Phosphorus in Canada's Aquatic Ecosystems

Severe algal blooms in Lake Winnipeg, Lake Simcoe and blooms of cyanobacteria in eastern Canadian lakes have been occurring in recent years, as well as re-emerging problems in Lake Ontario and Lake Erie, and in other Canadian water bodies.

Not since the 1970's, when Great Lakes algal blooms prompted legislation limiting phosphate levels in laundry detergents and sewage effluents, has public concern for nutrient loadings to aquatic environments been so high.

Scientists have been tracking and researching nutrients in freshwaters across Canada since the 1960's. The following web pages provide highlights of a national level assessment of nutrients in Canadian watersheds based on data from Environment Canada water quality monitoring stations operated in conjunction with federal, provincial and territorial partners.

Photo of green algal and cyanobacterial bloom in the Irishtown Road Reservoir, NB. (A. Baillargeon)

Concerns and Issues

For decades, phosphorus, a crucial nutrient for growth of aquatic plants and algae, has been considered a key driver of the overall productivity of freshwater ecosystems. Other nutrients, such as nitrogen in the form of nitrates and ammonia can intensify this fertilizing effect, especially in nutrient poor rivers in remote areas as well as estuaries or coastal areas.

Today, the delivery of phosphorus to Canada's surface waters occurs via natural and human inputs. Human inputs to Canada's waterways include:

- runoff from land cleared for agriculture, especially where fertilizers and manure have been applied in quantities that exceed nutritional requirements of crops
- runoff from forestry and urban expansion
- industrial emissions to soils and water (e.g. pulp and paper and mining)
- municipal and household wastewater discharge, including septic systems
- wind blown dust from bare soils

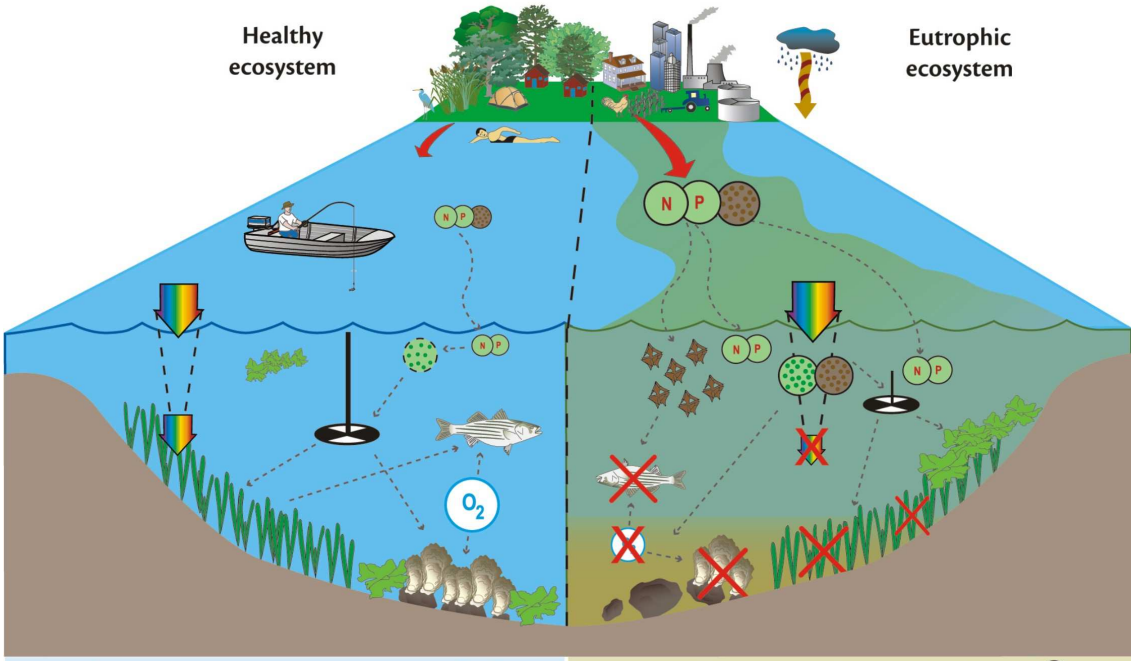
In the absence of human development, phosphorus exists only in phosphate-bearing rock and is introduced into water through soil and rock erosion. Consequently, the natural level of phosphorus in water is influenced by the amounts and types of rock and soil in the area. Water bodies in regions with a lot of soil, such as the Prairies, naturally have high phosphorus levels compared to water bodies in areas with little soil, such as the Canadian Shield.

Excess phosphorus can result in abundant growth of aquatic plants. This can lead to a shift in the assemblages of fish and invertebrates toward less desirable species, including pollution tolerant ones which may include invasive species.

Potentially toxic cyanobacteria (also known as blue green algae) can form blooms under certain conditions, such as high nutrient loadings and warm temperatures, and cause unpleasant taste and odour problems in drinking water. Some of these bacteria can release toxins in the water which can pose health risks to humans and animals.

Decaying and unsightly algal and aquatic plant growths can also clog intake pipes and impair navigation reducing the aesthetic and recreational value of aquatic ecosystems. Additionally, fish kills can occur as a result of concurrent declines in dissolved oxygen.

Conceptual diagram comparing a balanced ecosystem with one receiving excess nutrients



In healthy ecosystems, nutrient inputs, specifically nitrogen and phosphorus, occur at a rate that stimulates a level of macroalgal and phytoplankton (chlorophyll *a*) growth in balance with grazer biota. A low level of chlorophyll *a* in the water column helps keep water clarity high, allowing light to penetrate deep enough to reach submerged aquatic vegetation. Low levels of phytoplankton and macroalgae result in dissolved oxygen (O_2) levels most suitable for healthy fish and shellfish so that humans can enjoy the benefits that a coastal environment provides.

In a eutrophic ecosystem, increased sediment and nutrient loads from farming, urban development, water treatment plants, and industry, in combination with atmospheric nitrogen, help trigger both macroalgae and phytoplankton (chlorophyll *a*) blooms, exceeding the capacity of grazer control. These blooms can result in decreased water clarity, decreased light penetration, decreased dissolved oxygen, loss of submerged aquatic vegetation, nuisance/toxic algal blooms and the contamination or die off of fish and shellfish.

Source: Adapted from Bricker et al., 2007

Did you know ?

Phosphorus enrichment of surface waters continues to be a national issue in Canada. Between 2005 and 2007, 32% of all water quality monitoring stations (108 out of 336 stations in total) in Canada exceeded water quality objectives for phosphorus more than half of the time it was measured (Environnement Canada, 2009.

Tracking nutrients in Canadian waters

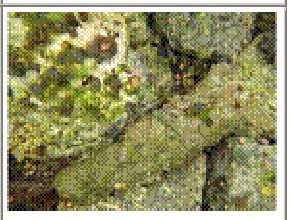
Recently, a first-ever national level assessment of nutrient levels in Canadian watersheds was completed based on nation-wide data from water quality monitoring stations operated by Environment Canada and jointly by Environment Canada and federal, provincial or territorial partners.

Different forms of phosphorus were measured and include:

- **Total phosphorus (TP):** a measure of all forms of phosphorus in water (including phosphorus found in organic matter, bound to suspended sediments and dissolved in the water).
- **Total dissolved phosphorus (TDP):** total phosphorus for a water sample that has been filtered through a membrane (0.45 µm). This fraction can be readily taken up by plants and is often referred to as the bioavailable fraction.

Across Canada, up to 102 stations in rivers and 7 Great-Lakes basins were used to measure concentrations of total phosphorus and total dissolved phosphorus between 1990 and 2006 in order to determine the recent status and trends related to nutrients in aquatic ecosystems.

The levels of nutrients and their expected effects in lakes and rivers can be categorized and described as their trophic status. Below is a description of the various trophic states:

- oligotrophic	<0.004	Very Low nutrients and plant growth, high water clarity		
Oligotrophic	0.004-0.010			
Mesotrophic	0.010-0.020	Moderate levels of nutrients and plant growth, reduced water clarity		
Meso-eutrophic	0.020-0.035			
Eutrophic	0.035-0.100	High levels of nutrients and plant growth, low water clarity		

Hyper-eutrophic	>0.100	Very high levels of nutrients and plant growth, very limited water clarity		

**Please note that in rivers and lakes, water clarity is not only determined by algal growth but also to other suspended particles, such as silt.*

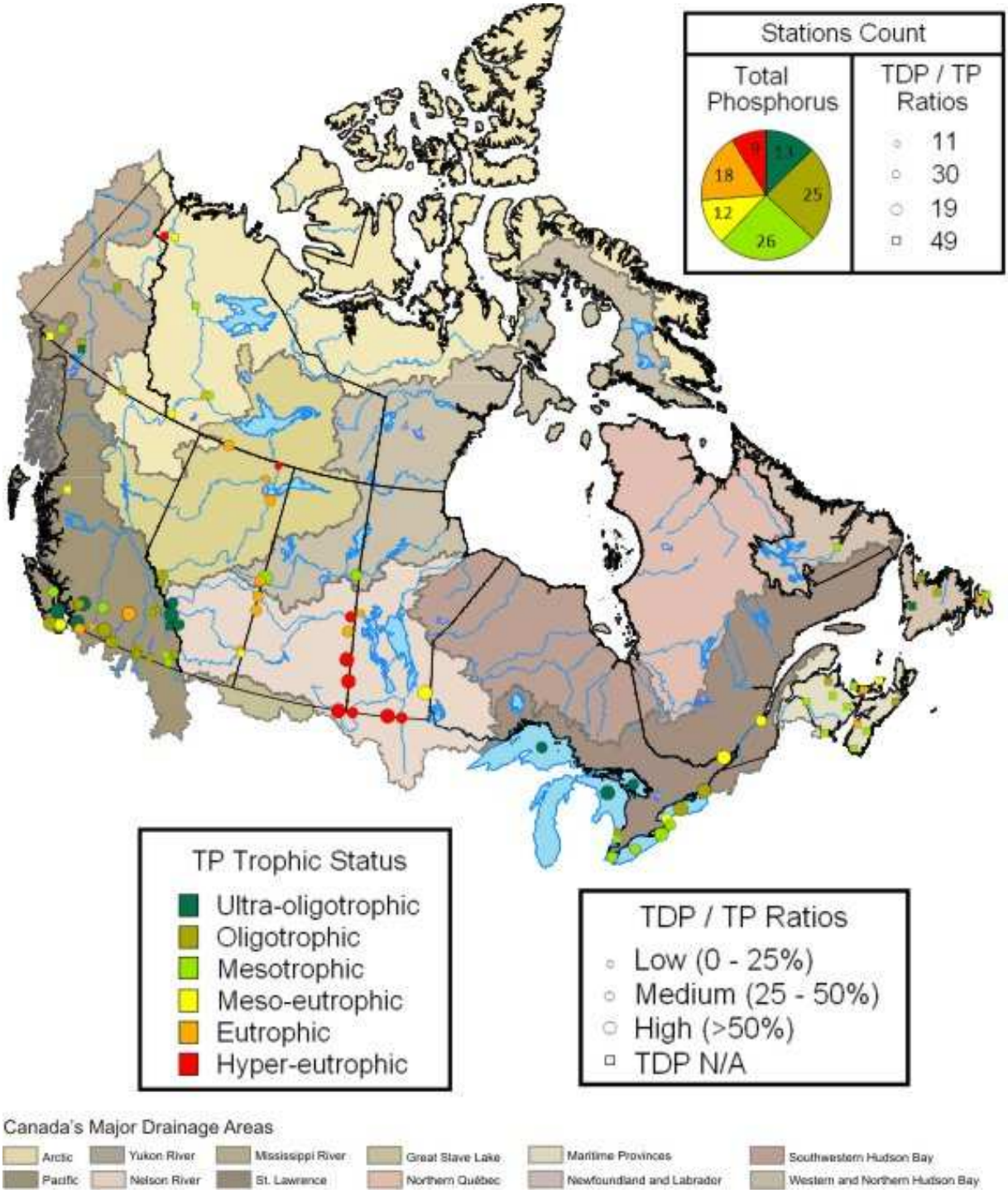
Did you know?

Trophic status of an aquatic ecosystem represents its level of nutrients (typically phosphorus) and plant growth. A lake or river with high phosphorus and plant growth is considered eutrophic. Note that eutrophic ecosystems are not always due to a human source of nutrients but can be representative of its natural state.

Status and trends of phosphorus in water bodies across Canada

The following map presents the median levels of phosphorus found at the monitoring sites. It is important to keep in mind that some areas of Canada have naturally low levels of total phosphorus (e.g. oligotrophic) and others have naturally high levels (e.g. eutrophic). Thus, the impacts of excess nutrients, such as algal blooms, may be seen in all areas, including those described as oligo- or mesotrophic. These impacts may be particularly marking where the dissolved phosphorus portion is high relative to total phosphorus.

Concentration levels of total phosphorus (TP) and ratios of total dissolved phosphorus (TDP) to TP in rivers and the Great Lakes, Canada, 2004 to 2006. Based on median values.



Notes: *High TDP/TP ratios indicate a higher proportion of phosphorus which is readily available for uptake by plants (i.e. not bound in sediments). TDP was not available at*

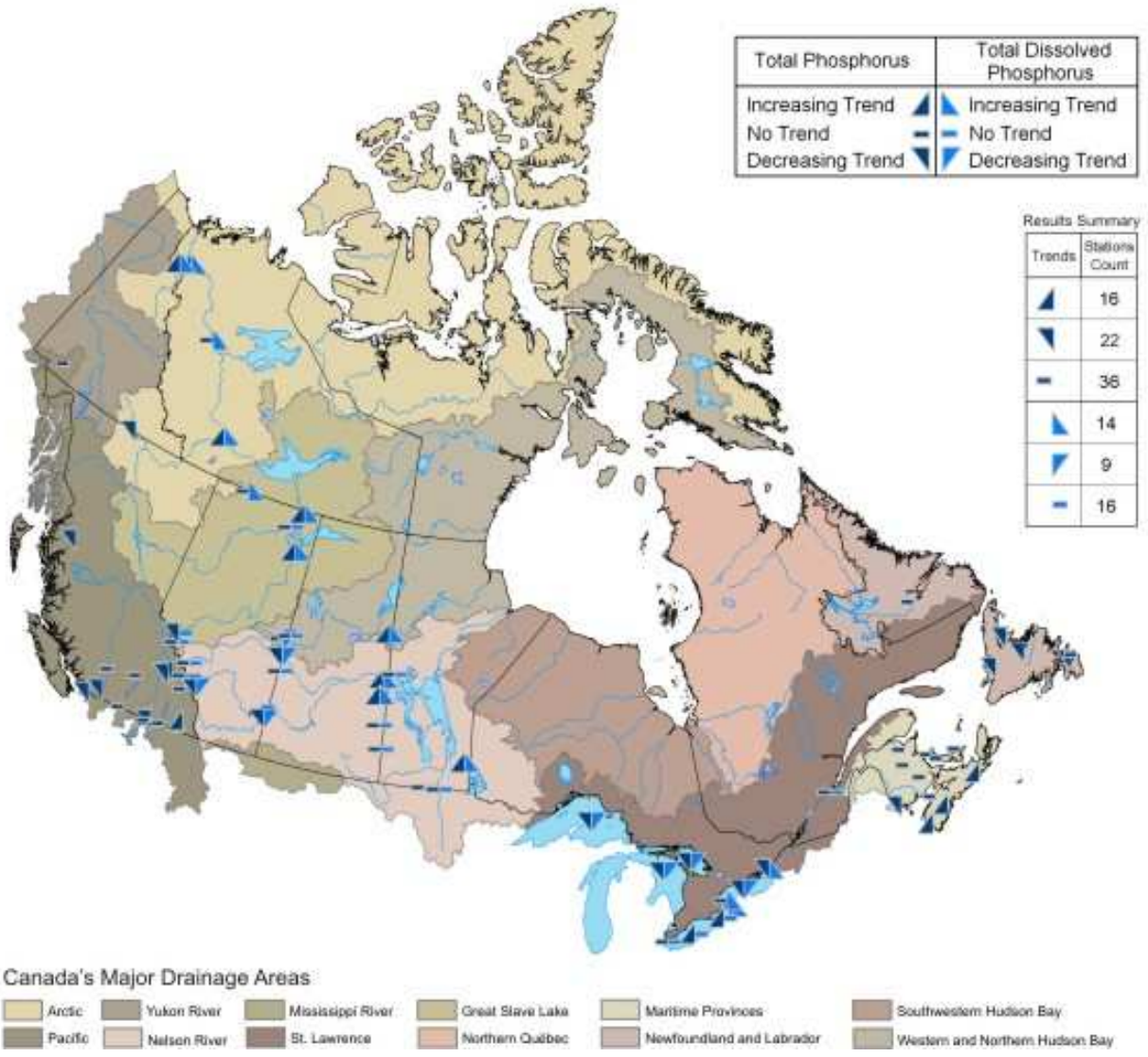
sites identified by a square symbol (□), with the exception of 2 sites, Bow River at Lake Louise in AB and Callaghan Creek at Callaghan Lake in BC, where median phosphorus levels were below detection limits and a ratio could not be determined accurately.

Data source: *Environment Canada water quality monitoring networks, including joint networks with British Columbia Environment, New Brunswick Department of Environment, Newfoundland and Labrador Department of Environment and Conservation, Prince Edward Island Department of Environment, Energy and Forestry, and Indian and Northern Affairs Canada.*

Recent results for total phosphorus and total dissolved phosphorus (2004-2006) show that…

- Overall median concentrations for TP and TDP were 0.014 and 0.005 mg/L, respectively, but TP concentrations ranged between <0.0005 and 1.88 mg/L, while those for TDP varied from <0.0005 to 1.60 mg/L.
- 70% of the sites with high levels of TP (eutrophic and hypereutrophic) were located in the Arctic and Nelson River basins (i.e. Prairies and Northern watersheds)
- Intermediary concentrations were measured in Lakes Erie and Ontario, and, except for a few hotspots, in the Pacific and Atlantic drainage areas (both the Maritime Provinces and Newfoundland and Labrador)
- The lowest concentrations were found in mountain rivers of Yukon, Pacific and upper Nelson Drainage Areas and the upper Great Lakes (Superior, Huron and Georgian Bay)
- Higher phosphorus levels tend to be observed lower in the watershed, compared to upstream locations. This pattern was observed in the Fraser River, South Saskatchewan River, the Great Lakes and the St. Lawrence River and is due in part to the cumulative effect of human activities in lower portions of watersheds but also to natural changes in rivers which occur along their course.
- The ratio of TDP to TP at individual stations varied from 3% to nearly 90%. A ratio of 3% indicates that most of the phosphorus is bound to sediment in the water. A ratio of 90% indicates that most of the phosphorus is dissolved and easily available for take up by plants.
- The ratio of TDP to TP varies among rivers and lakes across the country and is not necessarily related to the total amount of P in the water body. Some sites with high TP have low TDP and some have a relatively high proportion of TDP, even within the same basin. Local river hydrology, point source inputs and land use likely contribute to these variations.

Trends in levels of total phosphorus and total dissolved phosphorus (1990 to 2006)



Data source: *Environment Canada water quality monitoring networks, including joint networks with British Columbia Environment, New Brunswick Department of Environment, Newfoundland and Labrador Department of Environment and Conservation, Prince Edward Island Department of Environment, Energy and Forestry, and Indian and Northern Affairs Canada.*

Results of the trend analysis show that…

- Of the 74 sites with total phosphorus (TP) data, 16 (or 22%) have increases, 22 (or 30%) have decreases and 36 (or 49%) have no change over the period 1990-2006.
- For half of the sites with increasing TP, the magnitude of the increase was great enough to change the trophic status category by at least one category (for e.g., oligotrophic to mesotrophic).
- Of the 39 sites with total dissolved phosphorus (TDP) data, 14 (or 36%) have increases, 9 (or 23%) have decreases and 16 (or 41%) have no change.
- Of the 39 sites with both forms of phosphorus, 30 have similar results including 9 with concurrent increases, 8 with concurrent decreases and 13 with concurrent no change. The nine remaining sites have trend results which differ between the phosphorus fractions, but only 2 have opposite trends – both are lake outlet sites (Lakes Ontario and Erie) and exhibited increasing TDP and decreasing TP. In both cases, this change in nutrient dynamics could be related to the presence of the invasive zebra mussel which filters algae and other suspended particles containing phosphorus and excretes dissolved phosphorus.

Conclusion

Overall, there are areas in Canada where total phosphorus concentrations were found to be high – nearly one-third of sites assessed were classified as eutrophic or hyper-eutrophic. Of these 21 sites, 10 had TDP levels of less than 25% of the TP, indicating that the majority of phosphorus at these sites was in suspended sediment. However, 5 sites categorized within these upper trophic categories had a high amount of bioavailable P. Four of these sites were in the Prairies, and one in southern BC.

For TP, 16 of 74 sites (22%) had increases between 1990 and 2006, while 14 of 39 (36%) had increases in TDP, the form that is readily available for take up by plants. Only 2 out of 39 sites, with both TP and TDP showed opposite trends – the remaining sites had consistent results between the phosphorus fractions.

For some sites the magnitude of the change measured may be of concern as it was great enough to increase the trophic status of the aquatic ecosystem.

It is important to note that the monitoring sites included in this assessment do not cover all areas where excess nutrients are a problem (e.g. Lake Winnipeg) but only those for which sufficient data were available from Environment Canada's water quality networks.

Further work to better understand what is driving the trends and the levels of phosphorus across Canada is underway including the potential impacts to aquatic ecosystems, particularly for those watersheds which exhibit the highest magnitude of change.

The data and information generated by assessing water quality in our waters is used by water resource managers across the country in a variety of ways.

Documentation

Bricker S., B. Longstaff, W. Dennison, A. Jones, K. Boicourt, C. Wicks, and J. Woerner, 2007. Effects of Nutrient Enrichment in the Nation's Estuaries: A Decade of Change. NOAA Coastal Ocean Program Decision Analysis Series, No. 26. National Centers for Coastal Ocean Science, Silver Spring, MD. 322 pp.

Environnement Canada. 2009. Canadian Environmental Sustainability Indicators – Annual Report. Ottawa. ON. Accessed on June 21, 2010. *www.ec.gc.ca/indicateurs-indicators*.