

Evidence of impacts of human activities on the quality of Lake Winnipeg

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Lake Winnipeg is one of the largest lakes of the world with a surface area of some 23750 square km. It is larger than Lake Ontario and has an unusually large watershed that extends westward to the Rocky Mountains, eastward to Lake Superior and southward to South Dakota. In size, the watershed approaches 40 times the area of the lake itself. By comparison, the watershed of Lake Ontario is only 3 times the area of the lake, meaning that Lake Winnipeg potentially must assimilate more material transported into it than its Great Lake counterpart. If the comparison is made on a lake volume basis, the amount of material that must be processed by Lake Winnipeg per unit volume is even greater. The major rivers supplying the lake are the Winnipeg River from the east, the Saskatchewan River from the west and the Red River from the south. The outlet to the sea (Hudson Bay) is through the Nelson River to the north. The flows of three of these four rivers are regulated for the production of hydroelectricity. The Winnipeg River is the largest source of water but the Red/Assiniboine system is the largest in terms of suspended particles and plant nutrients. The Saskatchewan River supplied more suspended particles before the Grand Rapids Dam was built. These particles are important because they determine the penetration of light into the water.

The economic and esthetic values of the lake to Manitoba are huge. The obvious sources of economic wealth are the fish, the cottage and recreation industry, the hydroelectric power generated through use of the lake as a reservoir, and the ability of the lake to assimilate waste byproducts. There are also notable historic, cultural and subsistence values for First Nations communities situated on the lake and downstream on the Nelson River system. A number of these communities use the Nelson for drinking water.

In spite of its economic and cultural importance, Lake Winnipeg has had no sustained research program to develop an understanding of the impacts of human activities on it. The need for such programs was recognized long ago but little has happened partly as a result of jurisdictional confusion. For example, the summary of a Manitoba Government report on the South Basin in 1973 stated:

"Samples were collected on the southern portion of Lake Winnipeg.

The results showed that both nitrogen cycle and phosphate are high in the lake and above the critical level of 0.03 mg/l as PO₄.

Coliform organisms were often absent in the lake. The data collected is limited and do not permit a definite assessment of the water quality of the lake.

A comprehensive study should be commenced as soon as possible to prevent further degradation of Lake Winnipeg and to determine possible methods of lake restoration.” (Manitoba, 1974)

There have been several short-term studies which have offered some “snapshots” of the condition of the lake at the time of the study (e.g. Brunskill & Graham, 1979; Brunskill et al., 1980). Taken together, these studies indicate that significant changes have occurred and are continuing to occur. However, these short-term studies lack the rigor of a sustained effort and the conclusions remain open to scientific debate. When compared with historical data from the Laurentian Great Lakes, the changes in Lake Winnipeg are consistent with a lake suffering several kinds of stress.

1. Nutrient over-supply to the lake that results in nuisance algal blooms,
2. Changes in hydrological and light regimes in response to flow regulation,
3. Inputs of chemical contaminants (e.g. pesticides, mercury),
4. Invasions by exotic species

Nutrients and flow regulation

Algae need at least four things to produce blooms, namely light, food (nutrients nitrogen and phosphorus), warm water, and low water turbulence. Hence predicting algal blooms is a complicated exercise. We believe the production of algae in the South Basin is largely limited by poor light penetration (Healey and Hendzel, 1980). Particles contributed by the Red River and particles resuspended by wave action limit the penetration of light into the South Basin and consequently confine the growth of algae to a layer near the surface. A somewhat similar condition used to apply to the North Basin but construction of the Grand Rapids dam (completed in 1968) has decreased the supply of particles from the Saskatchewan River to the North Basin. These particles are poor in nutrients but they decreased the penetration by light. Consequently, since 1968 the water of the North Basin has become clearer and so light penetrates better. At the same time, the North Basin water and sediments have become richer in phosphorus (P). This can be explained by greater inputs of P to the lake and/or by greater retention and recycling of P within the lake. The Jenpeg dam (completed in 1976) on the Nelson River, controls water levels on Lake Winnipeg and probably has caused the lake to retain algae better. The net effect of changes to the import of mineral particles and export of algal cells particles is to produce algal blooms in the North Basin. The predominant supply of P to Lake Winnipeg is the Red River (about 58 %). With the Saskatchewan River accounting for only 10% of phosphorous inputs, it is likely that Red River sources of P are contributing to increasing North Basin phosphorous levels. With increased light and nutrient levels in the North Basin, algal blooms can be anticipated to become an even greater problem there.

As indicated, the major nutrients required by plants are nitrogen and phosphorus. If there is plenty of phosphorus but not enough nitrogen, then plants that can fix atmospheric nitrogen become favoured. A type of algae often called 'blue-green' algae can fix atmospheric nitrogen and we might expect to see these algae becoming more dominant in northern Lake Winnipeg. The limited data we have on algal populations suggest that that is in fact what has happened (See picture attached). We have higher algal populations now than we used to and they have become dominated by 'blue-green' types. Unfortunately these 'blue-green' algae also produce a number of toxins that affect animals. There are examples of animals being killed by algal toxins in Manitoba and the toxins themselves have been detected in surface waters scattered throughout southern Manitoba (Jones, 1999). We anticipate that these toxins will become water quality issues of growing concern for communities where lake water is consumed and for communities downstream on the Nelson River.

We know very little about the affect the increased amounts of algae will have on winter oxygen conditions in Lake Winnipeg. The long ice-covered period and the high summer plant biomass suggest that there should be significant plant matter to decay during the winter. This creates a demand for oxygen which can only be taken from the water. This is especially true when snow cover is heavy because it blocks light and under-ice algae cannot produce oxygen and release it to the water. Furthermore, any oxygen produced under ice does not mix well throughout the water column. Microorganisms responsible for decay can survive at lower oxygen concentrations than can fish and so winter oxygen depletion can threaten the survival of fish. Winterkills of fish are well known in nutrient rich lakes in central Canada and the north-central U.S. Many of the commercial fish species in Lake Winnipeg are not adapted to low oxygen conditions and are particularly vulnerable. Fish kills caused by low water oxygen also can occur in summer following the collapse of particularly extensive algal blooms when there is little wind to mix the upper waters in the lake.

While there remains much scientific detail to be debated and understood, the broad, consistent picture is that of a lake with a problem of excess nutrients and excess algal production, similar to conditions observed in the lower Laurentian Great Lakes during the 1970's prior to phosphorous regulation. Like Lake Erie then, Lake Winnipeg now can be classified as eutrophic on the basis of these excessive levels. However, because of the variability inherent in natural ecosystems and our shortage of data, we have not yet determined the ultimate capacity of the lake to accommodate excess nutrient inputs. To do so will require accurate input/output/recycling/storage budgets to be determined through future research. Nevertheless, indications to date are that the lake is already receiving excess plant nutrients and we urge the Panel to act in ways that will reduce these inputs, not sustain or increase them.

The implications of excess nutrients on other plants and animals are less well understood. Some of the implications probably can be predicted from experience with other lakes but the final word will come from Lake Winnipeg itself. For example, the state of the fishery has been used as one indicator of the

health of the lake. Following a 10-year decline, the walleye fishery is reported to prosperous although it is based on young fish. There are suggestions that the whitefish fishery may be less healthy but this is difficult to determine because of the way the quota system works in the commercial fishery. Biologically, we expect that increased primary production by algae will provide a larger food base for the entire biological community and so increased yields of fishes might be anticipated. Unfortunately, the increased production often ends up in species that we do not value highly (e.g. carp) rather than in species we do value highly (e.g. walleye, whitefish). We cannot predict the consequences of excess nutrients for the fishery of Lake Winnipeg. Sauger virtually disappeared from Lake Erie in the 1950s and walleye were reduced to very low levels about 1970. These events occurred during a period of growing nutrient problems in that lake that led to oxygen problems, but other events, notably fishing pressure and the arrival of rainbow smelt, may have been partially or fully to blame (Nepszy, 1977). Schneider and Leach (1977) argued that the decline in walleye in Lake Erie in the 1950s was related to a combination of three changes:

1. increasing exploitation in Canadian waters, causing a decrease in reproductive potential;
2. increased eutrophication, resulting in loss of habitat and a valuable food organism, *Hexagenia* sp. (mayflies);
3. the development of a very large population of rainbow smelt in the central basin.

The walleye in Lake Erie produced strong year classes in years following closure of the commercial fishery in 1970 due to high concentrations of mercury. This happened in spite of the status of nutrients in the lake and so nutrients alone were probably not the causes of the decline in walleye. Leach et al. (1977) and Colby et al. (1972) have tried to describe the responses of percids (walleye, sauger, perch) and coregonids (lake whitefish, lake herring) to eutrophication. The initial increase in productivity favours percids over salmonids, but continued eutrophication favours other species at the expense of percids. Lake Winnipeg was an extremely productive lake prior to recent nutrient increases. It probably was at a point where coregonid and percid productivity were at high levels without detrimental effects to either commercially important group. The multiple changes that occurred in the Laurentian Great Lakes – eutrophication, high exploitation, species introductions – are now occurring in Lake Winnipeg. We should anticipate extensive, difficult-to-predict changes in the fish community of Lake Winnipeg during the present period multiple stresses on the lake.

A mechanism to link eutrophication with fish productivity is through oxygen depletion and invertebrate communities used as food by the fish. Decreased oxygen levels force fish to move elsewhere and hence concentrate many individuals in smaller habitats. Invertebrate animals require oxygen themselves and large ones like the aquatic stages of mayflies also can be lost as a result of oxygen depletion. This mechanism deprives fish of feeding opportunities. We have very few data on the populations of invertebrate animals in Lake Winnipeg sediments but what little we have suggest unexpectedly low

densities of the larger invertebrates. Lake whitefish are primarily invertebrate feeders, and any decrease in the abundance of benthic invertebrates might be expected to result in decreased fish condition and growth, leading to lower economic returns to fishermen. Observations of stomach contents suggest that larger walleye are feeding on the recently arrived exotic species, rainbow smelt, more than on invertebrates and so the Lake Winnipeg walleye population may be taking advantage of a new food resource and be less vulnerable to changes in invertebrate populations. However, this may be a questionable advantage to human consumers of fish because high consumption of smelt sometimes has imparted an undesirable oily flavour and texture to walleye. Juvenile whitefish and cisco compete with smelt for small invertebrates and zooplankton and so are vulnerable to increased competition. Large whitefish do eat small smelt and other minnows and so may do well if they survive the juvenile stage. On the other hand, carp, for example, consume plant materials directly and can be expected to prosper.

Eutrophication may limit reproductive success of shoal-spawning fishes in lakes (Colby et al. 1972). Reproduction of reef-spawning salmonids and coregonids can be impaired by low oxygen and increased sedimentation that often accompanies increased eutrophication. The eggs of fish species that overwinter prior to hatching, such as lake whitefish or lake herring, may be affected the most by increased eutrophication.

Other chemical substances

In addition to nutrients, Lake Winnipeg is subject to inputs of a wide range of chemical substances (e.g. Stewart et al., 2000; Rawn et al., 2000). An unambiguous example of this was furnished by the Red River flood of 1997 which transported a small but measurable quantity of toxaphene from a source in North Dakota to Lake Winnipeg. This resulted in small but measurable increases in the levels of toxaphene in Lake Winnipeg fish. Another clear example is the observation of cesium-137 in sediments of Lake Winnipeg. Cs-137 (a byproduct of the testing of nuclear bombs in the atmosphere) is found in the layers of sediments that were laid down at the time of greatest testing (early 1960s). They also show evidence of a small subsequent input which represents losses from the Atomic Energy research laboratory at Pinawa. The fishery was closed in 1970 due to high mercury levels and sediment cores taken in 1994 have allowed the reconstruction of the history of mercury pollution of the lake (Lockhart et al., 2000). These cores reveal a number of changes in the lake over the 20th century. They suggest that fluxes of mercury to the sediments have declined somewhat since the 1970s but remain much above those typical of pre-1900. Since the fishery is not presently limited by mercury levels, one wonders why this has not occurred. Several possibilities come to mind. The first is the phenomenon of biomass dilution. Given the greater biomass of algae in the lake, the concentration of mercury per gram of biomass should be lower. Another is the marketing of younger fish. Mercury typically increases with increasing fish size and age so the fish being marketed now may be too young to

have accumulated high levels of mercury. A third is that small declines in the input of mercury may have been enough to produce declines in tissue mercury levels in the fish. A fourth is the change in feeding habits made possible by the spread of exotic species. However, feeding on rainbow smelt generally increases the contamination levels in predators. The data from the cores are surrogates for actual budgets of mercury and other substances. Rigorous data on which to calculate detailed budgets for mercury and a series of other contaminants are lacking.

In instances where fish consumption guidelines apply it is straightforward to determine whether fish concentrations exceed guideline levels established by Health Agencies. With the exception of mercury, there are no instances of chemical contaminants building up in the fish to levels that cause closures. The ecological effects on the fish and other biota are another matter. The biological implications of the mixture of chemical loadings to Lake Winnipeg are simply not known.

Exotic species

Recent invasions of the lake by two exotic species, rainbow smelt, and a plankton organism, *Eubosmina coregoni* have the potential to change greatly the food web structure of the lake. Stewart (2000) and Wright (2000) have outlined our current understanding of the invasion of Lake Winnipeg by rainbow smelt. Smelt were introduced to Lake Sakakawea on the Missouri River in North Dakota in 1971 and within a few years they spread throughout the Missouri/Mississippi system. This indicates the colonizing ability of the species. The source of the smelt to Lake Winnipeg is not clear; they may have come from intentional or accidental introductions to the Rainy and Winnipeg River watersheds or they may derive from introductions to the Red River or even to the South Basin. There was an anecdotal report of a smelt caught in the Red River in 1975. Smelt were first captured in the South Basin in 1990 and have spread throughout the lake and indeed down the Nelson River to its estuary at Hudson Bay. Wright (2000) has reviewed the state of our understanding of this and other introductions. Whatever the source, the spread in Lake Winnipeg is similar to a previous invasion by the white bass introduced into the newly created Lake Ashtabula in North Dakota in 1953. By 1963 white bass had reached downstream to Lake Winnipeg where they are now taken regularly in the fishery. Northern pike and walleye in Lake Winnipeg have switched to a diet largely of smelt but it has not been established whether this has had an impact on the quality of pike and walleye as human food. Smelt are not only the prey of larger species, but they also are predators of small fish and fish eggs. In this way smelt can reduce the abundance of native species. The effect of this is to introduce a new step in the food chain supporting top predators with the result that top predators become somewhat more contaminated with chemicals like mercury.

Although the exotic micro-crustacean *Eubosmina coregoni* will likely have less impact on fish community structure in Lake Winnipeg than rainbow smelt, it is probably more symptomatic of environmental deterioration in the North Basin.

This small cladoceran was detected in Lake Winnipeg in August 1999 and represents the first recorded change to zooplankton community structure of the lake since 1928. With the exception of a few individuals identified in the Winnipeg River inflow area, the likely entry-point, it was confined to the North Basin in close association with the extremely dense blue-green algal bloom found in that region. The fact that it has not been found in the South Basin or Narrows region supports the findings that the environments of the northern and southern parts of the lake are characteristically different. Prior to the appearance of *Eubosmina* in Lake Winnipeg, this species was only found in the Laurentian Great Lakes (Patalas et al. 1994) with a particular preference for the eutrophic western basin of Lake Erie.

Some additional exotic species that can be anticipated to reach Lake Winnipeg in the future are the zebra mussel, the Eurasian water milfoil and possibly even a European perch, the zander.

On the other side of the species argument, Lake Winnipeg may contain a remnant population of the shortjaw cisco. The short-jaw cisco at one time was an important part of the "tulibee" fishery of Lake Winnipeg (Scott & Crossman, 1973). Its current status is unknown but it is considered a threatened species.

Conclusions:

Lake Winnipeg shows signs of excessive inputs of chemical substances, especially plant nutrients, and also exotic species. Experience from other locations suggests that these changes will prove to be detrimental to the fishery and to the esthetics. Our purpose in making this presentation is not to comment on the management of agriculture in Manitoba but merely to point out that the downstream recipient of most of our waste byproducts is Lake Winnipeg. This lake already is receiving too much waste of too many kinds.

Recommendation:

We encourage this Panel to make recommendations that will lead to decreasing inputs, especially of phosphorus, to Lake Winnipeg, not to maintaining or increasing them. If increased loadings are to be made by one segment of society, then they need to be offset by even greater decreases in loadings made by other segments.

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