prior to the mid 1980s were trial years when the method was under development (Johnston *et al*. 2010).

A number of points should be considered when examining data from the index-net survey. First and foremost sampling effort is light for a lake the size of Lake Winnipeg. For example we estimate about 400 sets would be required to get the same coverage and ability to detect change as the Ontario Fall Walleye Index Netting (FWIN) survey (see Appendix IV.b). This number of sets is well above the current maximum of 73 sets in Lake Winnipeg. Hence subdividing data from the Lake in an effort to follow trends within regions is statistically questionable. Second none of the available data provide a record of the sets where a particular species was not captured, eliminating useful information from the estimation of abundance (Bannerot and Austin 1983). Last the number of gangs set in a specific year is not available across the entire survey period, so simple corrections to account for zero catches were not done.

Catch rates from the early (1979–2003) and recent (2005–2008) sampling periods are not directly comparable, but comparing trends within series can be revealing. If anything the more recent index-net surveys should more closely follow changes in abundance in the quota species because effort is not directed towards habitats where these species are being commercially exploited, which reduces the risk of hyperstability (observed catch rates do not decline proportionally to decreases in abundance – see above).

Walleye catch rates have varied throughout the period of index-net sampling, reflecting our best estimate of changes in abundance through time. Figure IV.6 illustrates the change in walleye CPUE throughout the sampling program. From the mid-1980s, the index nets show a decline, a period of stability and then another decline that reverses in the mid-1990s. There is a general increase in numbers after the mid-1990s. The change to a new protocol resulted in an immediate drop in observed CPUE, an expected result due to the broader focus of the survey and the location of some nets in areas not ideal for walleye.

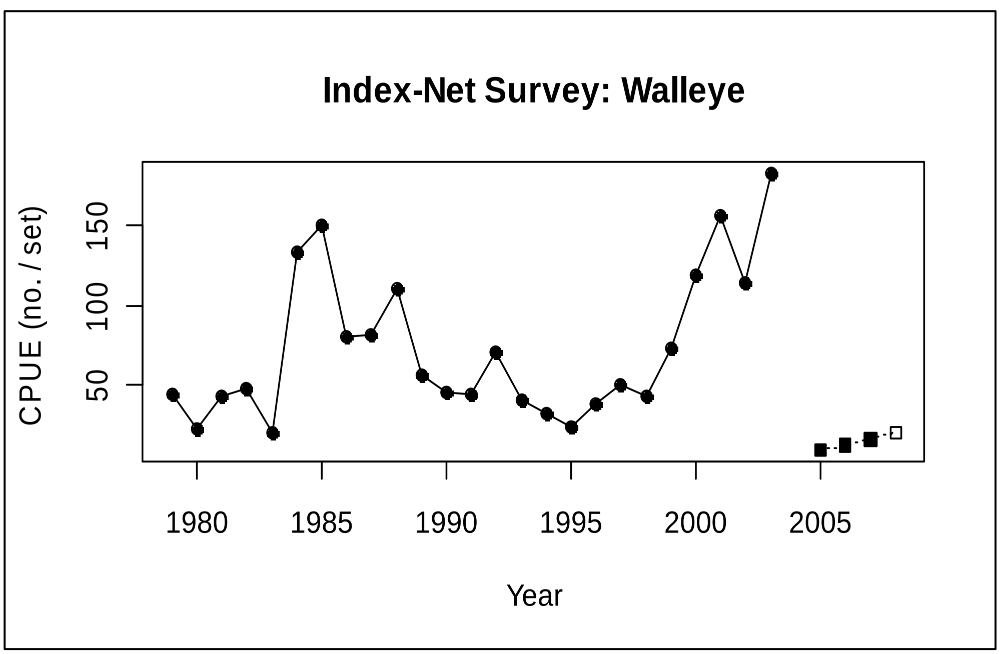

Figure IV.6. Walleye catch rates (CPUE) in the index-net surveys of Lake Winnipeg from 1979 to 2008. Effort is standardized within series with the same symbol (dot, filled square and open square). Walleye catch is in numbers.

The important point to note is that the CPUE continues to increase into recent years under the new protocol, and the 2008 data continue this trend. (See Appendix IV.b and IV.c for summary assessments of shortfalls in the programs on which these estimates are based.) Figure IV.7 shows that most fish caught are older individuals, with the 2001 age class especially numerous as age 7 fish. Index-net data are presented as number of fish, whereas the fishery is run in terms of weight. To change perspective from a biologist to a fish harvester, the 2008 samples can be reported as weight (also called "mass") by age class (Figure IV.8). This presentation emphasizes the current dominance of the 2001 (age 7) year class even more strongly.

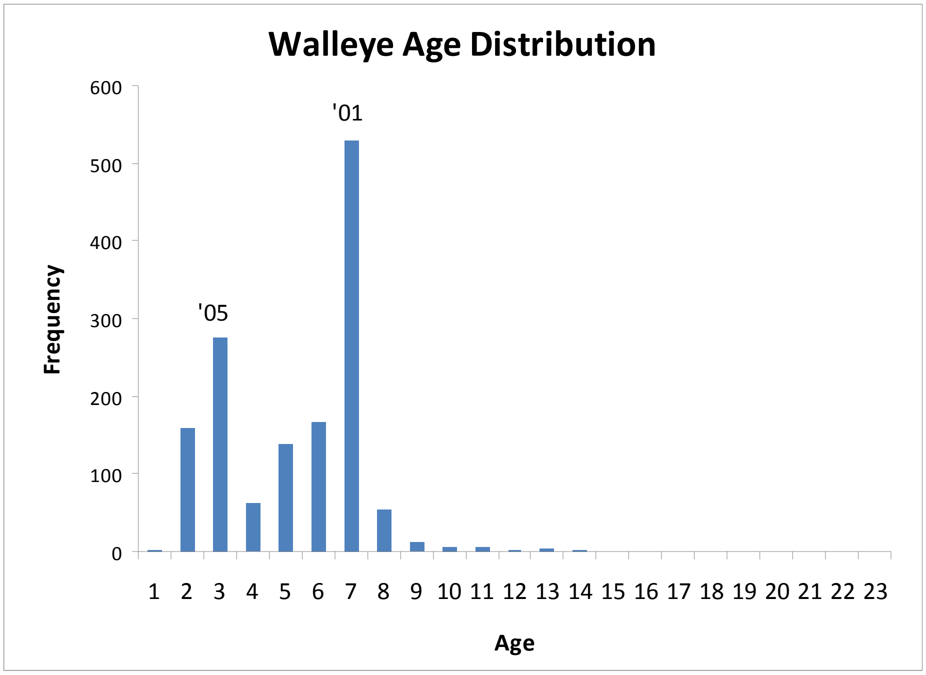

Figure IV.7. Walleye age-frequency distribution from the 2008 index-net program.

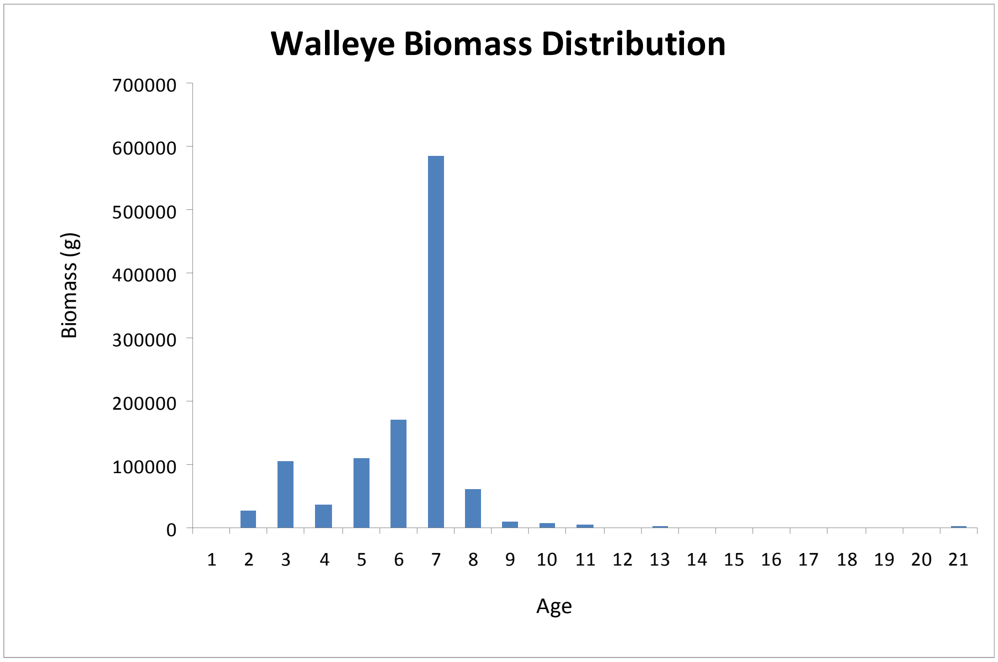

Figure IV.8. Distribution of biomass among age classes of walleye from the 2008 index-net samples.

Regardless of the perspective used the 2008 index-net samples indicate that both the numbers and biomass of walleye in Lake Winnipeg are dominated by the 2001 year class. Another good year class appears to be developing from 2005, but it does not appear to be as numerous as the 2001 year class. Such patterns of sporadic biological production are common and notoriously unpredictable. However, index surveys that sample pre-recruits (in this case with meshes smaller than the commercial minimum) allow insight into fishing expectations for the near future. Thus the 2005 year class is destined to be an important contributor to commercial walleye production in the future.

This walleye age structure indicates that commercial productivity will be tightly linked to the 2001 year class in the immediate future. The growth of walleye apparently slows considerably past age 7, especially in the South Basin (Lysack 1986a). However, there have been significant ecological changes in the Lake since this work was done (see Chapter V: Other Cautions and Opportunities), so current growth-rate patterns are yet to be determined. If growth in the current population slows at similar sizes as in the past then the 2001 year class should continue to be vulnerable and support the fishery in the immediate future (following 2008), but eventually its numbers will decline. At that point the 2005 year class would become the major contributor to the commercial catch. The 2005 numbers are already lower than the older 2001 year class, and it still has to face additional natural and fishing mortality in the coming years. Thus, even if growth and survival are similar to the 2001 year class, there will be fewer fish to catch in the future. Unfortunately the data available do not allow us to determine if this will have a serious impact on commercial production, although some reduction in catch rates is to be expected. Better catch-at-age data, in the form of age distributions of the commercial catch and current growth studies, would allow the development of a dynamic pool approach (Hart and Reynolds 2002) that could provide clearer forecasts of changes in available fish for management decisions.

Sauger catch rates in the index-net survey have also varied over time (Figure IV.9). Index-net data for sauger were not consistently available for the most recent years (2005–2008) so only the catch rates for years 2003 and earlier are presented here. These catch rates indicate a decline in the late 1980s followed by lower but relatively steady abundance for much of the remainder of the survey. The final years (2000 onward) appear to fluctuate wildly due to the small number of sets (3–4) that actually caught sauger. This small number of sets results in poor estimates that are unlikely to be representative of true changes in abundance. The general lower abundance and increasing absence of sauger in survey sets are cause for concern, even though index-net catch rates were relatively stable through the 1990s. However, the survey during this time period was directed towards catching a fixed number of walleye rather than broadly representing the fish community (pers. comm. Derek Kroeker). Thus these trends could also be the result of targeting index-net effort away from sauger in the 1990s to follow walleye more closely.

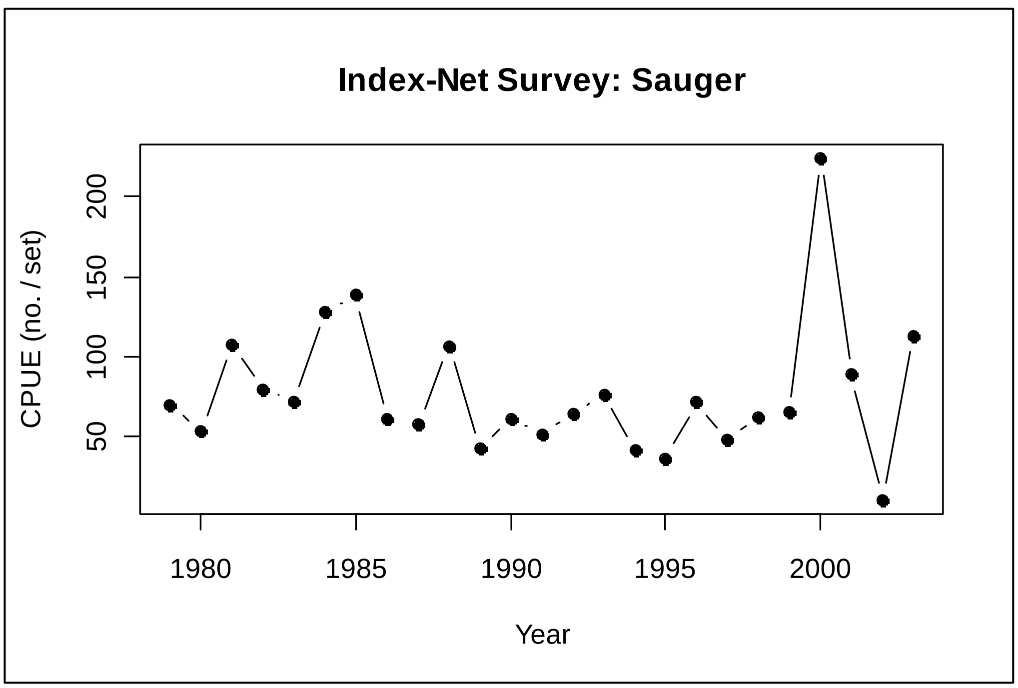

Figure IV.9. Sauger catch rates in the index-net survey from 1979 to 2003. Catch per unit effort (CPUE) is measured as the average number of sauger per set among those sets where sauger were caught.

The distribution of sauger ages and biomass appear superficially similar to those of walleye (Figure IV.10 and Figure IV.11). Numbers and biomass are also dominated by two age classes, illustrating that biological production is uneven among years. However, in this case, the younger age is more abundant than the older, which is the expected pattern under stable mortality and similar year-class strengths in good recruitment years.

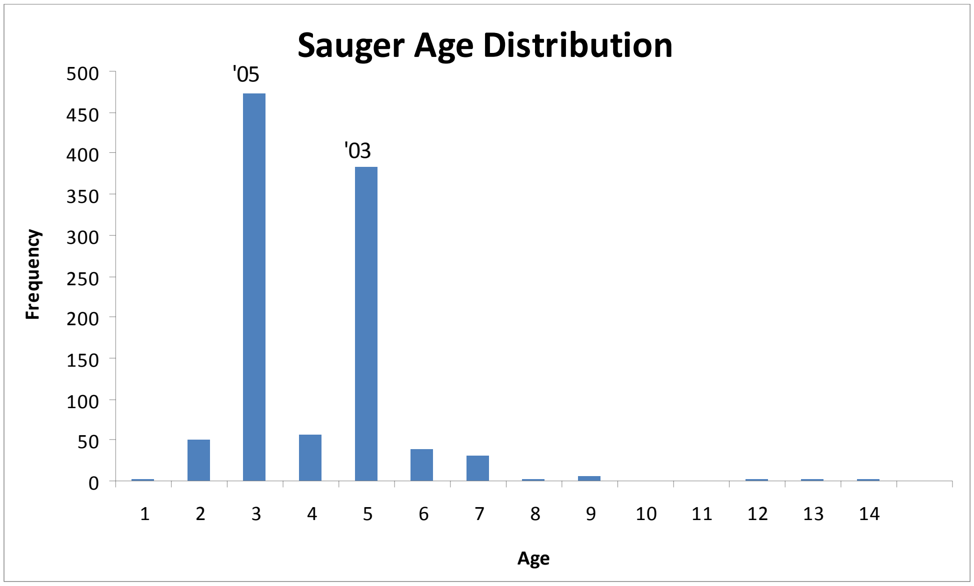

Figure IV.10. Sauger age-frequency distribution from the 2008 index-net samples.

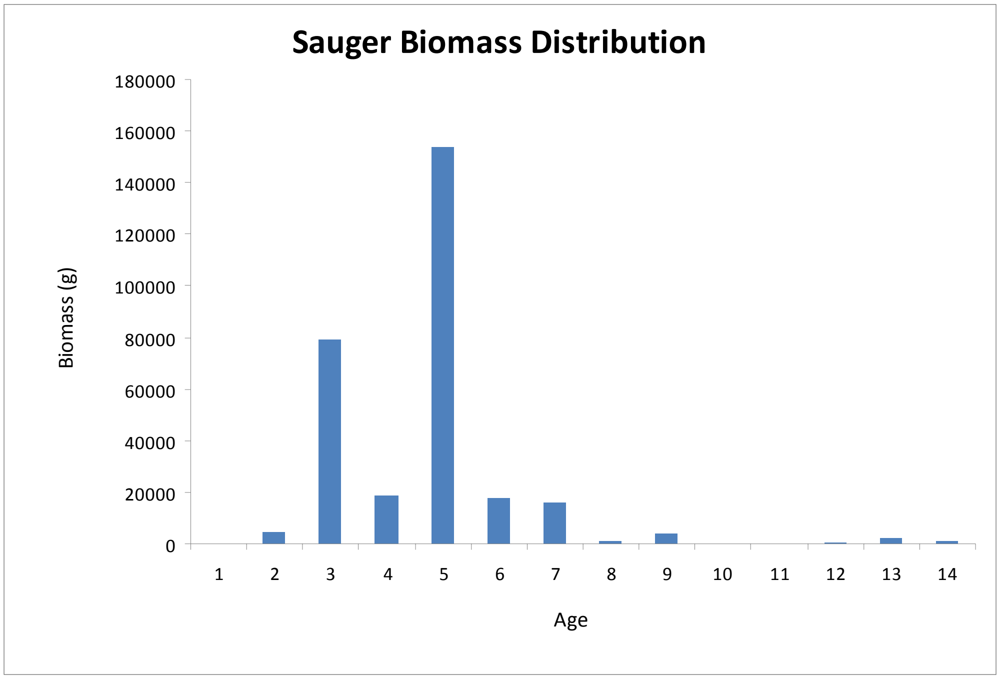

Figure IV.11. Distribution of biomass among age classes of sauger from the 2008 index-net samples.

Similar to sauger the index-net catch rates of whitefish declined in the late 1980s and then stabilized at a low level throughout the 1990s and into the 2000s (Figure IV.12).

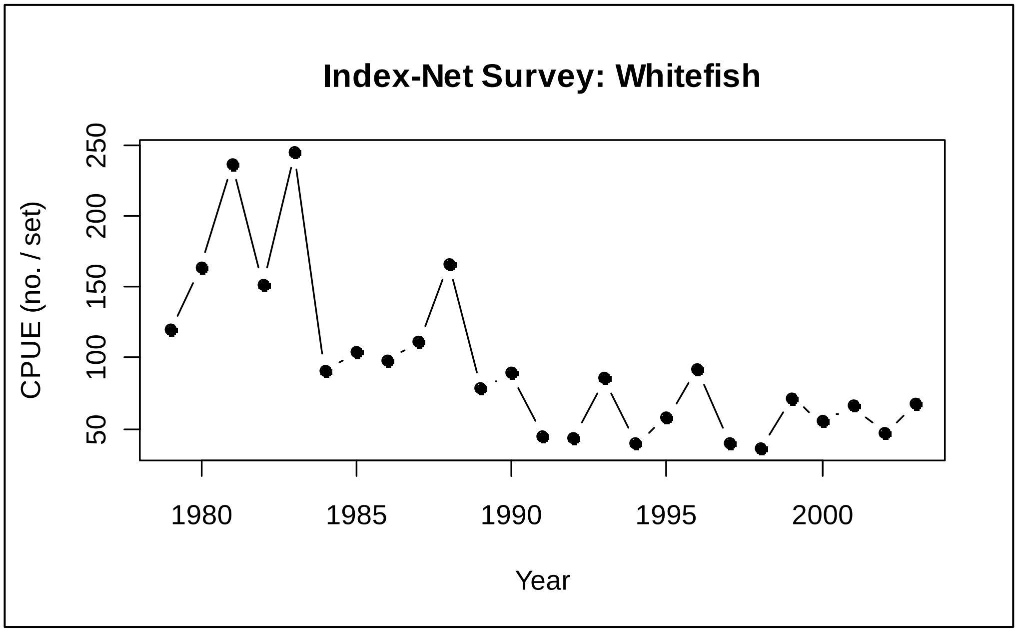

Figure IV.12. Whitefish catch rates in the index-net survey from 1979 to 2003. Catch per unit effort (CPUE) is measured as the average number of whitefish per set among those sets where whitefish were caught.

Unlike sauger the catch rates do not fluctuate wildly at the end of the series as a result of the small sample sizes. The greater stability of whitefish catch rates since 1990 suggests a stable but low abundance over the end of the early survey period. The distribution of age classes in the most recent survey also illustrates the dominance of two age classes in the 2008 fishery, but both numbers and biomass are spread more evenly among the age classes than in either walleye or sauger (Figure IV.13 and Figure IV.14). The lack of fish below age 3 initially suggests recent recruitment failure, but whitefish is long-lived and relatively slow-growing so the data likely only reflect a lack of vulnerability to the fishing gear used.

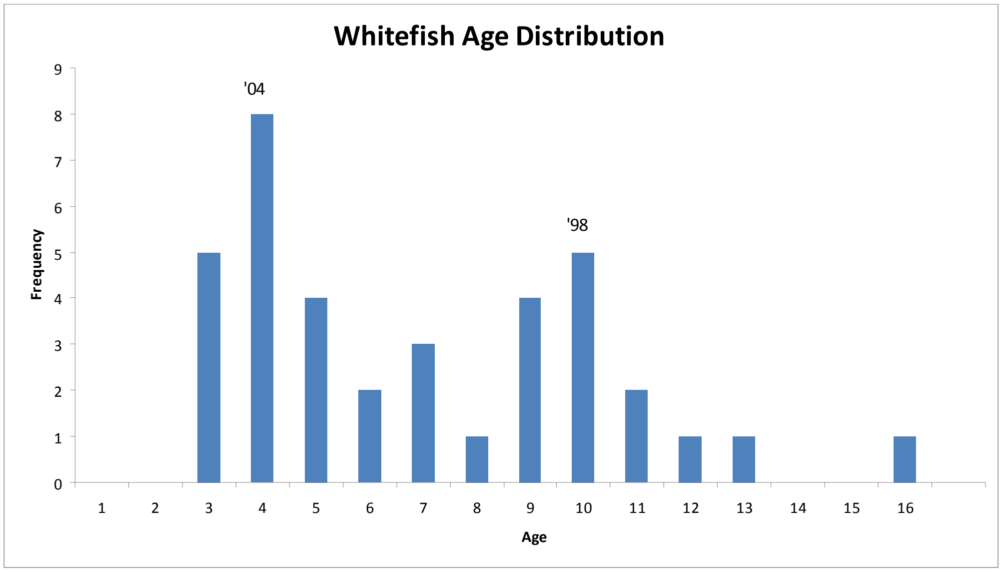

Figure IV.13. Whitefish age-frequency distribution from the 2008 index-net samples.

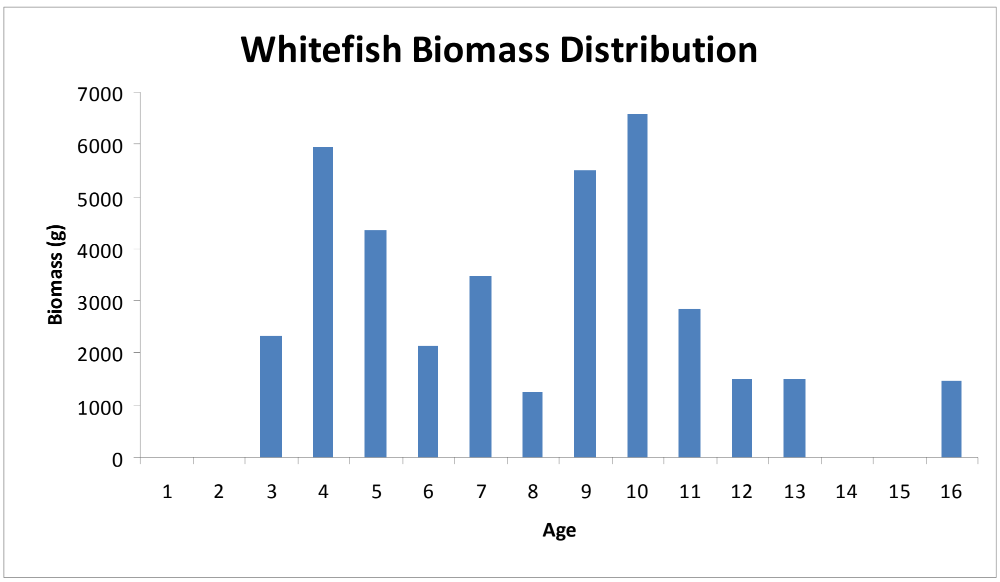

Figure IV.14. Distribution of biomass among age classes of whitefish from the 2008 index-net samples.

Estimates based upon commercial fisheries data

Commercial fisheries provide two main pieces of information for the estimation of biological productivity: landed catch and fishing effort. Fishing effort refers to some measure of fishing activity, ideally standardized in a manner that is comparable through time and among locations. Catch should be directly linked to effort records and provided for each species. With this information it is possible to generate CPUE indices similar to those made from survey data or to estimate absolute biomass using more sophisticated analyses. However, sophisticated methods often require information (such as the ages of the fish caught) that must be collected in addition to information provided from commercial sources.

Patterns in catch through time are often cited in the media and public forums to address changes in fish populations, but CPUE provides a less-biased perspective on trends in underlying fish abundance (see previous section: *Estimates based upon survey data* and Appendices III.b and IV.c). In Lake Winnipeg catch is provided by the sales records to the FFMC (by species) and the only measure of effort is the number of deliveries made to the Corporation. There are a number of issues with the commercial data that need to be considered during its interpretation. The key problem with the Lake Winnipeg data series is potential flexibility in the meaning of a "delivery". Operationally a delivery is simply the sale of fish to FFMC, but how much "fishing" does it represent? How many nets were set to fill the delivery? What mesh size was used? How long were the nets in the water? The collection of this information is required to allow commercial data to be used in a manner similar to index-net surveys. Otherwise trends in CPUE may reflect undocumented changes in fishing behaviour rather than fish abundance. (See previous section for other typical issues with CPUE use in other fisheries.)

Catch, effort and CPUE series for walleye are shown in Figure IV.15 for years for which delivery counts are available. It is clear that catch has fluctuated through the 1970s and 1980s and then increased greatly since the mid 1990s. However, catch increases must be considered in relation to effort: more fishing should tend to land more fish even when abundance is constant or has started to decline. From 1980 to 1983 there is an increase in catch but also an increase in the number of deliveries. There is a slight increase in CPUE during this time, which suggests that the catch increase is not entirely the result of increased fishing. However, in 1985, high catches correspond to reduced effort, reflected in an even larger increase in CPUE than in the early 1980s. Catches declined n the early 1990s, as did CPUE. In the middle of the 2000s the catch increased greatly while the effort declined, resulting in the greatest increases in CPUE through the years examined, which suggests that there was a very large population of fish available to the fishery. The data do not, however, tell us how long we can expect fishing to remain strong. In the most recent years both catch and catch rate have declined. The fishers on the Task Force attribute this result to a combination of effects, including: 1) a continuing high abundance of large fish that are growing beyond marketable size and 2) increased targeting on sauger due to improved market conditions, displacing walleye in the common quota. The biologists on the Task Force realize that these are possible causes, but feel that more detailed data on size distributions, market conditions and quota performance (proportion landed) in the fishery must be collated among agencies and regularly reviewed to distinguish such causes from actual declines in fish abundance.

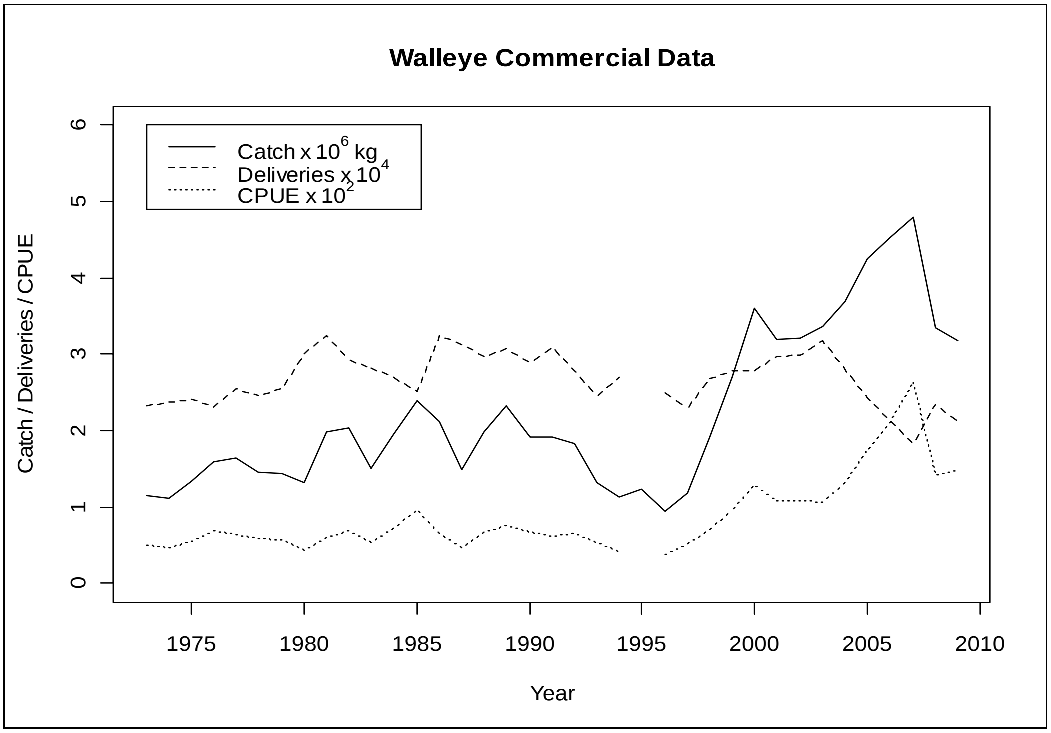

Figure IV.15. Walleye commercial catch per delivery, 1973–2009. CPUE = catch per unit effort.

The CPUE trends for sauger (Figure IV.16) and whitefish (Figure IV.17) can also be examined with the previous cautions in mind. Some general trends are apparent in these series. First sauger catch and catch rates have been in decline since the late 1980s. This long period of continuing decline is a cause for concern because it suggests declining abundances. However, there are patterns within this broader trend that should be considered. In the late 1990s the sauger catch declined while effort increased, which could reflect a decline in sauger or fishing behaviour that avoided sauger. In the mid 2000s declines in sauger catch are coincident with declines in the number of deliveries, suggesting that there is less opportunity for sauger to be caught because the quota is being filled by walleye. Of greater concern is the general declining CPUE throughout the last two decades. This trend may indicate declining sauger abundances or increasing sauger avoidance of areas where preferred fish (walleye) are being caught. The commercial data alone cannot distinguish between these interpretations for the most recent years. Thus the decline in sauger CPUE over the past two decades suggests a decline in abundance but behavioural effects (fishers targeting walleye, sauger avoidance of walleye areas) may be contributing to this pattern, especially in the most recent years. The possibility of changes in fishers' behaviour is supported by the increase in sauger catch and catch rate in 2009, corresponding to higher market value and greater interest among fishers in the past year.

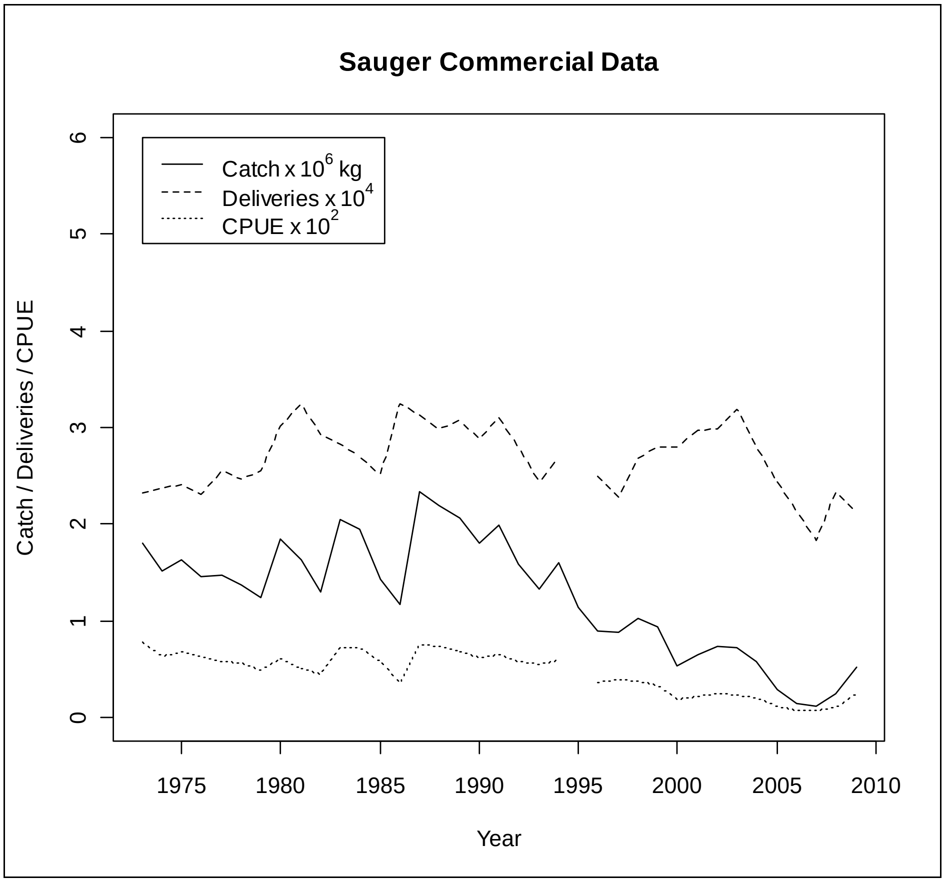

Figure IV.16. Sauger commercial catch per delivery, 1973–2009. CPUE = catch per unit effort.

The whitefish pattern is one of catch that follows the number of deliveries with a fairly even pattern of CPUE relative to the other quota species. This pattern is expected in a species that is mostly taken as bycatch without significant effort directed against it, i.e. more fishing results in more bycatch and vice versa.

Like the index-net data direct conclusions regarding population size or MSY cannot be drawn from the commercial CPUE data. Unlike the index-net data (particularly in recent years) commercial effort is expected to be directed towards the most profitable species and is relatively insensitive to changes in whitefish abundance (see previous section).

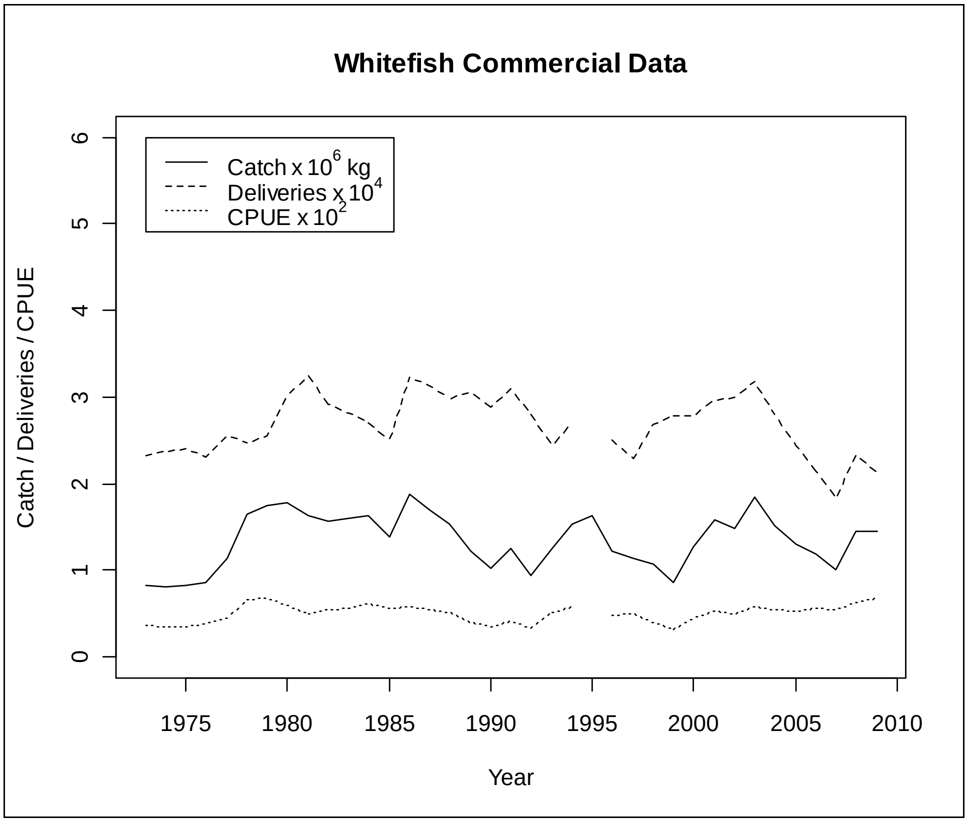

Figure IV.17. Whitefish commercial catch per delivery, 1973–2009. CPUE = catch per unit effort.

Observations Made By Fishers (Appendix V)

Questions 4 to 9 of the Fishers' Survey were related to observed changes in the quota species and fishing effort in the last 10 years. All fishers who participated in the survey (71) indicated that they target walleye, less than half, 45%, target sauger and 32% target whitefish. There was clear consensus among respondents that walleye fishing has improved in the last 10 years; walleye are more abundant and larger. Only two respondents indicated that walleye have declined or remained the same in the last 10 years. The language used to describe how whitefish fishing has changed in the last 10 years was less consistent than for walleye fishing, but overall 72% of the survey participants described a positive trend for whitefish and 14% of respondents indicated a decreasing, or fluctuating, trend or no change. The remainder did not know, did not target whitefish or did not respond to the question. The responses for sauger were both less consistent and less favourable than for walleye and whitefish. Just over half of the respondents indicated that they have observed a decrease in sauger, whereas nearly 17% had also observed a recent increase in sauger. Two fishers from Berens River and Selkirk areas observed sauger being replaced by walleye within the last 10 to 15 years. About 8% of respondents qualified their responses with reasons for the decrease in sauger, notably poor pricing and too-large mesh sizes.

Two-thirds of respondents indicated that it takes less time to fill their quotas than it did 10 years ago. Too few responses were received from the North Basin to evaluate whether a spatial relationship exists with fishing effort; however, it appears that, overall, the South Basin fishers are filling their quotas faster than they did 10 years ago. Nearly three-quarters of survey participants changed the way in which they fish in the last 10 years, 15% have not and the remainder did not answer the question. The most commonly cited changes included less travel, fewer nets and bigger mesh size. Only two fishers indicated that they now have to travel further.

Summary of Estimates of Biological Productivity

Absolute estimates of current or past biological productivity are not possible with the data currently available from Lake Winnipeg. Thus the proper application of MSY methods is not possible. However, this situation could change with increased data collection from the fishery, including:

1. Improved information on fishing effort (length of net, mesh size, set durations, set locations);
2. Age and size distributions of the commercial catch; and
3. Estimates of discarding (bushing).

Effort information would increase confidence in the interpretation of commercial data and allow the development of meaningful surplus-production estimates. More sophisticated catch-at-age analyses, more appropriate for the strongly age-structured populations of Lake Winnipeg, could be developed. At present the basis of our conclusions is limited to considerations of relative productivity and stock health based on catch rates in the index-net survey and commercial fishery.

Walleye commercial production is currently stronger than ever. Catch rates in the commercial fishery and index-net series suggest that walleye are abundant and healthy. However, the age structure of walleye shows that this abundance is mostly due to a single age class: fish hatched in 2001. This age class can be expected to sustain the fishery in the immediate future, but eventually the fishery will depend on the upcoming year classes. Upcoming age classes do not appear as abundant in the available data, suggesting a decline in catch rates in the future. There is not enough information currently available to state exactly what this means to future commercial production. To remedy this shortfall the age structure of walleye should be monitored closely and their current growth patterns should be examined. Age and growth information will provide expected abundances for future fisheries to guide management decisions.

The sauger situation is more tentative. Its decline in commercial catches has continued consistently since the late 1980s. Its presence in survey catches also declined in the late 1980s and remained low through the 1990s and into the 21st century. Furthermore, sauger were found in fewer index-nets around the turn of the century than in earlier years. However, its relatively low numbers appear to have been stable through the 1990s. Low sample sizes and lack of available data leave unclear trends in the most recent years. This situation may change if the recent index-net survey data can be developed in a consistent manner as has already been done for walleye.

The most recent sauger age data suggest that there are two years of good recruitment in the population. In addition biases due to the focus of commercial and survey efforts on walleye may make the downward trend discussed above appear more extreme than the underlying situation warrants. Together these trends indicate that the current situation should be one of caution rather than crisis. The improvements in data collection suggested for walleye would also assist in resolving the status of sauger populations.

Whitefish trends suggest that, as a species that is only weakly sought, its numbers are stable, if low. The index nets show a decline from the 1980s but stable lower catch rates afterward into the 2000s. The commercial data show a low, steady catch rate and a catch that mirrors changes in effort, as expected from less sought-after species. Furthermore, numbers and biomass of whitefish are spread more evenly among the observed age classes. It is likely that whitefish abundance is currently relatively low but stable in comparison to the other quota species. Still, information on less sought-after species is often poorest due to unreported discarding. Given the low catch rates and questionable changes in catch rate and other indicators of population health, whitefish should continue to be followed closely. Sampling independent of the regular commercial catch is especially important in such cases.

A Precautionary Approach for Lake Winnipeg

As noted previously there are no established reference indicators for Lake Winnipeg, although three monitoring criteria identified by MFB could serve as a starting point for development of reference indicators (see Chapter III: Use of Reference Indicators for Lake Winnipeg Sauger, Walleye and Lake Whitefish Stocks). Appendix IVc provides the Task Force’s assessment of other indicators that should be considered for a formal assessment process.

The lack of formal and agreed upon reference indicators aside there are various indicators that suggest the walleye fishery on Lake Winnipeg is in the Healthy zone at the moment. The average size of fish in the commercial catch and in index netting is large. Fishers report good catch rates, which also match those determined from index-netting and analysis of commercial CPUE. There are strong year classes from 2001 and 2005. However, the Limit reference point and Upper stock reference point have not been precisely determined.

In contrast the picture for sauger is uncertain and this species may be in the Cautious zone. This placement seems likely because there are lower catches despite being exposed to the same general effort pattern as walleye. In addition fewer sauger appeared in index nets than previously though there were increases in 2009. Most fishers thought that sauger had declined, but indicated that lower catches could be related to market factors.

Lake whitefish seems not to be changing but there is a high degree of uncertainty in this assessment. The limited data make it difficult to get a sense of the health of the stock. Whitefish could be in the Healthy or Cautious zone. As with sauger and walleye, insufficient information is available to calculate reference points.

OTHER CONSIDERATIONS

In the first part of this chapter we addressed a number of issues related to determining productivity of fish populations and determining potential levels of harvest that would ensure long-term sustainability of the stocks. In the following sections we turn to some issues that sound peripheral but that may, in certain circumstances, be pivotal.

Analysis of Sauger, Walleye and Whitefish Stock Genetics in Lake Winnipeg

The possibility of different genetic stocks of sauger, walleye and whitefish within Lake Winnipeg and how fisheries might impact upon those stocks may be important to our understanding of the health of Lake Winnipeg fish stocks now and in the future. Most of us are familiar with Atlantic and Pacific salmon and the knowledge that fish return to their natal streams (i.e. where they were born). We are also aware that commercial, recreational and subsistence fisheries are managed taking into consideration those discrete homing stocks of fish when the salmon return from the ocean to spawn. There is a general understanding that these stocks are adapted to the specific natural environment that they survive in and that these unique stocks should be maintained because they cannot be easily replaced by another stock naturally selected for a slightly different environment. What is not so well known is that different stocks of freshwater species have been found in large North American lakes as well. The implication for Lake Winnipeg is that if there are discrete stocks and this is not taken into consideration it would be possible to over-harvest certain stocks, without realizing it, to the detriment of the total lake production.

The concept of discreet stocks of fish as the unit of management has become fundamental to the management of most fisheries in the world including the large lakes of North America (Spangler *et al.* 1981). We examined this concept and its relevance to the sauger, walleye and lake whitefish stocks of Lake Winnipeg. There are many different definitions of a stock (e.g. Kutkuhn, 1981). We take the stock concept to mean that there are many spatially and genetically distinct localized populations that contribute in varying degrees to the total abundance of a species of fish in a water body and the subsequent commercial yield.

Spawning aggregations of whitefish, walleye and sauger on reefs and in rivers have been noted by fishers (Appendix V, questions 22 and 23) and biologists in many systems, and these aggregations often lead to an assumption that there are discrete stocks in a lake. Whether those spawning stocks are indeed discrete requires additional information. For example by tagging fish from spawning reefs in Lake of the Woods and determining where they were recaptured fisheries biologists from Minnesota and Ontario determined that, although most walleye were recaptured within 10–15 km of their spawning sites, a significant number dispersed across national and management sector boundaries and mixed with fish from other spawning areas (OMNR 2004). Stocks of freshwater fish species have also been identified using geographic distribution, behaviour (tagging studies), population variables and dynamics, physiology, meristics, morphometrics, colour patterns, scale patterns, calcified structures such as otoliths and spines and biochemical genetic analyses (nuclear and molecular genetics). (See Ihssen *et al.* 1981 for a general discussion of methods and what different techniques mean with respect to specific aspects of the stock definition.)

Many of the more obvious characters described above may be influenced by the environment and most recent efforts at delineating stocks have focused on biochemical genetic techniques, which provide a more direct method of identifying genetic differences among individuals and among stocks. Differences in allozymes (nuclear DNA studied through protein enzymes), mitochondrial DNA and micro-satellite analysis of nuclear DNA are now commonly used alone or in combination for genetic analyses of fish populations (e.g. Billington 1996, Cena *et al.* 2006). Biochemical genetic differences between stocks in different lakes have been commonly identified for whitefish (e.g. Clayton 1981, Ihssen *et al.* 1981) and walleye (e.g. Clayton *et al.* 1974, Billington *et al.* 1992) but not for sauger (Billington 1996).

More relevant to our understanding of the health of Lake Winnipeg fish stocks is the possibility of different genetic stocks within a large lake. The following observations have resulted from recent research on stocks:

- Numerous spawning populations of walleye have been identified in Lake Erie and Lake Huron. Tagging studies indicate that these stocks intermingle but return to their natal area to spawn (see McParland *et al* 1999, Einhouse and MacDougall 2010 and Stepien *et al.* 2010 for summaries);
- Tagging and recapture studies over many decades have helped to identify several discrete lake whitefish stocks in Lake Michigan (Smith and Van Oosten 1940, Walker *et al.* 1993) and in Lake Huron (Budd 1956, Casselman *et al.* 1981);
- Studies have shown migration and mixing of stocks but a general observation is that lake whitefish do not migrate as far as some walleye do (Smith and Van Oosten 1940; Casselman *et al.* 1981), though recent studies from the Great Lakes indicate significant movement of post-spawning lake whitefish populations (Ebener *et al*. 2010);
- Reef-spawning walleye may be less philopatric (home-loving) than river spawners (McParland *et al.* 1999);
- Tagging studies and mitochondrial DNA studies have shown that walleye from eastern Lake Erie sites are quite distinct from western Lake Erie sites, and a portion of western-basin stocks distribute basin-wide in Lake Erie where they are harvested by both commercial and recreational fishers before returning during autumn to their natal spawning areas in the west (McParland *et al.* 1999, Gatt *et al.* 2003;
- Allozyme and mitochondrial DNA markers were used to determine that 60–70% of the fish that were taken in the commercial trap fishery in the south end of Lake Huron came from stocks that spawned as much as 300–400 km south in western Lake Erie (Gatt *et al.* 2002);

- Genetically discrete lake whitefish stocks are subject to mixed-stock commercial fisheries in Lake Michigan (Sloss *et al.* 2007, VanDehey *et al.* 2009.)[10]; and
- Allozyme, mitochondrial DNA and microsatellite nuclear analysis were used to distinguish between walleye, sauger and walleye x sauger hybrids in the Ohio River (White *et al.* 2005). However, in comparison to walleye and lake whitefish, sauger have been poorly studied and much less is known about stock discreteness or movements.

There have been many studies of relationships among stocks of walleye and among stocks of whitefish in the Great Lakes but few dedicated studies on stock discreetness of the quota species of Lake Winnipeg. Kristofferson and Clayton (1990) used morphometric measures, meristic counts and frequencies of alleles of three metabolic enzymes to study lake whitefish stocks in Lake Winnipeg. Krostofferson and Clayton (1990) concluded there were five subpopulations or stocks in the Lake, based on the morphometric studies and meristic counts. However, the authors noted that environmental factors such as temperature, food and water chemistry can affect morphological differences. Kristofferson and Clayton's (1990) allozyme studies indicated that there were two stocks in Lake St. Martin–Dauphin River and one in the rest of Lake Winnipeg. The study provided evidence that there is a degree of homing in whitefish to natal spawning grounds but it was not possible to determine the success of whitefish stocking on the lake. In meetings with the Task Force, A. Kristofferson[11] pointed out that his study was done several years ago and that newer biochemical-genetic techniques may be able to detect subtler stock differences, i.e. there may well be other discreet stocks of whitefish in the Lake.

Studies of Lake Winnipeg walleye stock discrimination are equally limited. Tagging studies in the mid 1970s showed that walleye moved over 200 km within the Lake (unpublished, reported as a pers. comm. from W. Lysack in Watkinson and Gillis 2005). Watkinson (2001) and Watkinson and Gillis (2005) were the first to show formal evidence of stock structure in Lake Winnipeg. These authors analyzed scale shape from spawning populations of walleye from Grand Rapids, Matheson Island and Riverton and then used those results to examine commercial catch samples from Norway House, Frog Bay and Selkirk. The shape of walleye scales is subject to both genetic and environmental influences but differences in scale morphology have been used to distinguish stocks (Jarvis *et al.* 1978). Most of the Lake Winnipeg commercial catch samples were classified as being Riverton fish. It is possible that most commercially caught fish were of Riverton origin, but it is more likely that other stocks of unknown scale morphology were contributing. The number and location of Lake Winnipeg spawning sites are not known, so a definitive interpretation is not possible.

The only dedicated biochemical genetic study of walleye in Lake Winnipeg was recently undertaken by graduate student Stephanie Backhouse, working under the supervision of

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[10] Walleye and whitefish migrate between spawning grounds and home feeding areas but it is possible that, in many systems, this migration may be primarily a learned behaviour and the stocks may not be genetically discrete (see Colby and Nepszy 1981 for a review).
[11] Pers. comm. Allan Kristofferson.

Margaret Docker at the University of Manitoba. Backhouse has used sophisticated techniques of mitochondrial DNA analysis and nuclear microsatellite analysis to examine genetic stock structure. Her objectives were to determine: 1) the stock structure of walleye in the Lake; 2) the degree of genetic variation; 3) the relative abundance of spawning groups; and 4) the degree to which fishers targeted different spawning groups. She examined fish from 14 different walleye populations in the Lake and for comparison she examined walleye from Lake Manitoba, Falcon Lake and Lake of the Woods. She was unable to detect genetic population structure in Lake Winnipeg walleye (aside from slight differentiation between Grand Rapids and all other sampling sites, and Icelandic River and all other sampling sites) (Backhouse 2010). However, her analysis only examined selectively neutral genetic markers. Functional genes may better differentiate among the varied habitats within the lake and define local sub-populations not detected by the methods she used. Backhouse's assessment is that walleye stock delineation depends on future research[12].

The lack of knowledge of stock discreetness in Lake Winnipeg has implications for the health of whitefish, walleye and sauger. In mixed-stock fisheries it is unlikely that all stocks are being harvested uniformly. Thus the danger is that a few dominant stocks may be able to withstand heavy harvesting whereas other stocks may not, and as a result, could disappear over time. The loss of these weaker stocks would mean a loss of the genetic uniqueness that suited them to their local habitats in Lake Winnipeg. Similarly local environmental variability may result in increased or decreased production from individual stocks over time, raising their susceptibility to common harvest levels. A precautionary approach need not require management of each discreet stock separately, but fishers and managers should seek this information and take it into account. For example the current Lake Winnipeg management tool that restricts fishers to discreet areas rather than allowing all fishers access to all parts of the Lake is a precautionary approach. Although it is not quantifiable the approach offers some protection to individual stocks that might otherwise be over-harvested.

Analysis of Recreational Fish Harvests for Lake Winnipeg

In the most recent national survey of recreational fish harvests (DFO 2007) walleye ranked first, representing nearly a quarter of the total catch in Canada and over half of the total catch in Manitoba (Table IV.5). Whitefish are not targeted by most recreational fishers and there are no national or provincial statistics for whitefish caught by anglers. Sauger are fished recreationally but are not reported in the national survey because most anglers cannot distinguish between small walleye and sauger.

[12] Pers. comm. Stephanie Backhouse, November 2009.

Table IV.5. Numbers of recreationally harvested sauger, whitefish and walleye in Manitoba and Canada in 2005 (DFO 2007). (Data for species other than Lake Winnipeg quota species not shown here.)

Species	**Manitoba**	**Canada**
Sauger	Not reported separately from walleye	Not reported separately from walleye
Whitefish	Too small to report	Too small to report
Walleye	6,138,137 (50.8%)	50,718,019 (23.5%)
Total	12,068,682	215,027,343

Media reports on the Lake Winnipeg winter walleye fishery in the South Basin indicate that fishing interest and success have expanded significantly over the past six years, but especially in the last two years (Lamont 2009). Meaningful comparisons with past recreational fisheries or with the current commercial fisheries are problematic.

In many other large lakes data from recreational harvests are used as a tool for management of the fisheries (e.g. Thomas *et al.* 2009). Data on total harvest numbers and weight are particularly important, but information such as age structure, length and weight structure, fishing effort and harvest per unit of effort can be used. Changes in these variables and comparisons with commercial harvests over the same periods are used to better understand the dynamics of the population. For example Figure IV.18 compares long-term monitoring of sport and commercial harvests of Lake Erie walleye.

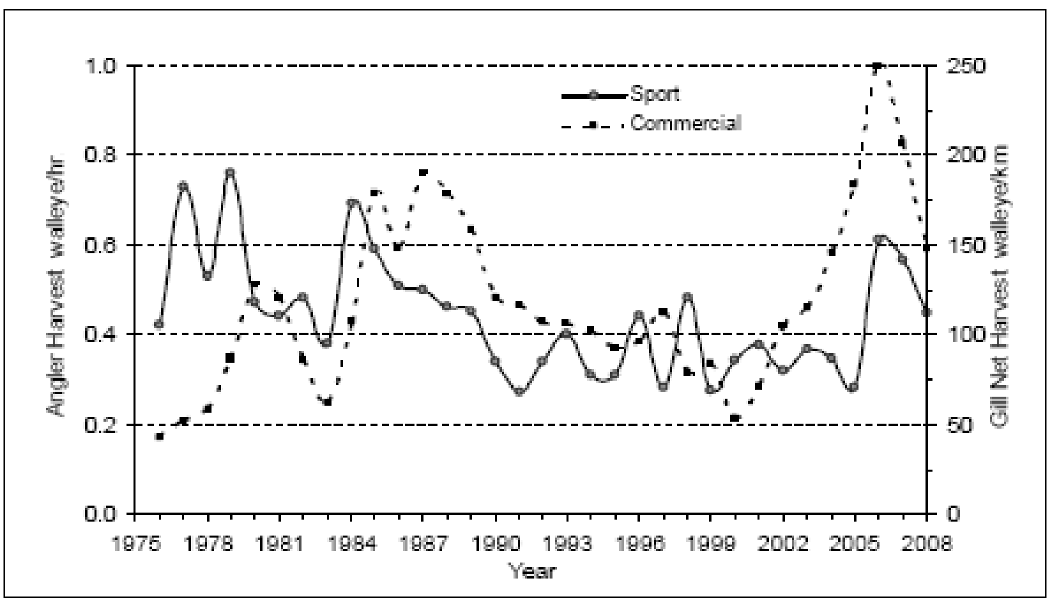

Figure IV.18. Lakewide harvest per unit effort for Lake Erie sport and commercial walleye fisheries, 1975–2008 (from Thomas *et al.* 2009).

Unfortunately we found only two completed studies and one study underway for Lake Winnipeg recreational fisheries. The MFB carried out a comprehensive creel census of the summer and winter fishery of the lower Red River In 1982 and 1983 (Lysack 1986b). The purpose was to look at changes in species, numbers and weights, changes in effort, age structure and growth of species, and if possible examine the relationship between walleye and sauger angled in the Red River and netted by commercial fishers in southern Lake Winnipeg. The survey covered the primary sites fished and used methods common to detailed surveys in other jurisdictions. The study involved fish caught and retained rather than caught and released. Summer harvests were much larger than in winter and sauger, freshwater drum and goldeye dominated the catch. Sauger and walleye were the most common species caught during the winter months (Table IV.6).

Table IV.6. Creel census of the lower Red River 1982–1983 (Lysack 1986b). CPUE = catch per unit effort.

	1982 May–October			**1983 January–March**		
	Number	**Mean Weight (kg)**	**CPUE (fish/angler/hr)**	**Number**	**Mean Weight (kg)**	**CPUE (fish/angler/hr)**
Walleye	7833	1.29	0.027	3491	1.37	0.070
Sauger	94,033	0.22	0.328	6709	0.20	0.132

Almost nine times as many sauger were harvested as walleye in the lower Red River, but the total weight harvested was much closer: 14,888 kg of walleye and 22,090 kg of sauger. The weights harvested would be 8.4% and 13.1% of the Lake Winnipeg mean commercial harvests for 1982 and 1983 for these two species (see Appendix III.d for commercial harvests). Walleye and sauger harvest per angler hour was lower in the Red River then in other lakes in southern Manitoba (Lysack 1986b). Based on a comparison of ages, lengths and weights Lysack (1986b) concluded that the walleye and sauger exploited by Red River anglers were from the southern Lake Winnipeg stock.

A similar study was done by MFB in 2007–2008 but the analyses are not yet completed (pers. comm. Derek Kroeker). However, it would be inappropriate to draw any firm conclusions and comparisons from two studies done over 20 years apart. It would also be difficult to compare the data with recent commercial harvests.

The federal and provincial governments do a nation-wide survey of recreational angling every five years (DFO 2007). The survey is done by mail and is quite different from the creel census described above. Although this national survey has been in place for some years, 2005 was the first year in which detailed questions were asked about recreational fishing in Lake Winnipeg and its major southern tributaries (Table IV.7).

Table IV.7. Survey of recreational angling 2005: data for Red River, Winnipeg River and Lake Winnipeg (Pers. comm. Robert Cann, 2009). CPUE = catch per unit effort. (Note—most of the fish caught were released and not harvested.)

	Walleye Caught	**Walleye Harvested**	**Angling Days**	**CPUE (fish/angler/day)**
Red River	283,351	66,443	244,279	0.271
Lake Winnipeg	31,958	22,678	55,800	0.406
Winnipeg River	169,780	61,412	31,581	1.944
Total	485,089	150,533	331,660	0 .454

Only walleye were recorded, not sauger, but it is possible that most fishers included sauger harvests under the walleye category especially because of the similar colour patterns of the two species in the Red River (pers. comm. Derek Kroeker). Sauger tend to be caught more frequently in the Red River than in Lake Winnipeg and are not often caught in winter fishing in Lake Winnipeg (pers. comm. Derek. Kroeker), presumably because of their preference for turbid waters. The data show that many more percids are harvested in the Red and Winnipeg rivers than in the Lake itself. If our assumption about reporting is correct then the 66,443 walleye reported from the 2005 survey is similar to the 112,066 walleye and sauger reported in the 1982–1983 creel census on the Lower Red River (Table IV.6). Any further comparisons between the results of the 1983–1983 and 2005 studies and any comparisons of the 2005 study with the 2005 commercial harvests are impossible. The national survey does, nevertheless, offer promise if carried out in the future.

In summary ongoing monitoring of recreational fisheries could contribute to the overall management of Lake Winnipeg fisheries, but the data series is not collected regularly enough to be useful at this time.

Analysis of Domestic Fish Harvests for Lake Winnipeg

Present day subsistence use of fish is not well documented in Canada but whitefish, walleye and northern pike are those species most commonly consumed in the boreal-forest area of Canada’s north (Wagner 1986). Nationally subsistence use may be as much as 10% of the inland commercial harvest (Berkes 1990), but nation-wide estimates by species for either domestic harvest or consumption are not available.

In Manitoba the first priority for allocation of fish beyond conservation is the aboriginal domestic harvest (Manitoba Water Stewardship 2006). Domestic or subsistence harvests of fish from Lake Winnipeg undoubtedly continue to be of importance to many communities; however, determining actual harvest levels is extremely problematic. The domestic harvest is typically not recorded by community members, nor are licences required. Therefore historical harvest records do not exist. In addition the few studies of domestic fisheries available in Canada are difficult to compare because they differ significantly in objectives, methods and scope. For example some studies have focused on fish harvested, whereas others have focused on fish consumed, making comparisons difficult. Berkes (1990) examined data from 93 communities across the Canadian North and mid-North and found that domestic fish harvests clustered around 60 kg per capita per year. For 15 northern Manitoba communities Green and Derksen (1984) found the range was from 17 to 52 kg per capita per year.

Heuring (1993) summarized recorded subsistence harvest of fish on Lake Winnipeg for the period 1887 to 1898 and calculated a mean subsistence harvest of 342,456 kg/yr, considered to be an underestimate. More recent reports are rare. We were only able to find three studies since 1973 that addressed domestic harvests from communities on Lake Winnipeg (Table IV.8). The earliest study determined annual domestic harvests of Norway House residents (Weagle 1973). The second study attempted to quantify domestic consumption of fish, birds and mammals in 10 Manitoba reserves, three of which (Berens River, Brokenhead and Hollow Water) are on Lake Winnipeg (Wagner 1986). Most recently 13 Fisher River Cree Nation residents were interviewed on the potential impact of climate change on the sustainability of freshwater fisheries in Lake Winnipeg, including the numbers of fish eaten and preferred species (Maclean 2007).

Table IV.8. Studies of domestic fish harvests for Lake Winnipeg.

Communities surveyed	**Per Capita Fish Consumption**	**Comments**	**Reference**
Norway House	28.0 kg/year	Based on harvests	Weagle (1973)
Berens River	10.0 kg/year	Based on actual consumption estimates. Most common species: walleye, whitefish, pike, sauger.	Wagner (1986)
Hollow Water	7.3 kg/year	Based on actual consumption estimates. Most common species: walleye, sunfish (freshwater drum), whitefish, pike.	Wagner (1986)
Brokenhead	12.9 kg/year	Based on actual consumption estimates. Most common species: walleye, sunfish (freshwater drum), pike.	Wagner (1986)

Fisher River	2 fish/week	Interviews with 13 fishers. Most common species: walleye, whitefish, sunfish (freshwater drum).	Maclean (2007)

The Wagner (1986) study was based on actual consumption estimates, rather than on harvest estimates as most domestic harvest studies have been. The ratio of consumption to harvest varies significantly with the species, size of fish and skill of the fisher dressing the fish, so we used a ratio of 75% to convert the Berens River, Hollow Water and Brokenhead consumption estimates to actual harvests of 13.3 kg, 9.7 kg and 17.2 kg, respectively (see Usher and Weinstein 1991 for conversion factor). These estimates are similar to the earlier estimate from Norway House but less than the mean harvests reported by Berkes (1990), Green and Derksen (1984) and Usher and Weinstien (1991) for other northern communities.

Relevance of the domestic harvest to the total production of Lake Winnipeg is of importance for our assessment. Actual data from each community on the Lake are lacking so we made a first approximation of harvests using the range of domestic harvests for the above communities. Using this approach the total domestic harvest of fish on Lake Winnipeg for the 14,350 First Nations residents (Indian and Northern Affairs Canada 2010) ranged from 139,673 kg (9.7 kg per capita) to 401,800 kg (28.0 kg per capita) annually, or 3.2% to 9.3% of the average total commercial harvest for the years 2000 to 2007 (see Table IV.1 for commercial harvests). Walleye, whitefish, sunfish (freshwater drum) and pike were the commonest species harvested.

In summary there is a paucity of data on subsistence harvests and Usher and Weinstein (1991) have pointed out that none of the existing estimates of subsistence fish consumption or harvest for northern Manitoba meet acceptable standards for data collection. Available information indicates that the domestic harvest comprises a small fraction of the commercial harvest, but it could be significant in some areas and under some conditions in the future.

Environmental Considerations

Lake Winnipeg is an ecosystem that is undergoing considerable change, the consequences of which are yet to be fully understood. Research has determined that the main stressors facing the Lake are eutrophication (see definition below), the introduction of non-indigenous (exotic) species and climate-related change. It is beyond the scope of this report to fully evaluate these factors, but it is nevertheless important to recognize that complex changes are occurring in the Lake that will inevitably impact the stability and sustainability of the fishery. This section provides a brief overview of the main stressors, drawing on the experience of Lake Erie to illustrate the complexity of interactions involved, the need for further on-lake research to better understand ecosystem structure and function, and perhaps most importantly, to illustrate the necessity of integrating fisheries management with water-quality management and research. The upcoming State of the Lake (SOL) Report and the Special Lake Winnipeg Issue of the Journal of Great Lakes Research should provide additional information that will allow a more in-depth evaluation of these stressors.

Lake Erie shares many common features with Lake Winnipeg, perhaps moreso than with the other Great Lakes. Similar to Lake Winnipeg Lake Erie has three basins: the shallow and productive western basin, central basin, and deeper, less productive eastern basin. Lake Erie is also very shallow, with roughly the same surface area as Lake Winnipeg (Table III.1), resulting in a small total volume of water and short water-renewal time. These features make both lakes susceptible to rapid change in response to environmental stressors. Eutrophication was the first major stressor to impact Lake Erie, and one that received widespread attention in the 1970s. Forty years later Lake Winnipeg is being compared to Lake Erie as it experiences many of the symptoms that reveal a similar trajectory of increasing eutrophication and water-quality deterioration. It is important to recognize that the Lake Erie story did not end despite the success of the phosphorus abatement program. As the IJC (2004) succinctly stated:

> *"Eutrophication was the predominant environmental issue in Lake Erie during the 1960s and 70s, toxic contaminants in the 1980s, and invasive species in the 1990s. In the new millennium, scientists are recognizing that all of these issues and others, such as habitat loss and degradation, climate change, and botulism, are occurring concurrently."*

Lake Winnipeg—Eutrophication

Eutrophication is the process whereby an aquatic ecosystem, such as a lake, becomes more productive due to nutrient enrichment, which stimulates the growth of phytoplankton or algae. The process is known as "cultural eutrophication" when nutrient inputs increase due to human activities (Dodds 2003). Two seemingly opposing consequences of eutrophication can affect the food web and ultimately the fishery: 1) overall increased productivity of the lake; and 2) oxygen consumption due to the decomposition of this increased productivity. Phytoplankton are a key component of the aquatic food web, serving as an important food source for organisms such as zooplankton, insects, mussels and small fish. The abundance of phytoplankton, therefore, can influence the productivity of higher trophic levels. However, increased production of phytoplankton may lead to its increased deposition to the sediments, where it undergoes decomposition, a process that consumes oxygen. If oxygen is not replenished through mixing, low oxygen (hypoxia) or oxygen depletion (anoxia) may occur, resulting in important changes in the food web and a reduction of suitable habitat. Low oxygen level is considered to be one of the major effects of degrading water quality on the quality of fish habitat (Hayes 1999). The eutrophication process has also lead the popular press to describe lakes such as Lake Erie and now Lake Winnipeg as "dead" or "dying". On the contrary a productive lake is the opposite of dead or dying. If oxygen depletion does occur it will adversely impact the biota in the lake resulting in significant change; however, the lake itself, is not dead.

There is considerable evidence to support the contention that Lake Winnipeg is experiencing increased productivity and other symptoms that are consistent with cultural eutrophication. Recent work by Bunting *et al.* (2010) suggests that Lake Winnipeg showed signs of eutrophication as early as the 1930s when land use in the Red River Basin became more agricultural. Since the early 1970s nitrogen and phosphorus loading to Lake Winnipeg has increased by 13% and 10%, respectively (Bourne *et al.* 2002). Total phosphorus and nitrogen concentrations (median flow-adjusted) in the Red River at Selkirk increased 29% and nearly 60%, respectively, between 1978 and 1999 (Jones and Armstrong 2001). Similarly the Winnipeg River (at Point du Bois) showed a 29% increase in total phosphorus concentration from 1972 to 1999 (Bourne *et al.* 2002). However, the Saskatchewan River showed no significant trend in total phosphorus concentration since the early 1970s (Bourne *et al.* 2002). The progressive increase in nutrient loading from the watershed has been supplemented in the last decade by additional sources within the Red River Basin, notably higher Red River discharge and more frequent flooding events, during which the concentration of phosphorus increases (pers. comm. Greg McCullough.). Thus, in addition to human activities, climate and basin hydrology are also important factors in nutrient loading to Lake Winnipeg.

In addition to increased nutrient loading to Lake Winnipeg there is also greater retention within the Lake, notably of phosphorus. In 1976, Manitoba Hydro began regulating Lake Winnipeg with the completion of the Lake Winnipeg Regulation Project, which included construction of the Jenpeg Generating Station and Control Structure on the west channel of the Nelson River upstream of Cross Lake. The primary role of Jenpeg is to regulate water outflow from Lake Winnipeg into the Nelson River; its secondary role is to produce electricity. In addition three channels (Two-mile, Eight-mile and Ominawin Bypass) were excavated to increase the volume of winter outflow from Lake Winnipeg via the west channel toward Jenpeg, and a dam was built at the outlet of Kiskitto Lake to prevent water from backing up into that lake (Manitoba Hydro 2009).

Manipulation of lake levels and discharge patterns by the Lake Winnipeg Regulation Project has resulted in important changes in the Lake Winnipeg ecosystem, the consequences of which are not fully understood. The necessity of producing more electricity in the winter means water is generally held back through the open-water season and discharged during the autumn and winter months. Natural outflow volumes of a lake would typically be greatest following the spring melt period and during summer months and would diminish during the autumn and winter months. Thus the natural flushing of Lake Winnipeg no longer occurs during the most productive time of the year, the summer, and nutrients are being retained in the Lake when they otherwise would have been exported. From 1994 to 2001 an estimated 75% of the total phosphorus entering Lake Winnipeg was retained in the Lake, whereas prior to regulation roughly 25% was retained (Table IV.9).

Table IV.9. Estimate of nutrient loadings and retention (t/yr) in Lake Winnipeg (Manitoba Water Stewardship 2006). TN = total nitrogen, TP = total phosphorous.

Nutrient load	**Before Regulation (1973)** [13]		**After Regulation (1994-2001)**	
	TN (t/yr)	TP (t/yr)	TN (t/yr)	TP (t/yr)
Entering lake (all sources)	61,920	5215	96,000	7900
Leaving lake via Nelson River (east and west channels)	27,410	3900	39,700	2000
Retained	34,510	1315	56,300	5900
% retention	**56%**	**25%**	**58%**	**74%**

The shallow depth and wind-driven turbulent mixing in Lake Winnipeg produces physical re-suspension of sediment, especially in the South Basin, and may release phosphorus back into the water column. Internal loading of phosphorus can also be caused by its release from sediment during periods of low oxygen (Hartig *et al.* 2007) and by biotic activity in the sediment, such as bioturbation and phosphorus remineralization by zooplankton, benthic invertebrates and fishes (Conroy *et al.* 2005). The relative importance and bioavailability of these internal sources of phosphorus are not known for Lake Winnipeg but could prolong watershed phosphorus abatement efforts by the Province.

The stimulated growth of phytoplankton or algae is obvious in satellite imagery for Lake Winnipeg, which has revealed more frequent and larger algal blooms (pers. comm. Greg McCullough). Blooms are especially apparent in the North Basin where the water is generally clearer than the South Basin, thereby allowing the penetration of light to support the growth of algae. Widespread surface blooms greater than 100 km^2 in size occurred in only four of eleven years between 1983 and 1994, whereas they occurred in eight out of nine years between 1995 and 2003 (pers. comm. Greg McCullough). In support of the satellite evidence all of the North Basin fishers who participated in the Fishers' Survey (Appendix V) indicated negative changes in water quality, notably increased algal growth and increased turbidity due to erosion. In contrast fewer South Basin fishers indicated negative changes in water quality.

In addition to larger, more frequent blooms there is evidence that composition of the algal community is also changing to one dominated by cyanophytes, or "blue-greens" as they are commonly called. Cyanophytes are a group of photosynthetic bacteria, which are generally considered an aesthetic nuisance and a poor source of food for zooplankton.

[13] Based on data from Brunskill (1973).

Many cyanophytes are able to regulate their buoyancy and to carry out nitrogen fixation, a process by which atmospheric N_2 (a gas) is converted directly into ammonium (NH_4), a form of nitrogen that can be used by cells (WHO 1999). Both strategies enable them to out-compete other types of algae that one might consider more beneficial to the ecosystem as a whole. In a study using sediment cores to quantify the timing, extent and cause of algal proliferation, Bunting *et al*. (2010) described a considerable increase in algal abundance between 1930 and 1990 followed by an important shift in the composition of the algal community from 1990 onwards, which was characterized by a ten-fold increase in akinete concentrations from cyanophyte species. Similarly, between 1969 and 2003, the August–September mean algal biomass increased nearly five times and the algal community changed from being relatively diverse with roughly 30% cyanophytes to one dominated by cyanophytes (pers. comm. Hedy Kling). Based on nitrogen fixation rates measured between 1999 and 2001 an estimated 9300 t/yr of nitrogen were introduced into Lake Winnipeg via nitrogen fixation by cyanophates (Hendzel 2004), a significant modification to the nitrogen budget of the Lake.

Many cyanophytes produce toxins, which may target the liver or nervous system when consumed. Symptoms may include stomach upset, vomiting, headache, skin, eye and throat irritation, and liver damage (WHO 2003). The water-quality guideline for microcystin (a liver toxin) in drinking water is 1.5 µg/L and the proposed guideline for recreational waters is 20 µg/L (LWSB 2006). In Lake Winnipeg levels of microcystin in raw lake water or in phytoplankton collected using a net are usually quite low (i.e. <1 µg/L) or below detection limits; however, very high concentrations (>2,000 µg/L) occasionally have been detected in whole water samples during algal blooms and along shorelines during bloom events (Kotak *et al.* 2009). There is also further concern that these toxins may bioaccumulate in the aquatic food web, although preliminary studies suggest that this is probably not occurring in Lake Winnipeg (Neumann *et al.* 2010).

A large algal bloom that is not dispersed by high winds may end up on the bottom of the Lake where it will undergo decomposition. This process consumes dissolved oxygen and, if it is not replenished through mixing, may lead to oxygen depletion at depths near the Lake bottom. Due to its shallow depth and large surface area, strong winds blowing over the surface usually result in effective mixing to all depths of the water column, including to the bottom of the Lake (Brunskill *et al.* 1980). Differences in temperature of several degrees have been measured between the surface and lower depths when the Lake is not fully mixed. This difference was especially apparent in the North Basin in 2003 when both a notable thermocline (6–7ºC difference) and oxygen depletion (2–3 ppm vs. 8–9 ppm at the surface) were recorded in mid-August (Stainton and McCullough 2003). Oxygen depletion and thermal stratification were again measured in 2007.

Additional changes are being measured in the rest of the lower Lake Winnipeg food web that can be attributed to both greater productivity and periodic low oxygen levels at depth. Benthos (aquatic animals that live in the sediment of the lake) play an important role in the aquatic food web as consumers of organic detritus and periphyton, and as a food source for juvenile and adult fish. Some benthic organisms also serve as useful indicators of water quality based on their ability to withstand low oxygen levels. The blood of tubificid worms, or aquatic sludge worms, contains hemoglobin, which transports dissolved oxygen from the water into their bodies allowing them to thrive under conditions of low oxygen. They are, therefore, good indicators of poor water quality. Conversely *Hexagenia* (burrowing mayfly) and *Diporeia* (freshwater shrimp), both important food for fish, are very sensitive benthic indicators (Hartig *et al.* 2007). The response of the benthic community indicates that, between 2002 and 2006, densities of benthic organisms in all parts of the Lake increased greatly since 1969, with a substantially higher density in the North Basin relative to the narrows and South Basin. However, there were also higher densities of tubificid worms and other indictor organisms, such as midge larvae, in the North Basin, while the sensitive *Diporeia* remained concentrated in the narrows (Hann 2008). Thus the general trend in the benthic community is similar to that of the algal community, i.e. increasing overall abundance with important changes in species composition, which reflect increasing eutrophy.

Similarly an initial analysis of changes in the zooplankton community of Lake Winnipeg is consistent with increasing trophic status of the Lake, and responses to other influences such as changing water levels and temperature (pers. comm. Alex Salki). Salki (2003) showed that zooplankton abundance in Lake Winnipeg had increased over 300% since 1969, exceeding levels found in Lake Erie during the 1960s. Zooplankton serve as an important food source for pelagic fishes, but increasing zooplankton densities can result in higher grazing rates on edible phytoplankton, which could favour the less palatable blue-greens (Salki *et al.* 2005). In addition compositional structure of the zooplankton community, particularly in the North Basin, has undergone considerable change. For example *Daphnia longiremis*, common in deeper northern lakes and typically abundant in the deep waters of the North Basin, was not found in the autumn of 2003 following the period of summer hypoxia, although it did return the following year (pers. comm. A. Salki). A complete analysis of changes in the Lake Winnipeg benthos and zooplankton communities remains to be done.

Much of the biological monitoring data on Lake Winnipeg has been generated over a short time frame, but there is compelling evidence that the lower food web of Lake Winnipeg is responding in a fairly predictable manner that is consistent with an increased state of eutrophication. Without more targeted research on the impacts of eutrophication on the Lake Winnipeg fishery one can only postulate, based on research from other lakes, that this increased productivity has contributed to the good condition and higher yields of walleye and possibly whitefish. In the same manner there will likely be further changes to the fish community if eutrophication intensifies, and these changes will be considerably less desirable to the fishery. The possible effects of low oxygen on fish behaviour and physiology are numerous, including: changes in schooling behaviour and vulnerability to predation; foraging efficiency of predators; community shifts from demersal (near bottom) to pelagic (open water); changes in swimming speed and movement; increased energy output for egg care; reduced levels of adenosine triphosphate or ATP; and possible endocrine disruption (Pollock *et al.* 2007). Low oxygen was implicated in the decline of the burrowing mayfly in Lake Erie in the 1960s, resulting in lower-quality habitat for yellow perch and walleye feeding (Hayes 1999). Leach *et al.* (1977) showed that, in the early stages of enrichment, increased lake productivity is reflected in increased growth rate and production of percids. However, as with the lower food web, the process is not continuous and the percid community will change with progressive eutrophication. From least to most tolerant of the detrimental effects of eutrophication (decreasing transparency due to algal growth, changes in the oxygen regime and invertebrate community), the order in which individual percid species respond is: sauger, walleye, perch species, ruffe and pikeperch (Leach *et al.* 1977). However, in Lake Erie and Lake of the Woods, decreasing transparency favoured sauger. Leach *et al.* (1977) described an unpublished study of 17 European lakes by showing a succession in fish yields with increasing eutrophication: coregonid (whitefish) yield was the first to decline, followed by percids, and after extremely high yields, the cyprinids (carp, minnows) (Figure IV.20). A strong decrease in the percentage of piscivores with increasing nutrients has been explained in part by differences in competitive ability related to turbidity (Scheffer 2001).

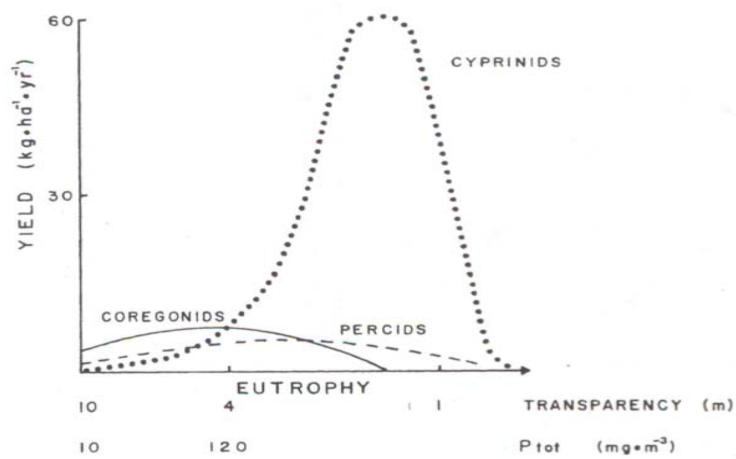

Figure IV.19. Relation between fish yields and increasing productivity in 17 European lakes (from Leach *et el*. 1977).

It is important to recognize that numerous factors affect the dynamics of fish communities, including nutrients, light, water clarity and temperature. Indeed walleye are so highly adapted to specific light regimes that light intensity has been considered an ecological constraint that can impact relative dominance of walleye in the community (Robillard and Fox 2006). Furthermore eutrophication is a process that occurs over time, during which additional stressors with differing temporal scales, such as climate change, exploitation, habitat degradation and the introduction of non-indigenous species, are also imposed on the ecosystem. These additional stressors render the cause–effect argument of “more nutrients more fish” somewhat less robust as the only explanation for higher fish yields, especially as the argument gives little account of the dynamics of species and trophic interactions (Minns *et al.* 1987). As described by Carpenter *et al.* (1985) potential productivity may be set by nutrient supply, but actual productivity will depend on nutrient recycling and partitioning among populations with different growth rates. The importance of the concept of trophic cascades, whereby consumers have a significant impact on species composition, biomass and productivity, has not been explored for the food web of Lake Winnipeg.

Exotic Species

Invasive exotic species are organisms that are not native to an ecosystem. Numerous exotic species are already established in Lake Winnipeg; however, their impacts have received little scientific attention. For example the zooplankter *Eubosmina coregoni* was first discovered in 1999 and has become well established in the North Basin. The Asian carp tapeworm was discovered in emerald shiners in 2006 and, because it is spread by ingestion, could impact predators such as walleye (Ralley 2008). Numerous exotic fish species have also entered the Lake Winnipeg ecosystem, including bigmouth buffalo, white bass, carp and rainbow smelt (Franzin *et al.* 2003).

Rainbow smelt entered Lake Winnipeg in 1990 via the Winnipeg River system. They prefer oligotrophic waters and are, therefore, found primarily in the North Basin. The ecological effects of rainbow smelt are difficult to predict (Swanson *et al.* 2003) so this fish is considered a pest by some and a benefit to fisheries by others (Hall and Mills 2000). Rainbow smelt often become a preferred prey for predators such as walleye (Scott and Crossman 1973), which can lead to increased growth rates (Swanson *et al.* 2003). Rainbow smelt have become important prey for walleye in Lake Winnipeg (Appendix V; Sheppard 2010) and a component of the whitefish diet in the North Basin of Lake Winnipeg (Appendix V). However, in becoming an important food item, rainbow smelt have, in effect, redirected energy flow of the ecosystem from native prey species that formerly occupied the niche. Furthermore fluctuating populations of rainbow smelt may result in an unstable and perhaps unsustainable food source for their predators, the consequences of which are all the more serious if rainbow smelt have displaced native species (Havey 1973). Fishers from Norway House have observed large die-offs of rainbow smelt following the spring spawn (Appendix V) but the reasons for this mortality are unknown. Mortality rates of rainbow smelt can fluctuate considerably and have exceeded 90% in the eastern basin of Lake Erie (Ryan *et al.* 2003). This mortality was attributed to the combined effects of fishery exploitation, increased predation, more frequent post-spawning die-offs from the parasite *Glugea* and general poor condition following winter.

The stability of the smelt population in Lake Winnipeg could also be affected by eutrophication and climate-related changes. If eutrophication progresses in the North Basin the range of rainbow smelt may contract because they prefer oligotrophic conditions. Interestingly rainbow smelt appear to be altering the size ratio of zooplankton in the North Basin. They graze on the larger species, thereby leaving the small zooplankton, which turn over phosphorus more rapidly and potentially promote the growth of blue-green algae (Salki *et al.* 2005). Similarly, increasing water temperatures may result in fewer suitable cool-water refugia for rainbow smelt and ultimately a range contraction. Indeed rainbow smelt are already considered to be limited by temperature in both basins of Lake Winnipeg (Franzin *et al.* 2005).

The arrival of several other exotic species to Lake Winnipeg is imminent. The spiny water flea (*Bythotrephes cederstroemi),* a predaceous zooplankter, established itself in Lake Erie in the 1980s and was first reported in Lake of the Woods in 2007. It has a long, barbed tail spine that makes up over three quarters of its length and renders it somewhat unappealing to predators. This zooplankter also has a voracious appetite, consuming smaller, native zooplankton such as *Daphnia* and other important food items for juvenile fish, forage fish and native predatory zooplankters. Once established the spiny water flea can have considerable impact on a lake, including a reduction in native zooplankton species, food-chain disruptions and water-clarity reductions (Zoltak and Brown 2008).

Viral haemorrhagic septicaemia (VHS) is an infectious disease believed to be limited to marine fishes on the Atlantic and Pacific coasts of North America as recently as 2005. However, there have been reports of wild fish mortalities associated with VHS in the Great Lakes where it was first detected in fresh water. Numerous species of fish have been affected by VHS in Canada and the U.S., including walleye, freshwater drum, smallmouth bass, muskellunge, northern pike and yellow perch (DFO 2006).

Asian carp are another serious concern. The term “Asian carp” refers to numerous species of related fish originating from Asia. Two species, the “bighead” (*Hypophthalmichthys nobilis*) and “silver” (*Hypophthalmichthys molitrix*) carps, escaped from aquaculture facilities in the southern United States and are now causing considerable economic and ecological damage in the Mississippi and Illinois river systems. These fish are voracious filter feeders, consuming large amounts of plankton: up to 40% of their body weight per day. They grow to extremely large sizes and up to 9 kg. Plankton form the base of the aquatic food web, so Asian carp compete for food with all life stages of planktivorous fish and the young of many native fish species. Furthermore silver carp has the ability to leap as high as 3 m out of the water, and can cause serious injury to fishers and recreational users as well as damage to boating equipment. The potential distribution of both species could be widespread in Canada, including northward to 55°N or 65°N.

The zebra mussel is perhaps of greatest concern in terms of future exotic threats to the Lake Winnipeg ecosystem. This species has gained global notoriety because of its negative ecological and economic impacts (Zoltak and Brown 2008). The zebra mussel was first reported in Lake Erie in 1988 and has quickly spread throughout the Great Lakes region and southern Ontario. Its arrival in the Red River Basin (Minnesota) in the autumn of 2009 was probably aided by unsuspecting boaters. In less than a year it was documented in the Red River in North Dakota. Unlike rainbow smelt, which surreptitiously installed themselves into the food web of Lake Winnipeg, it is unlikely, based on the experience of Lake Erie, that zebra mussels will go unnoticed if they establish themselves in Lake Winnipeg.

The effects of zebra mussels on Lake Erie’s fish community are still not completely understood but include reductions in fish production and growth rates in many important fish species, and shifts in fish community composition and structure (Ryan *et al.* 2003). Zebra mussels are extremely effective and selective filter feeders, removing microscopic plant and animal matter from the water as a source of food (Hartig *et al.* 2007). As a result water clarity increases and local algal densities and diversity decrease (Zoltac and Brown 2008, Ryan *et al.* 2003). Although this consequence may seem favourable it diverts phytoplankton production away from zooplankters, an important food source for planktivorous fishes. Moreover increasing water clarity allows greater penetration of sunlight, causing light-sensitive fish, such as walleye, to relocate to deeper, darker waters (Ryan *et al.* 2003). The zebra mussel has also been linked to the decline of *Diporeia*, an important food source for many fish species, especially bottom-feeders, such as whitefish. *Diporeia* represented up to 70% of the Great Lakes benthic biomass prior to the arrival of zebra mussels, but populations have declined significantly or disappeared in many areas, causing a major food-chain disruption (Zoltac and Brown 2008).

A typical adult zebra mussel infestation can reach densities in the thousands per square metre (Zoltac and Brown 2008). The debris that collects on the gills of zebra mussels and the feces generated by the mussels themselves build up on the lake bottom (Hartig *et al.* 2007), amounting to a considerable volume of waste. This waste redirects energy from the pelagic food web to the benthic food web (Hartig *et al.* 2007, Ryan *et al.* 2003). The feces of zebra mussels may also contain contaminants derived from the water, algae and sediment that the mussels have filtered. Some of the ingested contaminants are retained in mussels' tissues but much is also excreted and deposited to the sediments where it is consumed by the benthos and ultimately transferred to higher trophic-organisms such as bottom-feeding fishes (Hartig *et al.* 2007). The volume of feces generated also affects the physical habitat of spawning areas such as rocky reefs and other habitats that fish depend on (Zoltac and Brown 2008). Zebra mussels will also change the nature of spawning habitats by attaching themselves in high densities (Leach 1992).

Climate

Most climate scientists agree that human activities over the last 50 years are impacting the global atmosphere and climate is changing (Oreskes 2004, IPCC 2001). On a global basis the average surface temperature has increased over the 20th century by about 0.6°C, temperatures have risen in the lowest eight kilometres of the atmosphere and snow cover and ice extent have decreased (IPCC 2001). There is further consensus that human influences will continue to change atmospheric composition throughout the 21st century (IPCC 2001*)*. Modeling efforts that use doubled atmospheric CO_2 scenarios predict a 1 to 7°C mean global temperature increase and regional changes in precipitation patterns and storm tracks (Ficke *et al.* 2007). An evaluation of potential impacts of climate change in the Great Lakes region concluded that climate change will fundamentally change the character of this region (Kling *et al.* 2003).

Freshwater lakes will endure increased water temperatures and earlier and longer stratification as a result of climate change (Ficke *et al.* 2007). These changes may lead to more severe oxygen depletion, which could alter food-web structure, as described above, and change habitat availability and quality (Ficke *et al.* 2007). Water temperatures directly affect biological processes in lakes, especially those involving fish, which are not able to regulate their own body temperatures. Consequently the body temperature of a fish is generally the same as the water in which it lives, and each species has an optimum temperature at which it thrives (Kling *et al.* 2003). Increased water temperatures affect year-class strength, growth, recruitment and survival (Casselman 2002), trophic dynamics (Jackson and Mandrak 2002), available thermal habitat (Lester *et al.* 2004) and species distributions (Rahel 2002).

A number of climate-related changes are already occurring in Lake Winnipeg and its watershed. In the Winnipeg River Basin long-term gauge records indicate that stream-flow increased significantly during last 80 years, with winter stream-flow going up by 60–110% over the entire Basin. Records from both regulated and unregulated portions of the watershed show changes in annual and winter stream-flow, suggesting that the underlying cause is climate related (St. George 2007). Moreover the discharge of the Red River almost doubled during the period 1996–2005 compared to the period between 1971–1990, and has been attributed to increased precipitation (pers. comm. Greg McCullough). McCullough (2005) determined water temperatures for Lake Winnipeg in the last century (1909–2004), and observed two significant long-term trends: 1) September North Basin water temperatures have increased 1.0°C; and 2) August South Basin temperatures have increased 1.9°C. There were no significant trends towards earlier or later break-up or freeze-up of the Lake during the last century. McCullough (2005) also modeled potential changes in the thermal regime of Lake Winnipeg in response to climate warming, and predicted ice break-up and freeze-up times, yielding length of the open-water and ice-cover seasons. The climate model indicated that by 2045 the South Basin would open about a week earlier and the North Basin about one and a half weeks earlier than in the last century. By 2085 the North Basin would break-up two to three weeks earlier, and the South Basin a week and a half to two weeks earlier. No significant change was predicted in the time of freeze-up.

Climate warming effects on the Lake Winnipeg fish community were predicted to be more extensive in the South Basin than the North Basin due to the former's smaller volume of water and lower heat storage capacity (Franzin *et al.* 2003, 2005). However, climate warming, unless extreme, may not change the distribution of the overall fish community because most Lake Winnipeg species are nearer to their northern than their southern limits. Two main effects could result from a longer, warmer growing season and a shorter winter (Franzin *et al.* 2005). First warm-water species like walleye should produce larger young-of-the-year that would likely have greater survival through a short winter. However, less winter snow accumulation may result in less spring run-off, which could impact spawning habitat of streams (Franzin *et al.* 2003). The impacts of a change in thermal regime are less clear for cold-water species like lake whitefish and cisco because the development of eggs depends on a cold-water incubation period. Also whitefish larvae depend on zooplankton, the development of which must be somewhat synchronous (Franzin *et al.* 2005). Nevertheless lake whitefish, cisco and smelt would likely be lost from Lake Winnipeg (Franzin *et al.* 2003). Second higher temperatures and a longer growing season may also increase the overall productivity of the lake (Franzin *et al.* 2003).

The question of water quantity will play a critical role in spawning-stream habitat and maintaining suitable water-quality conditions (Franzin *et al.* 2003). Current climate models predict two main trends for the Lake Winnipeg drainage basin: increases in summer air temperatures of 6 to 9°C, and decreases in summer soil moisture of 30% to 50%, including lower snow accumulations in the winter. Overall these trends would lead to a long-term reduction in water supply to Lake Winnipeg, resulting in lower Lake and stream levels (Franzin *et al.* 2003). However, hydrological trends in the Winnipeg River Basin predict an increase of 20 to 30% in runoff in the Winnipeg River region and northern and central Manitoba by the middle of the 21st century (St. George 2007). To better understand the potential effects of the various aspects of climate warming on the fish community more intricate lake modeling is required (Franzin *et al.* 2005). To develop such models physical, biological and chemical data derived from on-lake research and monitoring are essential.

The complexity of the factors involved in understanding the impacts of multiple stressors on the fish community of Lake Winnipeg speaks to the need for continued on-lake research to better understand changes in ecosystem structure and function. Furthermore this situation highlights the need for a flexible management system, such as that proposed in this report, and one that integrates fisheries management with water-quality management and research.

V. CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The stated MFB guideline for managing commercial net fisheries is:

"*Quotas beyond the estimated MSY should not be considered*".

As we have discussed in Chapter III and IV the use of MSY is problematic. Further MSY does not capture the full dimension of the fishery that needs to be considered in developing harvest management goals. A sustainable biological resource is a necessary precondition to achieving any of these goals but it is critical that economic and social information be incorporated in annual decisions in addition to the underlying biology of the system.

Explicit harvest policies that incorporate biological, social and economic considerations are beyond the mandate of this Task Force and will need to be established by the Lake Winnipeg Co-management Board. The proposed annual cycle of technical review followed by presentation to the Management Board (see our recommendations below) will allow this to occur, as an iterative process, throughout the coming years. Examples of development of harvest policies can be found among the papers in Bence et al. 2008.

We have carried out our review of the status of the Lake Winnipeg fishery following the key principles of biological sustainability and a precautionary approach when uncertain over impacts. In summary we have found significant uncertainty in the fishery data of Lake Winnipeg, which is exacerbated by environmental uncertainty from factors such as exotic species, nutrient loading and climate change. The lack of knowledge of fish stocks and the environment makes it problematic to determine the following: 1) whether increases in the walleye population observed in the past decade are likely to continue or are a result of the normal cycles of fish populations in any system; or 2) whether the decrease in sauger harvests is a result of a decline in the population or a shift in fishers' preference towards more-available and higher-priced walleye; and 3) whether the lake whitefish population could withstand higher fishing pressure or it is close to its long-term sustainable yield.

Catch rates in the commercial fishery and the index-net series suggest that walleye are abundant and healthy; commercial production is currently stronger than it has ever been and there is a growing recreational fishery for walleye on the Lake. However, the age structure of walleye shows that their abundance is mostly due to a single age class: fish hatched in 2001. This age class can be expected to sustain the fishery in the immediate future, but eventually the fishery will need to depend on the upcoming age classes. The available data indicate upcoming age classes are not as abundant, suggesting a decline in catch rates in the future. The position of sauger is more tentative. Its decline in commercial catches has continued consistently since the late 1980s. Its presence in the survey catches also declined in the late 1980s and remained low, albeit stable, through the 1990s and into the 21st century. Low sample sizes and lack of available data leave the trends in the most-recent years unclear, although the most-recent age data suggest that there are two years of good recruitment in the population. Observations by the fishers on the Task Force indicated that sauger harvests are influenced by walleye prices and abundance and may not accurately reflect actual abundance of sauger in the Lake. Whitefish trends suggest that, as a species that is only weakly sought, harvests have remained stable over the past two decades. Still the information on lower-value species within a multi-species quota can be poor due to unreported discarding of catch. Given the low catch rates and questionable changes in catch rate and other indicators of population health, whitefish should continue to be followed closely. Sampling independent of the regular commercial catch will be important in cases like this.

As a result of our work the Task Force has reached three major conclusions as follows:
1. The available fisheries information and analysis from MFB monitoring and research programs, fisheries harvest data from the FFMC, fishers' knowledge of the fishery, and results from other government, university, non-government organizations and the private sector are inadequate to determine absolute estimates of current or past biological productivity for Lake Winnipeg. The proper application of standard stock-assessment methods based on biomass or indices is impossible with the data at hand.
2. Due to the lack of data we are unable to recommend either increases or decreases in the total RAH of 6.52 million kg for the Lake.
3. The uncertainty and lack of adequate information to make informed decisions about possible changes in RAHs will continue unless there are changes made to data-collection systems by the MFB, FFMC and fishers, and additional research is carried out to enhance our understanding of the fishery, the fish and the broader ecosystem.

It is important to emphasize that although the Minister of Water Stewardship has primary legislative authority for the Lake Winnipeg fishery and the MFB has the major operational responsibility, in a co-management arrangement the other major participants—the fishers and the FFMC— also have important roles and responsibilities. The Task Force was established by the Minister of Water Stewardship, but our conclusions and recommendations are also directed at fishers and the FFMC. All parties must be involved if our recommendations are to be implemented successfully.

Our recommendations are presented as a series of inter-related actions. First should be the development of separate RAHs for each species. Separate RAHs should be based on partitioning of the current total combined allocation into an initial and separate RAH for each species based on the current quota. A reference indicator system needs to be developed to provide more objective advice on increasing or decreasing RAHs in the future. The reference indicator system must be supported by adequate surveys and monitoring to provide the necessary data. The monitoring and decision-making processes must be supported by research, new knowledge and proper data management. Most critical is an open and transparent adaptive co-management process. The process would be responsible for future stock assessment recommendations and reporting to the Minister or Co-management Board for fisheries management decision-making. The Task Force is confident that implementing this adaptive co-management process will lead to better and more timely decision-making, and will ensure transparency and build trust and support with all involved communities.

RECOMMENDATIONS

1. RAHs For Sauger, Walleye and Lake Whitefish. *The Task Force recommends that the current multi-species quota of 6.52 million kg for sauger, walleye and lake whitefish be partitioned into three separate RAHs for the three species in a ratio of 19% for sauger (1.24 million kg), 56% for walleye (3.65 million kg) and 25% for lake whitefish (1.63 million kg).*

In general the scientific assessment is that a multi-species quota does not meet the Precautionary Principle for fisheries management of these three species. Whitefish, walleye and sauger have very different life histories, prices between the three species can vary significantly and fishers can selectively harvest the more desirable species (see details in the Assessment Section). There is a significant capacity to over-harvest one species while under-harvesting the others.

The partitioning for lake whitefish is based on the mean percentage of whitefish of total quota species reported harvested and delivered to the FFMC during the years 2000 to 2008, i.e. 25%. The further partitioning of the remainder to walleye and sauger is based on the CPUE of each species in the current MFB index-netting program for the years 2006 to 2009, i.e. 56% and 19% for walleye and sauger, respectively.

The Task force urges extreme caution in relying on this partitioning for long-term management. The whitefish portion is based on commercial harvesting that has an overall tendency to select for walleye and sauger, so it may be an underestimate. Anecdotal reports of bushing of whitefish by fishers indicates that the actual harvest is probably higher. The partitioning between walleye and sauger is based on very few years of data and very few nets, and the results differ considerably from results of the commercial fishery. We know that fishers are selecting walleye but the extent is unknown. Our conclusions above regarding the health of the stocks of the three fish species are also relevant. We know a bit about the harvest but not much about the populations.

The Task Force assumes that RAHs will be adjusted in the future following the other recommendations in this report.

2. RAHs for a Lake Whitefish/Percid Option for Establishment of Quotas. *The Task Force recognizes that the overall authority for the fishery (i.e. either the Minister of Water Stewardship, or a new Lake Winnipeg Co-Management Board) may choose not to separate the current multi-species quota into species quotas but may retain a combined percid quota. In this event RAHs should still be established for all three species and future management decisions on increases or decreases of a combined percid quota should be on the basis of the species whose stock status is rated in the Cautious Zone or Critical Zone even if the other species is rated in the Healthy Zone. This recommendation follows the Precautionary Principle and assumes that the recommendations below for reference indicators and a new assessment process are fully implemented.*

Scientifically a multi-species quota does not meet the Precautionary Principle for fisheries management of these three species. However, the fishers on the Task Force have emphasized that there are strong practical, operational reasons for establishing a common percid quota for sauger and walleye and that sustainability of the Lake Winnipeg fishery depends upon social and economic considerations as well as biological considerations. They also emphasized that the fishery has remained successful under the current management regime for the past 40 years.

The Task Force recognizes that this is to be an adaptive co-management process and has considered how a percid quota might be achieved within a precautionary approach. Technical advice must still be provided in terms of a RAH for each species. The biological assessment process must be maintained and monitoring enhanced as described in the following recommendations. As well as closure of the fishery when the quota for the most vulnerable species is reached management factors that need to be considered for co-management of the fishery and protection of a vulnerable stock from over-harvesting include the following: 1) FFMC pricing; 2) different mesh sizes for nets; 3) changes in fishers' behaviour; 4) modified use of tolerances; 5) changes in seasonal openings and closings; 6) changes in regulatory areas; and 7) additional protected areas. As described below the options must be discussed and agreed upon before problems arise with the fish stocks.

3. Reference Indicators for the Future. *The Task Force recommends that the Minister of Water Stewardship, or a new Lake Winnipeg Co-Management Board, implement a biological reference indicator process for annually assessing the status of lake whitefish, sauger and walleye stocks of Lake Winnipeg and determining whether changes to the RAH are necessary.*

In Chapter III we discussed the United Nations FAO Code of Conduct for Responsible Fishing and the fundamental need to implement a reference-indicator process. We also outlined how a traffic-light approach has been used in other data-poor fisheries where precise measures of important reference indicators have not been established. Implementation of such a process will need the full support of the fishers and the government, presumably though the proposed Lake Winnipeg Fisheries Co-Management Board. The following evaluation matrix demonstrates how the recommended process might proceed *for each species*. The Task Force proposes that at least six indicators (Mohr and Ebener 2005) that describe the status and health of the stocks (including the first six in Table V.1) be considered against pre-defined criteria indicating current risks to the stock.

It is important to recognize that this matrix is not definitive. The Task Force did a preliminary evaluation of the indicators to use (Appendix III)—the two left columns in the matrix below—but the importance of each indicator should be re-evaluated, and will differ between species. Furthermore establishing decision points for deciding whether a stock is in the red (Critical), yellow (Cautious) or green (Healthy) Zone will take significant additional work involving fishers and scientists with experience in establishing reference indicators. This additional work should proceed only after the overall process has been agreed to and approved by the Minister or Co-Management Board.

Table V.1. Example of "Traffic Light" approach to the use of reference indicators for decision-making for the Lake Winnipeg Fishery.

Indicator	Importance of Indicator	Critical Zone High Risk "Red Light"	Cautious Zone Medium Risk "Yellow Light"	Healthy Zone Low Risk "Green Light"
1. CPUE (commercial)	High	Declining trend	Stable or increasing trend	Increasing trend
2. CPUE (index-netting)	High	Declining trend	Stable	Increasing trend
3. Number of Year Classes (commercial)	High	Less than a defined number	Equal to defined number(s)	Greater than a defined number
4. Number of Year Classes (index-netting)	High	Less than a defined number	Equal to defined number(s)	Greater than a defined number
5. Mean Age of Stock (index-netting)	Low	Decreasing trend	Stable	Increasing trend
6. Mean Age (commercial)	Low	Decreasing trend	Stable	Increasing trend
7 Size at Age (commercial and index-netting)	Med	Decreasing trend when stock size is stable	Stable	Increasing trend when stock size is stable
8. Age at Entry to Commercial Fishery Compared With Mean Age at Maturity	Med	Less than defined limit	Within defined limits	Greater than defined limit
9. Recreational Abundance Index	Med	Low index	Mid index	Increasing or high index
10. Inshore Seine Abundance	Med	Decreased from previous year	Stable	Increased from previous 3 years
11. Domestic/ subsistence Harvest	Low	Decreasing	Stable	Stable or increasing

12. Additional Indicator[14]	-	-	-	-
13. Additional Indicator	-	-	-	-
Etc.	-	-	-	

Table V.1 shows 11 indicators only but a higher number would be desirable and would be possible if the monitoring programs recommended below are enhanced as described. Values for classification of each indicator as high, medium or low risk need to be pre-defined. For example for Lake Huron lake whitefish stocks, less than seven year classes in the commercial harvest would be a red light, whereas presence of more than 12 year classes would be a green light. Similarly a decline of CPUE over three consecutive years would be a red light, whereas an increase over two years would be a green light. Managers and fishers need to agree, in advance, on values for Lake Winnipeg sauger, walleye and lake whitefish.

Changes in the RAH would be based on the overall status of those assessments. Individual indicators would be assessed as Healthy (RAH up), Cautious (RAH remain) or Critical (RAH down). Changes in the RAH would be based on the number of indicators that were in a high risk (red light), medium risk (yellow light) or low risk (green light) zone. Allowable changes to the RAH would be limited to plus or minus 10% change from current levels. This annual assessment would take place in Step F in the adaptive co-management assessment process described in Recommendation 6 below.

The Task Force discussed individual indicators and what would constitute a green, yellow or red assessment but cannot presently make specific recommendations. The task is comprehensive, and cannot be started until a decision is made by the Minister of Water Stewardship and/or the Lake Winnipeg Co-management Board on the recommendation above to partition the multi-species quota into individual RAHs. A 1 to 2 day workshop of external specialists, provincial biologists and experienced fishers charged to develop the indicators and criteria for assigning risk has been effective in other jurisdictions. Separate 1 to 2 day workshops for lake whitefish and percids would probably be necessary. In preparation for these workshops preliminary assessment models should be constructed with available data allowing first approximations to quantitative reference points such as total instantaneous mortality (Z), instantaneous fishing mortality (F) and spawning stock biomass per recruit (SSB/R).

4. Monitoring and Surveys. *The Task Force recommends that the Department of Water Stewardship do, or arrange for other agencies to do, an integrated series of monitoring and surveys in support of the reference-indicator system recommended above and the management decision process described in the final recommendation below.*
Specific recommendations are as follows:

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[14] See Appendix VI for comments from peer reviewers on suitability of specific indicators and for additional indicators that should be considered.

<u>4a. Commercial fisheries harvest and effort monitoring program.</u> *The Task Force recommends that Lake Winnipeg fishers, the FFMC and MFB, working under the direction of the Minister of Water Stewardship or a new Lake Winnipeg Co-Management Board, modify the current FFMC delivery slip system to ensure that each delivery of fish also incorporates, at a minimum, information on the number of nets, lengths of nets, mesh size of the nets and nights set and that this information is used to establish commercial fisheries CPUE for each species.*
To reiterate our previous point current harvest data from the FFMC is deficient because the number of deliveries is not inadequate as a measure of fishers' effort. Acceptable comparisons of CPUE are impossible with the current system and CPUE is a critical indicator of change in stock status. This change should not be complicated but it would involve integration of information between FFMC and MFB in a readily accessible manner including catch, effort and index-net data. This change should facilitate annual updates of standard analyses.

Commercial CPUE data are a critical indicator of the health of a fishery. The current FFMC record of deliveries informs about fishers' harvest but does not account for actual fishing effort. (See Deroba and Bence 2009) for an analysis of how best to evaluate CPUE of commercial fisheries.) The simple addition of effort metrics to the reporting system will significantly enhance the usefulness of the commercial CPUE data for decision-making on changes to RAH for sauger, walleye and lake whitefish.

<u>4b. Index gill netting monitoring program.</u> *The Task Force recommends that MFB increase the coverage of the index-survey program to provide statistically valid data.*
Analysis of the program suggests that the number of sets should be closer to 400 index sets annually, compared to roughly 80 presently used, to properly track changes in stocks. A five-fold increase may be daunting to the department but the Task Force recommends that fishers be involved to do some of the work. A one- or two-year effort by the department may be needed initially to determine the variability of results by area and time. Once this initial large survey is completed the number of sets could be apportioned according to a pattern that would best reduce statistical uncertainty. Areas could be identified where fishers could do the sampling to reduce costs to the department.
The current index-netting program focuses on percids whereas the Mossy Bay program focuses on lake whitefish. These two programs need to be integrated with appropriate stratification to ensure adequate sampling of all relevant habitats.

<u>4c. Commercial catch sampling program.</u> *The Task Force recommends that MFB review the current catch-sampling program and consider options for including data in addition to age.*
The current program samples fish at the Transcona plant, but the fish are headless dressed, so there are no weight data. Proxy weights are calculated using the weight to age relationship derived from the index gill-netting program. Thus a reference indicator based on commercial catch sampling is compromised, i.e. it

lacks independence from the index-netting program. A sentinel fishery program (described below) could address this issue by including age structures in the sampling

4d. Sentinel fishers monitoring program. *The Task Force recommends that Lake Winnipeg fishers, the FFMC and MFB, under the direction of the Minister of Water Stewardship or a new Lake Winnipeg Co-Management Board, establish a new sentinel fishers program to develop a reliable commercial index of abundance of stocks of walleye, sauger, whitefish and non-target species.*

A sentinel fishers monitoring program would involve specific fishers who would record statistics on their catches and catch rates year after year. There would be regular (at least weekly) interaction between departmental staff and selected fishers.

A sentinel fishers program would have advantages for tracking CPUE over other options, such as a general fisher's logbook program, for several reasons:

i) There would be direct involvement and communication between assessors of the fishery and resource harvesters. Both parties would work towards the same objective of having a productive and sustainable fishery, which will build trust and a sense of common purpose;

ii) The problems of hyperstability and hyperdepletion in catch rate analysis (Chapter III: *Commercial Data in Fishery Assessment*) may be avoided or reduced; and

iii) Factors that influence CPUE in the fishery that may be obscured in an overall logbook program are often revealed, e.g. effects of market price, weather and changes in the experience of active fishers.

4e. Small fish trawl program. *The Task Force recommends that MFB continue the Offshore Small Fish Trawl program for another five years with annual assessments of its efficacy as a predictor of future walleye recruitment into the commercial fishery and as an estimator of abundance of forage fish (including rainbow smelt) and the abundance of exotic species.*

The aims of the current program are: 1) to describe the seasonal distribution and abundance of small-bodied fishes in the offshore waters of Lake Winnipeg; and 2) to establish geographic patterns of estimated age-0 walleye densities during the spring, summer and autumn.

4f. Recreational Surveys. *The Task Force recommends that the Department of Water Stewardship ensure that the National Sport Fishing Survey is modified to include sauger as well as walleye as a species to be identified. Also the Department should survey recreational fishing on Lake Winnipeg, and important tributaries, on an annual basis to determine recreational harvests of walleye and sauger and recreational CPUE.*

Effective management of the fish stocks requires knowledge of all significant sources of harvest mortality. The limited surveys that have been done indicate that recreational fishers harvest a proportionally small, but not insignificant, number of walleye and sauger. Recent anecdotal observations indicate that these fishers

are starting to exploit Lake Winnipeg walleye more heavily in the winter through the ice fishery, but actual harvests are not known. Changes in recreational harvests can also be an indicator of changes in the abundance of walleye and sauger.
A full creel census every year might not be necessary. The type of survey done should considered. A mail-in survey, similar to the National Sport Fishing Survey carried out every five years could be used. Alternatively a relatively simple estimate of total effort, e.g. number of ice huts or number of boats, calibrated by a more detailed creel census on a periodic basis, could provide the necessary indicator of changes in abundance and allow determination of annual mortality of walleye and sauger attributable to recreational fishers.

4g. Domestic (subsistence) survey. *The Task Force recommends that the Department of Water Stewardship arrange for completion of a comprehensive survey of the harvest and consumption of fish from Lake Winnipeg by First Nations communities.*
Effective management of fish stocks requires knowledge of all significant sources of harvest mortality. Very little is known of the domestic harvests of fish from Lake Winnipeg, although constitutionally protected aboriginal domestic harvests are the first priority after conservation for all Manitoba fisheries. Our analyses indicate that current domestic harvests could range from 5% to 10% of recent commercial harvests but we have little confidence in the accuracy of this estimate. The survey needs to consider all First Nations communities around the Lake, it needs to address harvest number and weight by species on an annual basis, and consumption by people. Depending on the size and variability of harvests, as determined by the survey, a decision can be made about continuing a monitoring program on an annual or periodic basis. Ongoing monitoring of domestic harvests could contribute to future determinations of the health of the quota species and changes in relative abundance of other species, particularly exotic species.

5. Areas of Needed Biological Research for Lake Winnipeg Fisheries. *The Task Force recommends that the Minister of Water Stewardship seek the support of Fisheries and Oceans Canada, university researchers, Manitoba Hydro, the LWRC, Lake Winnipeg fishers and the Centre for Indigenous Environmental Resources, amongst others, to support research initiatives related to the fish and fish habitat of Lake Winnipeg.*

Effective management depends on scientific, local and traditional knowledge and understanding. Environmental research on Lake Winnipeg has increased in recent years but in total it pales in comparison to efforts on other large lakes in southern Canada. The Task Force has identified the following areas of needed research:

5a. Research in support of the monitoring programs we have recommended.
The monitoring programs we have recommended need to follow appropriate adaptive management protocols in their ongoing operations but they also need to be supported by specific research. For example the statistical validity of all of the

programs needs to be reviewed using power analyses based on observed variability in collected data, followed by modification if warranted.

5b. Diets of lake whitefish, walleye and sauger. Fishers have observed (Appendix V) that rainbow smelt predominate in the diets of walleye in the North Basin and that even lake whitefish are feeding on rainbow smelt. Sheppard *et al.* (2010) found that smelt comprised 100% of the diet of walleye over 181 mm in fork length in the North Basin. Changes in diet can affect growth rates, survival and quality of fish. Predation on rainbow smelt may be a factor in the increased abundance of walleye in the North Basin and also may be of significance for lake whitefish and sauger. Diets of the three quota species need to be investigated, especially in comparison to historical data. Information on diet, abundance and growth could be used to evaluate predation effects of walleye on the fish community and sustainability of the fishery harvests.

5c. Genetic stock structure. Understanding of genetic stock structure of a large lake such as Lake Winnipeg is important for effective management and stock protection. There have been only three or four such studies on lake whitefish and walleye in the Lake and none on sauger. New techniques and broader spatial studies need to be applied to all three species. In particular the belief by many that walleye migrate between the North and South Basin may be addressed, at least in part, by a better understanding of genetic stock structure.

5d. Seasonal migrations of walleye, sauger and whitefish. Fish move widely within the Lake. Movements occur between spawning, rearing and feeding areas in response to water-level changes, winds, storms, water-temperature and season. Fishers are knowledgeable bout timing and direction of regular changes but their knowledge is not well documented and the importance of movements for stock health and for stock assessments is unknown. A fishers' knowledge study, combined with scientific tagging studies and genetic studies, is necessary for a fuller understanding of the importance of these movements.

5e. Incorporate fishers knowledge into research priorities. Fishers' knowledge can be incorporated into management decisions through data collection and surveys of locally specific information, but fishers' input in asking relevant questions, study design and interpretation should not be ignored (Stanley and Rice 2007). Fishers frequently raise many questions that might well be addressed by the scientific community, and a formal mechanism for identifying those questions would facilitate priority setting for the scientific community. The proposed Lake Winnipeg Fisheries Co-Management Board should make input by fishers one of their primary responsibilities. A specific mechanism for encouraging this involvement would be through the assessment team activities described in Figure V.1 (box F), below.

5f. Ecological model for Lake Winnipeg. An ecological model would aid in understanding the effect of changes in food-web structure on fisheries productivity. In effect it would help to bridge the knowledge being acquired in recent aquatic environmental studies coordinated through the LWRC and the fisheries management sector. An ecological model could also aid in understanding the impact of changes in fisheries management procedures on fish stocks. For example ECOPATH/ECOSYM has been used effectively to model ecosystem effects on fisheries (Bundy et al. 2008). The Task Force emphasizes, however, that implementation of an ecological model for Lake Winnipeg fisheries would not replace the need for improvement of actual monitoring programs as described above. Such models generate hypotheses about how an ecosystem will respond and cannot be taken as final proof of the future results of any specific management action.

5g. Information on critical habitats and habitat components. Baseline information is needed on critical habitats of the Lake including: 1) an aerial inventory of habitats in the North Basin and channel areas, a fish-habitat classification system and an assessment of the use of streams and reefs for fish spawning; 2) a full understanding of the effects of rainbow smelt and its relationship to the quota species, to other prey species such as cisco and to lower trophic levels; 3) understanding of the impact of artificial changes in water flow regimes in Lake Winnipeg on fish movements, spawning success and productivity; and 4) ongoing monitoring of the chemical, biological and physical variables of the Lake ecosystem of both the pelagic and nearshore areas to support development of a whole-ecosystem model and to gain a better understanding of trophic dynamics as affected by eutrophication, climate change, exotic species and other stressors to the ecosystem.

5h. Management changes should be the subject of systematic evaluation. Managers and fishers can learn from the success or failure of management actions but only if the rationale and expectations for proposed changes are explicitly stated, decision points for success or failure of the new approach defined, results monitored and the changes reversed or accepted for future operations.

6. Data Stewardship and Management. *The Task Force recommends that an integrated data management system that includes all relevant data be developed for the Lake Winnipeg fishery.*

Currently there is no organized data-management system other than that maintained by the FFMC. In order to efficiently analyze fisheries the data need to be organized with consistent fields and formats and maintained over time. Data need to be readily accessible, especially if there is to be a multi-player technical working group (see below). Meeting these needs is not a trivial task, and will require additional resources and new levels of coordination between agencies and stakeholders.

For example Appendix III summarizes current and historic fisheries data sources, and provides brief assessments of the use and usefulness of the data for fisheries stock assessment. However, these data sets have not been assembled into a common location or standardized format and thus are not readily available for analysis. Further many data series (e.g. aging structure methods) vary among years without current standardization. There needs to be improved data quality and integration particularly in support of the use of more sophisticated models, e.g. surplus production models, as a starting point, and moving towards age-structured models such as statistical catch-at-age models. Discussions with MFB staff indicate that initiatives in standardization are underway.

7. Adaptive co-management assessment process. *The Task Force recommends that the Minister of Water Stewardship or the new Lake Winnipeg Co-Management Board implement an adaptive co-management process for the annual assessment of lake whitefish, walleye and sauger for Lake Winnipeg.*

The Task Force feels very strongly that acceptance of decisions by the Minister of Water Stewardship and/or the new Lake Winnipeg Co-Management Board will be more trusted and have greater acceptance by fishers, government and FFMC personnel, community leaders and the general public if the process by which annual recommendations on the status of fish stocks, and any changes to RAH levels flowing from the reference-indicator system described above, occurs within an open and transparent process subject to the appropriate levels of examination and scrutiny. Adaptive management is a cyclical process of identifying management alternatives or options, development of key indicators and designing an effective monitoring system (Walters 1986). In other words it is a system of institutional learning from trial and error that includes documenting decisions, evaluating results and responding to the evaluation (Hilborn 1992). Adaptive co-management is "*a long-term management structure that permits stakeholders to share management responsibility within a specific system of natural resources and to learn from their actions*" (Armitage *et al.* 2007). For Lake Winnipeg this process would involve fishers, government biologists, FFMC managers and others and would be critical to sound decision-making by the proposed new Lake Winnipeg Co-Management Board.

The process we present here is an annual cyclical process shown in Figure V.1. The key components are summarized as follows:

A. Co-Management Board/Minister of Water Stewardship makes decision on annual quota (May 1);

B. Fishers begin fishing (May 15);

C. MFB, FFMC and fishers collect data from commercial fishery and from index surveys (May 15 to Oct. 31 for open water and Dec. 1 to Mar. 31 for winter fishery);

D. Fishing ends (Mar. 31);

E. MFB biologists collate the fishery and index-survey data. They analyze these data for changes and potential trends in the fishery's indicators (Nov. 1 to Mar. 1);

F. Assessment Team (MFB biologists, fishers, FFMC and outside scientists by invitation if desired) reviews data and makes recommendations to Management Board/Minister of Water Stewardship (Apr. 15 to 20) on RAH levels;

G. Independent science/fishers review of the assessment process, reference indicators and state of knowledge of fish-stock health. The independent review is established by and reports to the Lake Winnipeg Management Board (or Minister of Water Stewardship) regularly every five years and by special request of the Board in other years if considered necessary; and

H. Regular public reporting of results of the ongoing assessment program through an ongoing SOL Report, or other similar mechanism if the SOL report is not established on an ongoing process.

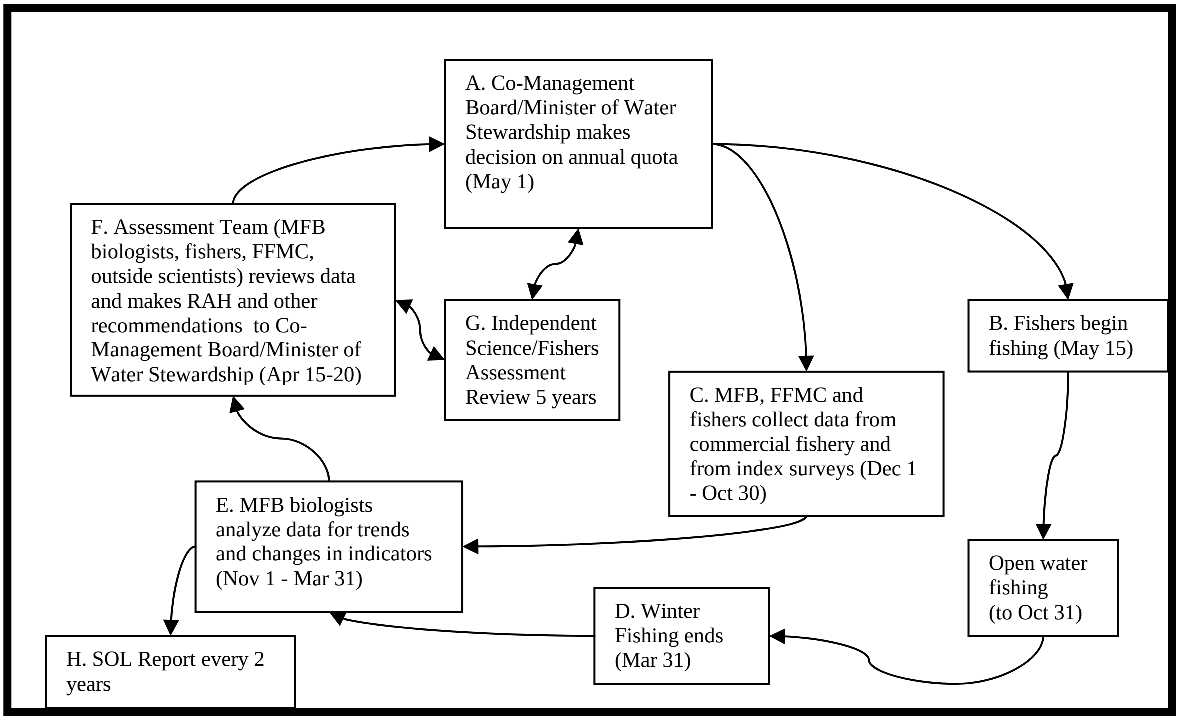

Figure V.1 Schematic diagram of a proposed model for the annual, cyclical, adaptive co-management process of stock assessment of the lake whitefish, walleye and sauger fisheries of Lake Winnipeg.

Figure V.1 is an outline of how an adaptive co-management process might work for Lake Winnipeg. It is not complete and many aspects of the outline may be subject to challenge and change. The Joint Strategic Plan and lake committee model used in the Great Lakes has had success getting disparate parties to work together and may also provide guidance. However, further refinement requires input from those who will be directly involved, following the principle of stakeholder involvement espoused by Armitage *et al.* (2007). It is important to note that the process of adaptive co-management requires that there must be a clear, regular record of all management decisions and actions with supporting rationale maintained for the Minister, Co-Management Board and the Assessment Team including, but not limited to, QE changes, openings and closings, net changes, price changes, etc.

CONCLUDING SUMMARY

The Task Force emphasizes that the fisheries of Lake Winnipeg are generally in a healthy state and given proper management the resource will be biologically, economically and socially stable in the future. However, the lack of adequate information means that there are uncertainties about the actual productivity of the Lake and there are environmental uncertainties for the future. The Task Force is confident that implementation of the above recommendations will assist the government, fishers and industry to ensure that the fishery remains sustainable.

The Task Force also emphasizes that the fishery will be at risk without the implementation of the recommendations. Our recommendations for RAHs are only a starting point. The fishery is at an historic high but natural systems are subject to significant fluctuations. The history of Lake Winnipeg fish stocks has been one of significant variability and it is relevant for us all to remember that in the early 1940s sauger harvests were as high as walleye harvests are at present (see Figure I.1). We have seen other systems, such as Lake Erie and Lake Winnipegosis (Lysack, 2006), experience extremely high catches for a number of years followed by dramatic collapses. In Lake Winnipeg there have been unprecedented levels of algal production in the last decade and smelt are providing a new food source for quota species. These changes may have fuelled an increased carrying capacity; however, it is well documented that over-production can lead to the destruction of systems.

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APPENDICES

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Appendix I. LWTF - Acronyms and Glossary

Adaptive Management	This is a resource management process in which managers and fishers learn from their successes and failures. It can be described as a three step process of documenting decisions, evaluating results and responding to the evaluation or similarly identifying options, development of indicators and monitoring results.
Adaptive Co-management	Adaptive co-management combines the shared management responsibility of co-management with the cyclical process of adaptive management
Allozymes	In genetic terms these are different forms of an enzyme or protein that are coded by different alleles at the same locus.
Co-management	A long-term management structure that permits stakeholders to share management responsibility within a specific system of natural resources. For Lake Winnipeg this process would involve fishers, government biologists, FFMC managers and others.
CLAs	Community Licensing Areas. There are 12 Areas plus Norway House. The whitefish fleet is also treated as a CLA for some management actions.
CPUE or CUE (Catch Per Unit Effort)	Catch Per Unit Effort. The amount of fish caught for a given level of fishing effort e.g. number of fish caught per gill net per night (standard length of net and size of mesh).
D	Mean depth.
DFO	Department of Fisheries and Oceans (Canada)
F	Instantaneous fishing mortality
FAO	Food and Agricultural Organization of the United Nations
FFMC	Freshwater Fish Marketing Corporation. The primary buyer, processor and marketer of commercial freshwater fish caught from Lake Winnipeg, the prairie provinces, the NWT and northwestern Ontario
Fishers Knowledge	This is the knowledge held by fishers. It comes from their own experiences and the shared experiences of other fishers. It may also be called traditional knowledge or local knowledge depending on the specific circumstances. For this report it is their knowledge of the Lake Winnipeg fishery that is important.
Fishery	The act, process, occupation or season of taking fish.
FWI	Freshwater Institute. Regional headquarters and research center for the Department of Fisheries and Oceans on the University of Manitoba campus.
FWIN	Fall Walleye Index Netting. Standardized index netting program of OMNR to assess health of walleye stocks in Ontario
Haplotype	In genetics, a haplotype is a combination of alleles at multiple

	loci that are transmitted together on the same chromosome. In fisheries genetic studies information about haplotypes can be used to determine whether different groups or stocks of fish are genetically discrete or non-interbreeding.
Hyperstability	As abundance declines the remaining fish often concentrate in the best locations at densities similar to those present under high abundance. Fish harvesters know these locations and prefer to set their gear there. Thus commercial catch rates can remain similar or stable as abundance declines.
Hyperdepletion	When fishing occurs away from the areas that fish prefer then numbers may appear to decline in the commercial catch rates even though the majority of the population remains unfished and the stock is not actually depleted.
ITQ	Individual Transferable Quota. A means of regulating commercial fisheries in which individual fishers are allocated a share of a total allowable catch (TAC) established for a specific stock(s) for a particular time (season or year). Individual quotas may be bought, sold or leased following specific rules. The ITQ system for Lake Winnipeg is referred to as Quota Entitlement (QE).
LWRC	Lake Winnipeg Research Consortium. A charitable corporation that coordinates scientific research on Lake Winnipeg. Membership includes agencies representing various government and university departments, and corporate and other groups.
MEI	Morphoedaphic Index. A statistical method of predicting the expected harvest of fish from a particular lake based on the mean depth of a lake and the total dissolved solids in the water. This method was developed for small northern Canadian lakes for which little other biological or fishery information was available. It has been used as a first approximation of fish yield not for predicting annual variability in fish populations.
MFB	Manitoba Fisheries Branch. The provincial agency with primary responsibility for management of the fisheries of Lake Winnipeg.
MSY	Maximum Sustainable Yield. This is theoretically the largest yield or catch that can be taken from a population of fishes over an extended period. Examples of many fisheries have shown that attempting to manage fisheries at a MSY is not in practice sustainable. The stated MFB guideline for managing commercial net fisheries is *"Quotas beyond the estimated MSY should not be considered"*.
mtDNA	Mitochondrial DNA. Used as molecular markers to track female lineages.
Microsatellite of nuclear DNA	Polymorphic loci present in nuclear and organellar DNA. They are used as molecular markers which have wide-ranging

	applications in the field of genetics, including kinship and population studies.
NWT	Northwest Territories
OMNR	Ontario Ministry of Natural Resources
Precautionary Approach	As used in this report the precautionary approach to fishery management is the practical application of the Principle in terms of tactical decisions for quota setting. The Canadian Federal Government Precautionary Approach framework as applied to fisheries prescribes three stock status zones viz. "critical zone", "cautious zone" and "healthy zone" and management decisions are to be based on the stock status zone.
Precautionary Principle	A general philosophy to managing threats of serious or irreversible harm where there is scientific uncertainty. The precautionary approach was defined in the 1992 UN Conference on Environment and Development as "In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation. For Lake Winnipeg this Task Force interprets the Precautionary Principle to mean that we should err on the side of conservation when we consider sustainable harvest levels particularly when the chance of irreversible changes may mean that future generations may not have access to the fish stocks that the present generation does.
QE	Quota Entitlement. This is the ITQ system for Lake Winnipeg. Individual fisher quotas are established by season, and area for a combined three species quota for lake whitefish, walleye and sauger.
RAH	Recommended Allowable Harvest. Biological advice on future levels of fish harvests following established procedures following a precautionary approach for a sustainable fishery. Advice delivered to management decision makers for decisions on TAC, QE or other fishing regulations.
Reference Indicators	Reference indicators are simple measures or statistics that are scientifically credible and representative of a fish stock or population. They can help us to keep track of trends in the state of the stocks and measure progress towards a desired point. For example CUPE is often used as a reference indicator for fish stocks. See the discussion in the Text for a fuller description of reference indicators, related terminology and how the information they convey can be used in fisheries management. See Appendix IV.c for a fuller description of different reference indicators and their potential applicability for Lake Winnipeg.

SOL	State of the Lake (report).
SSB/R	Spawning stock biomass per recruit.
Stock	There are many different definitions of a “stock” of fish. In this report we follow a broad definition which includes management considerations - a population of fish which, interbreeds freely in a given geographic location is sufficiently discrete to warrant consideration as a self-perpetuating system which can be managed.
TAC and TAH	Total Allowable Catch or Harvest. This is the total harvest or catch of fish allowed annually or seasonally for a species or multiple species in a given area using a particular gear type. It may be further divided into individual quotas for fishers or vessels. For Lake Winnipeg this is referred to as the Quota Entitlement system. TAC or TAH or QE is a management or policy decision based on biological, economic and other considerations.
TDS	Total Dissolved Solids
Tolerances	Tolerances are the allowable harvest levels of walleye and sauger for certain sectors and seasons. For example the whitefish fleet may only harvest 20% of their QE as walleye and sauger.
U of M	University of Manitoba
VHS	Viral haemorrhagic septicemia
Z	Instantaneous mortality

Appendix II. LWTF TOR, Members Biographies and Outside Experts Consulted

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Appendix II.a. Lake Winnipeg Quota Review Task Force Terms of Reference Feb 5, 2009

1.0 General

The Lake Winnipeg Quota Review Task Force, hereinafter referred to as the "Task Force", will be directing and advising a technical assessment of available information on Lake Winnipeg fish stocks to assess the status, health and sustainable harvest levels of the fisheries resource. The work of the Task Force will address the question of whether Lake Winnipeg fishers can be allowed to harvest more fish.

This work is the initial phase of a more comprehensive review of the Lake Winnipeg fishery quota management system to be undertaken by a proposed new co-management board. The future work of the co-management board will address questions such as the fairness of existing quota allocations; the need for policy and administrative changes to the quota system; and how any potential quota adjustments can be fairly implemented.

The Task Force report is intended to provide a common foundation of scientific, fisher and traditional knowledge and information for the work of the co-management board.

2.0 Objectives

The objectives of the Task Force shall be to:

(a) direct a review of the analysis of status of the Lake Winnipeg fishery following the key principles of biological sustainability and a Precautionary Principle when uncertain over impacts;
(b) evaluate scientific and local fish harvesters knowledge, information and analyses to determine stock status;
(c) identify informational gaps and challenges;
(d) provide advice on monitoring and assessment programs; and
(e) provide recommendations to government on the health of fish stocks, sustainable harvest levels, and factors that should be considered in future quota adjustment decisions.

3.0 Roles and Responsibilities

In pursuance of its objectives, the Task Force shall:

(a) be expected to fulfill their responsibilities in the best interests of the public and evaluate the health of fish stocks on Lake Winnipeg;
(b) direct the coordination and consolidation of available fisheries information, knowledge and understanding from government, academia, private sector, fishers and other industry participants, in accordance with the above objectives; including

a. science-based stock assessment information;
b. harvesting activities;
c. factors affecting fish stocks (e.g. eutrophication, hydrology, introduced species, differences in habitat within the lake, increasing complexity of the ecosystem); and
d. advice on the review of alternative methodologies (best practices) in fish stock management.

(c) identify challenges and associated risks to the health of fish stocks; and
(d) report findings and make recommendations to government to meet the above objectives.

4.0 Composition

The Task Force will be comprised of the following members:

a. Chair / facilitator with experience working with co-management fisheries governance;
b. Three research specialists from fisheries scientific / academic community; and
c. Three Lake Winnipeg commercial fishers experienced with representing the industry.

5.0 Resources

(a) For the purposes of, and to meet the Terms of Reference;
  a. Task Force members shall contribute sufficient time to meet the objectives; and
  b. The Manitoba government will provide resources to assist the Task Force in meeting these objectives.

(b) The Task Force shall recommend secretariat service requirements, including financial resources, to meet objectives.

6.0 Procedures

The Task Force shall:

(a) be established as soon as practicable and engage government, private sector, and industry in accessing available fisheries information as part of the biological review;
(b) meet as required in order to reach the objectives within identified timeframes;
(c) meet with government officials and others as appropriate to request any additional fisheries information to complete evaluations and assessments; and
(d) complete a preliminary report and steps to completion to government for consideration by April 1, 2009.
(e) complete and present draft results to government for consideration by June 1, 2009.

Appendix II.b. Biographies of Lake Winnipeg Task Force Members

G. Burton Ayles
Winnipeg, MB
Aylesb@mts.net

Dr. Burton Ayles worked for 25 years as a fisheries research scientist and manager with Central & Arctic Region of the federal Department of Fisheries and Oceans (DFO). He served as Regional Director of Fisheries and Habitat Management, Regional Director of Research, and Regional Director General retiring in 1998. He was a Canada member of the Great Lakes Fishery Commission from 1995 to 2001 and Chair of the Commission from 1998 to 2000.

He has been active planning and organizing workshops, planning sessions and reviews for a range of fisheries and aquatic environmental activities including: Arctic fisheries and oceans research, water quality in the prairies, Lake Erie walleye allocation conflicts, Alberta oil sands aquatic monitoring and science needs for Lake Winnipeg, amongst others.

He is a member of the Canada/Inuvialuit Fisheries Joint Management Committee a co-management committee responsible, with the DFO, for fisheries resource allocation and other aquatic resource management activities in the Canadian Arctic. His recent publications have focused on the adaptive co-management of fish and marine mammal resources in the western Canadian Arctic.

Burton received his B.Sc. and M.Sc. from the University of British Columbia and his Ph.D. in fisheries genetics from the University of Toronto (1972).

Ken Campbell
Gimli, MB
kcamp@mts.net

Ken Campbell is a commercial fisher from Gimli, Manitoba. He began his career in fisheries as a student with the Department of Natural Resources in 1966. He worked as a Fisheries Technician, Fisheries Biologist and Regional Fisheries Manager in the Interlake Region. During his tenure with the Interlake Region he worked primarily on the commercial fisheries of Lake Winnipeg, Lake Manitoba, Lake St. Martin and Cedar Lake.

Ken retired from the Manitoba government in 2002 and became a full time commercial fisherman in the South Basin and Channel areas of Lake Winnipeg. He served as the Chairman of the Lake Winnipeg Fisherman's Advisory Board for many years, both during his tenure as the Regional Fisheries Manager, and later as a commercial fisherman. He served as the chairman of the Manitoba Commercial Inland Fishers Federation for two years, and is presently a Director on the Freshwater Fish Marketing Corporation Board.

Darren Gillis
Winnipeg, MB
dgillis@umanitoba.ca

Dr. Darren Gillis is an Associate Professor in the Department of Biological Sciences, University of Manitoba. He teaches in the areas of ecology and fisheries with emphasis on quantitative methods. His research program examines patterns in the catch from commercial fisheries that result from the interaction between fish behaviour and fishing activities. Locally, he has supervised graduate studies on walleye morphology and fishing effort in Lake Winnipeg. He also has active research collaborations in both Atlantic Canada (groundfish trawl and snow crab trap fisheries) and Europe (North Sea beam trawl fishery). His research indicates that accurate information from fish harvesters is required to interpret the relationship between landed catches and the underlying fish populations.

Darren received his BSc Hon. from Dalhousie University, his MSc from McGill University and his PhD from Simon Fraser University (1993).

Langford Saunders
Norway House, MB
lmdsaunders@hotmail.com

Langford Saunders is a Lake Winnipeg commercial fisher from Norway House. He has been fishing for 16 years in Playgreen Lake and the North Basin of Lake Winnipeg. He has been a member of the Norway House Fishermen's Co-op Association for the past 12 years. He has been on the Board of Directors for several years and is currently serving as President of the Association. He was a member of the Lake Winnipeg Fisheries Advisory Board from 1998 to 2002.

Karen Scott
Winnipeg, MB
photuris@shaw.ca

Dr. Karen Scott is an environmental consultant who works with a variety of non-government, government and First Nations organizations on water-related issues, with a particular interest in communicating science to non-scientists. Since 2003 she has worked with the Lake Winnipeg Research Consortium, where she developed the Education Program, including the Lake Ecology Field Program for schools, and currently serves as Science Program Coordinator. Other ongoing work includes geo-referenced aerial photography of aquatic ecosystems and the associated land use practices impacting their health, as well as digital asset management. In addition to her work in the Prairie Provinces, she has done research on mercury bioavailability in Alaska, Slovenia, and the Canadian Shield. She served as science advisor for the Water Protection Council, Southern Chiefs' Organization (2006-2008) and board member of the Red River Basin Commission (2006-2008).

Karen has a B.Sc. in chemistry and physical geography and a Ph.D. in microbiology.

Ross Tallman
Winnipeg, MB
ross.tallman@dfo-mpo.gc.ca

Dr. Ross Tallman is Section Leader Arctic Stock Assessment and Integrated Ecosystem Research, Department of Fisheries and Oceans (DFO), Central and Arctic Region at the Freshwater Institute in Winnipeg. Dr. Tallman joined DFO as research scientist and head of flatfish research and stock assessment of in the Gulf of St. Lawrence in 1987. In 1991 he returned to Winnipeg with DFO as research scientist and head of Arctic fisheries population dynamics and modelling. He has authored or co-authored over 80 publications in fisheries biology. His recent research has focused on biology and population studies of Coregonids (whitefish sp.), Salvelinids (char sp.) and other freshwater and anadromous fishes in the Canadian Arctic. Most recently he acted as senior editor of the proceedings of an international symposium on the biology of Coregonid fishes. He has supervised graduate students and served as Adjunct Professor, Department of Zoology, University of Manitoba. He is also a sessional lecturer in ecological methodology at the University of Manitoba.

Ross received his B.Sc. and MSc. from the University of Manitoba and his Ph.D. in salmon population studies from the University of British Columbia (1988).

Norm Traverse
Lake St. Martin, MB
normanTravers@live.ca

Norm Traverse is a Lake Winnipeg fisher from Lake St. Martin. He has fished on the lake for over fifty years, started out on Lake St. Martin and had his first fishing licence at14 years old to go winter fishing as an assistant to his father. In 1958 he started winter, summer and fall on Lake Winnipeg. In 1980 he purchased whitefish quota and began operating a large whitefish boat in 1992.

Norm has been a member of the Dauphin River fishermen’s association since it first started and has served as director on several occasions. He was a member of the Lake Winnipeg Fisheries Advisory Board from its inception till its demise. He is currently a member and on the executive of the Manitoba Commercial Inland Fishers Federation. He served his community as Chief of Lake St. Martin First Nations for 6 years and as councillor for 20 years.

Appendix II.c. Outside Experts Consulted by LWTF

Consultant	Topic
Peter Ashcroft, Commercial Fisheries Coordinator, Saskatchewan Ministry of Environment, Regina, SK. peter.ashcroft@gov.sk.ca	Saskatchewan commercial fisheries, multi species quotas, stock assessment methods for establishment of Saskatchewan fish quotas.
Stephanie M. Backhouse, MSc Student, Biological Sciences, U of M, Winnipeg, MB, umbackhs@cc.umanitoba.ca	Lake Winnipeg walleye genetic stock structure using mitochondria DNA and microsatellite DNA.
Dave Bergunder Freshwater Fish Marketing Corporation, Winnipeg. daveb@freshwaterfish.com	Lake Winnipeg commercial fisheries production and marketing.
Peter Colby, Research Biologist (retired), Ontario Ministry of Natural Resources, Thunder Bay. pete.colby@lakeheadu.ca	External Peer Reviewer Marine Stewardship council certification process. Walleye population health assessment methodologies. Lake Nipigon, whitefish and walleye management and assessment, index netting, and relevant walleye literature. Development of reference indicators for walleye and whitefish populations.
Dr. Margaret Docker Assistant Professor, Biological Sciences, University of Manitoba, Winnipeg, MB. dockerm@cc.umanitoba.ca	Lake Winnipeg walleye genetic stock structure using mitochondria DNA and microsatellite DNA
Larry Dow, District Manager, DFO, Inuvik, NT. Larry.dow@dfo-mpo.gc.ca	NWT fisheries management and management of whitefish in Great Slave Lake.
Mark Ebener, Inter-Tribal Fisheries Assessment Program, Chippewa/Ottawa Resource Authority, Sault Ste. Marie, Mich. mebener@lighthouse.net	External Peer Reviewer
William Galbraith Manitoba Water Stewardship Bill.Galbraith@gov.mb.ca	Lake Winnipeg fisheries management, licencing, QE operations
Michael J. Hansen, Professor of Fisheries, University of Wisconsin - Stevens Point, College of Natural Resources, Stevens Point Wisconsin mhansen@uwsp.edu	External Peer Reviewer
Tom Johnston, OMNR Cooperative Freshwater Ecology Unit, Laurentian University, Sudbury, ON. tjohnston@laurentian.ca	Research on abundance, growth and life history characteristics of sympatric walleye and sauger in Lake Winnipeg.
Stephen Kendall, Vice President Operations, FFMC, Winnipeg, MB stephen.kendall@freshwaterfish.com	Historical and recent changes in commercial harvests of whitefish, walleye and sauger in Lake Winnipeg including total production, deliveries and prices. And the implications of marketing for stock assessment methodologies.
Al Kristofferson, Coordinator, Lake Winnipeg Research Consortium, Gimli. coordinator@LakeWinnipegResearch.org	Summary of environmental research and research priorities for Lake Winnipeg. Genetic sub-populations of the whitefish stock in Lake Winnipeg.
Derek Kroeker, MFB, Manitoba Water Stewardship.	Lake Winnipeg fisheries biological assessment and monitoring.

Derek.Kroeker@gov.mb.ca	
George Low, Research biologist (retired), DFO, Hay River, NT. geobarbgeo@hotmail.com	History of fisheries and establishment of fish quotas for Great Slave Lake.
Chelsey Lumbe MFB, Manitoba Water Stewardship. Chelsey.Lumb@gov.mb.ca	MFB organization, fisheries management, biological assessment and monitoring of Lake Winnipeg fisheries.
Bruce Maclean, Research Associate Centre for Indigenous Environmental Resources (CIER), Winnipeg, MB. bmaclean@cier.ca	Traditional knowledge of climate change impacts on biological, social, cultural, and economic sustainability of freshwater fisheries of Fisher River Cree Nation including subsistence consumption.
Wayne MacCallum, Biologist (retired), OMNR, North Vancouver, BC wmaccallum@mac.com	Establishment of the Ontario quota management system in Lake Superior.
Tom Mosindy, Biologist/Supervisor, Lake of the Woods, OMNR, Kenora, ON. Tom.mosindy@ontario.ca	Lake of the Woods, commercial fisheries quota management system, species quotas, recreational fishing, fish community index netting program, recreational creel harvests, fall walleye index netting, YOY beach seining, commercial sampling, climate impacts.
Kevin Reid, Assessment Manager Ontario Commercial Fisheries Association, Blenheim, ON Kevin.reid@ocfa.on.ca	Lake Erie commercial fisheries monitoring programs.
Rick Salmon, Unit Supervisor Lake Nipigon , OMNR, Nipigon, ON. rick.salmon@ontario.ca	Lake Nipigon fisheries, stock assessment process, index netting for walleye, community index netting for whitefish, commercial catch monitoring, multi species quotas in Ontario.
Peter Thompson, Regional Director Policy (retired), DFO, Sarnia, ON. Peter.Thompson@dfo-mpo.gc.ca	Management of NWT fisheries.
Lindsay Wazny, Research Technician, Water Quality Technician, Prairie and Northern Region, Winnipeg, MB. Lindsay.wazny@ec.gc.ca	Lake Winnipeg and Netley/Libau Marsh forage fisheries research and monitoring
Robert Young, Division Manager, Arctic Aquatic Research, DFO, Winnipeg, MB Robert.Young@dfo-mpo.gc.ca	External Peer Reviewer

Appendix III. Lake Winnipeg Harvest and Monitoring Data

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- Appendix III.b. Lake Winnipeg Commercial Fish Harvests by Species and Year Page 121
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Appendix III.a. Lake Winnipeg Current and Historic Fisheries Data Sources

Data are the foundation of any biological assessment. The methods used for any analysis will be limited, and sometimes determined by the type and quantity of data that are available. Without reliable data, biologists and managers are unable to assess the health of fish stocks reasonably. This appendix summarizes current and historic fisheries data sources, and provides brief assessments of the use and usefulness of the data for fisheries stock assessment. However, these data sets have not been assembled into a common location or standardized format and thus are not readily available for analysis. Further, many data series e.g. ageing structure methodologies, vary among years without current standardization. Discussions with MFB staff indicate that initiatives in standardization are underway.

Data Source[15]	**Time Period**	**Description of the Program**	**Type of Data Collected**
FFMC commercial fisheries harvests	1972–2009 (ongoing)	Commercially marketed harvest. Non continuous record for some species from 1883 to 2009 and continuing.	Catch (round weight equivalent by species) and effort (number of deliveries). (Finer scale detail is also available, e.g. number of deliveries, delivered weight by date and delivery point and more, but not number of nets, time set or area set).

[15] Data from a number of different monitoring programs are available to assess the health of sauger, walleye and lake whitefish. Programs have changed over the years with a major break occurring in 2003.

MFB current commercial catch sampling	2005–2009	Commercial catch monitoring of walleye, sauger and lake whitefish. Plan is to sample catch from two delivery points per basin per fishing season (summer, autumn) for each quota species. Note: More intensive commercial catch sampling was done in 2009. Plan is to sample twice during summer fishing season and twice during autumn to better characterize age composition of the catch. Sampling takes place at the FFMC Transcona plant.	Age structures collected only (dorsal fin rays from walleye and sauger, pelvic fin rays from lake whitefish). Prior to 2008, scales only were collected for aging. Weights and lengths are not collected because of the sampling location.
MFB current index gill net program	2005–2009	Annual stock assessment index gill net surveys. A standard index net consisting of five panels of mesh, each 25 yards long (2”, 3”, 3.75”, 4.25” and 5” mesh) set overnight on the bottom. The target is 10 sets per location, with two locations per basin (South, channel, North) per year. 2005 considered a pilot year due to new staff and methods. 2009 standard index net expanded by adding 12.5-m-long panels of 1.5", 2.5" and 3.5" mesh to better assess smaller fish. Program operated by Central Region.	Individual length, weight, sex, maturity and age structure collected from walleye, sauger and lake whitefish (few lake whitefish caught due to net-set locations). Fish scales were collected from 2005–2007 (because scales had historically been age-structure collected), scales and otoliths were collected in 2008, otoliths were collected in 2009. Species caught in index gill nets (other than walleye, sauger and lake whitefish) were counted and bulk-weighed, by species and by mesh size.
MFB Mossy Bay (North Basin) index gill net program	2001–2008	Annual stock assessment index gill net surveys in Mossy Bay. A standard index net of 5 panels, 6 feet deep and 50 yd (25 yd since 2005) long (2”, 3”, 3.75”, 4.25”, 5” mesh) set overnight on the bottom during the summer. Eight to 32 sets annually (25-yd panels). Program operated by NE Region.	Primarily whitefish harvest. Numbers and individual lengths, weight and ages (pelvic fin rays) per gang. For the period 2005–2008, the net sets were the same as the MFB current index gill net program
Mid-water trawl surveys	2002–2009	Sampling of young and small fish using 3 m^2 beam-trawl tows near 65 lakewide, long-term monitoring stations in the offshore waters of Lake Winnipeg during spring, summer and autumn.	Length and weight of all species caught. Age structures collected from walleye and sauger in 2007–2009 (ages interpreted from 2007 walleye only to date). There are concerns about possible identification errors between sauger and walleye in early years of the program. Biomass density (g/1000 m^3) estimated for six most commonly caught species in trawls by year, season and basin. An assessment tool that is independent of the fishery.

Recreational Fisheries Harvests	1980–2005	National mail-in survey of recreational fishers done every five years.	Angler profiles, effort, harvest and expenditures summarized by province. Data available from Lake Winnipeg and the Red and Winnipeg Rivers only from the 2005 survey. Only walleye are identified in the survey, so it is assumed that anglers would have recorded sauger as walleye.
MFB historic commercial catch sampling	1979–2003	Commercial catch monitoring of size and age of walleye, sauger and lake whitefish from various delivery points around the Lake. Samples were taken in most years from several locations during summer and autumn.	Length, weight and age (primarily using scales). Unlike the current commercial sampling program, fish were sampled whole.
MFB historic index gill net surveys	1979–2003	Annual stock assessment index gill net surveys done during late spring and early summer. Multifilament nylon, multi-mesh, benthic gill nets set overnight (16–18 hr) within 2 km of shoreline. Nets were 6 ft deep and made up of 8 panels, 100 yards wide, mesh sizes 3", 3.25", 3.5", 3.75", 4", 4.25", 5" and 5.25" in. Program standardized in 1979, eroded during the late 1990s and ended after 2003.	Fork length, weight, sex, maturity, age of walleye, sauger and lake whitefish. Prior to 1986, all walleye, sauger and lake whitefish were processed individually. After 1986, a minimum target of 250 fish of each species from each sampling location was established for individual processing. Fishers kept fishing until the needed number of fish was caught. Note because this survey program was established to obtain biological information (age, weight, length etc) but not on abundance the data is not valid for fishery independent estimates of CPUE.
MFB historic near-shore trawl surveys	1976–1983	Sampling of young walleye and sauger and other small fish using 11.5 m semi-balloon otter trawl tows in the South Basin and channel of Lake Winnipeg from late July until the end of August (87–322 trawls per year). In the early years of the program, trawling was primarily inshore. In later years, it was primarily offshore. Primarily viewed as a habitat-use study of young percids.	Length and age of walleye and sauger were determined. Geographical, temporal and vertical distributions of young-of-the-year, yearling and two-year old walleye and sauger were determined. Seasonal trends in abundance of other species were determined. An assessment tool that is independent of the fishery.

Environment Canada, Lake Winnipeg and Netley/Libau Marsh fisheries research	2009	This project has only operated for one year as a trial. Fish were caught using either a 30-ft or 100-ft seine net with 1é4 in mesh or a 100-m gill net with mesh size ranging from 1.5`to 12`. Gill nets were set for 4 hr each in either 1 or 3 m of water. Lake Winnipeg sites included Manigatogan, South Shore, Gimli Beach, Hecla Village and Grand Beach.	The focus is on all species harvested: numbers, size, ages and stomach contents. There was considerable inconsistency in the methods used but the seining is considered to have potential as an assessment tool for the future (pers. comm., L. Wazny).

Appendix III.b. Lake Winnipeg Commercial Fish Harvests by Species and Year

Lake Winnipeg Commercial Fish Harvests 1883 to 2008 (kg round weight)

YEAR	No. of deliveries	WHITEFISH	WALLEYE	SAUGER	BASS	STURGEON	PIKE	CISCOE	PERCH	TROUT	CATFISH	GOLDEYE	DRUM	SUCKER	BULLHEAD	CARP
1883		72867														
1884		359000														
1885		759730	6455			19091		4182	227		1136					
1886		800000														
1887		781625	30909			11364	24091	18182			11364					
1888		1004556	99252			7027	64822	47775	453	5500	1639					
1889		1270350	127911			58576	170623	27190	1637	55	355	227				
1890		1546465	229867			85377	338219	81227								
1891		1312052	184218			22282	71181	77773								
1892		1712090	187640			42314	37027	68182								
1893		1732252	182494			16909	47682	3182			4614					
1894		1288956	454509			34668	153755	153647	8379		27154					
1895		1666609	364245			47382	127907	122091	10659		36238					
1896		1668555	398786			79885	108035	104545	18545		80909					
1897		1250256	486795			102554	124685	116414	21562		42120					
1898		1153191	429737			203414	159535	100645	29905		74710					
1899		907509	292617			202176	122390	65885	27733		56660	11764				
1900		1770500	569727			446136	138318	53136	21818		83818	1636				
1901		2272727	1136364			272727	454545	227273	12955		250000	90909				
1902		2727273	1363636					272727	18182		272727	136364				
1903		3181818	1818182				545455	545455	454545		227273					

[16] Commercial fisheries data provided by Chelsey Lumb, MFB. Assembled from various sources including FFMC. Interested individuals should contact MFB for sources and descriptions of what is included or excluded from these data.

1904		3409091	1931818				556818	818182	56818		250000					
1905		2954545					568182				227273					
1906		2272727	2045455			90909	454545	727273	34091		90909					
1907		909091	1250000			68182	342727	568182			79545	181818				
1908		1022727	750000			36136	215909	170455	16636		91682	261364				
1909		1576409	1017500			23727	354455	311000	26364		39636	380636				
1910		1326136	1085955			92727	190409	781364	23364		35955	339227				
1911		1419682	1664091				282955	324045	27000							
1912		1453409	697955				200136	382273	15864							
1913		973455	763045				123636	614091	11045		29455	223636				
1914		1021636	1094818				197409	1588136	16136		34136	323091	1636			
1915		1202409	470682				118318	2064136	18500		63000	165500	364			
1916		1262545	656727			52636	167727	1876409	368500		49318	277545				
1917		1279591	845500			38773	182682	2033727	368318		18182	344045				
1918		1387500	725500			6136	150136	2504409	22318		31682	160091				
1919		1352500	741500			5636	171682	1270182	18864		19864	34636		509091		
1920		1319545	962182			18045	230182	1226682	3045		10909	129773		529318		
1921		3243000	1393045			39727	198591	1722273	6273			95818		22591		
1922		2639400	974000			11409	151773	1722045			35364	95409		18500		
1923		1626400	1357545			23955	281545	655273	82727		35955	515091		8136		
1924		1591000	1182455			40273	292545	602182	67364		63545	164273		11318		
1925		2559000	723500			31682	190636	1266136	39864		161182	186455		17091		
1926		3741700	1411500			14045	331227	2429136	74864		28682	245091		51364		
1927		2826000	1982318	100955		15364	281818	3254773	17273		65182	327773	8818	3955		
1928		3089300	2235409	165136			297773	3270227	26364		46273	201409	6455	20909		
1929		3287800	2024091	323227			642182	2651955	19049		5273	307864		26364		
1930		1565727	1242227	394636			470636	1589364	25182		15409	162182	273	5000		
1931		1634900	1039554	699583			143473	165472	17736			59240		11884		
1932		2103783	1054386	866098			84188	433004	25039			84732				
1933		2417718	1326136	1493876			93622	281366	21002			76703		8573		
1934		1777375	1663159	1708655			124603	585049	31162	91		43727		27805		
1935		1139935	1387281	1462079			240633	640842	29076			47446		45677		

1936		303184	1900708	2964211			310986	846775	57970			79017		21002		
1937		929511	1891318	3280504		12338	163068	330990	36832			91082		8210	5818	
1938		952146	1946884	4326091		10387	188107	803230	49896			102513		3901		
1939		920439	1466525	3921210		4491	162841	489613	69491			36696		5942		
1940		1588270	1787626	4034564		5489	1391636	841604	248344			15876		4944		
1941		1819831	1635716	4641522		5534	137667	752291	119432			17055		2449		
1942		1876803	1252517	3446203		2948	203937	1072349	128731			24721		1497		
1943		1695546	1625964	2893722		1315	391817	681666	95981	45		11975		703756		1950
1944		1069037	2171369	2270797		318	332940	219768	49578			7757		65363		45
1945		1234328	2282908	1724621		499	453098	1040688	90311			1497		383199		42774
1946		1098113	2238910	1798558			424159	554704	101515			272		63277		21727
1947		815159	2194820	1618752			495509	1950376	114080			590		75705		5398
1948		694865	2460991	1789440			403429	1826998	109725			1588		62506		4899
1949		1097387	2326998	3152635			363830	598975	86274			1452		56110		4128
1950		1601878	2534065	2160256			336705	1161163	96026			3175		102785		4808
1951		1243899	2701941	1701442			425383	1395219	183798			3719		121110		19051
1952		1166697	2348907	1658850			582056	778917	234873			816		125556		16329
1953		836841	2274744	995373			362016	296017	129094			318		110904		20094
1954		978590	1966207	1004400			269437	904609	111177			1225		127007		18734
1955		987844	2182119	1398258			356845	1171233	217092			8936		188424		29166
1956		748390	1773519	1455049			356573	1175723	176994			9208		217772		30663
1957		759594	1239136	1289803		5489	232378	432006	123378			15513		49578		20412
1958		733149	998911	1959176		7530	234510	915268	178581			12247		198313		99837
1959		848453	523496	1165654		3719	137258	890638	122154			4037		149233		63322
1960		507938	616892	1629683		4082	177674	578518	154767			544		161118		93895
1961		632405	957679	1152454		3583	219677	690874	188878			2223		69899		8981
1962		758233	1271614	1361154		3039	234736	226662	157534			1996		231561		29801
1963		597206	924340	1903202		2404	291844	321283	114760			726		146512		33702
1964		666153	556201	1352173		2313	226617	215096	110224			726		51347		54296
1965		691509	395491	1421800		1270	242402	237141	154722			953		358160		52889
1966		455547	293114	1328314		590	207203	295065	167151			408		179262		33475
1967		641023	270480	1016057		181	307221	114760	62460			136		98385		66089

1968		374172	354395	1647464		544	405062	287399	72213					131725		90175
1969		341950	389125	922761		3402	327611	103512	57970					171398		103465
1970		0	0	0			0	0	0		227		204	219361	227	81433
1971		637779	46894	187655			16627	1801	1012					8947		8864
1972	23220	778561	1075766	1665042		277	432794	4042	21229					38511		0
1973	23781	823857	1149543	1801296	46779.8	95	391115	155698	41227				46780	66636		10782
1974	24029	814586	1121610	1511568	41630.3		371958	335263	58353		184	108	41630	131747		1601
1975	23108	822109	1334586	1633767	8836.35	31	464742	252759	45503		3403	592	8836	101868	140	88654
1976	25489	857406	1587028	1451542	6256.95		536097	11402	32115		1985	8328	6257	1764	2247	12646
1977	24646	1130181	1644801	1469870	1744.5		413273	5011	30952		2282	1389	1745	46591		18825
1978	25553	1639817	1449556	1372843	8660.7	48	372796	1639	48853		5913	172	8661	59287	4	31645
1979	25533	1745422	1437302	1239200	18899.4	77	395047	36985	47031		11385	63	18899	209168		122104
1980	30092	1772091	1325057	1841055	1996.2		352835	90	76785		13370	1381	1996	130371	7052	131098
1981	32492	1623924	1987034	1630279	345		393345	106	81762		13199	1614	345	62866		134648
1982	29220	1572145	2030373	1301108	16		342265	223	38665		2798	354	16	120505	2	38466
1983	28204	1592891	1499130	2050428	4080		224240	34	62050		981	409	4080	21695		46206
1984	26987	1636523	1952983	1946611	4725	68	229237	24	80067		2857	216	4725	71450		48765
1985	25049	1384209	2401607	1433531	18606	22	231876	944	34682		3565	90	18606	43549		45941
1986	32370	1876997	2121922	1168156	29707		192596	2171	54999		2029	1872	29707	2566	23	105752
1987	31291	1696465	1489847	2330069	11428		175286	86	110806		3064	1315	11428	4149		57265
1988	29784	1536900	1980885	2189531	5885	62	204818	2	121919		1326	3450	5885	10160		56349
1989	30668	1215641	2326035	2064145	19466		145484	11	134364			8705	19466	1586		1445
1990	28837	1020521	1916407	1799356	49722		97167	0	71085			63502	49722	0		43357
1991	30974	1251163	1915693	1994231	75356		84474	0	48560			3379	75356	324427		85483
1992	27929	939336	1824664	1590762	73248		82897	206	50198			433	73248	51		12004
1993	24387	1259682	1318613	1323958	51796		64572	103	62762			391	51796	103308		31459
1994	27010	1537825	1140002	1599780	36005		83577	11	121139			3683	36005	86376		42800
1995		1638109	1235710	1143408			995989	1	430464	118288						
1996	24977	1213457	937696	890971			927232	29	302124	140201		802	80889	154786		
1997	22829	1131411	1183557	872879	38220		1000005	332	287824	208298		5835	43742	164280		
1998	26792	1071375	1911576	1016380	22837		354493	12	157884	147921		7811	20466	6782		
1999	27907	851027	2701056	929538	43049		237477	47	96612			306	26746	64481		

2000	27917	1260778	3602324	533653	28621		140650	3	61544			1450	240377			
2001	29674	1580631	3186071	653367	33073		130065	8	60846			748	229451			
2002	29907	1485338	3209535	733799	27435		105000	350	88850			2650		257700		182000
2003	31790	1845187	3367468	726426	14829		105650	150	83150			5550		217500		56850
2004	27976	1523821	3687095	572836	11561		128350	1850	68350		50	4000		157150		59000
2005	24307	1295241	4245581	292001	6712		62650	50	31200			6850		114550		118300
2006	21403	1193523	4515430	149462	14742		86700	100	16650			42000		97700		142350
2007	18239	959671	4811228	120205	5186		64723	12	23183	14	0	26053		57336		107674
2008		1597282	4608356	270468	8269		102102		22148	34		9755		94935		85363

Appendix III.c. Value of the Lake Winnipeg Fishery from 2000 to 2010.[17]

Lake Winnipeg by Year, including Initial Payments to Fishers and Delivered Weight in kg (Based on FPT weights)

Year	Export Whites	Walleye	Sauger	N. Pike	Perch	Mullet	Carp	Other	Total Kgs	Initial $	No. of fishers
2000/2001	1,145,987	2,949,095	465,541	94,907	61,544	167,638	58,053	55,545	4,998,310	$16,593,641	845
2001/2002	1,436,776	2,493,830	554,324	87,971	60,846	161,319	117,472	62,419	4,974,957	$15,339,023	856
2002/2003	1,350,217	2,507,940	632,620	70,201	88,684	161,682	108,009	50,013	4,969,366	$16,440,140	877
2003/2004	1,677,388	2,722,735	614,714	70,797	83,126	146,132	28,708	47,399	5,390,999	$16,712,300	911
2004/2005	1,385,281	2,989,296	497,120	84,831	64,257	99,895	29,649	63,737	5,214,066	$15,383,486	909
2005/2006	1,177,474	3,281,000	242,640	41,835	31,137	76,401	84,525	44,461	4,979,473	$15,557,643	890
2006/2007	1,084,962	3,369,811	126,066	57,783	16,628	64,893	58,592	81,917	4,860,652	$16,977,543	882
2007/2008	872,349	3,469,713	105,187	43,312	23,183	38,224	64,475	55,224	4,671,667	$17,797,541	871
2008/2009	1,452,027	3,344,466	242,144	68,082	22,148	63,330	51,115	37,148	5,280,460	$19,623,797	878
2009/2010	1,448,773	3,175,962	521,874	72,411	36,203	75,797	4,130	33,537	5,368,687	$17,725,593	867
Mean	1,303,123	3,030,385	400,223	69,213	48,776	105,531	60,473	53,140	5,070,864	$16,815,071	879

Lake Winnipeg Value (Initial $) of Quota Species (Export Whitefish, Pickerel, Sauger) by Year

Year	Export Whites	Walleye	Sauger	Total
2000/2001	$1,887,441	$12,596,636	$1,495,784	**$15,979,861**
2001/2002	$2,155,164	$10,466,605	$2,137,474	**$14,759,243**
2002/2003	$2,107,689	$11,343,417	$2,382,447	**$15,833,553**
2003/2004	$2,266,152	$11,718,652	$2,363,576	**$16,348,380**
2004/2005	$1,762,078	$12,005,013	$1,585,813	**$15,352,904**
2005/2006	$1,570,751	$12,992,760	$831,876	**$15,395,387**
2006/2007	$1,601,404	$14,682,267	$429,255	**$16,712,926**
2007/2008	$1,239,608	$15,665,755	$394,557	**$17,299,920**
2008/2009	$2,937,451	$15,274,177	$997,876	**$19,209,504**
2009/2010	$2,707,757	$12,888,054	$1,887,097	**$17,482,908**
Mean	$2,023,550	$12,963,334	$1,450,576	**$16,437,459**

[17] Data from D. Burgunder, FFMC.

Appendix IV. Biological Stock Assessment and Monitoring Overview

- Appendix IV.a. Interpreting Linear Empirical Models for Management Decisions Related to the Lake Winnipeg Fishery. Page 128
- Appendix IV.b. Sample size in the Lake Winnipeg index net survey – How many sets do we need? Page 132
- Appendix IV.c. Assessment of Possible Indicators for Future Decisions on Changes to Recommended Allowable Harvest (RAH) Levels for Lake Winnipeg Lake Whitefish, Sauger and Walleye. Page 136
- Appendix IV.d. Guidelines for data organization and preparation for analysis. Page 149

Appendix IV.a. Interpreting Linear Empirical Models for Management Decisions Related to the Lake Winnipeg Fishery

Empirical models in ecology have a long history of use and debate (Rigler 1982). Simply defined, they are statistical models of ecological relationships that do not assume specific mechanisms in the underlying ecology. For example, we could expect warmer temperatures to be associated with more rapid hatching of fish eggs, but we do not have to specify the biological causes (physiology) to produce a graph of the data or to draw a statistically meaningful line.

Linear regression is one of the most popular methods used in the biological sciences. It allows a statistical analysis to be added to graphical presentations. This analysis provides a clear, quantitative description of a straight-line relationship between two variables. It also allows predictions to be made based on past observations. However, the validity of these predictions depends upon the validity of the method's underlying assumptions. These assumptions are well known and described in most introductory statistical textbooks (e.g. Quinn and Keough 2002). In this Appendix, we would like to focus on interpreting the results of a valid application of linear regression to an analysis in the context of fisheries biology and management.

The Ryder Morphoendaphic Index (MEI, Ryder 1965) and its use to predict fish production in lakes is well known in freshwater ecology. It predicts the expected harvest of fish (all species) from a lake based on two common limnological variables: total dissolved solids (TDS) and mean water depth (D). Ryder divided TDS by D to create a characteristic lake index, the MEI, that could be used to predict lake harvest. He based his analysis on 23 Canadian lakes that he considered moderately to heavily exploited.

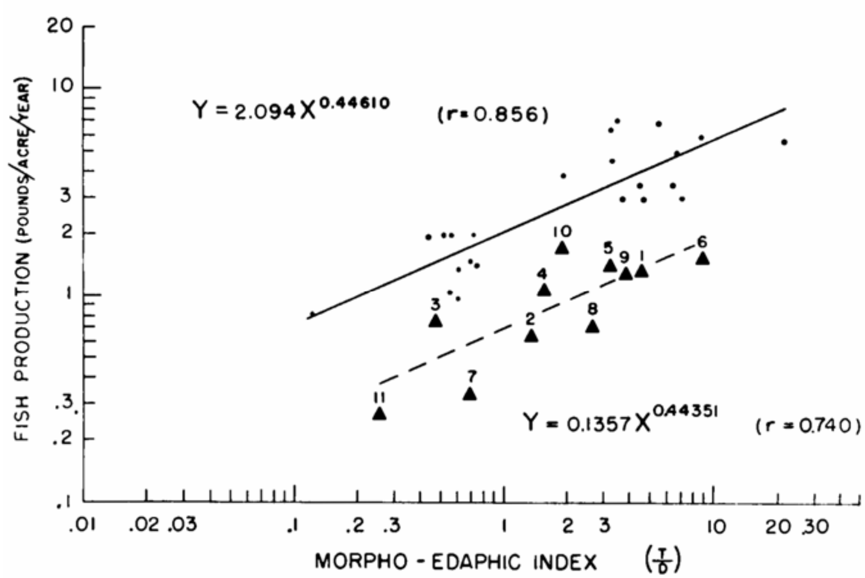

Figure App IV.a.1 Relationship between Ryder's (1965) morphoedaphic index and fish production

To meet the statistical assumptions of linear regression, Ryder (1965) examined the relationship between MEI and fish harvest on a logarithmic scale, producing Figure App. IV.a.1. The triangles in Figure App. IV.a.1 represent underexploited lakes and will be ignored here. The dots in Figure App. IV.a.1 represent the 23 lakes defining the main relationship, and the equation is determined from the linear regression of the logarithms of fish production and the MEI. The upper line passed through the points in a manner that appears to represent the relationship well. The upper equation suggests that, if we know the MEI of a lake, we can predict its fish harvest. However, we can also see that the points do not fall exactly on the line; the line defines the general relationship but not the expected variability around the relationship. We can approximately define the variability around the line as the range in which we expect to see 95% of the observations (points) occur: the prediction interval. The prediction interval differs from the confidence interval of the line, which is more narrow and reflects our uncertainty in the location of the line itself. Neither of these intervals were readily available to researchers in the 1960s but can now be easily calculated in most statistical packages.
We have reanalyzed Ryder's (1965) data using R Development Core Team (2009) to illustrate modern interpretation of regression models such as those discussed in this report.

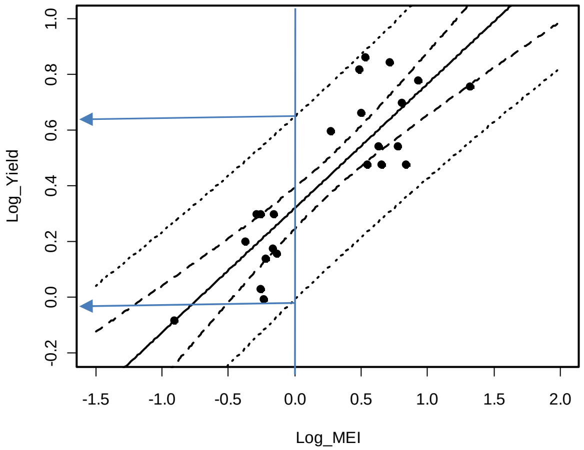

Figure App IV.a.2. Reanalysis of Ryder's (1965) morphoedaphic relationship.

The dotted lines in Figure App IV.a.2 represent the range of values that could be expected for a prediction based upon this regression. For example, when $Log_{10}MEI = 0$ (MEI = 1.0), the regression indicates fish yields somewhere between 0.98 and 4.4 lb/acre/yr ($Log_{10}Yield$ = [-0.00818, 0.649]). For a lake around the size of Lake Winnipeg, the predicted fishery yield would be somewhere between 6 and 26 million lb. This wide range reflects the level of information for prediction provided by the original data, i.e. the prediction contains so much uncertainty that it cannot be used with confidence in setting management goals.

References

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R Development Core Team. 2009. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0. Available at R website: http://www.R-project.org.

Rigler, F.H. 1982. Recognition of the possible: An advantage of empiricism in ecology. Canadian Journal of Fisheries and Aquatic Sciences 39:1323–1331.

Ryder, R.A. 1965. A method for estimating the potential fish production of north-temperate lakes. Transactions of the American Fisheries Society 94:214–218.

Appendix IV.b. Sample Size in the Lake Winnipeg Index-net Survey – How Many Sets Do We Need?

The appropriate sample size for the Lake Winnipeg index-net survey is currently poorly defined and limited by resources rather than sound statistical principles. Since 1979, the sample size has varied between 10 and 73 sets. Obviously, a single net set is not enough to measure the relative productivity of a lake the size of Lake Winnipeg but how many nets are enough? Every additional set adds new data and improves the assessment but to run an index-net survey program costs time and money. To set more nets in more locations than necessary is a waste of time and money, but to spend time and money to do a survey that is biologically and statistically questionable is also a waste of time and money. Therefore, the Task Force examined other studies to assess the level of effort appropriate for the Lake Winnipeg survey program.

The waters of Lake of the Woods (LOW) cover an area of 3850 km^2 on the Canada–US border between northwestern Ontario, Manitoba and Minnesota (OMNR 2004). Low is only about 16% of the surface area of Lake Winnipeg, but it shares a similar geography, with its the southwest portions being on prairie soils and northeast portions being on the Canadian Shield. In addition, walleye and lake whitefish are important for the commercial fisheries. The Ontario waters of LOW have been divided into six sectors for fisheries management purposes by OMNR (OMNR 2004, pers. comm. Tom Mosindy). Each year two sectors, usually adjacent, are fished in the index-netting program over a four-month period in the summer (May to September). Index netting is done for two years in a row, and then it moves to two other sectors. In a typical year, there are eight to 10 sets per month per sector, or typically 64 to 80 sets annually. OMNR also operates an autumn walleye index-netting program in the same two sectors, making approximately 40 to 60 net lifts to obtain a target of under 20% relative standard error measures on the mean number of walleye per net (CPUE). Lake Nipigon, north of Lake Superior, is similar in size to LOW (4510 km^2). The walleye fishery has been significantly reduced but a strong commercial fishery for lake whitefish continues, and the index-netting program is an important tool for stock assessment. For the purpose of the sampling program, Lake Nipigon has been divided into 16 sectors. Annually, four to five sectors are sampled with a target effort of 64 to 80 net sets per year (pers. comm. Rick Salmon).

Lake Erie is of a similar size to Lake Winnipeg (25,800 km^2) and has a large commercial and recreational fishery. One of the index-netting programs is operated cooperatively with industry[18]. The Ontario waters of the lake have been divided into six different basins and different sites are selected within each basin with top and bottom sets at each site. For the 2009 program, the contract called for between 306 and 348 total sets (OMNR-OCFA 2009).

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[18] OMNR–OCFA (Ontario Commercial Fisheries Association) Lake Erie Partnership Program.

In summary, the data from these other large lakes indicates that the 10 to 73 sets annually for Lake Winnipeg would not be considered adequate in Ontario. In the initial assessment data summary provided to the Task Force, indicated that 25 index-net samples were adequate in the early survey. However, the method used to develop this estimate was not described in sufficient detail to evaluate the claim. Regardless, a sample size of 25 sets seems unrealistically small given the practices of OMNR's FWIN program (Morgan 2002) for monitoring walleye populations. Recommended sample sizes for the FWIN are shown in Table App. IV.1.

Waterbody Surface Area (ha)	**Number of Net Sites**
<200	8
201–500	12
501–1000	14
1001–2000	18
2001–300	22
3001–5000	28
5001–10,000	36
10,001–20,000	48

Table App. IV.b.1. Recommended sample sizes of the FWIN survey in Ontario (from Morgan 2002).

Lake Winnipeg has an area of 23,750 km^2 (2,375,000 ha) suggesting that even the maximum tabulated sample size of 48 sets (Table App. IV.b.1) would be too small to reach the FWIN standards. The area vs. sample size relationship of the FWIN program is illustrated in Figure App. IV.b.1.

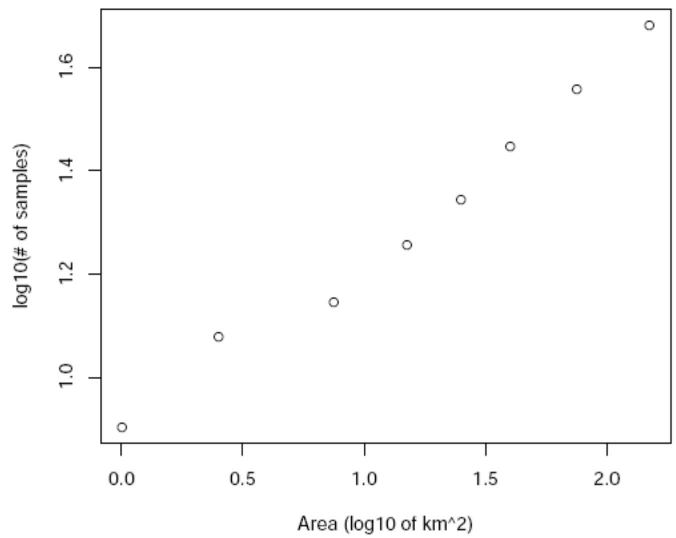

Figure App IV.b.1. FWIN sample sizes for lakes with different areas

Linear extrapolation of this relationship, based on lakes greater than 750 km^2, suggests that Lake Winnipeg would require 397 index-net samples to reach the same level of sampling intensity as the Ontario program. However, Lake Winnipeg sampling should not simply be designed to mimic another program. Instead, the number of samples should be based on a formal analysis of statistical power (Quinn and Keough 2002). If the habitats and distributions of fishes within Lake Winnipeg are less variable than Ontario lakes, then smaller sample sizes may be adequate. The Task Force suggests that a statistical professional, such as available through the University of Manitoba's Statistical Consulting Service, be employed to examine past survey data and assist in the design of future surveys. The resulting index-net program would have clearly quantified uncertainty based on variability in the distribution and abundance of the fish being sampled. Without this information, there will always be the risk that large changes in abundance of fish will not be detected by the index-net program and that patterns observed may reflect sampling error (in the statistical sense) rather than actual changes in fish abundance.

References

Morgan, G.E. 2002. Manual of instructions – Fall Walleye Index Netting (FWIN). Ontario Ministry of Natural Resources, Fish and Wildlife Branch,

OMNR (Ontario Ministry of Natural Resources). 2004. Ontario-Minnesota Boundary Waters fisheries atlas. OMNR, Northwest Science and Information, Thunder Bay, Ontario. 100 p. + app.

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Appendix IV.c. Assessment of Possible Indicators for Future Decisions on Changes to RAH Levels for Lake Winnipeg Lake Whitefish, Sauger and Walleye.

A fundamental principle of the FAO Code of Conduct for Responsible Fishing (FAO 1995) is that government agencies need to establish target and limit reference points or indicators and determine actions to be taken if those points or indicators are exceeded (FAO 1995).
Reference points are only relevant if placed in their management context as part of a fishery management decision making process that must include industry and management. The key criterion is acceptance by fishers and managers. This Appendix was prepared to assist in the future discussion of the application of indicators to the management of the Lake Winnipeg fishery. Incorporated into the fishery management process they can provide a way of responding to changing conditions, e.g. increasing or decreasing fish stocks. Readers will note that potential indicators are often quite similar among “data sources” because they are usually based upon the standard data collected from most fisheries (e.g. CPUE from the FFMC and from the MFB index-netting program) but different data sources have different strengths and weaknesses. Important indicators that are desirable in most fisheries, but not available for Lake Winnipeg due to current data limitations, are also included. Many of these indicators would become available with improved effort and age-distribution data from the commercial catch. We have included them because 1) they would greatly improve our confidence in the interpretation of trends, and 2) considering them now will add to the justification for new methods to improve data collection, documentation and organization. Specific references are not provided here; they can be found in the discussion of reference indicators in Chapter III of the main body of this report.

We stress that the selection of only a few indicators would be a mistake because their performance in the Lake Winnipeg fishery is unknown. Using a “basket” of indicators should point towards the need for management action. As many indicators as the available data will support should be developed and followed. The strengths and weaknesses of the potential indicators, as described here, can be used to weigh their use in advice and decision-making at the present time. Rice and Rochet (2005) proposed an eight step framework for the objective selection of a suite of indicators for use in fisheries management and provide guidance on pitfalls to be avoided at each step. A formal “decision analysis” process was used to determine the relative importance of different indicators for application for Lake Erie walleye management (Lake Erie Walleye Task Group 2005). Once a series is on record, the performance of these indicators should lead to re-evaluation in the future. It would also be useful to "hindcast" these indicators and examine their performance through periods of changing fishery abundance. This exercise is typical in other fisheries agencies and should be done by MFB as soon as the data are available in the proper format to support the analysis.

Indicator	Data Source(s)	General Notes and Risks in Interpretation	Comments/Assessment from LWTF
Catch-Rate- Based Indicators			
1. Commercial Harvest	FFMC	Relative abundance. Total harvests reflect changes in species abundance but are subject to harvest reporting, fishers' efforts, price of targeted species, experience of fishers, weather, changes in species abundance, amongst others.	This is the largest data set in size and scope. As the single primary buyer, FFMC records should be more consistent and reliable than commercial catch records would be from other systems.
2. Commercial CPUE	FFMC and commercial fishers	Relative abundance. Commercial CPUE is a primary indicator for many world fisheries and is better estimator of abundance changes than total harvests because effort is standardized. Interpretation is subject to effort measurements. Also, if fishers can target particular species, catch rates are expected to be less responsive to changes in species abundances.	There is no good measure of effort for Lake Winnipeg, only deliveries. A single delivery could reflect many nets set for several days or few nets set for only one day. Lake Winnipeg CPUE based on deliveries does show trends but their interpretation is problematic. In other fisheries, delivery reporting systems include number and type of nets and period set. Potentially a good candidate reference indicator if FFMC records also included effort information.
3. Commercial Index Fishers (Sentinel Fishers) CPUE	Commercial fishers (potential)	Relative abundance. Detailed catch and effort from an experienced, reliable subset of fishers from all areas of the Lake can be more meaningful than a CPUE based on all fishers because of more consistent reporting and more consistent fishers' expertise. Fishers' log books could reflect various effort measures including net size, location, time of set, etc.	This type of system is not in place in Lake Winnipeg. If implemented, select fishers would maintain log books. The results of these fishers would be used in coordination with commercial CPUE to calibrate the commercial CPUE. They could also contribute to a commercial-catch sampling program. Problems of implementation may include local differences in fishing patterns, logistical problem of access to certain areas because of the complexity of the Lake and funding. Also, if fishers can target particular species, catch rates are expected to be less responsive to changes in species abundances. There would be a need to assign responsibilities and resources within the management agency to ensure success of the system.
4. Index-Netting CPUE	MFB index-netting program	Relative abundance. Stratified random surveys independent of fishing activities can be better estimators of abundance changes than commercial fisheries because they are not subject to changes	There are significant geographical and temporal shortfalls in the MFB index-netting program that compromise any interpretation of results at this time. The current program has been in place for only five years and the average number of

		in fishers' behaviour (e.g. changing focus to a different species because of price changes). Multisize mesh nets are less biased than commercial nets and give a truer picture of what is in the Lake. Standardized methods must be maintained year over year or comparison validation sets must be used to make the results comparable. Information is limited by the extent of sampling, i.e. there must be enough index sets to make the results statistically valid.	sets per year has been less than 50, whereas close to 400 sets would be necessary if the intensity was comparable to the Ontario FWIN program (see Appendix DG II). Also, the standard net set changed in 2009 because the first four years of the program inadequately sampled smaller fish. Geographical/habitat shortcomings are particularly evident for lake whitefish because hardly any whitefish are captured in the index nets. Even if the number of sets was extended significantly, the key factors of design and stratification would have to be modified for this program to be meaningful. It is also possible that fishers could be involved in the index program. In Lake Erie, one of the index-netting programs is operated, and largely paid for, by the commercial fishers association (OCFA). Other models of fishers' involvement would also be possible but industry buy-in and committed fishers are essential. A more complete data set could be used in coordination with commercial CPUE to calibrate the commercial CPUE.
5. Recreational CPUE	Creel surveys	Relative abundance. A recreational fishery is quite different from a commercial fishery, and thus, results can complement estimates of abundance based primarily on gill net harvests. Surveys must be done regularly (annual or bi-annual) to be of value. Recreational fisheries are often more limited geographically/spatially then commercial and index fisheries.	The open-water recreational fishery on Lake Winnipeg is very small but there has been a growing recreational ice-fishery in recent years. The national survey of recreational fishing is done only every 5 years and it does not distinguish between walleye and sauger. Provincial creel surveys have been very limited, and are infrequent, they make CPUE comparisons inappropriate. Simple effort estimates on a regular basis may be a possible measure of walleye and sauger abundance in some areas of the Lake if correlated with regular, more-complete creel surveys. Recreational fishers rarely catch whitefish so this indicator would not be useable for that species. The national survey, done every five years, is useless for measuring recreational CPUE changes.
Age-Based Indicators			

6. Age Structure of Commercial Catch – Number of Age Classes in Fishery	MFB current commercial-catch sampling	Age diversity of fishable stock. A fishery dominated by a single age class (cohort) is subject to sudden drops in productivity (biological and commercial) in the future as that dominant age class moves through the fishery. Age data must be representative of the entire fishery, otherwise bias will result. Also, commercial age structure may not reflect population age structure due to directed fishing on larger fish or smaller fish, depending on price differences.	*Presence of three year classes at greater than 15% each in the commercial fishery is currently one of the indicators considered by MFB*. This indicator could be implemented at present. MFB does commercial-based sampling of walleye, sauger and whitefish at the FFMC Transcona plant. The present program has only been operating for five years. The annual plan is to sample several times a year from each delivery point—250 fish from each delivery point, twice during the fishing season. Most fish are headless dressed so it is not possible to do weight and length measurements or to determine age using otoliths. Ages are determined using dorsal spines and pelvic fin rays, and any analysis of age, weight and growth relationships depends on links to the MFB index-netting program. The program requires examination of up to several thousand spines per year. Measurement of age structure is a fairly important measure and could involve fishers (Note: see reference to sentinel fishers above). Comparisons with the historic catch sampling should be possible, although different aging structures were used in the past. One of the reviewers (M.E.) has noted that age sturcture changes slowly and this may be problematic in a rapidly changing environment.
7. Age Structure of Commercial Catch - Diversity (H) of Age Classes in the Fishery (Shannon Diversity Index – H – Takes into Account Number of Age Classes and Evenness of Age Classes)	MFB current commercial-catch sampling	Age diversity of fishable stock. A fishery dominated by a single age class (cohort) is subject to sudden drops in productivity (biological and commercial) in the future as that dominant age class moves through the fishery. Age data must be representative of the entire fishery, otherwise bias will result. Also, commercial age structure may not reflect population age structure due to directed fishing on larger fish or smaller fish, depending on price differences. This diversity index is a better indicator than simply the number of age classes in the fishery.	MFB does commercial-based sampling of walleye, sauger and whitefish at the FFMC Transcona plant. The present program has only been operating for five years. The annual plan is to sample several times a year from each delivery point—250 fish from each delivery point several times during the fishing season. Most fish are headless dressed so it is not possible to do weight and length measurements or to do age determination using otoliths. Ages are determined using dorsal spines and pelvic fin rays and any analysis of age, weight and growth relationships depends on links to the MFB index-netting program. The program requires examination of up to several thousand spines per year. This is a fairly important measure and could involve fishers (Note: see reference to sentinel fishers above). Comparisons with historic catch sampling should be possible, although different

			aging structures were used in the past.
8. Age Structure in Index Nets—No. of Age Classes in Sampled Population	MFB index-netting program	Age diversity of fishable stock. A fishery dominated by a single age class (cohort) is subject to sudden drops in productivity (biological and commercial) in the future as that dominant age class moves through the fishery. Age data must be representative of the entire fishery, otherwise bias will result. Also, commercial age structure may not reflect population age structure due to directed fishing on larger fish or smaller fish, depending on price differences. Concerns stated above for commercial data would be minimized in a properly designed index-net survey.	An index-net survey should provide a better statistical estimator than a commercial survey because of the greater number of mesh sizes, i.e. there is a broader size and age range of fish captured. However, as for the MFB index-netting CPUE indicator assessed above, the problem for Lake Winnipeg is the limited number of net sets each year and the limited number of years the program has been done (2005–2009).

9. Age Structure in Index Nets—Diversity (H) of Age Classes in Sampled Population	MFB index-netting program	Age diversity of fishable stock. A fishery dominated by a single age class (cohort) is subject to sudden drops in productivity (biological and commercial) in the future as that dominant age class moves through the fishery. Age data must be representative of the entire fishery, otherwise bias will result. Also, commercial age structure may not reflect population age structure due to directed fishing on larger fish or smaller fish depending on price differences. This diversity index (H) is a better indicator than simply the number of age classes in the fishery. Concerns stated above for commercial data would be minimized in a properly designed index-net survey.	An index-net survey should provide a better statistical estimator than a commercial survey because of the greater number of mesh sizes, i.e. there is a broader size and age range of fish captured. However, as for the MFB index-netting CPUE indicator assessed above, the problem for Lake Winnipeg is the limited number of net sets each year and the limited number of years the program has been done (2005–2009).
10. Age of Entry into the Fishery or Age of Recruitment	MFB current commercial-catch sampling	Age diversity of fishable stock. This index is a measure of when a cohort of fish first becomes susceptible to a fishery. It will vary among years as mesh sizes vary, e.g. if the fishery is focused on larger fish and then changes to focusing on smaller fish there may appear to be a change in the age at which fish first become susceptible, but in reality it is just a change in net size. This index may also vary as growth rates vary. Tracking this index is critical to examining lake-wide impacts of fishing. (Note that age-at-entry is not the same as size-at-entry.)	Interpretation of this indicator can be problematic. For example, in Lake Winnipeg, two-year-old walleye are currently being harvested in the fishery in smaller mesh nets. This result may be a reflection of a smaller population of young fish, which now have relatively more food to spread amongst fewer fish, or it may be more rapid growth because the Lake is becoming more productive and there is more forage available. Understanding of ecosystem relationships and changes is critical for a correct interpretation of what this indicator means. Additional research might be required to make this reference indicator useful for Lake Winnipeg.
11. Mean age in fishery	MFB commercial-catch sampling	Age diversity of fishable stock. The mean age of fish in the Lake can decline as a result of over-fishing. As a result, each fish has fewer opportunities to spawn, potentially leading to a decline in the total number of fish in the Lake. (Note that size is not a proxy for age and that quality of ageing data is critical.)	*Stable or increasing mean age is currently one of the indicators considered by MFB.* This indicator could be implemented at present. It is not as meaningful as age structure because it can be biased by a large year class. It is not sensitive to bimodality in age classes, so caution must be applied to management directives.

12. Age at (10%, 50%, 90%) Maturity	MFB index-netting program	Spawning opportunities. The mean age of fish in the lake can decline as a result of over-fishing. As a result, each fish has fewer opportunities to spawn, leading to a decline in the total number of fish in the Lake. (Note that size is not a proxy for age and that quality of aging data is critical.)	MFB presently calculates this indicator, but as with other indicators based on the index-netting program, the problem is the low number of net sets and the number of years of the program. Interpretation is also not straightforward. For example, if fish mature earlier, then it may indicate over-harvesting because the fish may be reaching a minimum size for maturity more quickly. However, it is not clear how measuring 10% or 90% maturity would contribute more than knowing age for 50% maturity. It is possible, with significant fishing pressure, that the distribution will be compressed. Variation in environmental factors, especially temperature, should also be considered.
13. Difference between Age of Entry to Commercial Fishery and Age at 50% Maturity	MFB commercial-catch sampling and MFB index-netting program	Spawning opportunities. This indicator represents number or spawning classes in a population. If there are only a limited number of spawning opportunities, one bad year can have a devastating effect on the population. It should also be remembered that older spawners are generally more successful. Ideally 1–2 years of maturity should pass before fish become vulnerable to the fishery. This indicator can change suddenly if fishers start to use smaller mesh sizes.	*Mean age at maturity compared to mean age of the catch is currently one of the indicators considered by MFB.* This indicator could be implemented at present. The shortfalls with the two sampling programs, as described above, remain a problem.
Mortality-Based Indicators			

14. Total Mortality of a Cohort (Z)	MFB index-netting program—catch curve analysis	Mortality rates of fish. This indicator combines natural mortality (M) and fishing mortality (F) into a single value (total mortality – Z). Major changes in total mortality may reflect increased fishing pressure, poor environmental conditions or both. Regardless of the cause, if M increases, the population is in a poorer position. Z is calculated from an analysis of age classes of fish in the Lake over several years.	Sufficient age-structured data are not currently available for trends in Z to be determined for Lake Winnipeg fish stocks. MFB is beginning these types of analyses. It might be 3–5 years before this indicator would be useful. The more years are added the better the estimate. MFB has now calculated this index for the 2009 index-netting program, and there is some indication of differences between areas of the Lake. Differences between sites over a number of years would indicate local depletions. These calculations cannot be done for sauger because not enough older sauger are caught in the index nets. Improved effort records for the commercial fishery and data integration are required for this indicator to be applied fully.
15. Fishing Mortality (F)	MFB commercial-catch sampling, FFMC	Mortality rates of fish. Virtual Population Analysis (VPA) or Statistical Catch at Age (SCAA) of commercial CPUE and age analyses from commercial catches are used to determine F.	MFB is beginning these types of analyses. It might be 3–5 years before this indicator would be useful. The more years are added the better the estimate. Improved effort records for the commercial fishery and data integration are required for these methods to be applied fully.
16. Natural Mortality (M)	MFB commercial-catch sampling, FFMC	Mortality rates of fish. VPA or SCAA is used to estimate M and examine within the larger analysis. Typically M is poorly estimated or assumed. This indicator is important but not often calculated.	Improved effort records and data integration are required for these methods to be applied fully to the Lake Winnipeg fishery.
17. Ratio F:M	MFB commercial-catch sampling, FFMC	See above comments on M.	Improved effort records and data integration are required for these methods to be applied fully to the Lake Winnipeg fishery.
Recruitment-Based Indicators(all future fishable stock)			

18. Predicted Recruitment Strength from Research Surveys	Mid-water trawl survey, MFB index-netting program. Environment Canada, Lake Winnipeg and Netley/Libau Marsh fisheries research	Future fishable stock. This indicator estimates the size of the cohort or fish that will enter the fishery in future years. One major advantage is that it is independent of the fishery and fishery models. A number of years of trawl sampling are necessary to develop the relationship between the number of fish caught in pre-recruitment trawls and the number of fish that eventually become available for the commercial fishery. Trawl surveys need to be large enough and extensive enough to be representative of major parts of the lake and ecosystems important for the pre-recruits.	For Lake Winnipeg, 10 years of data are probably necessary to be useful. A trawl program needs to be stratified and structured to assess important habitats for the target species. Trawls done on the Namao give some indication of abundance of small fish, but the trawls are mostly done offshore not inshore where most of the young walleye and sauger are rearing early in the year. The Namao trawling does catch young-of-the-year (YOY) walleye, but few sauger or whitefish. There was also a problem of identifying sauger vs. walleye in early years of the program. The present MFB index-netting program now uses mesh as small as 1.5”, which may be useful as a measure of pre-recruitment in the future but the low number of net sets, as identified above, remains a problem. The Environment Canada program is just a preliminary research study at present but it could contribute in the future. A beach seining program and a trawl-netting program for YOY walleye and sauger are done in LOW and Minnesota. Abundance and size in August are used as predictors of future year-class strengths in the fishery. Any program needs to be stratified and well-structured.
19. Trends in Recruitment from VPA or SCAA	MFB commercial-catch sampling, FFMC	Declines in fisheries are a major concern. Improved effort records and data integration are required for these methods to be applied. Values are estimated values calculations done with VPA or SCAA population models. Estimates are affected by the quality of data entered into the model. Errors are compounded due to the nature of calculations in VPA. However, as long as the methods for sampling and calculation are kept consistent, the relative changes from year to year will be accurate. Estimates are usually derived from catch data—biological sampling of the catch to characterize the catch at age.	Normally, landings (or deliveries) would be sampled (200 fish per major delivery to gather age, length and weight). The current system for Lake Winnipeg only samples fin rays, not length or weight, so length-at-age must be calculated from the index-netting program. This estimate will result in more error to the VPA, and hence recruitment estimates. VPA is also generally “tuned” or calibrated using CPUE data from a research survey. If survey coverage is poor, such as with Lake Winnipeg, then there will be much more measurement error in the process.
20. Spawners per Recruit (SpR) or spawning stock biomass from	MFB commercial-catch sampling, FFMC	Declines in fisheries are a major concern. Improved effort records and data integration are required for these methods to be applied. See above comment—VPA requires accurate data and	See above comment.

VPA or SCAA		proper data.	
Growth-Based Indicators(all growth rates of fish)			
21. Size (Length) at Maturity	MFB index-netting program, MFB commercial-catch sampling	If the length of fish that are reaching maturity for the first time is declining, it can be an indicator of a response to high fishing pressure. Note that one would also expect that, in the initial stages of a fishery, growth rates would increase with a moderate amount of fishing pressure due to the release of competitive constraints. Variation in environmental factors, especially temperature, should also be considered.	Consistent age determination, with proper quality assurance and quality control, is essential. There must be sufficient coverage of the stock when sampling. A statistical analysis should be done to determine sufficient sample size to detect change. This measure can be an effective tool for determining change size at age, but many variables can cause this change.
22. Size at Age (for some Standard Age)	MFB index-netting program	If the length of fish at a predetermined standard age is declining, it can be a sign of high fishing pressure. Variation in environmental factors, especially temperature, should also be considered.	Quality of the result will depend on the quality of the input data. Back-calculation is a useful way to estimate growth, except that the estimate will be based solely on the survivors. Early growth changes may be masked by this.
23. Von Bertallanfy growth equation ($w = L_{inf}*k$, where w = , L_{inf} = , and k = .)	MFB index-netting program, MFB commercial-catch sampling (backcalculated size-at-age data fit to Von Bertallanfy growth equation)	This indicator represents early growth. Size-at-age data are back-calculated to fit a Von Bertallanfy growth equation. Poor early growth may result from poor conditions in the Lake (food and environment) or a very large population size (many competitors). Caution is needed for interpretation.	
Spatial Indicators (all lake habitats used by fish)			

24. Coefficient of Variation (CV) of Catch Rates	MFB index-netting program	A greater CV indicates that fish are concentrating in preferred habitats. Catches remain high in those areas but decline in others. Increased concentration is often associated with declining abundance even when overall catch rates are stable. Conversely, as a population grows, fish are found more frequently in new areas of the Lake. This information is easily biased or missed in summaries that only consider non-zero catches.	This approach requires a much more complete index-netting program then is presently in place.
25. Percentage of Null Catches (or Below a Threshold)	MFB index-netting program. Commercial fishers (sentinel fleet). Threshold could be one fish or a low number for a more ubiquitous species.	An increase in null catches indicates greater concentration of fish and possible reduction in overall abundance. This information is easily biased or missed in summaries that only consider non-zero catches.	This indicator could be measured in Lake Winnipeg by a commercial fishers sentinel fleet or a more complete index-netting program.
26. Gear Set (Effort) in Area Throughout Season	FFMC, commercial fishers	This measurement is a direct indication of fishing pressure in different areas or habitats. This information would help to resolve differing viewpoints around the Lake as to the state of the fishery, and improve the tracking of abundance.	This indicator requires better effort data than are currently available from the commercial fleet. A sentinel commercial fleet could collect the necessary data for this indicator. A careful constructed fishers' survey might also act as a surrogate for increasing or decreasing habitat use by key species.
Biomas- Based Indicators (None Possible at this Time, but a Few Provided for Discussion)			
27. Estimates of Exploitable Biomass	FFMC, commercial-catch sampling (VPA or SCAA), commercial fishers	Total biomass of fish. A general assumption is that high biomass would be preferred, but a very high biomass may result in slower fish growth. It may be useful to keep biomass slightly below the maximum possible to have faster-growing and larger fish.	This indicator depends on a successful VPA, which means suitable data from commercial-catch sampling and research surveys. These data, especially on effort, are not currently available for Lake Winnipeg.
28. Ratio of Estimated Exploitable	FFMC, commercial-catch sampling (VPA or	Total biomass of fish. This measurement indicates how close a fishery is to full exploitation. Fisheries generally operate by taking	See above. This indicator requires improved effort data.

Biomass to Harvest Biomass	SCAA), commercial fishers	some small fraction of the exploitable biomass. This is especially important when the most of the spawning stock is within the exploitable size range – usually the case. Too close is risky.	
29. Spawning Stock Biomass	FFMC, commercial-catch sampling (VPA or SCAA), commercial fishers	Total biomass of spawners. A general assumption is that high biomass would be preferred, but again, distribution of the biomass may be the most important aspect. More biomass is better.	Atlantic groundfish had high spawning-stock biomass when they collapsed but no large, old females. The quality of the offspring was poor and recruitment failed. This indicator requires improved effort data.
Ecosystem Indicators (all prey and/or competitor abundance)			
30. Rainbow Smelt Biomass Indicator	Mid-water trawl survey, fishers' survey	Changes in abundance of smelt may be an indicator of future changes in walleye, sauger or lake whitefish. Interpretation may be problematic.	In Lake Winnipeg smelt are the primary prey of adult walleye in the North Basin but not in the channel or South Basin. A major advantage of using this indicator is that the sampling program would be independent of the commercial fishery and trawling would be independent of gill nets.
31. Inshore Fish Communities	Environment Canada, Lake Winnipeg and Netley/Libau Marsh fisheries research	Changes in relative abundance or growth of other species and appearance of exotic species may be an indicator of future changes in walleye, sauger or lake whitefish. Interpretation can be problematic. Some changes may be positive, others negative and some changes may be initially positive but negative in the long run.	The Environment Canada program is just a preliminary research study at present but it could contribute in the future. A major advantage of using this indicator is that the sampling program would be independent of the commercial fishery and seining would be independent of gill nets.

References

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Appendix IV.d. Guidelines for data organization and preparation for analysis.

In preparation for annual stock assessments past and ongoing information needs to be organized consistently and effectively. It has been suggested by one of the peer reviewers (M.E.) that the following metrics should be available. The LWTF notes that some of the metrics are already available from MFB in published or data report form but not presented in our report.

FFMC commercial fishery harvests:

- Summarize harvest by year for the entire lake by species as below;
- Attempt to describe changes in fishing effort;
- If possible summarize harvest by species and year for each basin of Lake Winnipeg .

MFB historic commercial harvest sampling 1979-2003 (focus on past production):

- Create table of annual age composition of the commercial harvest by species and year;
- Estimate mean length & weight at age in the commercial harvest by species and year;
- Estimate catch curve mortality rate by year and species.

MFB current commercial catch sampling 2005-2009:

- Create table of annual age composition of the commercial harvest by species and year;
- Estimate catch curve mortality rate by year and species;
- Conduct study to develop relationship between headed & gutted weight and round weight;
- Estimate mean length & weight at age in the commercial harvest by species and year after developing dressed to round conversion, if possible;
- Develop ageing error matrix between scales and spines and scales and fin rays.

MFB historic index gill net program 1979-2003:

- Summarize fishing effort and catch by spatial, depth, and season;
- Estimate annual CPUE for sauger and walleye by using a mixed model ANOVA that accounts for spatial efforts, depth, and season;
- Create table of annual age composition of the survey catch by species and year;
- Estimate mean length & weight at age in the survey catch by species and year;
- Estimate age-specific maturity schedule by species and year;

- Develop recruit index for each species; i.e. cumulative CPUE at first three ages caught in the survey.

MFB current index gill net program 2005-2009

- Create table of annual age composition of the survey catch by species and year;
- Summarize fishing effort and catch by spatial, depth, and seasonal scales;
- Estimate annual CPUE for sauger and walleye by using a mixed model ANOVA that accounts for spatial efforts, depth, and season;
- Estimate mean length & weight at age in the survey catch by species and year;
- Estimate age-specific maturity schedule by species and year;
- Develop ageing error matrix between scales and otoliths for 2008;
- Develop recruit index for each species; i.e. cumulative CPUE at first three ages caught in the survey.

MFB Mossy Bay (North Basin) index gill net program

- Summarize fishing effort and catch by spatial, depth, and seasonal scales;
- Estimate annual CPUE and its standard deviation for whitefish by using a mixed model ANOVA that accounts for spatial efforts, depth, and season;
- Create table of annual age composition of the survey catch for whitefish by year;
- Estimate mean length & weight at age by year;
- Estimate age-specific maturity schedule by year.

MFB historic near-shore trawl surveys 1976-1983

- Summarize fishing effort and catch by spatial, depth, and seasonal scales;
- Estimate annual CPUE by species using a mixed model ANOVA that accounts for spatial efforts, depth, season, and species caught (i.e. catch interference, species associations);
- Create table of annual age composition of the survey catch by species and year;
- Develop recruit index for each species; i.e. cumulative CPUE at first three ages caught in the survey.

Mid-water trawl surveys 202-2009

- Summarize fishing effort and catch by spatial, depth, and seasonal scales;

- Estimate annual CPUE for sauger and walleye by using a mixed model ANOVA that accounts for spatial efforts, depth, and season;
- Create table of annual age composition of the survey catch by species and year;
- Develop recruit index for each species; i.e. cumulative CPUE at first three ages caught in the survey.

Recreational Fisheries Harvests

- The limited information maybe useful at a later date.

Environment Canada, Lake Winnipeg and Netley/Libau Marsh Fisheries Research

- This could be a very valuable, simple, and inexpensive way to assess recruitment, food habits, habitat use, etc.

Appendix V. Lake Winnipeg Fishers Survey

The Lake Winnipeg Quota Review Task Force was established as a co-science task force bringing together both scientists and fishers to jointly assess the health of Lake Winnipeg walleye (pickerel), lake whitefish, and sauger stocks. Although limited, scientific papers on Lake Winnipeg and the three quota species are accessible in the published literature. However, knowledge of the Lake and fishery acquired by fishers through practical experience is not as readily accessible because it is typically not formally recorded in a written format. Acquiring new information was originally not part of the Task Force's responsibilities; nevertheless, members considered fishers' knowledge an essential part of the overall assessment of the health of the fish stocks, and consensus amongst members was that a complete assessment could not be carried out without this knowledge. Thus, the fishers' survey was conceived. It had the aim to gather further knowledge about: 1) the status and health of the fish stocks; 2) changes in fishing behaviour; 3) changes in water quality; 4) observations regarding exotic species; 5) changes in by-catch, climate, spawning grounds and fish habitat; and 6) views regarding quota adjustments. Space was also provided for additional comments.

Initially, the Task Force considered a simple mail-out survey to fishers. However, it was decided that community visits organized and lead by the fisher members of the Task Force would result in greater participation by fishers, which would ultimately strengthen recommendations of the report and acceptance of these recommendations. All Task Force members provided input on the development of the survey. The Task Force recognizes the limitations of such an approach but believes that, over time, a more formal and structured method should be developed and implemented to capture the knowledge of fishers on an ongoing basis.

METHODS

All fishers received letters outlining the purpose of the survey, the information being sought and the meeting dates and locations (App.V.1 and App.V.2). The fisher members of the Task Force also provided information locally to inform fishers of the upcoming meetings.

The Lake communities were divided into three areas with responsibilities of Task Force members as follows:

North/Northeast. **Lead fisher: Langford Saunders. Scientific support: Karen Scott**
Communities: Norway House, Poplar River, Berens River, Grand Rapids;

Northwest. **Lead fisher: Norm Traverse. Scientific support: Burton Ayles**
Communities: Dauphin River, Fisher River (includes Jackhead and Peguis); and

***South Channel/South Basin.* Lead fisher: Ken Campbell. Scientific support: Ross Tallman**

Communities: Matheson Island (includes Pine Dock, Bloodvein, Princess Harbour and Loon Straits), Riverton (includes Hecla, Hnausa and Arborg), Gimli (includes Arnes and Winnipeg Beach), Grand Marais (includes Selkirk, Eastern Beaches and Pine Falls). Meetings took place after the automn fishing season during the last week of October and in November. Each community meeting had one fisher member and one scientist member in attendance, except for the meeting in Peguis, which did not have a science member of the Task Force present due to a scheduling conflict. Consequently, the fishers present at the meeting requested that it be re-scheduled so that a science member could attend. The meeting was re-scheduled; however, no fishers were confirmed to attend and the meeting was subsequently cancelled.

At each meeting, the role of the Task Force was described, the rationale for the survey explained, and questions answered. Fishers then filled out the surveys (App.V.3), which were collected at the end of the meeting. Some deviations from this approach did occur: Norway House fishers requested that the survey be filled out together as well as individually, and one fisher from Berens River requested that the survey be reviewed together with the science support member of the Task Force. In some instances, blank surveys were left in the community to be filled out and sent to the Task Force by those not able to attend the meeting. However, none of these surveys were returned.

It should be noted that the survey skips from question 4 to 7, an oversight and completely unintentional. Survey responses were collated, summarized (see SURVEY RESULTS) and used, where appropriate, in assessing health of fish stocks. Also, while reviewing the survey responses, it quickly became evident that question 10 was not clear to participants and it was, therefore, omitted from the survey results.

SURVEY RESULTS

A total of 71 fishers from 21 different communities participated in the survey; 28 fished the South Basin, 21 the channel, and 27 the North Basin. The number of years fished ranged from three to 60 years (Table App.V.1).

Table App.V.1. Description of survey participants (SB = South Basin, C = Channel, NB = North Basin).

Meeting Location	No. of Fishers	Communities (Number of fishers)	Fishing Area			Years Fished
			SB	*C*	*NB*	
Selkirk	13	Vic Beach, Beaconia, Manigotogan, Selkirk (5), St. Andrews, Winnipeg, Wanipigow, Traverse Bay (2)	13	-	-	15 - 60
Riverton	6	Hnausa (3), Riverton (3)	3	3	-	13 - 50
Gimli	12	Gimli (10), Sandy Hook, Winnipeg Beach	12	3	-	3 - 47
Berens R.	2	Berens River	-	2	-	40
Matheson Island	17	Matheson Island (10), Pine Dock (2), Loon Straits (2), Princess Harbour (2), *NR (1)	-	11	6	13 - 37
Dauphin R.	4	Dauphin River	-	3	4	25 - 51
Norway H.	10	Norway House	-	-	10	8 - 40
Grand R.	7	Grand Rapids	-	-	7	4 - 40
Poplar R.	0					
TOTAL	**71**		**28**	**21**	**27**	**3 - 60**

*NR = no response

Question 4: Quota species and changes in quota species.

All fishers indicated that they target pickerel, less than half (32) target sauger, and 24 target whitefish. In addition, fishers target a number of non-quota species, such as goldeye, perch, mullet, and pike.

***Pickerel* –** Table App.V.2 indicates a clear consensus among respondents that pickerel fishing has improved in the last ten years; pickerel are more abundant and larger. Two fishers remarked that pickerel also grow more rapidly. Only two respondents indicated that pickerel have declined or remained the same in the last ten years, and four fishers did not respond to the question. Note that the total number of responses per community may not equal the number of fishers if a respondent used more than one term in his answer.

Table App.V.2. Responses related to how pickerel fishing has changed in the last ten years.

Meeting Location	No. of fishers	Increased abundance	Bigger	Fatter	"Good"	Increased growth rate	Same	Decreasing	No Response
Selkirk	13	7	5			1	1	1	
Riverton	6	3	4	1	1	1			
Gimli	12	10	4						
Berens River	2	1	1		1				

Matheson I.	17	15	4		1				2
Dauphin River	4	4							
Norway House	10	8	5	1	5				1
Grand Rapids	7	5			1				1
TOTAL		**53**	**23**	**2**	**9**	**2**	**1**	**1**	**4**

Whitefish - The language used to describe how whitefish fishing has changed in the last ten years was less consistent than that for pickerel fishing, ranging from “plenty” to “tonnes and tonnes” (Table App. V.3). Overall, most responses (51) described a positive trend for whitefish with less than 10 respondents indicating a decreasing, no change or fluctuating trend. Seven fishers did not know or did not target whitefish and ten fishers did not respond to the question. Two responses from Norway House indicated that whitefish eat smelt. Note that the total number of responses per community may not equal the number of fishers if a respondent used more than one term in his answer.

Table App.V.3. Responses related to how whitefish fishing has changed in the last ten years.

Meeting Location	**No. of Fishers**	**Increased abundance**	**Bigger**	**“Good” or “ok”**	**Same**	**Fluctuates**	**Decreasing**	**Don’t know or Don’t target**	**No Response**
Selkirk	13	6	1		2		1	3	
Riverton	6	2			2				2
Gimli	12	9						3	
Berens River	2			1					
Matheson I.	17	9	1	1	2	1		1	3
Dauphin River	4			3	1				
Norway House	10	5	7						2
Grand Rapids	7	6			1				1
TOTAL		**37**	**9**	**5**	**8**	**1**	**1**	**7**	**10**

Sauger **–** Table App.V.4 summarizes responses regarding how sauger fishing has changed in the last ten years. Overall, responses indicate a much less favorable trend for sauger than for pickerel and whitefish. A total of 25 fishers indicated that they have observed a decrease in sauger. One fisher from the Norway House area stated that the decrease occurred “in the last six to seven years”. Another fisher with 40 years experience from Berens River reported that he used to fish only sauger, not pickerel. Then in the 1990s there was a decline and hardly any sauger were caught. In about 1994/95, sauger were again very abundant off Berens Island but “after that, nothing”. This fisher believes that sauger may have been overfished. Another fisher from Selkirk stated that 10 to 15 years ago, there was only sauger, no pickerel, but now it is the opposite. This timeframe is consistent with the observations in Berens River. It should be noted that five of the nine responses from Matheson Island indicating a decrease in sauger specified that the decrease was due to pricing. In addition, one fisher indicated that the decrease was due to mesh size. Otherwise, the rest of the responses indicated an actual decline in abundance. Note that the total number of responses per community may not equal the number of fishers if a respondent used more than one term in his answer.

Table App.V.4. Responses related to how sauger fishing has changed in last ten years.

Meeting Location	**No. of fishers**	**Declined**	**Declined Increasing**	**Fluctuates**	**Same**	**Increasing**	**No sauger in the area**	**NR**	**Don’t know**
Selkirk	13	6	3		2		1		1
Riverton	6	1	4		1				
Gimli	12	3	5	1		2			1
Berens R	2	1						1	
Matheson I	17	9			1	1		3	3
Dauphin R	4				1		1		2
Norway H	10	5					3	2	
Grand R	7				2	2	1	1	1
TOTAL		**25**	**12**	**1**	**7**	**5**	**6**	**7**	**8**

Twelve fishers, primarily from the South Basin, have observed a decline in sauger but also a recent increase. The timeframes associated with the increase were fairly consistent. One fisher from Selkirk indicated an increase last season, two fishers indicated an increase in the last three to five years and another within the last five years. A Gimli fisher remarked that between 1999 and 2005 there was a decrease in sauger followed by an increase between 2005 and 2009. Again, the increase observed was consistent with the other respondents. Five fishers observed an increase in sauger in the last ten years, of which three fishers noted that they were also bigger.

The “no sauger in the area” responses (6) are difficult to interpret. These responses could mean that there have never been sauger in the area or that there are no longer any sauger in the area. Eight fishers indicated that they did not know if sauger fishing has changed, and seven fishers did not respond to the question.

Question 7 to 10. Fishing effort in the last ten years.

Two-thirds of respondents indicated that it takes less time to fill their quotas than it did ten years ago (Table App.V.5). There were too few responses from the North Basin to evaluate whether a spatial relationship exists with fishing effort; however, it does appear that, overall, the South Basin fishers are filling their quotas faster than they did ten years ago. Four fishers stated that the time to fill their quotas depends on factors such as the weather, high winds, south winds, fish, product, and less fish. Finally, nine fishers indicated no change, (Note: One response “four weeks summer, four weeks fall”, was interpreted as no change), two took longer due to the weekly limits imposed by the FFMC, and ten fishers did not answer the question.

Seventy-two percent (51) of fishers have changed the way in which they fish in the last ten years, 15% (13) have not, and seven fishers did not answer the question. The most commonly cited changes included less travel, fewer nets, and bigger mesh size. Only two fishers indicated that they now have to travel further.

Table App.V.5. Responses related to changes in fishing effort in the last ten years.

Meeting Location	**No. of Fishers**	**Has time to fill quota changed?**				
		Yes faster	*Yes longer*	*No*	*Depends*	*No Response*
Selkirk	13	10		2	1	
Riverton	6	5		1		
Gimli	12	11				1
Berens River	2	1		1		
Matheson I	17	11		3		3
Dauphin River	4	1		1	2	
Norway House	10	4	2	1		3
Grand Rapids	7	3			1	3
TOTAL	**71**	**46**	**2**	**9**	**4**	**10**

Questions 11 to 13. Changes in non-quota species.

Aquatic ecosystems under the threat of cultural eutrophication undergo numerous changes at all levels of the food web. Initially, increased nutrients entering an aquatic ecosystem support the growth of algae, an important food item for zooplankton (small floating animals), which in turn support the forage fish community and ultimately larger fish. From some perspectives, i.e. the commercial fishery, the initial changes associated with eutrophication could be considered favorable; as the lake becomes more productive through the addition of nutrients, so does the fishery. However, as water quality continues to deteriorate due to increasing nutrients, notably phosphorus, numerous other less-favorable changes occur. Within the fish community, a dramatic increase in cyprinids (minnows and carp) has been observed in lakes that have become highly turbid due to the excessive growth of algae resulting from very high levels of phosphorus. The purpose of this series of questions was to determine if fishers have observed any consistent changes in the non-quota species, especially cyprinids, in Lake Winnipeg and to get fishers' feedback on the reasons for the changes, if any.

Tables App.V.6 and App.V.7 list the more- and less-frequently caught non-quota species cited by respondents. Tullibee (10 responses) and sunfish (8 responses) were most-often cited as having increased throughout the Lake (Table App.V.6). Smelt (7 responses) were cited to be increasing in the North Basin, sucker (6 responses) in the channel area and North Basin, and goldeye (6 responses) in the South Basin. Carp also were observed more frequently in both the north and South Basins of Lake Winnipeg. However, only four fishers mentioned this species, less than half as often as tullibee.

Pike and burbot were the species most cited as being caught less often, a trend apparent throughout the Lake (Table App.V.7). Sturgeon (North Basin) and perch (whole lake) were the next most frequently mentioned species to be caught less often (6 responses each).

A drawback with this type of question is that it requires fishers to go back in time and remember details about their catches. Some fishers may not be willing to invest this effort, others may not remember such details, and others may not have been fishing for more than a few years. An annual survey would overcome this issue because the question would pertain specifically to the last fishing season. Over time, changes in non-quota species composition would be revealed in a more reliable manner.

Table App.V.6. Non-quota fish observed ***more frequently,*** and general area fished.

Meeting Location	**Carp**	**Sucker**	**Bullhead**	**Bass**	**Sunfish**	**Catfish**	**Smelt**	**Burbot**	**Perch**	**Goldeye**	**Crappy**	**Pike**	**Sturgeon**	**Tullibee**
Selkirk	2				2	3				4		2		4
Riverton									1					
Gimli				1		1			1	2				1

Berens R		1	1		1									
Matheson I		1							1			1		
Dauphin R	1	1					1					1		1
Norway House	1	3			5		2	2						4
Grand Rapids				1		1	4				1			
TOTAL	**4**	**6**	**1**	**2**	**8**	**5**	**7**	**2**	**3**	**6**	**1**	**4**		**10**

Table App.V.7. Non-quota fish observed ***less frequently,*** and general area fished.

Meeting Location	**Carp**	**Sucker**	**Bullhead**	**Bass**	**Sunfish**	**Catfish**	**Smelt**	**Burbot**	**Perch**	**Goldeye**	**Crappy**	**Pike**	**Sturgeon**	**Tulibee**
Selkirk								2	1			1		
Riverton		1						1	1					
Gimli				1				3	1			1		1
Berens R												1		
Matheson		3		2				1	1			1		1
Dauphin R								1	1				1	
Norway House								1				3	5	
Grand Rapids									1			2		
TOTAL		**4**		**3**				**9**	**6**			**9**	**6**	**2**

Question 14: The occurrence of rainbow smelt.

Rainbow smelt is an exotic, invasive species that entered Lake Winnipeg via the Winnipeg River system in 1990. It is found predominantly in the North Basin, and its range now extends to Hudson Bay. Exotic invasive species can affect the rest of the food web, e.g. through competition for food and predation on other organisms. In Lake Winnipeg, rainbow smelt have become an important food source for both pickerel and whitefish, and they may, therefore, play an important role in the sustainability of the commercial fishery and/or the quality of the catch. Input from fishers about rainbow smelt was, therefore, sought through Question 14.

Understandably, most observations about rainbow smelt came from fishers in the North Basin, especially Norway House. These fishers noted a huge increase in rainbow smelt over the years, including up the Nelson River system. Interestingly, smelt used to be bigger and fewer, but now they are small and more abundant. The increase was particularly noteworthy on the west side of the Lake since about 2000. The east side of the Lake generally had fewer smelt until about five years ago, when they started to become more abundant. One fisher noted fewer smelt this year (2009). In the spring, large numbers of smelt have been seen floating in “some areas just like a blanket of them floating” and covered in a white fungus. One fisher observed increased numbers of smelt floating around after a strong wind. Apparently, they smell bad and seagulls and other birds do not eat them. By June, they start to pile up on the shoreline to depths of eight inches in some areas. It was also noted that smelt cause both pickerel and whitefish to become greasy and more yellow in colour.

Fishers from Grand Rapids also observed an increase in the abundance of smelt. Of the fishers who responded to the question, most considered smelt to be “good feed” for pickerel, and one fisher attributed the abundance of pickerel to smelt. Similar to Norway House, it was observed that smelt make pickerel greasy. Dauphin River fishers observed that smelt are abundant in their area (“more than ever, too much”) and that pickerel are full of smelt.

Conversely, rainbow smelt have not increased in abundance in the Berens River area in the last ten years. A fisher from this community stated that most smelt are found at depth north of Berens Island and no white fungus is observed on the fish. Similarly, the other channel and South Basin fishers generally commented that rainbow smelt are rarely, if ever seen. For example, “caught one in the last five years”, “less than five in the last 16 years”, “seen about 15 in the last ten years”. Some fishers noted that they used to encounter smelt more often (i.e. 15 years ago, caught often in the 1990s) than they do now. One fisher commented that smelt rot the stomachs of pickerel faster. Another fisher (Berens River) noted that the gut contents of an eight-inch smelt included small crabs.

Question 15. Observed changes in the quality of the catch.

A number of environmental factors may cause or predispose fish to increased susceptibility to disease and abnormalities, such as lesions and deformities. Environmental stressors may be biological (i.e. bacteria, viruses, fungi or parasites), chemical (toxins, pollutants, degraded water quality) or physical (high temperature, trauma) and may occur naturally or be caused or exacerbated by human activities. In an ecosystem like Lake Winnipeg, which is undergoing rapid changes in water quality, there are inevitable changes in the abundance of organisms and in the structure of their communities, as observed by the scientific community. Fishers also observe changes in the quality of their catch, which may reflect a changing ecosystem. Question 15 was intended to capture some of this knowledge.

The observation that pickerel are bigger, fatter and healthier looking was common among fishers with the exception of one fisher who considered them to be “way too fat”. It was acknowledged that there would always be some abnormal fish in a population. Based on the responses, abnormalities were generalized as: 1) deformities, 2) skin-related changes, and 3) taste- and texture-related. Deformities included bent spines, backwards scales, missing fins, stubby or midget fish (pickerel and whitefish), shorter and fatter fish, skinny pickerel with big heads, and cripples. The skin-related changes included warts, lesions, red blotches, shiny skin (whitefish), lumps, and purple tumors or growths. One fisher from Berens River observed that about five years ago, lesions in all three quota species resembled cigarette burns, whereas now they look more like a cancer and a larger area is being affected as if the fish rubbed persistently against something. A fisher from Dauphin River noted that pickerel are now getting some growths like sauger. Two fishers from different communities observed large warts on both sauger and pickerel, one described them as being “the size of a thumb tip”. Last, the taste- and texture-type changes include watery, soft whitefish in the spring. A total of 21 fishers did not respond to the question.

Questions 16, 17, and 20. Changes in the water quality of Lake Winnipeg.

Algal blooms are a common, natural phenomenon in many lakes, Lake Winnipeg included. However, in recent years, the blooms on Lake Winnipeg have become larger and more frequent due to increasing nutrient loads from its large watershed. Furthermore, the algal community is changing to one that is dominated by cyanophytes, or “blue-greens”, some of which may produce lethal toxins, which further degrade the quality of the water. Fishers in the North Basin of Lake Winnipeg were among the first to describe these large algal blooms and how they were affecting the fishing. Unlike the North Basin, the water in the South Basin is turbid due to more suspended sediment. Turbidity can impede the penetration of light into the water column, thereby preventing the growth of algae, which need light to grow. Consequently, the South Basin has been relatively bloom free, except for a few years.

Thiry-six respondents observed changes in the water quality of Lake Winnipeg, 23 fishers had not observed changes, and 12 did not respond to the question (Table V.8). Of those who indicated that they observed changes in water quality, five considered the changes favorable, largely due to better fishing, and the remainder considered them to be negative.

Table App.V.8. Responses related to observed water quality changes in Lake Winnipeg.

Meeting Location	Observed changes in water quality?			
	No	Yes Negative	Yes Positive	No Response
Selkirk	6	5	1	1
Riverton	4	1	1	
Gimli	5	3	2	2

Berens River		2		
Matheson Island	8	2	1	6
Dauphin River		4		
Norway House		8		2
Grand Rapids		6		1
TOTAL	**23**	**31**	**5**	**12**

Fishers from Norway House observed two main changes in water quality: increased algae and increased turbidity. They identified green and brown algae, both of which are abundant and increasing in abundance. The green algae burns if it enters the eyes and dries out the hands, causing the skin to crack. One fisher remarked that green algae forms blooms when southern Manitoba floods. The brown algae is more dense than the green, forms “snot-like clusters” and smells like excrement, hence its common name, “brown shit”. Fishers also remarked that the shoreline used to be clean but now experiences more erosion, and consequently, there is higher turbidity (“muddy water”) further off-shore, especially when there is a strong south wind. Due to these changes, fishers can no longer drink the water or use it for bathing, and are obliged to transport bottled water for such needs. In addition, algae slows down the boats and increases fuel consumption. More work is required to clean nets and boats more often.

Fishers in the other most northerly community, Grand Rapids, also identified both green and brown algae, considered them to be increasing in abundance, and noted that algal blooms form on calm days. In addition to algae, higher water levels and associated increased erosion were included in the observed water quality changes, without further elaboration. The algae cause sores on the hands and wrists, and cleaning algae from boats and nets increases the work load.

A fisher from Berens River identified seven different kinds of algae: light blue, dark blue, light green, dark green, brown, brown with jelly, and black. The latter two types smell bad and are present near the bottom of the Lake in the winter. This fisher’s father had first observed light green-coloured algae in about 1978. By 1988, the algae appeared darker. It was around this time that he first noticed the brown jelly-like algae, which seems to form in late June but is also found in nets in the winter. This year (2008/2009) there was less of the brown algae but the green was particularly bad. In the summer, the greens are at the surface of the lake, and sink as the temperature gets colder. Blue and green algae affect movement of the boat in the autumn. Algae have increased the work load because gear and boats need to be cleaned more often. In addition, fishers no longer drink the lake water without first boiling it.

The remaining communities were brief and less descriptive in their responses about changes in water quality. All respondents acknowledged algae as a water quality issue that has impacted fishing. Some fishers considered the impact positive, largely because of better fishing. The remainder considered the presence of algae a detriment to fishing. For example, algae attaches to the nets, which then become heavy and get pulled down with the current. Additional adverse consequences of increased algae included: 1) can no longer drink the water in the winter, 2) can no longer see the bottom of the Lake in the winter, 3) fish later, 4) have to pull up and move to different locations, and 5) get less catch.

Question 20 dealt with under-ice algae. Unfortunately, we did not include a question that specifically asked if fishers were active in the winter. Consequently, an answer of “no” with no elaboration could indicate that the fisher does not fish in the winter, as opposed to affirming that he has not encountered under-ice algae. Therefore, only the ‘yes’ answers and those that had some explanation were considered in the analyses because these fishers clearly fished in the winter.

A total of 26 fishers indicated that they have experienced under-ice algae to varying degrees. The description of winter algae ranged from “a little dirt” to “brown-black jelly that stinks”. Most fishers considered under-ice algae to be detrimental to fishing because fish avoid it and “fish avoid it with the exception of the odd maria”, it sinks nets, and fish die more quickly. Sometimes the black algae floats and may freeze under the ice, “only garbage fish are caught when this occurs”. However, the fish do return once the algae have gone. Only one fisher stated that under-ice algae had a positive effect on fishing but did not elaborate. Two respondents stated that under-ice algae have no effect on fishing. Interestingly, one fisher observed that there are fewer under-ice algal blooms when there is more snow. This is likely due to a lack of light, which is required for the growth of algae.

Questions 18 and 19. Changes in climate and associated impacts on fishing.

Overall, these questions appeared to meet with little interest from fishers (Table App.V.9). The ‘no response’ tally was high and fishers tended not to elaborate much in their responses. Nevertheless, Table V.9 shows no clear consensus among participants that any consistent climate-related trends are being observed. A “later freeze-up” was most consistently cited with no observations of an “earlier freeze-up” to oppose it. In contrast, the responses for “ice-off” included observations for both an earlier and later break-up. Additional observations included changes in ice quality, less snow, thinner ice, thicker ice, and depends on the weather.

Table App.V.9. Trends in climate-related changes in the last ten years. (NR = no response.)

	Changes in the date of ice off?			Changes in the date of freeze up?			Changes in ice thickness?			Changes in snow cover?		
	Yes	No	NR	Yes	No	NR	Yes	No	NR	Yes	No	NR
Riverton	-	4	2	-	4	2	-	4	2	1	3	2
Gimli	4	6	2	5	5	2	4	5	3	5	5	2
Matheson	3	11	3	3	11	3	2	12	3	3	11	3

Selkirk	2	9	2	5	6	2	4	7	2	3	8	2
Norway H	7	1	2	8	-	2	7	1	2	7	1	2
Berens R	1	1	-	2	-	-	1	-	1	-	-	2
Gr Rapids	4	1	2	3	2	2	5	1	1	3	2	2
Dauphin	4	-	-	4	-	-	1	1	2	1	1	2
TOTAL	25	33	13	30	28	13	24	31	16	23	31	17

Question 21. Fluctuations in FFMC landings over time.

Contributing factors identified by fishers for the unprecedented **increase in landings of pickerel** since the late 1990s include the following: more abundant, more feed, smelt, flood of 1997, flooding (= nutrients), high water, high water provides access to streams, underwater streams affecting water temperatures and water levels, spawn testing, good spawning, good year class, Grand Rapids fish stocking, price, more winter quotas filled in open water, the quota system and Mother Nature.

Contributing factors identified by fishers for the ***decrease in landings of pickerel*** in the mid-1990s include: no smelt, low water, poor spawning, season open too early, fishing spawning fish, no spawn testing, algae, Manitoba Hydro, better regulations, mesh size, and Mother Nature.

Contributing factors identified by fishers for the ***decrease in landings of sauger*** since the late-1980s include: no food, pickerel competition, water levels, season open too early in the North Basin, whitefish fishers, fishing of spawning fish in North Basin and channel, using 3” mesh in the south, net size, habitat destruction by carp, not targeted, and prices.

Contributing factors identified by fishers for the comparatively ***stable landings of whitefish*** include: low prices, less fishing pressure, protected spawning grounds, good habitat, low quotas, quotas met every year, and smelt.

Overall, there was no consistent reason among fishers to explain the various trends in landings of the three quota species over time.

Questions 22 and 23. Spawning habitat.

Figure App.V.1 summarizes fishers’ responses to spawning ground locations. Fishers from Norway House expressed concerns over a number of spawning habitats in the North Basin that have become degraded due to the build-up of sand, which either blocks fish passage or covers spawning habitat. The sites identified include Belanger Point, Spider’s Creek, and Simpson Lake. Playgreen Lake was also identified as an area where whitefish no longer spawn due to serious habitat degradation. Additional comments included beaver dams, bank erosion due to Hydro, silting, and algae.

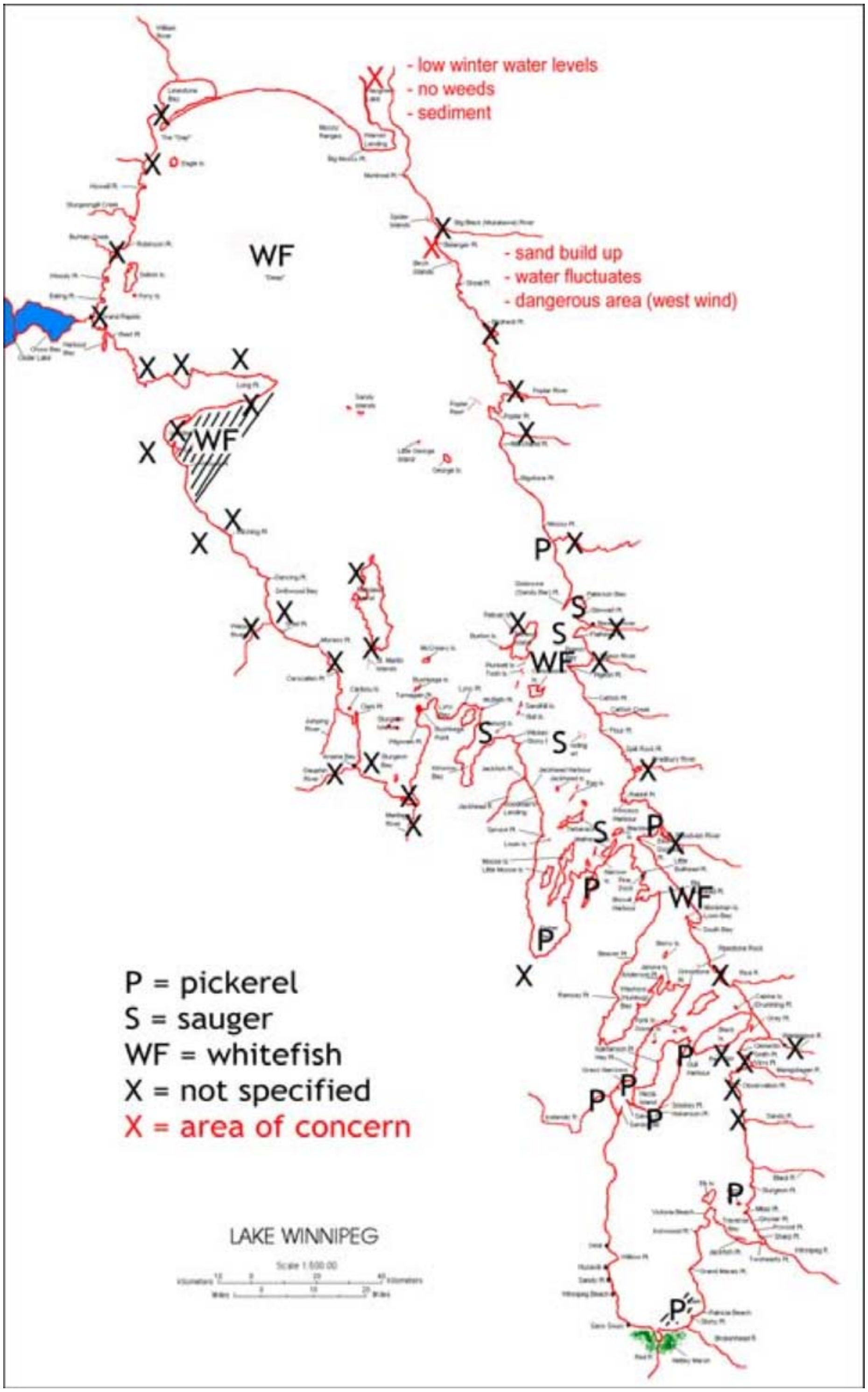


Figure App.V.1. Spawning ground locations of the three quota species in Lake Winnipeg. (Collated from fishers' responses to Question 12.)

Question 24. Changes in the quota.

There was a good response to Question 24, with only five abstentions (Table V.10). Some responses could be considered a conditional yes and were, therefore, tabulated in a separate column. Thirty-two fishers (45%) would like to see the lake quota changed, six fishers would like it changed under certain conditions, 28 fishers (39%) would not like the lake quota changed. At the end of the meeting at Matheson Island, there was agreement among those present to unanimously vote against changing the lake quota.

Table App.V.10. Summary of responses on whether the lake quota should be changed.

Meeting Location	No. of Fishers	Should lake quota be changed?			
		Yes	Conditional Yes	No	No Response
Selkirk	13	2	3	7	1
Riverton	6	2	1	3	
Gimli	12	9	1	1	1
Berens River	2	1	1		
Matheson Island	17			17	
Dauphin River	4	4			
Norway House	10	8			2
Grand Rapids	7	6			1
TOTAL	**71**	**32**	**6**	**28**	**5**

Some of the reasons and/or suggestions in support of a change in the Lake quota:

- should be increased as a B quota, not on individual quotas
- increase whitefish quota
- open up whitefish and take off the quota
- separate whitefish from pickerel and sauger
- there is plenty of fish, catch them while they are there
- increase for each fisher as a percentage applied to each quota
- for existing fishers only
- increase number of quotas
- stop non-active quota holders
- give more quotas to areas that need them (i.e. North Basin)
- increase year by year

Some of these conditions would need to be met if the Lake quota was to be changed:

- make sure fish can be sold
- temporary increase of 10% for all fishers if it is sustainable
- provided existing quotas are not devalued
- main quota is left alone
- if it is equitable and sustainable
- must keep track of stocks

Some of the reasons against a change in the Lake quota:
- not enough information
- lake cannot sustain more harvest
- wait to see if abundance continues
- danger of quota being lowered in the future
- might devalue current quotas

CONCLUSIONS

Administration (Future Considerations and Recommendations)

The Task Force recommends that a fishers' survey be continued on a regular basis to promote knowledge exchange and improve communication between fishers, scientists and managers. Although a positive first step, the survey carried out by the Task Force could be improved in a number of ways, described below.

1. Better timing of notices and more up-to-date contact information for fishers. The Task Force sent letters informing fishers about the upcoming survey on September 1st and again on October 23rd, 2009. The fisher representatives of the Task Force also posted local notices within the communities. Despite the two months notification, fishers remarked that they were not notified early enough about the survey and some fishers did not receive letters at all. The former issue is perhaps more related to the timing of the notification, during the fishing season, as opposed to the actual length of time between notification and the survey proper. Timing of notices should be taken into consideration for future surveys. To resolve the latter issue, MFB will need to maintain current contact information on fishers and, fishers in turn, will need to notify MFB of address changes.

2. Improving survey participation. Less than 10% of licenced fishers participated in the survey, and among those who did, participation effort varied widely from minimal to engaged. Some possible reasons for the lack of engagement include: lack of interest, language barriers, literacy barriers, poorly worded questions, length of survey, written format of survey, and mistrust. Although there are advantages to a written format, an oral approach (single or group interviews) could be a more effective way to exchange knowledge and enhance communication to the benefit of everyone, and would overcome many of the aforementioned reasons for lack of engagement. As an example of more effective knowledge exchange and communication, many fishers now encounter large algal blooms, which cause many problems including an increased workload, skin and eye irritation, and drinking water issues. However, fishers seemed largely unaware of the toxins that some algae produce and the serious health concerns that are associated with them. Conducting an oral survey, rather than written responses, would allow a more effective exchange of this type of information.

Research and Monitoring (Key Issues that Arose from the Survey)

The survey was not intended to generate specific research questions of interest to the fishing community. However, some of the observations and comments that arose during the community meetings could be used as a starting point for further discussion within the co-management board framework, and for possible collaborative research and monitoring projects between the scientific community and fishers. Some examples are included below.

Two water quality issues that are of concern to some North Basin fishers are large algal blooms and increased turbidity due to erosion caused by high water. In addition, a number of spawning habitats in the North Basin have become degraded due to the build-up of sand, which either blocks fish passage or covers spawning habitat. The sites identified include: Belanger Point, Spider's Creek, and Simpson Lake. Playgreen Lake was also identified as an area where whitefish no longer spawn due to serious habitat degradation. These observations deserve more attention. The observations regarding changes in rainbow smelt could also warrant further scientific investigation in collaboration with fishers.

Management

The Task Force was not mandated to address management-related issues but felt it important to summarize some management-related comments by fishers for consideration by the co-management board.

There were perceived discrepancies over mesh-size regulations, season opening dates, quota allocation and the decision-making process, which appeared to derive from different management strategies for the North and South basins. Possible communication issues were also of concern. Related to these issues were comments and concerns regarding the prevalence of whitefish bushing and the fishing of spawning fish.

Appendix App.V.1. Letter to fishers providing an update on Task Force activities and notifying them of the fishers' survey.

Lake Winnipeg Quota Review Task Force
September 1, 2009

Dear Fisher

I am writing to you to provide an update on our review of the health of Lake Winnipeg fish stocks. On November 20, 2008, Mr. Don Norquay, the Deputy Minister of Manitoba Water Stewardship, wrote to you about the establishment of the Lake Winnipeg Quota Review Task Force. The focus of the Task Force, which consists of three Lake Winnipeg fishers, three scientific experts and a chair, is on the biological productivity and assessment of the fish stocks **not on how access to those stocks is allocated to fishers**. This work was conceived by the Minister as the initial phase of a more comprehensive review of the Lake Winnipeg fishery quota management system to be undertaken upon the establishment of a new Lake Winnipeg Fishery Resource Management Board.

On March 2, 2009 representatives of the Community Licencing Areas (CLAs) formally asked the Minister to temporarily suspend the work of this Task Force as the Lake Winnipeg fishers' committees had not been established nor had the proposed new co-management board. Further, one of our fisher members had resigned. Task Force members agreed that we needed to have the full support of the fishers to complete our task so we suspended our formal work on the review on an interim basis. We now have a new fisher member, Langford Saunders of Norway House to join the other fishers, Ken Campbell and Norm Traverse, the three scientist members, Karen Scott, Darren Gillis and Ross Tallman and the Chair Burton Ayles and we have restarted our review.

Our Task Force has been examining published scientific and technical information and data on the pickerel (walleye), sauger and whitefish stocks of Lake Winnipeg. In addition, we recognize that in order to obtain a more complete understanding of the stocks we must include fishers' knowledge in our assessment. To this end, we will be carrying out a survey of fishers' knowledge of the status of the fish stocks. Our initial plan is for Task Force representatives, one fisher and one scientist, to visit each community in early November to participate in a public meeting of fishers. At the meeting fishers will be asked to fill out a questionnaire. Task Force representatives will explain how the information will be used and will serve as facilitators for the meeting.

We will be contacting you further about the survey in the near future.

On a personal note, the fishers and scientists on the Task Force have asked me to express to you their complete support for this unique endeavour to bring together fishers and scientists on an equal basis to work on this important issue. While our work was delayed over the summer, they sincerely hope that this delay will not further impede this cooperative venture.

Sincerely

G. Burton Ayles
Chair, Lake Winnipeg Quota Review Task Force

Appendix App.V.2. Letter to fishers regarding community visits related to the fishers' survey.

Lake Winnipeg Quota Review Task Force
October 23, 2009

Dear Fisher

I am writing to you to provide an update on the Lake Winnipeg Quota Review Task Force (LWTF) and our review of the health of Lake Winnipeg fish stocks. On September 1, 2009 we wrote to all fishers summarizing our progress and informing you that we would be contacting you further about a planned survey of fishers' knowledge of the status of the fish stocks. As the fall fishing season is coming to a close we are now ready to carry out that survey early in November.

The surveys will be presented, discussed and completed by fishers in a series of meetings in communities around the Lake. The community meetings are being organized by the fisher members of the Task Force and our plan for each meeting is to have one fisher member and one scientist member at each meeting. At the meetings, the role of the LWTF will be described, the rationale for the survey explained and any questions answered. Fishers will then be asked to fill out a questionnaire about the health of the fish stocks in Lake Winnipeg.

<u>The schedule for the meetings is as follows:</u>

North and north east Communities Organizer: Langford Saunders

- Norway House Nov 3rd 1:00 pm Co-op office
- Poplar River Nov 4th 10:00 am place tbd
- Berens River Nov 4th 1:00 pm United Church Hall
- Grand Rapids Nov 5th 1:00 pm Band Hall

North west Communities Organizer: Norm Traverse

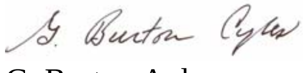
- Dauphin River Time and place to be determined
- Fisher River Time and place to be determined

South Channel/Basin Communities Organizer: Ken Campbell

- Gimli Nov 2nd 1:00 pm Lakeview Resort
- Riverton Nov 3rd 1:00 pm Riverton Curling Club
- Matheson Island Nov 4th 1:00 pm Community Hall
- Selkirk Nov 5th 1:00 pm Smitty's Restaurant

If you have any questions about the survey we will be prepared to address them at the meetings.

Sincerely



G. Burton Ayles

Chair Lake Winnipeg Quota Review Task Force

Appendix App.V.3. Fishers survey developed by the Lake Winnipeg Quota Review Task Force.

Lake Winnipeg Fishery Survey

This survey was developed by the Lake Winnipeg Quota Review Task Force as part of their assessment of the biological sustainability of the fishery. It is intended for all licensed commercial fishers on Lake Winnipeg in recognition of their knowledge of this ecosystem and fishery. All answers are confidential and the summarized results of this survey will be included in the final report prepared by the Task Force.

1) Where do you live?

2) Where do you fish? North Basin _____ Channel _____ South Basin _____

3) How many years have you fished on Lake Winnipeg?

4) What species do you target?

a) How has **pickerel** fishing changed in the last 10 years?

b) How has **sauger** fishing changed in the last 10 years?

c) How has **whitefish** fishing changed in the last 10 years?

7) Has the time it takes to fill your quota(s) changed in the last 10 years? Explain.

8) In the last 10 years, have you changed the way in which you fish? YES or NO

9) If you answered YES to the question above, please describe what you have changed and why. (For example - net location, distanced traveled, distance from shoreline, depth, mesh size, gear.)

10) In the last 10 years, have you noticed a change in the distribution of quota species? Describe.

11) What **other species** do you most commonly find in your nets? (From most to least common)

12) Have you seen any changes in the **other species** of fish being caught? YES or NO

13) If you answered YES to the previous question

a) Which **other species** are now being caught more often? (List)

b) Which **other species** are now being caught less often? (List)

c) Do you have thoughts on the reasons for these changes?

14) What observations have you made about **rainbow smelt** in Lake Winnipeg?

15) In the last 10 years, have you observed any changes in the quality of your catch? (For example - size, skin health, fat content, taste, colour, deformities, etc.)

16) Have you observed changes in the **water quality** of Lake Winnipeg? YES or NO

17) If you answered YES to the previous question

a) Describe the changes you have observed

b) When did these changes begin to appear?

c) How have these changes impacted you as a commercial fisher?

18) In the last 10 years, have you observed changes in

a) the date of ice off YES or NO

b) the date of freeze up YES or NO

c) the thickness of the ice YES or NO

d) the snow cover YES or NO

19) If you answered YES to any of the questions in 18) above, please describe your observations.

20) If you fish in the winter, have you encountered under ice algae on your nets? YES or NO

a) If you answered YES to the above question - in the years with high under ice algae, is the pickerel catch positively or negatively affected, or not at all?

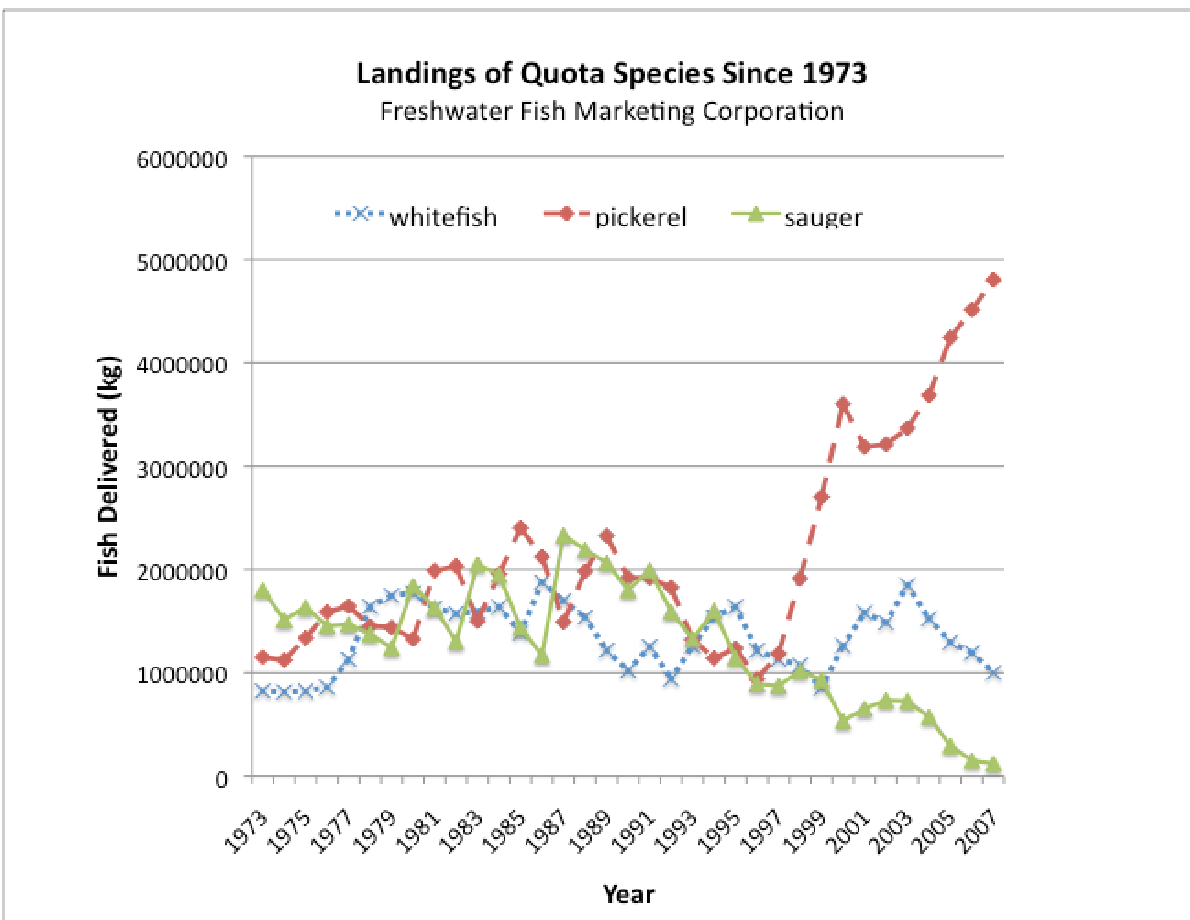
21) The graph on the next page shows **FFMC landings** of the three quota species since 1973.

a) **Pickerel -** What factors do you attribute the increase since the late 1990s to?

b) **Pickerel -** What factors do you attribute the low in the mid-1990s to?

c) **Sauger** - What factors do you attribute the steady decrease since the late 1980s to?

d) **Whitefish** – What factors do you attribute the comparatively stable landings to?



22) If you are aware of the locations of spawning grounds (pickerel, sauger and/or whitefish), please indicate their locations on the attached map(s).

23) Have you observed any changes associated with the spawning grounds of your target fish species? Explain.

24) Based on your experience fishing, should the lake quota be changed? YES or NO
How and why?


ROSS ISLAND
Little Playgreen Lake
Norway House
Gunisao
Wabisi Lake
Nelson
Limestone Bay
Playgreen Lake
Mercer Lake
Cotter Lake
Lebrix Lake
Warren Landing
Mossy Point
EAGLE ISLAND
53° 30'
Belanger
MANITOBA
LAKE AGASSIZ
Grand Rapids
Lake Winnipeg
Mukutawa
Long Point
Poplar
53°
-18 m
Weaver Lake
Wrong Lake
Leaf
52° 30'
REINDEER ISLAND
Berens River
BERENS ISLAND
Lake Winnipeg
COMMISSIONER ISLAND
McBeth Point
Sturgeon Bay
Anama Bay
52°
St. Martin Meteorite Crater
Gypsumville
Matheson Island
Bloodvein
Little Bullhead
Fairford
Lake Manitoba
MANITOBA
Fisher Bay
51° 30'
Steep Rock
Grahamdale
Mantagao Lake
Dallas
GRINDSTONE
Guynemer
Spearhill
Moosehorn
LAKE AGASSIZ
Hodgson
Wanipigow
Ashern
Eddystone
Shergrove
Manigotagan
HECLA ISLAND
51°
Mulvihill
Riverton
Eriksdale
Arborg
Alonsa
Chatfield
ELK ISLAND
Victoria Beach
Harcus
98° 30'
98°
97° 30'
97°
96° 30'
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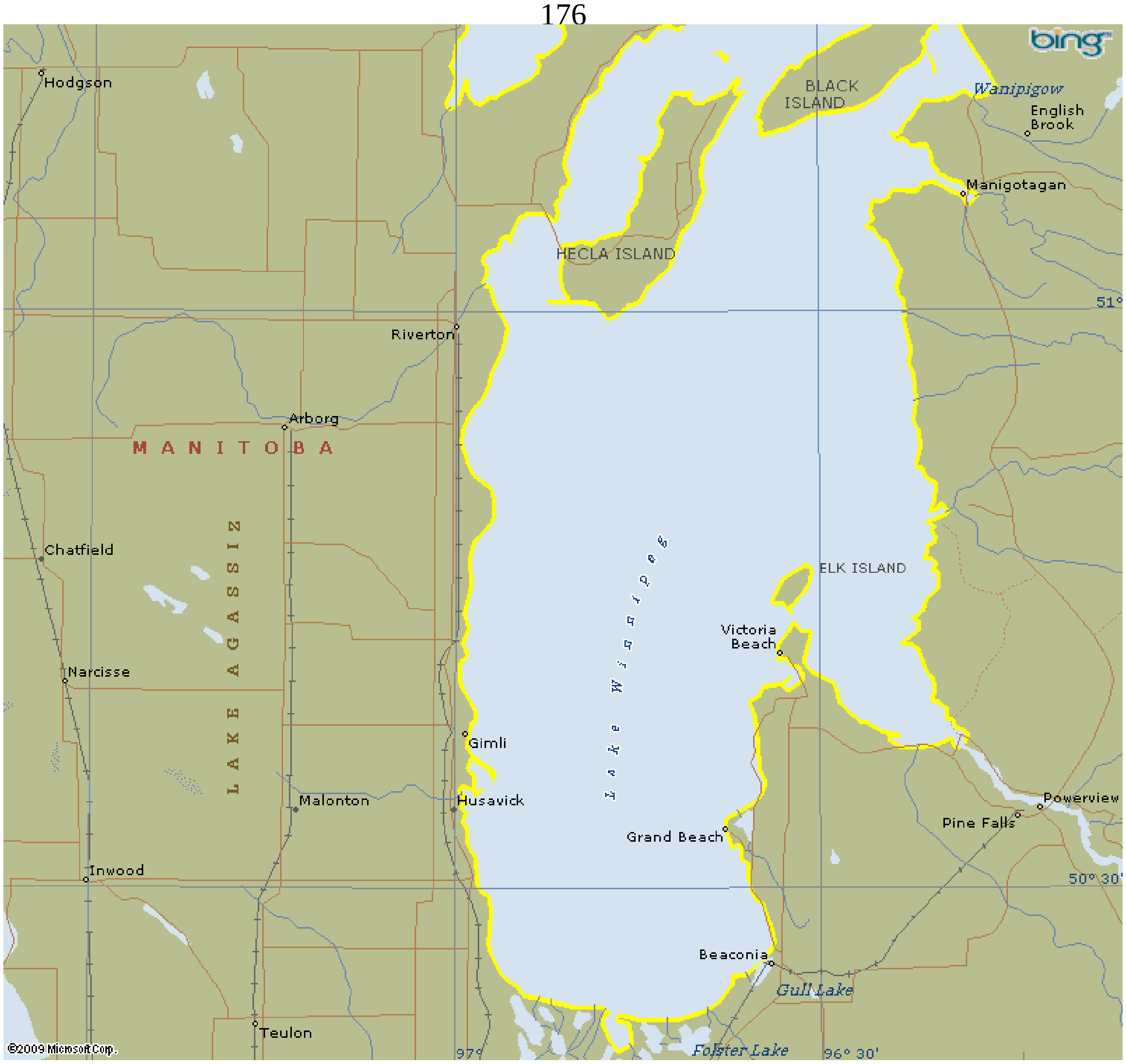
Hodgson
HECLA ISLAND
BLACK ISLAND
Wanipigow
English Brook
Manigotagan
51°
Riverton
Arborg
MANITOBA
LAKE AGASSIZ
Chatfield
ELK ISLAND
Victoria Beach
Narcisse
Lake Winnipeg
Gimli
Malonton
Husavick
Powerview
Pine Falls
Grand Beach
Inwood
50° 30'
Beaconia
Gull Lake
Teulon
97°
Folster Lake
96° 30'
©2009 Microsoft Corp.

Appendix VI. Comments from Peer Reviewers

The critical review of reports by independent scientists prior to publication is a key component of accepted scientific processes. We asked four experienced scientists and managers to review the draft report of the Task Force. Normally the assessments of external reviewers would not be published as part of a report such as this but we feel that they have provided a very valuable perspective that has helped us with this report but will also help the future Management Board and the technical groups that will provide support. The reviewers were:

- Peter Colby is a retired research scientist with OMNR. He has published widely on walleye productivity in the Great Lakes and in smaller northern lakes with particular emphasis on model development. He currently serves on a technical advisory group for the Lake Nipigon fishery and has advised management agencies on the acceptability, for the Marine Stewardship Council, of their fisheries management processes.
- Mark Ebener is an assessment biologist, with the Inter-Tribal Fisheries and Assessment Program of the Chippewa Ottawa Resources Authority – the agency responsible for exercising treaty-reserved fishing rights on Lake Superior, Huron, and Michigan. He conducts research and assessment projects and is an active participant in the technical committees that coordinate research and management in the Great Lakes. He is currently chair of the Lake Superior committee.
- Mike Hansen is a Professor of Fisheries at the University of Wisconsin Stevens Point. He previously held positions as an Associate Scientist with EA Engineering, Science & Technology, as Great Lakes Sport Fishery Specialist with Wisconsin DNR, and Chief of Resource Assessment and Fish Community Dynamics with the U.S. Great Lakes Science Center. He is a U.S. commissioner of the Great Lakes Fishery Commission and recently competed a term as chair of the Commission.
- Robert Young is the manager of Fisheries and Ocean Canada's arctic research program headquartered in Winnipeg. During his career his research has focused on the environmental impact of the Normal Wells pipeline on aquatic communities, factors affecting fish/invertebrate productivity and the population dynamics of sea lamprey and most recently, approaches to integrating heterogeneous and environmental data into stock-assessment models. His current research management responsibilities include stock assessment of subsistence and commercial fish and marine mammal stocks as well as the ecosystem impacts of development and climate change in the Canadian Arctic.

We asked the reviewers to provide us with a broad review but we also asked them to focus on some particular issues. We were especially interested in their assessments of the following:

- Our discussions on methods for fisheries stock assessment and monitoring and their relevance for Lake Winnipeg;
- Our analysis of the three-species quota for whitefish, sauger and walleye, the proposal for partitioning the quota into species-specific RAHs, and possible ways to manage a common percid quota;

- The proposed “traffic-light” decision management tool for the Lake Winnipeg walleye, sauger and whitefish fisheries and the establishment of RAHs, our assessment of potential reference indicators for Lake Winnipeg fisheries and the proposed adaptive co-management planning cycle to make the process more transparent and to draw fishers, scientists and industry together into decision making.

The reviewers had many positive things to say about our report and they had a number of recommendations for change. We have made a number of additions and changes based on their assessments. They also made some suggestions for further analyses and suggestions for management actions that go beyond the mandate of this Task Force. We did not necessarily agree with all of their recommendations but we do think that their perspective would be of value for readers of this Task Force Report. In the following sections we summarize some of the main points raised by the reviewers. We quote directly from their reviews but without attribution. The full assessment of each of the scientists, and Task Force comments on key points, will be maintained for Lake Winnipeg Management Board.

General Comments

The reviewers made a number of general comments about the entire report. They ranged from statements about the completeness of the report and our assessment of the fishery:

> “The report is comprehensive and thorough and covers all the issues required to obtain a sustainable fishery. The walleye harvest in Lake Winnipeg is an anomaly and the fishery is unique. The recent annual walleye harvests (4.5 million Kg.) are twice what I would expect for the lakes in that region.”

to the adequacy of our analyses:

> “To be candid, I found much of the document to be lacking in detail that is important for evaluating status of the populations and reviewing your interpretation of the status of the stocks. I also thought the document contained too much hand-wringing about inadequacies of the data.”

to the conclusions:

> “I disagree with these conclusions… …For walleye, an alternative hypothesis is also plausible: the stock is unstable… …For sauger, an alternative hypothesis is that the population is declining without evidence of stock recovery… …For whitefish, an alternative hypothesis is that the population is relatively high…”

and recommendations:

> “I think the recommendations section is good and the authors certainly point to all the right issues.”

Comments on methods for fisheries stock assessment and monitoring

The reviewers made a number of useful suggestions and comments that were incorporated into the text of the report. They also suggested alternative analyses that should be considered in the future. They generally agreed that the data available were inadequate and one individual went so far as to suggest that the use of FFMC delivery data as a surrogate for effort was misguided and that our limited description of CPUE of the commercial fishery should be removed from the report. One of the reviewers recommended that in preparation for annual stock assessments certain metrics should be available. We have acknowledged this recommendation by including the list of metrics in Appendix IV.d. of the report. The following are some significant comments on our analyses:

- "In appendix IV you use Ryder's (1965) MEI to illustrate that empirical models such as his contain so much uncertainty that they cannot be used with confidence in setting management goals. It may be of interest to you that this model was criticized in the literature and we had to develop a more valid model to obtain first order estimates of potential fish yield. This model is a statistically valid analog to the MEI and includes more lakes. I am not sure how much precision this model would provide, but likely your conclusion would be the same: too much uncertainty for setting management goals."
- "A quota management system for the Lake Winnipeg walleye fishery could be based on target and limit reference points from the Baccante and Colby model, with prescriptions for management actions as in the precautionary approach (Figure III.V). In my opinion, the Colby model suggests that walleye yield from the 1940s through the 1990s (0.6 – 2.0 million kg) hovered near the sustainable level (1.6-million kg), whereas walleye yield during the 2000s (3.9 million kg) exceeded the sustainable level. The Colby model can be further used to define risk levels of any observed level of yield by comparing the yield in any year or years to the distribution of the prediction interval. Similarly, total yield from Lake Winnipeg (3.5 – 7.7 million kg) hovered near the yield predicted by MEI (6.7 million kg)."
- "I recommend that your committee base future recommended harvest levels on the results of stock assessment models rather than current harvest for the reasons stated in your report i.e. relatively few year classes currently in the fishery, potential for whitefish discards, etc. There are several modeling options that should be explored given the data sources at your disposal. Percid productivity should be explored with a surplus production model as a first step under a percid/whitefish allocation option. The description of effort in the commercial fishery may not be ideal and could exacerbate uncertainty."
- "The fisher survey results were very informative and should be useful to managers and anyone else interested in the fishery. The survey should be ongoing, if not annually at least periodically. Traditional knowledge was useful when we developed our sampling program for Lake Nipigon. Elders and fishers knowledge regarding location of spawning grounds, nursery areas, species location, behaviour, food habits, seasonal movements, and history of the lake has been very helpful in developing the program."
- "The discussion of fishery independent assessment systems would benefit from a bit more discussion of how such surveys must overcome the effect of zero catches on precision of relative abundance indices (CPUE); that is, fishing in areas where a species is not present leads to zero catches that increases variance of the CPUE index and therefore must be counter-balanced by increasing sample units (net sets). As written, the text led me to think that fishery independent surveys will necessarily lead to greater understanding of fish stock density, which fails to

acknowledge that increased accuracy comes at a cost of low precision (all else being equal)."

Comments on our analysis of the three-species quota for walleye, sauger and walleye, the proposal for partitioning the quota into species specific RAHs, and the possible ways to manage a common percid quota.

The reviewers strongly agreed that percids and whitefish should not be the subject of a common quota and that if a common percid quota was to be considered there should still be specific RAHs for each species. They did not all agree with our partitioning of the current TAC into three separate RAHs. In general they were more precautionary than the Task Force and recommended lower initial RAHs. The following are some significant comments on our approach:

- "The Marine Stewardship Council (MSC) would rule that management of the fishery against a single quota for the three species (6.4 million kg for sauger/walleye/whitefish) is fundamentally unsustainable. Neither would they buy into a combined percid quota. The council would require partitioning the multispecies quota into three separate species quotas."
- It is questionable whether MSC would accept a combined percid quota as a sustainable procedure. To be sustainable each or the three species has to be monitored separately using agreed upon reference indicators to determine their status. If these indicators show a given species at risk then a predetermined and previously agreed upon action has to be taken. Actions can vary from changes in fishing methods to quota reduction such as 10% or greater if necessary. If these conditions are met, then MSC or any management body would likely agree that LWTF recommendation 2 is sustainable and acceptable."
- "You have made a strong case for developing a separate quota for percids and whitefish in Lake Winnipeg. These two groups clearly occupy different habitats in the lake and can be differentially targeted by fish harvesters. Sauger and walleye likely occupy similar enough habitat that the differentiation in the harvest will have to be accomplished using other regulatory tools such as mesh size, season closing etc. as described in your report."
- I understand the fishers need for harvest flexibility in dealing with vagaries of the market (market prices, size preferences, seasonal demands) plus weather and fish availability. There is no reason why this flexibility cannot be reasonably maintained in a precautionary environment having separate species quotas."
- "The analysis is simple, and therefore elegant, but left me wondering why decadal mean yield was reduced to percentages. This step is particularly dangerous in light of the decision to use mean yield during the most recent decade (2000–2009) for walleye and sauger, during which walleye yield increased dramatically over the preceding six decades (doubling any preceding decade) and sauger yield was quite low. I expected to see that the recent increase in walleye yield would not be considered as a sustainable level of fishery yield, because the most recent decade was so unusual in relation to the preceding 60 years."
- "For sauger, an alternative hypothesis is that the population is declining without evidence of stock recovery. The conclusion of the report (tentative stock status) seems overly non-committal, for reasons that are not obvious to me. Fishery

independent CPUE, fishery dependent CPUE, and fisher opinions all suggest that the stock has been declining for 2–3 decades."

- "For whitefish, an alternative hypothesis is that the population is relatively high because the fishery rarely targets whitefish and trends in both survey and fishery CPUE have varied without trend for 2–3 decades."

Comments on the proposed "traffic-light" decision management tool for Lake Winnipeg walleye, sauger and whitefish fisheries and the establishment of RAHs; our assessment of potential reference indicators for Lake Winnipeg fisheries; and the proposed adaptive co-management planning cycle to make the process more transparent and to draw fishers and scientists and industry together into decision making..

The reviewers were supportive of our "traffic-light" approach as a decision management tool and of our adaptive co-management planning cycle. Some of the reviewers have already had positive experiences with such an approach in other systems. The following are some relevant comments:

- "Your precautionary approach to fisheries management along with the traffic light concept of using numerous reference indicators to define the status of the three fish species is excellent. The adaptive co-management planning cycle is very good. The time table for data collection, data analysis, assessment of indicators, and quota determination… ...should work well for you. The assessment team membership could be broader to give the greater transparency that you want. Membership could also include a representative from management, a tourist outfitter, a first nation fisher or elder, and a fish and game club representative."
- "The report does a good job outlining the case for using the stop light approach. The stop light approach needs to be coupled with a stock assessment model so that you can include quantitative reference points like Z, F, and SSB/recruit."
- "The list of biological indicators described in the document is good, but I would delete mean age in the catch and add in spawning stock biomass per recruit."
- "Not all of the indicators are of equal importance so a simple counting of red and green lights will be unsatisfying. I recommend that you conduct a formal decision analysis so that indicators are weighted appropriately and recommended changes reflect the weight of the indicators."

Other important comments

- "I think the recommendations section is good and the authors certainly point to all the right issues. My primary concern here is that there is no discussion on development of a harvest management strategy. Development of harvest limits is driven by the subjective management decision of what strategy to use to project the harvest limit."
- "The periodic flooding, nutrient loading and nutrient retention in the lake due to outflow control at the Jenpeg, along with the possible effect of global warming creates an environment for producing these large harvests of walleye as you know. You are right to point out that this acceleration of eutrophication must be reversed for both human health and the health of the fishery. The manner in which

these nutrients are removed will be important (N/P ratio) so as not to give the blue-green algae a competitive advantage."

- "Appendix IV, indicator 4, index netting CPUE was very informative in that it would require 400 sets to get results comparable to Ontario's using their FWIN program. This is a lot of effort for any assessment unit. Compare Lake Winnipeg which has the Province of Manitoba with federal assistance to collect data to Lake Erie which has 4 state, 2 national, 2 international agencies plus private sector involvement to share the workload."