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Increased nutrient concentrations in Lake Erie tributaries influenced by greenhouse agriculture

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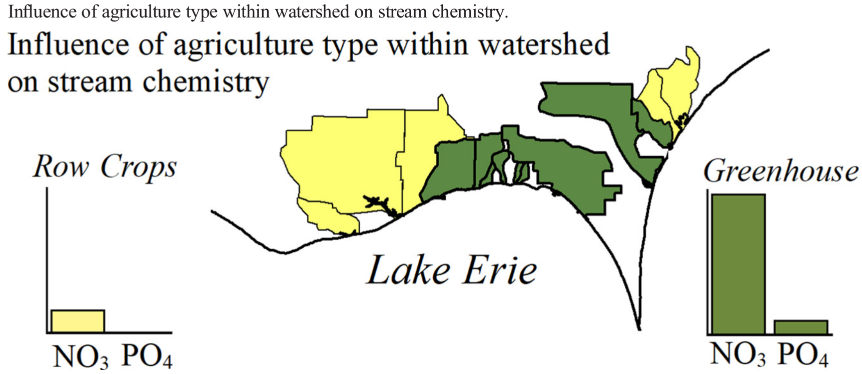
HIGHLIGHTS

- Greenhouse production of vegetables is a globally important industry.
- Nutrients and trace metals quantified in greenhouse and non-greenhouse rivers.
- Greenhouse river concentrations were 4× to 28× higher than non-greenhouse rivers.
- Concentrations in greenhouse rivers appeared to decrease over time.
- Increased precipitation likely diluted greenhouse influenced river concentrations.

GRAPHICAL ABSTRACT

Influence of agriculture type within watershed on stream chemistry.



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ABSTRACT

Greenhouse production of vegetables is a growing global trade. While greenhouses are typically captured under regulations aimed at farmland, they may also function as a point source of effluent. In this study, the cumulative impacts greenhouse effluents have on riverine macronutrient and trace metal concentrations were examined. Water samples were collected Bi-weekly for five years from 14 rivers in agriculturally dominated watersheds in southwestern Ontario. Nine of the watersheds contained greenhouses with their boundaries. Greenhouse influenced rivers had significantly higher concentrations of macronutrients (nitrogen, phosphorus, and potassium) and trace metals (copper, molybdenum, and zinc). Concentrations within greenhouse influenced rivers appeared to decrease over the 5-year study while concentrations within non-greenhouse influenced river remained constant. The different temporal pattern between river types was attributed to increased precipitation during the study period. Increases in precipitation diluted concentrations in greenhouse influenced rivers; however, non-influenced river runoff proportionally increased nutrient mobility and flow, stabilizing the observed concentrations of non-point sources. Understanding the dynamic nature of environmental releases of point and non-point sources of nutrients and trace metals in mixed agricultural systems using riverine water chemistry is complicated by changes in climatic conditions, highlighting the need for long-term monitoring of nutrients, river flows and weather data in assessing these agricultural sectors.

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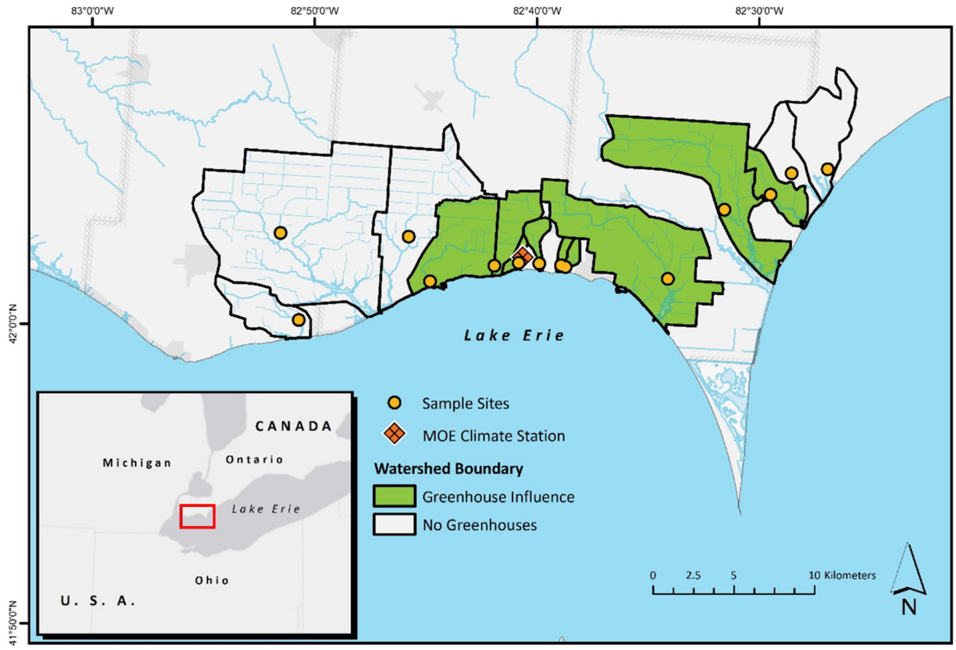

Fig. 1. Site map of 14 rivers sampled every other week for five years in southern Ontario. Samples were collected from 2012 to 2016 and weather data was retrieved from the Ministry of the Environment weather station located adjacent to the study area. Rivers were designated as greenhouse or non-greenhouse influenced when their watersheds exceeded 1% greenhouse coverage.

1. Introduction

Greenhouse agriculture is a commercially important means of growing produce in all climates and has been well established in Canada, the United States, Netherlands, Spain, Southeast Asia, China, and South America (Cantliffe, 2003; Min et al., 2012). Globally 86 million tons of greenhouse vegetables are produced annually (Cantliffe, 2003). In North America approximately 15.5 million m^2 of greenhouse installations produce 1 billon dollars a year from tomatoes alone (USDA, 2012; Wang, 2016).

Commercial greenhouse operations typically use fertigation, a soil-less drip irrigation method that requires both large quantities of water and nutrients. To ensure nutrient uptake by the cultivated plants and to prevent salt accumulation, plants are over irrigated by 25% to 45% (Lévesque et al., 2009). The excess water is collected, treated and recirculated back to crop. This cycle has the potential to continue indefinitely. Occasionally spent irrigation water and nutrients must be removed from the production facility and is either land applied under the Canadian Nutrient Management Act, removed by a waste hauler for disposal, or treated in municipal wastewater facilities. Historically wastewater was disposed using a direct discharge approach, however this practice is no longer acceptable and ongoing outreach and compliance efforts aim to ensure this practice is terminated. An average composition of the spent drainage solution collected from a commercial greenhouse cultivating tomato is approximately (μmol l^{-1}): nitrate (NO_3) 25,000, phosphorus (P) 513, potassium (K) 12,800, iron (Fe) 52, manganese (Mn) 11.1, molybdenum (Mo) 1.35, and zinc (Zn) 8.56 (Hultberg et al., 2013).

The release of spent nutrient solutions from greenhouses is a recognized source of NO_3 in groundwater and increased nitrogen (N), P, and K concentrations in soils (Miyama et al., 2009; Raviv et al., 1998). The impact nutrient solutions from greenhouse agriculture have on rivers has yet to be broadly defined. Lotic nutrient impacts from greenhouses are of particular interest in regions where nutrient loadings and the subsequent harmful algal blooms are a recognized challenge such as in the Laurentian Great Lakes. Nutrient loading from point and non-point sources has been identified as a primary source of concern with respect to Lake Erie (Lake Erie Partnership,

Table 1
Watershed attributes were determined for each river in the study area adjacent to Leamington and Kingsville, Ontario. Watershed area was defined as km^2. *n* indicates the number of sample collections events at each site where all nine macronutrients and trace metal concentrations were determined (e.g., PO4, total P, NO3, K, Cu, Fe, Mn, Mo, and Zn). Watershed greenhouse index is equal to the number of greenhouses area per the whole watershed, including the downstream area of the monitoring site.

Site name	Watershed area	Watershed greenhouse index	River type	Latitude	Longitude	*n*
Mervin Drain	17.96	0	Non-greenhouse	42.09509	−82.44677	54
Albert Gunning Drain	1.5	0.148	greenhouse	42.03985	−82.67678	64
Lane Drain	8.76	0.174	Greenhouse	42.03790	−82.69486	80
Mill Creek	21.62	0.056	Greenhouse	42.02859	−82.74285	81
Wigle Creek	35.3	0.003	Non-greenhouse	42.05323	−82.75953	69
Cedar Creek	96.99	0	Non-greenhouse	42.05373	−82.85540	35
Fox/Dolson's Creek	12.12	0.001	Non-greenhouse	42.00551	−82.84039	65
West Two Creek	10.37	0.01	Non-greenhouse	42.09243	−82.47369	64
Muddy Creek	8.46	0.012	Greenhouse	42.08044	−82.48916	56
Lebo Creek	42.16	0.027	Greenhouse	42.07160	−82.52361	50
Sturgeon Creek	46.58	0.061	Greenhouse	42.03251	−82.56495	71
Judson-Morse Drain	1.41	0.271	Greenhouse	42.03807	−82.64175	80
Rowley Drain	1.02	0.181	Greenhouse	42.03892	−82.64516	79
Esseltine Drain	2.68	0.178	Greenhouse	42.03971	−82.66140	81