Comment to the IJC on proposed water quality standards for the Red River at Emerson

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In its proposal (Figure 6) the International Red River Board Water Quality Committee (IRRB) reports that phosphorus concentrations in the Red River at Emerson have increased dramatically since the 1990s and continue to increase in even the most recent years. The increase is closely associated with increased algal biomass in general in Lake Winnipeg (McCullough et al. 2012) and with increased frequency and magnitude of surface blooms of Cyanobacteria (bluegreens) in particular (Binding et al. 2019). There is a wealth of evidence in the scientific literature indicating that this can be reversed by reducing phosphorus loading to the lake, and in consequence, I fully support water quality objectives that would have the effect of reducing phosphorus load at the U.S.-Canada border, in the lower Red River, and in Lake Winnipeg.

However, I do not support the IRRB recommendation to reduce nitrogen concentrations and loads. Total nitrogen has not increased in the Red River at Emerson since the 1990s (Figure 6 in IRRB proposal). In any case, while there is ample evidence—both by experiment and demonstrated in case histories—that eutrophication can be reversed by phosphorus reduction alone, there is no equivalent evidence that it can be reversed by nitrogen reduction. Moreover, it is clear from the IRRB data that the ratio of nitrogen to phosphorus (N:P) has decreased in the Red River over the same period. This is of concern, because lowering the N:P ratio gives Cyanobacteria (which can draw nitrogen from the atmosphere) a competitive edge over algae that must survive on nitrates delivered in tributary rivers and which do not form surface blooms, do not produce toxins and yet, equally well, support a productive fishery.

The IRRB rely on two lines of evidence in support of their recommendations: modelling stressor response in the Red River itself, and a "downstream approach" related to nutrient objectives for Lake Winnipeg. Here, I do not refer to the results of the stressor response model for the river, but I do submit that the health of Lake Winnipeg should not be accepted as a rationale for nitrogen reduction in the Red River.

With regard to the downstream approach (i.e. concern for Lake Winnipeg) the IRRB list "a number of pieces of information collected over the past almost 20 years" (bullet points on p. 6 and 7 in the IRRB proposal). They offer minimal comment on the significance of each to their nutrient objectives recommendations. I offer my own concerns here.

Nitrogen not increasing at Emerson

At IJC hearings in Winnipeg on 12 February, the first reason presented for considering nutrient objectives was that nutrient concentrations are increasing. (I refer to the oral summary of rationale for nutrient objectives by Robert Phillips, Canadian Liaison. I believe this rationale was also presented in Fargo, see slide 8 in Gabriel & Phillips presentation linked on the IJC website.) With regard to Manitoba Sustainable Development's study of time series of nutrient concentration in Manitoba streams, there have indeed been increases in both phosphorus and nitrogen in many small streams, including for nitrogen in the Red River just upstream of, and just downstream of Winnipeg. However, I draw your attention to the IRRB's finding for the Red River at Emerson: there has been no significant change in nitrogen concentrations as measured by Environment Canada at Emerson (where the IRRB is recommending a reduction) since the mid-1990s. The earlier, higher values may be due to a change in the analytical method in 1994—though it is worth noting that prior to that analytical change, nitrogen concentrations had been decreasing since observations began in 1980. That is, although records indicate that nitrogen concentrations have been increasing in the Red River north of the border, the IRRB did not present any evidence that the same is true south of the border.

Phosphorus reduction alone can reverse eutrophication and surface blooms

In support of their recommended nutrient targets, the IRRB refer to work by Dr. P. Leavitt (Bunting et al. 2011) and by myself and others (bullets 3 and 4, p. 7). The IJC should be aware that McCullough et al. (2012) demonstrate strong correlation between phosphorus loading and algal biomass in Lake Winnipeg, as does a more recent paper by Dr. Karen Binding of Environment and Climate Change Canada and others. (I am a co-author.) The former shows the dramatic increase in algal biomass that followed a roughly 50% increase in phosphorus loading in the 1990s.The latter show that together phosphorus loading and lake temperature explain fully 89% of the interannual variability in severity of surface blooms of Cyanobacteria (Fig. 1). Neither paper refers to nitrogen loading.

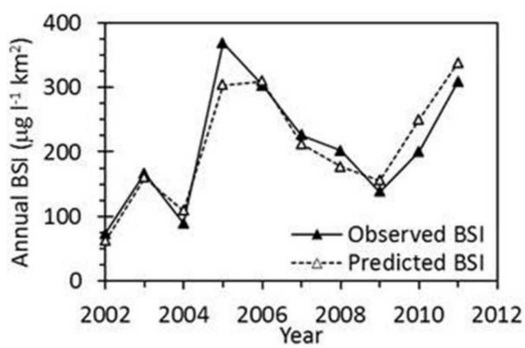

Fig. 1. Bloom severity index (BSI) predicted by multiple regression on spring phosphorus loading and summer lake temperature (Fig. 7a in Binding et al. 2018).

Moreover, Dr. Leavitt and his colleagues did not suggest that reducing nitrogen loading to reverse the eutrophication of Lake Winnipeg. They recommended only that "TP concentrations be reduced to ~50 µg P L^{-1} (50% decrease) to suppress to suppress current outbreaks of diazotrophic Cyanobacteria" (p. 36 and 37 in their report to the Province of Manitoba; for a copy, follow the link in bullet 3 on p. 7 in the IRRB proposal). Although they go on to hypothesize deleterious changes that might result from *further increases* in nitrogen loading should we fail to reduce the phosphorus influx, they nowhere suggest that *reducing* nitrogen loading would not help. In fact, while phosphorus continues to increase in the Red River at Emerson, nitrogen does not (and has not since at least the mid-1990s; more on that later).

Reducing nitrogen may favour Cyanobacteria blooms

The IRRB also refers to a paper on a nutrient response study by numerical ecological modeling, by Zhang and Yerubandi (last bullet on p. 7) but they do not refer to the results. In fact, the authors actually caution against *excessive* nitrogen reduction. Using their model, they demonstrated that that "reducing phosphorus alone with relatively higher percentage (>12%) is an effective management approach for the improvement of ecological status of Lake Winnipeg" with the proviso that "if nitrogen is also controlled, then the N reduction rate should be kept low (<7%) and increase the phosphorus reduction accordingly". ("Nutrient-reduction scenarios" in Zhang and Yerubandi, 2012).

Indeed, while higher phosphorus loading explains greater productivity of algae in general in the lake, it more likely the declining ratio of nitrogen to phosphorus in the lake that explains the increasing frequency and intensity of surface blooms of nitrogen-fixing, sometimes toxin-producing Cyanobacteria. For explanation, I refer you to Schindler et al. (2012) from which I quote this paragraph (page 6):

> *To summarize, in the four decades for which nutrient information is available for Lake Winnipeg, phosphorus has increased much more rapidly than nitrogen. Increased phytoplankton abundance has occurred almost entirely from Cyanobacteria (Kling, 1998; Kling et al., 2011; McCullough et al., 2011), among which nitrogen fixing species have accounted for most of the increase. Consequently, <u>we conclude that controlling nitrogen inputs would contribute little to reversing eutrophication in Lake Winnipeg</u>. The many successful whole-lake experiments and case histories where lakes have been recovered by decreasing inputs of phosphorus alone indicate the most likely path to successfully reducing eutrophication of the lake. A recent model of the responses of phytoplankton in Lake Winnipeg to phosphorus control is in good agreement (Zhang and Rao, 2011). As shown by Schindler et al. (2008a) and Paterson et al. (2011) discussed by Schindler (in review), <u>attempts to control N inputs can actually aggravate a eutrophic situation by selecting for the very N fixing species that are the major cause of concern in Lake Winnipeg</u>.*

For a fuller discussion of this point as it applies to Lake Winnipeg, please see the paper that I extracted it from, as well as a more general discussion in Schindler (2012). I have attached pdfs of both.

In the RESPEC report prepared for the IRRB the authors claim that "excessive concentrations of TP and TN have resulted in low N:P ratios which are indicative of conditions that can be preferential to developing river Cyanobacteria blooms" (RESPEC report, p. 66). In fact, at Emerson, only phosphorus concentrations have increased over the last decades, while nitrogen concentrations have not. It is that history that has led to low N:P ratios, not "excessive concentrations" of both. On average, algae require nitrogen and phosphorus in the molar ratio of 16:1. The molar ratio is in the Red River at Emerson is of the order of 11–15, and it has decreased since the mid 1990s (Fig. 2). It is illuminating that in the north basin (where surface blooms are most severe) of Lake Winnipeg the N:P ratio is twice that, over 30 on average. (Both values are based on total nitrogen and total phosphorus.) Nitrogen concentrations are driven up in the lake by Cyanobacteria which convert nitrogen gas from the atmosphere to useable (by algae) nitrates, first incorporated into their own bodies, and when they die and decompose, in the lake. More desirable algae simply cannot do that, and they fail to compete, except in spring or late fall when the lake is too cool for the Cyanobacteria to thrive.

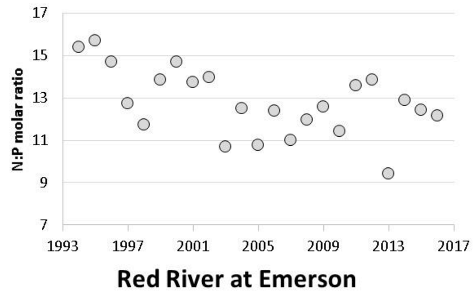

Fig. 2. Molar ratios of N:P calculated from data in Figures 2 in the IRRB proposal.

Summary

It is phosphorus, not nitrogen, that has been increased, and that continues to rise in concentration in the Red River at Emerson. Lowering nitrogen concentration or nitrogen loads in the Red River at Emerson (or elsewhere) will not contribute to reversing cultural eutrophication in Lake Winnipeg. Nor will lowering nitrogen lessen the frequency or magnitude of surface blooms of Cyanobacteria; indeed, it could increase the latter problem. The health of Lake Winnipeg will not be improved by enforcing nitrogen objectives (implying nitrogen reduction) in the Red River at the U.S.-Canada border.

References

Bunting, L., P.R. Leavitt, B. Wissel, K.R. Laird, B.F. Cumming, A. St. Amand and D.R. Engstrom. 2011. Sudden ecosystem state change in Lake Winnipeg, Canada, caused by eutrophication arising from crop and livestock production during the 20th century. 72 p. http://digitalcollection.gov.mb.ca/awweb/pdfopener?smd=1&did=18978&md=1

Binding, C.E., T.A. Greenberg, G. McCullough, S.B. Watson, E. Page. 2018. An analysis of satellite-derived chlorophyll and algal bloom indices on Lake Winnipeg. 443(3):436-446.

McCullough, G.K., S.J. Page, R.H. Hesslein, M.P. Stainton, and D.G. Barber. 2012. Hydrological forcing of a recent trophic surge in Lake Winnipeg. Journal of Great Lakes Research 38:95-105.

Schindler, D.W. 2012. The dilemma of controlling cultural eutrophication of lakes. Proc. Royal Society B 279:4322-4333.

Schindler, D.W., R.E. Hecky and G.K. McCullough. 2012. The rapid eutrophication of Lake Winnipeg: Greening under global change. J. Great Lakes Research 38:6-13

Zhang, W. and R.R. Yerubandi. 2012. Application of a eutrophication model for assessing water quality in Lake Winnipeg. J. Great Lakes Research. 38:158-173.