1.0 Introduction

Highlights

- Nutrients are chemical substances that provide nourishment and promote growth of micro-organisms and vegetation. They include nitrogen, phosphorus, carbon, hydrogen, oxygen, potassium, sulfur, magnesium and calcium, as well as other elements required in smaller quantities: iron, zinc, copper, manganese, boron, molybdenum and chloride.
- A surplus of nutrients in an ecosystem can lead to increased plant growth and changes in biodiversity. Ammonia, nitrate, and nitrite are also toxic to aquatic and terrestrial animals, including humans, when present in quantities well in excess of requirements.
- An oversupply of nitric oxide to the atmosphere can contribute to the creation of acid rain and urban smog.
- This report meets the Government of Canada's commitment, in its response to the 1994 review of the *Canadian Environmental Protection Act* (CEPA), to determine the nature and extent to which nutrients derived from human activity may be impairing Canadian ecosystems and affecting the quality of life and health of Canadians.

1.1. Issue Context

The purpose of this report is to meet the commitment made by the Government of Canada to determine the extent to which nutrients derived from human activities may be impairing Canadian environments, contributing to quality-of-life concerns for Canadians, or endangering their health.

Nutrients are elements essential to plant growth and are present naturally in the environment; however human activity has increased the supply of biologically reactive forms of nutrients, particularly nitrogen (N) and phosphorus (P). Nutrient addition from human activity includes runoff water from land cleared for agriculture, forestry, mining, urban expansion and recreational developments; losses associated with agricultural practices such as fertilizer and manure application to soils and cultivation of crops such as legumes that fix N; industrial emissions to air, soils and water; and household wastewater discharge.

This report examines the role of nutrients, particularly N and P derived from human activity, in contributing to excessive plant production in aquatic and terrestrial ecosystems, thereby, affecting fish and wildlife; imposing a toxic threat to plants and animals, including humans; and, in contributing to quality of life concerns for Canadians. Nitrogen and phosphorus should only be referred to as "nutrients" when examined in the context of plant growth. Nutrient toxicity, specifically nitrogen toxicity, occurs when an element essential for growth is available in quantities well in excess of requirements. Nitrogen does not serve a nutritive role in phenomena such as nitrogen-induced acidification or nitrogen-oxide-enhanced ozone production. This report focuses only on the "nutritive" effects of N and P on Canadian environments.

Nutrients Defined

Nutrients are essential elements for all organisms. Nutrients include nitrogen, phosphorus, carbon, hydrogen, oxygen, potassium, sulfur, magnesium and calcium (collectively known as macronutrients because they are needed in relatively large amounts) as well as other elements required in smaller quantities (micronutrients such as iron, zinc, copper, manganese, boron, molybdenum and chloride). These elements are present naturally in air, soil and water.

The *1999 Canadian Environmental Protection Act* (CEPA) defines a nutrient as any "substance or combination of substances that, if released in any waters, provides nourishment that promotes the growth of vegetation". Under the Act, the Governor in Council may, on the recommendation of the Minister, make regulations "for the purpose of preventing or reducing the growth of aquatic vegetation that is caused by the release of nutrients in waters and that can interfere with the functioning of an ecosystem or degrade or alter, or form part of a process of degrading or altering, an ecosystem to an extent that is detrimental to its use by humans, animals or plants" (CEPA 1999 Part 7, Division 1, 118(1)).

Because the Government of Canada committed to a comprehensive study of nutrients that would determine whether effects are limited to water or to entire ecosystems including wildlife, the definition of nutrients for this assessment was expanded beyond the CEPA definition to include terrestrial ecosystems. For the purpose of this assessment "nutrients" included any element that:

- has nutritive value, in particular the two major nutrients nitrogen and phosphorus;
- may be supplied in excess as a result of human activity; and
- may interfere with the normal functioning of aquatic or terrestrial ecosystems.

Assessment of ecosystem effects also included more than the CEPA endpoint of prolific growth of aquatic vegetation.

1.2. Federal Control Programs and Actions to Date

With the identification of the critical role of nutrients (specifically P and N) in controlling eutrophication of aquatic systems, countries around the world began to implement controls for reducing nutrient inputs to aquatic ecosystems. In Canada, the federal government instituted the *Canadian Environmental Protection Act* (CEPA) in 1988, which is the only federal act to address environmental concerns related to nutrients directly.

CEPA gives the federal government authority to regulate nutrients that can cause excessive growth of algae and aquatic weeds. Phosphorus in laundry detergents is the only nutrient source currently regulated. The *Phosphorus Concentration Regulations* (DOE 1989), the only regulation made under this part of CEPA, prohibit the manufacture, use and sale of laundry detergents that contain P in concentrations greater than 2.2 % phosphorus (by weight).

The *Fertilizers Act*, administered and enforced by Canadian Food Inspection Agency, also addresses nutrients although not from the perspective of adverse environmental impacts of nutrients *per se.* The *Fertilizers Act* regulates the safety, efficacy, and labeling of fertilizers (including animal manure) and supplements imported into or sold in Canada. It identifies as nutrients: nitrogen, phosphorus and potassium (primary nutrients); calcium, magnesium, and sulfur (secondary nutrients); iron, zinc, copper, manganese, boron, molybdenum, chloride and, in certain situations, sodium (micronutrients). The fertilizer definition excludes soil supplements defined as "any substance or mixture of substances, other than a fertilizer, that is manufactured, sold, or represented for use in the improvement of the

physical condition of soils or to aid plant growth or crop yields". For example, peat moss would be considered a supplement.

1.3. Rationale for this Study

In recognition of the fact that science is constantly evolving, CEPA was passed with the intent that it be reviewed by Parliament every five years. The 1994 review of CEPA identified two issues related to nutrients and their environmental impact and management: that only one class of nutrient (phosphorus in laundry detergents) is currently regulated and that other nutrient classes (e.g., nitrogen compounds) and sources (e.g., other cleaning agents, fertilizers, industrial wastewater) may be adversely affecting the environment (HCSCESD 1995).

In their review of the 1988 CEPA (HCSCESD 1995), the Parliamentary Standing Committee on Environment and Sustainable Development recommended that Environment Canada:

- "regulate the phosphate content of cleaning agents other than laundry detergents under Part III of CEPA";
- "determine whether regulation is required for nutrients in cleaning agents other than phosphates", and
- "determine whether sources of nutrients other than cleaning agents are adequately regulated by the provinces and territories, and if they are not, that the powers of Part III be broadened to include these other nutrient sources".

In response to the recommendations of the Parliamentary Standing Committee, the Government of Canada committed to undertake "a comprehensive study of nutrients that enter the environment through human activities … to determine whether or not nutrients in general are causing negative environmental effects; whether only certain nutrients, rather than nutrients as a class, are problematic, and; whether those effects are limited … to water or to entire ecosystems, including wildlife" (Government of Canada 1995). The Government of Canada is therefore committed to assess scientifically the nature and extent of damage to the environment caused by nutrients from sources other than laundry detergents prior to any further regulation or other control action on nutrients.

The 1995 Memorandum of Understanding (MOU) among the four federal natural resource departments (Environment, Natural Resources, Agriculture and Agri-Food, and Fisheries and Oceans) was identified as a good framework under which a scientific assessment of nutrients could be undertaken. As a result, a working group entitled *Nutrients in the Canadian Environment* was established under the MOU in 1997-98 to conduct the nutrient science assessment. The names of the members of the working group and their departmental affiliation are listed on page iii of this report. The MOU was renewed and expanded to include Health Canada effective January 1998.

1.4. Objectives of this Report

This report presents a synthesis of current knowledge of the effects of anthropogenic nutrients on the Canadian environment and the quality of life of Canadians. Nutrients for the purposes of this report follow the definition given in the 1999 CEPA (see text box, “Nutrients Defined”). The report evaluates:

- nutrient cycles in the environment;
- anthropogenic contributions to nutrient loading;
- enrichment responses to nutrient addition;
- toxic effects of nutrients;
- rationales for current practices for managing anthropogenic nutrients, and
- emerging issues related to the management of nutrients.

Case studies from a variety of ecozones are used to illustrate the effects of added nutrients on Canadian environments (Figure 1.1). The information is then used to identify the presence, extent and source of environmental problems caused by excess nutrients in Canada, and assess whether nutrients as a class, certain nutrients, or nutrient-containing products are problematic.

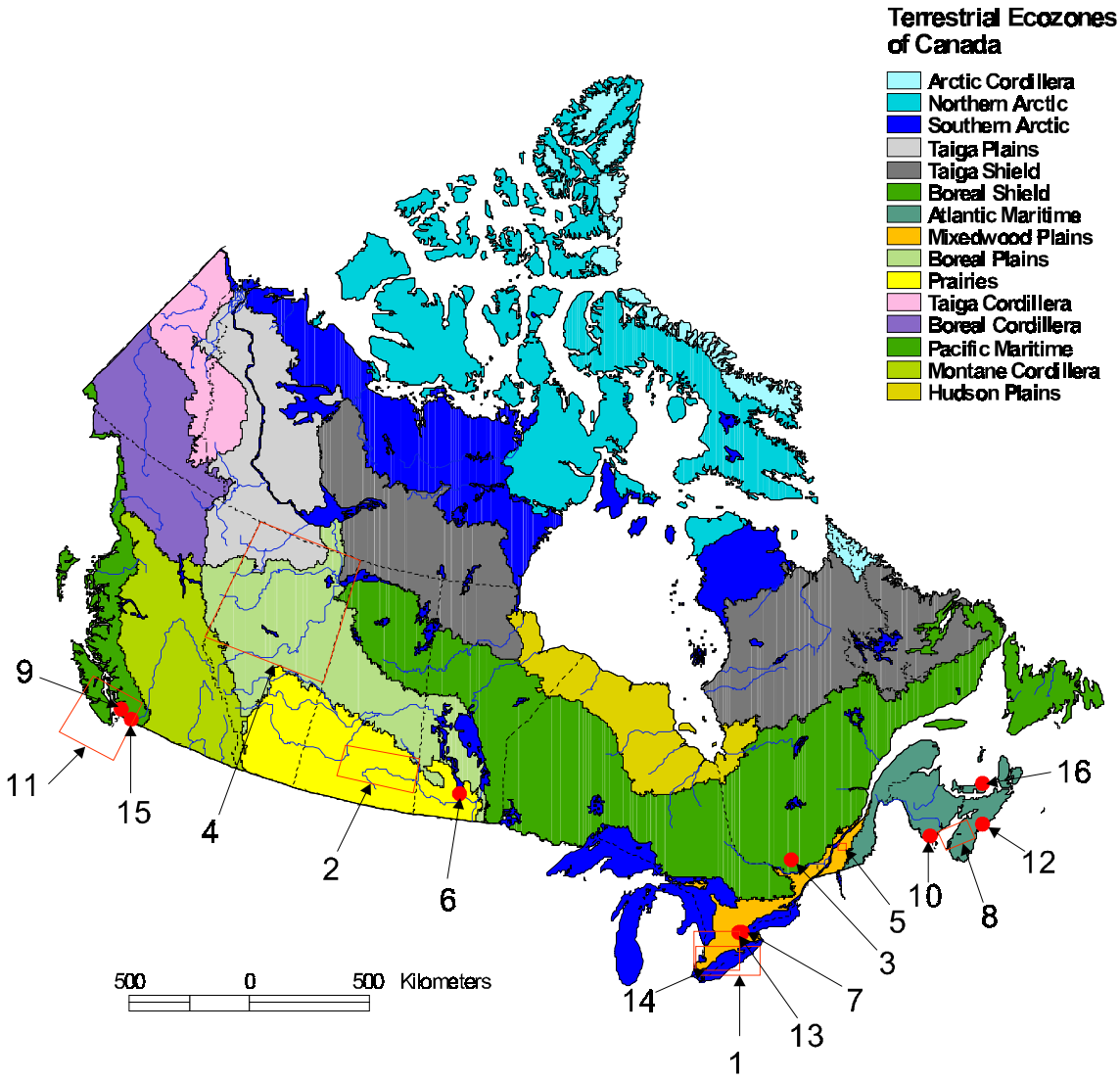

Figure 1.1. Locations of case studies presented in this report, 1998.

1	Lake Erie, ON	-effects of nutrient addition on a Great Lake (p. 64)
2	Qu'Appelle Lakes, SK	-effects of nutrient addition on a chain of prairie lakes (p. 67)
3	Lac Heney, QC	-effects of nutrient addition caused by aquaculture (p. 69)
4	Northern Rivers, AB	-effects of nutrient addition on a large northern rivers (p. 73)
5	Yamaska River, QC	-effects of nutrient addition from agriculture on a river (p. 75)
6	Delta Marsh, MB	-nutrient status of a prairie wetland (p. 79)
7	Cootes Paradise, ON	-effects of urban activity on a Great Lakes marsh (p. 80)
8	Bay of Fundy, NS	-nutrient cycling in a coastal salt marsh (p. 82)
9	Fraser River Estuary, BC	-effects of urban development and nutrients on a coastal marsh (p. 83)
10	Bay of Fundy, NS	-effects of marine aquaculture on coastal ecosystems (p. 85)
11	Georgia Basin, BC	-nutrient loading to the Strait of Georgia (p. 86)
12	Halifax Harbour, NS	-nutrient loading to Halifax Harbour (p. 88)
13	Cambridge, ON	-effects of nutrient loading from a domestic septic system (p. 92)
14	Southwestern ON	-effects of nutrients on amphibian (p. 118) and fish (p. 120) populations
15	Abbotsford Aquifer, BC	-effects of agricultural nutrients on ground water (p. 125)
16	Cardigan River, PEI	-links between nutrients and contaminated mussels (p. 128)