COMMENT

LAKE WINNIPEG, THEN AND NOW: ANOTHER PERSPECTIVE

by

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ABSTRACT

The 2006 Lake Winnipeg Stewardship Board Report is used, together with a paper and reports by Dr. G. J. Brunskill and his colleagues, to assess change in the nutrient status of Lake Winnipeg since the late 1960's and early 1970's.

Nutrient loading to Lake Winnipeg is very high; hydrologically driven, it is also quite variable, year-to year. Supply of nitrogen (N) and phosphorus (P) to the lake does not appear to have changed over the past 3 or 4 decades as a consequence of large increases in utilization and disposal of N and P that occurred on the terrestrial watershed.

Nutrient supply is excessive, relative to the growth requirements of Lake Winnipeg algae. Low light penetration, as a function of high turbidity, can be an important limiter of phytoplankton productivity.

The current strategy for improving Lake Winnipeg, which focuses on effecting small (10%) reductions in external N & P loading, may be disappointing. Anticipated corresponding improvements in the nutrient chemistry of the lake will not likely be discernible. Nor, is it likely that improvements in algal species composition and/or a reduction in algal productivity will be realized.

Development of sound and optimal management strategies for the protection of Lake Winnipeg will require that future research be broad-based. A number of potentially important topics for investigation are identified.

COMMENT

Lake Winnipeg water quality is perceived to have deteriorated significantly over the last three to four decades, as evidenced by increases in frequency, duration, and intensity of algal blooms;[1] noxious blue-green algae, in particular. Having concluded that changes in algal populations have been a consequence of increased nutrient loading to the lake, Manitoba Water Stewardship developed a Lake Winnipeg Action Plan in February, 2003 that focuses on a nutrient management strategy aimed at reducing external inputs of nitrogen (N) and phosphorus (P) by thirteen (13) and ten (10) percent (%), respectively, in order to attain pre-1970 nutrient levels in the lake. The Action Plan included establishment of the Lake Winnipeg Stewardship Board, the primary mandate of which was to identify actions necessary to reduce inputs of N and P to the lake. The December, 2006 Lake Winnipeg Stewardship Board Report[1] contains numerous recommendations for action, ranging from public education – to restricting cosmetic use of P-based fertilizers – to reduction of nutrients in municipal, industrial, and agricultural effluents – to long term monitoring of and research on Lake Winnipeg and its watershed. The Government of Manitoba has, apparently, accepted the recommendations in this report; a number of the actions recommended to reduce nutrient loads to Lake Winnipeg, some very expensive, are already in progress.

Almost four decades ago, Dr. G. J. Brunskill and his colleagues carried out a limnological investigation of Lake Winnipeg which produced a very comprehensive description and characterization of the lake and its contributing watershed. Their field studies commenced in the fall of 1968, concluded in spring 1971, and included nine multi-station surveys of Lake Winnipeg starting in October, 1968 and ending in March, 1970.

In 1973, Dr. Brunskill published his first paper on Lake Winnipeg which was a preliminary presentation of nutrient supply rates to the lake.[2] The masses of total N (TN) and total P (TP) supplied annually to Lake Winnipeg by its major tributaries were reported to be 61,920 and 5,215

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[1] Reducing Nutrient Loading to Lake Winnipeg and Its Watershed. Lake Winnipeg Stewardship Board. Report to the Minister of Water Stewardship. December, 2006. 78pp.

[2] Brunskill, G.J. 1973. Rates of Supply of Nitrogen and Phosphorus to Lake Winnipeg, Manitoba, Canada. Verh. Internat. Verein. Limnol. 18(3): 1755-1759.

tonnes, respectively. Although flows were less than 1/5 of the Winnipeg River, the Red River's contribution to total annual nutrient load to Lake Winnipeg was 33% for TN and 59% for TP. The City of Winnipeg was reported to supply, annually, 5,320 tonnes TN and 1,010 tonnes TP (9% and 19% of the total annual inputs of TN and TP by the major tributaries). Nutrient supply rates, expressed per unit lake surface area, relative to mean depth, indicated mesotrophy (moderate nutrient enrichment) on a whole lake basis; but, when considered separately, a very high degree of eutrophy was indicated for the relatively small and shallow south basin.

From the work of his co-investigators, Brunskill (1973)[2] also offered some other important preliminary observations on the state of Lake Winnipeg. On the open-water lake surveys, blue-green algal blooms had been observed frequently in both the south and north basins. But, algal growth rates (phytoplankton primary productivity) did not appear to be nutrient-limited, particularly in the very turbid south basin, which was thought more likely to be limited by low light penetration into the water column.

In 1976, P. Campbell and E. Sorba produced multi-year hydrological and chemical baselines for Lakes Winnipeg and Manitoba. These baselines served as the starting points from which they predicted the impact the North Dakota Garrison Diversion Project might have had on the water quality of the two lakes.[3] Annual water and nutrient budgets for the south basin and for the narrows/north basin of Lake Winnipeg were compiled for six years, 1969-1974. Contributions from minor drainages and atmospheric deposition directly on the lake surface were included in addition to those from major tributaries. The years 1969-1974 were relatively wet; over the last century, half of the total annual inflows to Lake Winnipeg would have been less than for 1973, the driest year considered by Campbell and Sorba.

External loads of TN and TP entering the south basin of Lake Winnipeg ranged from 25,400 to 69,600 tonnes and from 2,300 to 9,460 tonnes per year, respectively; year-to-year differences were as much as three times (3X) for TN and four times (4X) for TP. On average, 45% of TN and 40% of TP supplied by external sources were retained by the south basin.

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[3] Chapter VI and Attachment 18. *in* Water Quality Committee Report to the International Garrison Diversion Study Board. International Joint Commission. October, 1976. 459 pp.

Although not as large for the south basin, inter-annual variations in rates of supply of TN and TP to the narrows/north basin were up to 2X (48,900 to 83,000 tonnes per year for TN and 3,190 to 6,480 tonnes per year for TP).

Inter-annual differences in gross nutrient loading rates appeared to be mainly hydrologically driven, i.e. simply a function of year-to-year differences in water supply rates. Total annual discharge of water to the south basin, predominately the Winnipeg River (flows = 4-9X those of the Red River), varied by 2X from the driest year (1973) to the wettest year (1974). The annual contribution of water by the smaller, but nutrient-rich, Red River varied by over 4X during the 1969-1974 baseline period. Although relatively dilute, inflows originating from the Precambrian Shield, including the Winnipeg River were estimated by Campbell and Sorba, in drier years, to contribute up to 60-75% of the TN and TP supplied to the south basin of Lake Winnipeg from all external sources.

Brunskill, Elliott and Campbell (1980)[4] presented rates of transport of TN and TP from the eight major tributaries to Lake Winnipeg for each of the years 1969-1974. They also gave the ranges of TN and TP supplied annually to the whole lake *via* rivers, but excluding deposition directly on the lake surface. Annual input of TN to the whole lake, from major rivers only, ranged from 47,020 to 108,260 tonnes per year; inputs of TP ranged from 2,980 to 10,570 tonnes per year. From 1969-1974, inter-annual differences in external nutrient supply rates to the whole lake were over 2X for TN and 3-4X for TP. The Red River supplied 13-42% of the TN and 30-72% of TP. These authors also reported annual nutrient supply to the lake varied in proportion to annual river discharge. And, they noted that, when expressed as yield per unit drainage area, nutrient export rates from Precambrian Shield watersheds are similar to prairie river watersheds.

The Lake Winnipeg Stewardship Board Report presents the average annual nutrient loading to Lake Winnipeg for the period 1994-2001.[1] One of these years, 1997, was hydrologically, exceptional (the flood of the century). Discharge into Lake Winnipeg in 1997 was extremely high and, concomitantly, produced unusually large inputs of nutrients to the lake that year. For the

[4] Brunskill, G.J., S.E.M. Elliott, and P. Campbell. 1980. Morphometry, Hydrology, and Watershed Data Pertinent to the Limnology of Lake Winnipeg. Can. Manuscr. Rep. Fish. Aquat. Sci. No. 1556. 32pp.

years 1994-2001, the total annual external input of nitrogen to Lake Winnipeg was reported to be 96,000 tonnes (77,200 tonnes when atmospheric deposition and internal fixation of atmospheric nitrogen by blue-green algae are excluded). And, the annual load of phosphorus to the lake for the same period was reported to be 7,900 tonnes (7,400 tonnes, excluding atmospheric deposition). Annual loads of nitrogen and phosphorus to Lake Winnipeg for the years 1994-2001[1] are well within the ranges reported for the years 1969-1974.[4]

I suspect that the small increases in loading rates of nutrients to Lake Winnipeg purported to have occurred over the past three decades, +13% for N and +10% for P, are not real and/or significant. I am doubtful for two reasons. First, because 1994-2001 average loads of N and P to Lake Winnipeg,[1] despite an exceptional loading year, fall well within the ranges reported for the period 1969-1974.[3,4] Secondly, because it would be very difficult, if not impossible, to detect, with the precision implied, such small (10-13%) changes in a hydrologically driven system that exhibits huge (hundreds of percent) inter-annual variability in nutrient supply (recall that, from 1969-1974, on a whole-lake basis, year-to-year differences in loading were up to 2X for TN and up to 3-4X for TP)[4]. Although it is my opinion that there has not likely been any measurable, anthropogenically-induced change in nutrient supply rates to Lake Winnipeg over the past thirty or so years, it is also very surprising to me. Brunskill, Elliott, and Campbell (1980) predicted that, from 1970 to 2000, nutrient supply to Lake Winnipeg would at least double (their most conservative "best case" scenario).[4]

The prediction that rates of supply of nutrients to Lake Winnipeg would at least double between 1970 and 2000 was based primarily on projected increases in population of humans and livestock, and projected increases in agricultural application of artificial fertilizer. Fertilizer was cited as the most rapidly growing nutrient source in the Lake Winnipeg watershed. Fertilizer N and P were forecasted to increase in the most conservative, "best case" scenario by roughly an order of magnitude between 1970 and 2000.[4] The Lake Winnipeg Stewardship Board reported 2006 population numbers for humans and livestock[1] which are very close to those predicted by Brunskill, Elliott, and Campbell for the year 2000.[4] Since 1970, the number of humans in the watershed has increased by over 30%; livestock populations have nearly doubled.[1,4] The Board also cited changes in synthetic fertilizer application rates in Manitoba between 1965 and 2005;[1] the

application rate of nitrogen increased by 10.6X, and the application rate of phosphorus increased by 4.2X. Changes in fertilizer application rates observed in Manitoba between 1965 and 2005 are, on an areal basis, about the same magnitude as those used by Brunskill, Elliott, and Campbell in their 1970 to 2000 "best case" scenario for all agricultural lands in the watershed.[4]

The preceeding gives rise to an important question, likely different from those asked up to now. Why have the substantial changes in anthropogenically-driven utilization and delivery of nutrients that have taken place on its terrestrial watershed over the last 3 or 4 decades not translated into corresponding, large and discernable increases in rates of supply of N and P to Lake Winnipeg? Perhaps the answer to this question is that nutrient consumption, utilization, and disposal practices since 1970 have, overall, been at least adequate to have prevented realization of the anticipated response, "at least a doubling" in supply of N and P to Lake Winnipeg *via* its tributaries.[4] As examples, I offer two cursory observations that perhaps lend some credence to this hypothesis: 1. The Lake Winnipeg Stewardship Board Report presented data showing that, from 1965 to 2005, the bulk of fertilizer-P added to agricultural lands in Manitoba was either retained in the harvested crops or cultivated back into the soil,[1] and 2. Since 1970, loads of N and P attributable to the City of Winnipeg may have declined significantly – by 30% and 60%, respectively. Recall that Brunskill (1973)[2] reported annual N and P inputs from City of Winnipeg effluents were 5,320 tonnes of nitrogen and 1,010 tonnes of phosphorus. According to the Lake Winnipeg Stewardship Board report, today's yearly contributions by the City are 3,700 tonnes N and 400 tonnes P.[1]

It is interesting and instructive to compare Lake Winnipeg and its tributaries with other systems. It is perhaps surprising, but large rivers such as the Red, Fisher, and Saskatchewan which drain agricultural areas were found to have nutrient transport rates per unit land area similar to native prairie and small Precambrian Shield watersheds in boreal forest.[4] Nevertheless, supply rates of N and P to Lake Winnipeg are very high, mainly as a function of a very large drainage basin feeding, particularly in the case of the south basin, a relatively small lake. That the nutrient supply rate to Lake Winnipeg is extremely high is nicely illustrated by comparing the south basin with Lake Erie. In the early 1970's supply of P, expressed per unit lake surface area relative to mean depth, was 3X higher for the south basin of Lake Winnipeg than for Lake Erie.[4]

Brunskill et al. (1979)[5] reiterated "that Lake Winnipeg phytoplankton had nutrient supplies in excess of their requirements for growth, and that extreme light attenuation by these turbid waters limits the growth of photosynthetic organisms, especially in the south basin of the lake." Vertical light extinction coefficients were highly correlated with concentrations of suspended sediment (SS); most SS samples appeared to be largely inorganic matter.

Temperature may also be an important regulator of algal growth in Lake Winnipeg (Brunskill, Campbell and Elliott. 1979).[6] "Water temperature likely controls the growth rates, reproduction cycles and zoogeographic distribution of many organisms...", and, referring specifically to Lake Winnipeg, "During rare, prolonged calm and hot weather, algal blooms appear at the surface...".[6] The latter observation is echoed by the Lake Winnipeg Stewardship Board, "Algal blooms generally develop in the south basin of Lake Winnipeg during periods of calm, warm, and sunny weather."[1]

To conclude, I am unconvinced that, over the past 3 or 4 decades, there has been a significant anthropogenically-induced increase in nutrient loading to Lake Winnipeg. Further, I would be surprised, for a system as nutrient-rich and light-limited as Lake Winnipeg, if small increases in gross N and P loads (+13% and +10%) were to have caused dramatic increases in frequency, duration, and intensity of blue-green algal blooms.[1] I suspect that a Lake Winnipeg amelioration strategy that focuses primarily on attempting to reduce inputs of nutrients originating on the terrestrial watershed to what are believed to be pre-1970 levels may be very disappointing. Lake Winnipeg is a very complex, heterogeneous system.[2,3,4,5,6] Anticipated improvements in the nutrient chemistry and biota of Lake Winnipeg, corresponding to ten percent reductions in external supply of N and P, will almost certainly be difficult to detect and, therefore, most likely inconclusive.

I think future research aimed at developing sound and optimal management strategies for Lake Winnipeg will, of necessity, have to be broad-based. Nutrient studies should include a range

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[5] Brunskill, G.J., D.W. Shindler, S.E.M. Elliott and P. Campbell (1979). The Attenuation of Light in Lake Winnipeg Waters. Can. Manuscr. Rep. Fish. Aquat. Sci. No. 1522. 79pp.

[6] Brunskill, G.J., P. Campbell, and S.E.M. Elliott. (1979). Temperature, Oxygen, Conductance and Dissolved Major Elements in Lake Winnipeg. Can. Manuscr. Rep. Fish. Aquat. Sci. No. 1526. 127pp.

of investigations, in addition to those focusing on external supply rates of N and P. Examples include: determining the potential for, and quantifying the relative importance of internal recycling of nutrients; nutrient bioavailability (especially for P) as a limiter of primary productivity; and, nutrient stoichiometry (impact of N:P ratios on algal species composition). Thorough examination of the light and temperature regimes would also likely prove useful, particularly in relation to elucidating and understanding the impacts of ecosystem alterations or disruptions such as by dams, reservoirs, and climate change. Managing to protect the future Lake Winnipeg will, obviously, also require a good understanding of its biological communities; not just in terms of knowing quantity and composition, but especially being cognizant of the potentially very important consequences of community interactions (both species and trophic-level interactions).

Lake Winnipeg is comprised of 3 main parts, the south basin, the narrows, and the north basin which, most of the time, are hydrologically, chemically, and biologically quite distinct from one another. Ideally, future investigations on the lake would recognize and be designed to take into account the very real and important differences in these 3 entities. And, optimally, future strategies to manage and protect the lake would be tailored individually for each of the south basin, narrows, and north basin.