CHIRONOMID AUTOECOLOGY OF THE PAST AND PRESENT, AND A CAUSAL ANALYSIS OF RECREATIONAL SHORELINE DEVELOPMENTS ON HYPOLIMNETIC OXYGEN IN ALGONQUIN PARK LAKES

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Abstract

Recreational cottages continue to be leased within Algonquin Park despite inadequate assessments of cottage impacts on lake water quality and ecosystem integrity. Cottages can increase phosphorus export to lakes, resulting in increased productivity and declines in hypolimnetic oxygen. Algonquin Park lakes contain dense populations of lake trout (*Salvelinus namaycush*) and brook trout (*Salvelinus fontinalis*), which are sensitive to declining hypolimnetic oxygen. Dipteran subfossil remains were used to calibrate a VWHO inference model (RMSEP = 1.7 mg O_2 L^{-1}) to determine baseline VWHO (historical, pre-European settlement, < ca. 1850 CE) and assess VWHO change since then using a top-bottom paleolimnological approach. Despite increased anthropogenic activity in the park, inferred VWHO did not change predictably since circa 1850. We did not detect a significant effect of cottages on VWHO. However, regional declines in phosphorus export may be responsible for muting the effects of anthropogenic phosphorus inputs on VWHO in Algonquin Park lakes.

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Dedication

To my future self, I hope this was worth it.

“You can do what makes you happy, just get the paper first.” – T.B.

Table of Contents

List of Figures

List of Tables

List of Abbreviations

DOC	Dissolved organic carbon
DIC	Dissolved inorganic carbon
eHOF	extended Huisman-Olff-Fresco
Fe	Iron
MAT	Modern analogue technique
TN	Total nitrogen
TP	Total phosphorus
P	Phosphorus
PLS	Partial-least squares
RDA	Redundancy analysis
RMSEP	Root-mean squared error of prediction
SA	Surface area
VWHO	Volume-weighted hypolimnetic oxygen
WA	Weighted-averaging
WA-PLS	Weighted-averaging partial-least squares
Z_{max}	Maximum depth
Z_{mean}	Mean depth

Chapter 1: Introduction

1.1 Background

Algonquin Park was established in 1893 to protect the ecosystems of the Algonquin highlands from logging and resource depletion (Killan 1993). The park contains thousands of freshwater lakes on the Canadian Shield, which are being affected by multiple stressors because of anthropogenic activities (OMNR 2013a). The effects of regional-scale disturbance, primarily climate change, may be enhanced due to watershed-scale disturbance such as cottage use (OMNR 2013a). Private cottages have been leased within Algonquin Park since 1905 (Killan 1993). Presently, there are 303 lots which contain 326 cottages distributed along the shorelines of 22 lakes (Table 1.1). Cottage use can have various impacts on aquatic environments such as enhancing nutrient loading (Dillon and Rigler 1975), which can dramatically increase algal productivity and reduce hypolimnetic oxygen, leading to substantive shifts in aquatic biotic communities (Brodersen and Quinlan 2006). Reductions in hypolimnetic oxygen could be especially detrimental for brook trout (*Salvelinus fontinalis*) and lake trout (*Salvelinus namaycush*), both of which are widespread in Algonquin Park, but require cool or cold oxygenated waters (OMNR 2013a; Shuter et al. 1998).

The private cottage leases in Algonquin Park were set to expire on December 31, 2017, and previous management reports stated that there would be no provision for renewal beyond this date (OMNR 1998). However, lease extensions were granted until 2038 (OMNR 2016) without adequate consideration of the potential ecological impacts of private cottage-use on Algonquin Park lakes. Therefore, affected lakes should be examined for their responses to multiple stressors to appropriately inform future management decisions within the park.

This study looked at the impact of multiple stressors on lakes within Algonquin Park to determine if hypolimnetic oxygen has significantly declined over time. Private cottage lakes were compared to reference lakes (lacking private cottage development) with similar limnological conditions to determine whether private cottage development has driven further reductions in hypolimnetic oxygen. Since historical lake data are absent for most lakes in the park, a top-bottom paleolimnological approach (Smol 2008) was used to reconstruct pre-industrial (<1850) conditions for comparison to present-day conditions (Cumming et al. 1992). The chitinized larval head capsules of Chironomidae and Chaoboridae (Insecta: Diptera) were used as biological proxies as they are well preserved in sediment and are found in association with specific limnological conditions (e.g. dissolved oxygen) (Brodersen and Quinlan 2006).

While this paleolimnological research approach has previously been used in this region (Hall & Smol 1996, Quinlan et al. 1998), these were from sediments collected in 1991. Most of the post-1850 CE warming this region has experienced has occurred after 1995 (Lemieux 2007); an assessment of the ecosystem effects of watershed disturbance must incorporate the new paradigm of considering the effects of climate warming within the region.

1.2 Literature Review

This chapter will briefly summarize important topics considered within this thesis and the associated literature which has led to this study. A general description of the Algonquin Park landscape is included here as it is relevant to all subsequent chapters.

1.2.1 Description of Algonquin Park

Algonquin Park is situated within 45 to 46^{o} N latitude and 77 to 79^{o} W longitude (Figure 1.1) and spans more than 7, 700 km^{2} of Canadian Shield bedrock, primarily formed of quarts-feldspar-biotite orthogneiss (OMNR 1998). The Algonquin Park landscape is characterized by a dome feature which forms the Algonquin Park Highlands. The dome has a slight orographic effect, generating increased precipitation to the west (Remmel 2009).

The location of the park along the transition zone between the northern boreal and southern Carolinian forests (Figure 1.2), coupled with the differences in microclimate generated from the Algonquin Park dome, have resulted in differing vegetation compositions across this landscape. The warmer, drier landscape to the east contains a mix of aspen, birch, and pine and the colder, wetter landscape to the west is a mix of hardwood trees like sugar maple (*Acer saccharum*) with some softwood species including white pine (*Pinus strobus*). Many lowland areas are dominated by black spruce (*Picea mariana*) forests (OMNR 1998). Sixty years of extensive logging of red and white pine occurred in the region prior to the official establishment of Algonquin Park in 1893, after which point only sustainable logging practices have been sanctioned within the park.

1.2.2 Algonquin Park lake management

The relatively high elevation of the Algonquin Park landscape makes it an important source for the headwaters of Amable du Fond River, Petawawa River, Bonnechère River, Madawaska River, York River, Muskoka-Haliburton River, Magnetawan River, and South River (Remmel 2009). Algonquin Park contains thousands of freshwater lakes, some of which are densely populated with lake trout and brook trout. Important recreational fisheries rely on these fish species to support the estimated 512, 000 hours spent per year on fishing within the park boundary (OMNR 1998). Recent changes to the Algonquin Park Management Plan have increased protection zones in the interest of maintaining sustainable native trout populations (OMNR 2013b).

The optimal habitats for brook trout and lake trout are < 20 ^{o}C with > 5 mg O_2 L^{-1} (Spoor 1990), and < 10 ^{o}C with > 7 mg O_2 L^{-1} (Evans 2007), respectively. Since lake trout are more sensitive to environmental changes because of the higher demand for dissolved oxygen and colder temperature requirements, lake management in Algonquin Park must consider lake trout when identifying lake water quality targets.

The relationship between phosphorus loading and oxygen depletion has led to the development of water quality guidelines which seek to reduce phosphorus inputs to lakes with low oxygen concentrations. The Provincial Water Quality Objective (PWQO) for Ontario aims to protect all forms of aquatic biota, however, it has set the minimum dissolved oxygen concentration for lakes at 6 mg O_2 L^{-1} (MOEE 1994) which does not sufficiently meet the oxygen requirements for lake trout at 7 mg O_2 L^{-1} (Evans 2007). Since lake trout are considered important ecological, and recreational fish, the Ministry of Natural Resources has established an oxygen criterion for lakeshore capacity assessments which aims to limit the amount of

development along shorelines of at-risk lakes. If dissolved oxygen concentrations are measured at or below 7 mg O_2 L^{-1} for three years, then a lake is at capacity and no additional shoreline development should be allowed (MOE 2010). Five Algonquin Park private cottage lakes have been previously designated as “at capacity”, including Canoe, Smoke, Cache, Galeairy, and Source (OMNR 2013c). However, despite this designation, provincial recommendations can only suggest that development cease along these shorelines, but the enforcement of these recommendations must occur at the municipal level.

1.2.3 Paleolimnology

Assessments of changes in lakes requires historic lake data to compare present-day conditions to, however, historic data are severely lacking for most lake systems (Frey 1988). Paleolimnology is one method of addressing this problem by using indicators as proxies for inferring past characteristics of lakes and surrounding catchments (Smol 1992). Sedimentation of proxies from the overlying water column contribute to the formation of sediment layers which are representative of the lake conditions during the time of deposition. Sediments are preferentially deposited in the deep profundal zone of lakes (the deepwater region below the maximum depth of light penetration) (Frey 1988) where low current speeds enable sediment accumulation without much risk of resuspension (Hofmann 1988). The chronology of sediments collected from the deep basin of lakes using a coring device can be determined through radioisotope dating (Bennion 2011). However, dating procedures are expensive and are often not logistically feasible for studies involving numerous lakes. In such cases, chronology can be assumed based on *a priori* knowledge of the region’s average sedimentation rate, estimated from prior studies where detailed radioisotope dating of lake sediment cores was carried out. For sediment cores from

south-central Ontario lakes, sediment below 15 – 20 cm are considered representative of pre-Industrial Revolution (pre-1850 CE) conditions (Hall and Smol 1996).

1.2.4 Chironomids and chaoborids as paleoindicators

The choice of biological proxies used for paleolimnological assessments depends on the research question of interest. Biological proxies include diatoms and cladocerans for assessments of pH (Dixit et al. 1992; Krause-Dellin 1986), trophic state (Barker 1994; Whitmore 1989; Chen et al. 2010), and water level (Nevalainen et al. 2011). Similarly, chironomids have been used as indicators of lake depth (Korhola et al. 2000), temperature (Larocque and Hall 2003), and more importantly, oxygen (Little and Smol 2001; Luoto and Salonen 2010). Since this study aims to address lake oxygen dynamics, chironomids have been selected as the most suitable biological proxies.

Chironomids are insect larvae from the family Chironomidae which can be used as reliable paleoindicators as they are broadly distributed and well-preserved in lake sediments (Hofmann 1988). Chironomids often dominate benthic macroinvertebrate communities (Fulton 1983; Dougherty and Morgan 1991; Brooks 2000), especially in polluted systems (Tang et al. 2010). Chironomid taxa have been found in association with environmental variables based on taxa-specific tolerance ranges. For example, *Micropsectra* species are often found in high oxygen environments (Little and Smol 2001), whereas *Chironomus anthracinus*, and *Procladius*, have demonstrated higher tolerances for hypoxic and anoxic conditions (Nagell 1978; Hamburger et al. 1994; Quinlan et al. 1998).

In addition to chironomids, insect larvae from the family Chaoboridae are also considered in some paleolimnological assessments of lake oxygen (Quinlan and Smol 2010b). Diel vertical migration (a coordinated daily movement up and down the water column) is observed in

chaoborids, a behaviour which is enhanced by the presence of fish (Dawidowicz et al. 1990; Shigeto and Hanazato 2008). In lakes with fish, chaoborids utilize anoxic hypolimnia and bottom sediments as refugia from predation (Gosselin and Hare 2003). Since most of the lakes considered in the following study contain fish, the presence and abundance of *Chaoborus* should be an important indicator of anoxic conditions (Quinlan and Smol 2010a).

The autoecology of chironomids and chaoborids in association with dissolved oxygen has enabled the development of dipteran-based oxygen inference models (Quinlan et al. 1998; Quinlan and Smol 2001; Quinlan and Smol 2010b), the basis of which was applied in the following study for Algonquin Park lakes.

In Chapter 2, the autoecology of chironomids and chaoborids along a volume-weighted hypolimnetic oxygen (VWHO) gradient was established using extended Huisman-Olff-Fresco (eHOF) models. VWHO eHOF relationships from the present Algonquin Park lake study was compared to a previous Muskoka-Haliburton lake study (Quinlan and Smol 2001) to determine if any post-1995 limnological changes have altered the dipteran-VWHO relationship for various taxa. Similarly, limnological associations with volume-weighted hypolimnetic oxygen (VWHO) will be established for both studies and compared to determine whether the relationship between VWHO and other lake variables have changed over time. The ultimate goal of this chapter is to develop a new dipteran-based VWHO inference model for reconstructing past VWHO values, as climate has substantively changed in this region since the original VWHO inference model was generated.

In Chapter 3, the newly developed inference model for Algonquin Park was used in a top-bottom analysis to determine whether lake water quality (as hypolimnetic oxygen) has changed over time, and if private cottages have significantly impacted VWHO. Lakes will be assessed

based on changes in dipteran assemblages between historic and present sediment samples, with further emphasis on VWHO indicator taxa. Inferred change in VWHO over time will be assessed for all lakes to determine whether significant regional reductions in VWHO have occurred since the onset of the industrial revolution (ca 1850 CE). Finally, a causal model will identify whether anthropogenic TP inputs from private cottages are having a significant impact on VWHO.

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1.4 Figures and Tables

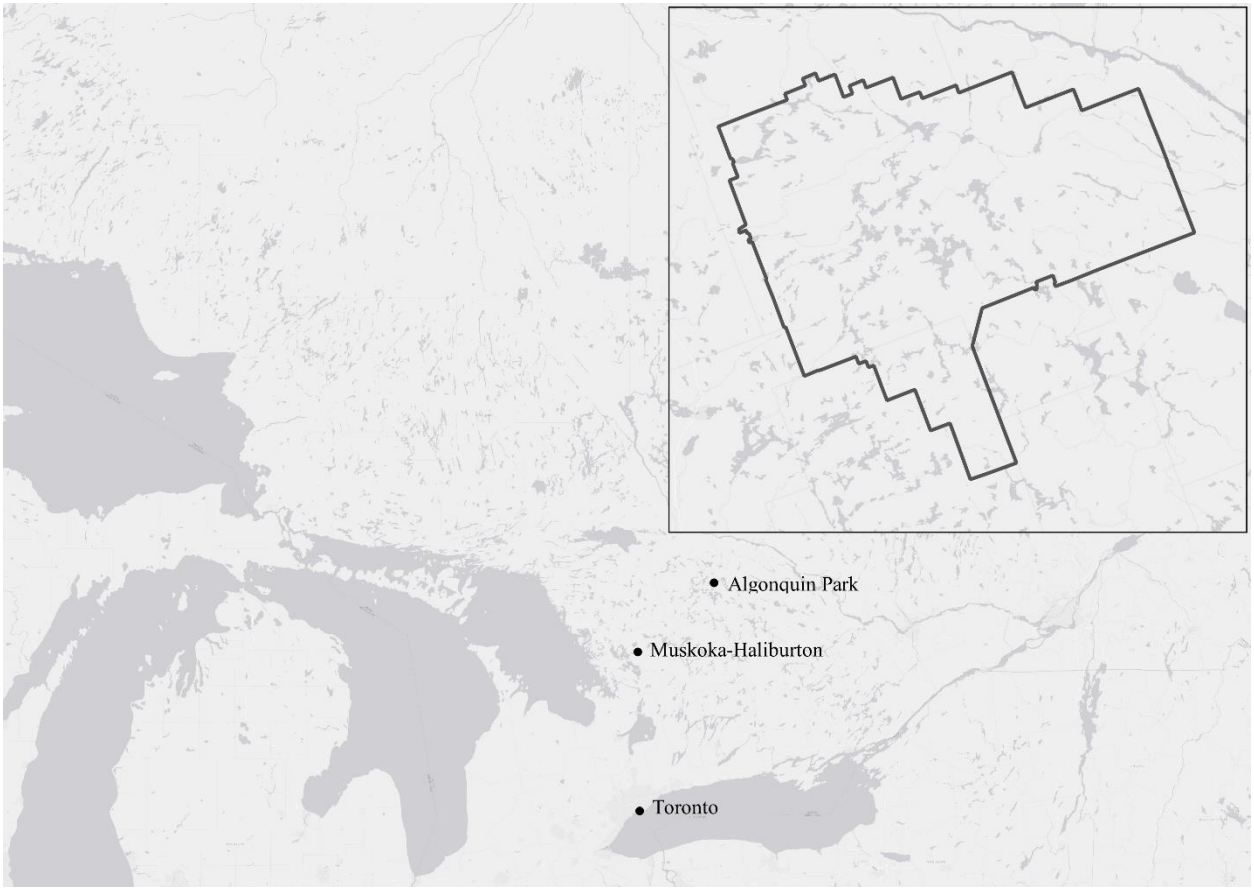

Figure 1.1 Map of Algonquin Park boundary, Ontario. Map generated with ESRI imagery.

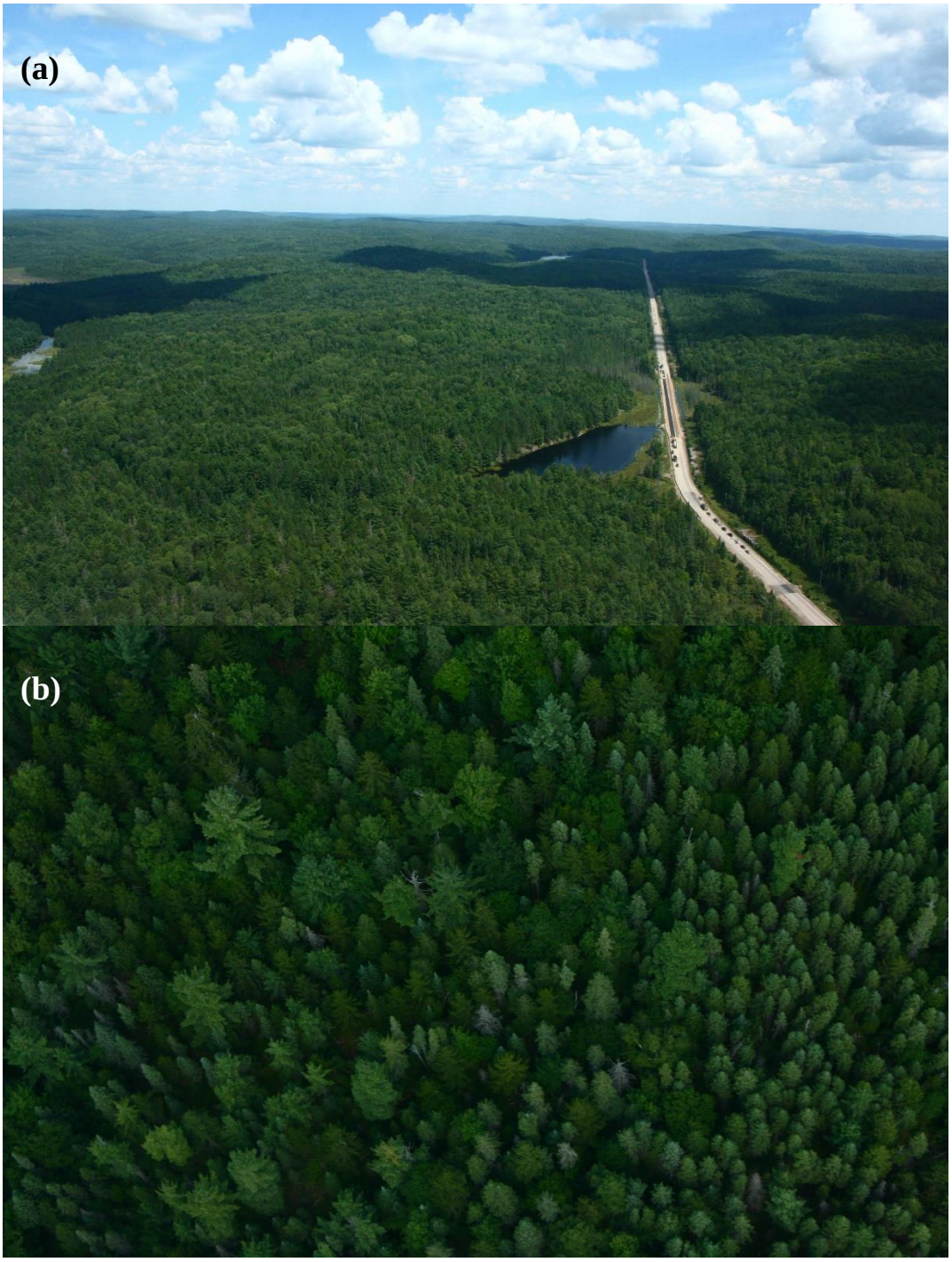

Figure 1.2 Photos of Algonquin Park showing (a) The Highway 60 corridor, and (b) Aerial view of mixed forest. Photos courtesy of Patrick Moldowan.

Table 1.1 Distribution of private cottages over 22 lakes in Algonquin Park, Ontario. Lakes are listed in ascending order of number of cottage leases. Bonita is not included in the following study as there was no evidence of stratification, and therefore, no VWHO could be calculated.

Lake	Number of cottages
Bonita	1
Cauchon	1
Galeairy	1
Little Joe	1
North Tea	1
Rain	1
Brule	2
Grand	2
Manitou	2
Kioshkokwi	3
Radiant	4
Little Cauchon	5
Joe	6
Lake of Two Rivers	6
Whitefish	9
Cedar	10
Tea	10
Source	15
Rock	24
Canoe	48
Cache	62
Smoke	89

Chapter 2: Limnological and biotic relationships with volume-weighted hypolimnetic oxygen (VWHO) in Algonquin Park lakes and the development of a new dipteran-VWHO inference model

2.1 Introduction

Algonquin Park lakes are under threat from multiple stressors which may interact to reduce hypolimnetic oxygen concentrations. Climate warming in the region has increased the ice-free period, leading to strengthened summer stratification (Futter 2003; Winder and Schindler 2004) and prolonged hypolimnetic anoxia (Zhang et al. 2015). Additionally, anthropogenic nutrient inputs (e.g. phosphorus) can lead to cultural eutrophication which is one of the primary water quality concerns due to the resulting increase in algal blooms (Schindler 1974; Schindler 2012) and fish kills (Lu and Hodgkiss 2004; San Diego-McGlone et al. 2008). Despite the relatively low measured phosphorus concentrations in lakes throughout Algonquin Park, there have been multiple documented instances of algal blooms. For example, Dickson Lake, found in the Algonquin Park interior, experienced a sudden algal bloom in 2014 which reappeared in 2015 and caused a downstream bloom in Lake Lavieille (Favot et al. 2019). Interestingly, a multi-proxy paleolimnological analysis of the Dickson Lake blooms did not show any strong signals to the cause (Favot et al. 2019), although it seems likely that regional shifts in climate may be responsible. On a larger scale, climate warming in south-central Ontario has been suggested as a contributing factor to the significant increases in algal blooms observed between 1994 and 2009 (Winter et al. 2011).

Regional climate warming has increased the mean annual air temperature of Algonquin Park by 1.07^{o} C since 1915 (Favot et al. 2019) and this can result in rapid warming of surface

water temperatures (Schneider and Hook 2010). Increasing water temperatures can have detrimental impacts on cold-water fish species if hypolimnetic oxygen concentrations are insufficient to provide suitable cold-water habitat for such fish species (Evans 2007). In Algonquin Park, reductions in volume-weighted hypolimnetic oxygen (VWHO) can result in shifts in benthic assemblages to hypoxic- and anoxic-adapted community composition while the effects on brook trout (*Salvelinus fontinalis*) and lake trout (*Salvelinus namaycush*) may be fatal (Evans 2007). Consequently, deviations from the natural or background levels of volume-weighted hypolimnetic oxygen can be an important determinant for lake water quality and ecosystem health.

Unfortunately, the lack of historic lake information makes assessments of change difficult without knowledge of previous lake conditions. As such, paleolimnological methods are often used to reconstruct past environmental conditions based on the relationship between present biological proxies and an environmental gradient of interest (Smol 1992). Chironomids (Chironomidae) have been associated with taxa-specific oxygen thresholds enabling the use of subfossil chironomids as biological proxies for inferring historic oxygen levels (Brodersen and Quinlan 2006). A chironomid-based VWHO inference model has already been developed for nearby south-central Ontario lakes (Quinlan and Smol 2001), however, this study examined surficial sediments acquired more than two decades before the field sampling conducted for this study; regional climate warming has persisted in Algonquin Park in the decades following Quinlan and Smol (2001) such that present-day chironomid autoecology may reflect community responses to warmer temperatures. Moreover, the uniquely domed landscape of Algonquin Park is responsible for microclimate differences across the park which may further impact

chironomid-environment relationships compared to those observed for the Muskoka-Haliburton region.

Broadly the aim is to identify whether dipteran taxa can still be used to infer VWHO in a region influenced by multiple environmental stressors. We are comparing limnological and biological relationships between the present study conducted in AP and the Quinlan and Smol (2001) conducted in Muskoka-Haliburton region in 1991. Our research questions were (1) Did the relationship between limnological conditions and volume weighted hypolimnetic oxygen change over time? (2) Did the response of indicator dipteran taxa to VWHO change over time? (3) Can inference models be used to relate present-day subfossil assemblages and VWHO?

2.2 Methods

2.2.1 Data collection, field sampling, and laboratory methods

All study lakes (n = 52) were sampled from within the Algonquin Park boundary in south-central Ontario (Figure 2.1, Figure 2.2, Table 2.1). Maximum depths of the study lakes range between 8.2 and 65.3 m.

Lake bathymetric data was collected from the Ministry of Natural Resources and Forestry (MNRF) for all lakes except Galeairy Lake. Summer temperature and oxygen profiles were collected in 2015 using a YSI-sonde. Present-day volume-weighted hypolimnetic oxygen (VWHO) was calculated for each lake using the following equation:

$$VWHO = \frac{\Sigma([O_2]_s * V_s)}{V_t}$$

Where $[O_2]_s$ is the oxygen concentration for the stratum and V_s is the volume of the stratum and V_t is the total hypolimnetic volume.

Since average VWHO at September 15 for three years (1995, 2006, 2010) of oxygen sampling at Galeairy Lake was 2.6 mg O_2 L^{-1} (OMNR 2013), this value was assigned as the present-day VWHO for Galeairy Lake.

The depth of the upper limit of the hypolimnion was defined by the depth below the thermocline at which the temperature changed less than 1 ºC with a 1 m change in depth. VWHO was calculated at 1 m stratum resolution as it is preferred over 2 m resolution without *a priori* knowledge of lake hypolimnetic volumes (Quinlan et al. 2005). Temperature and oxygen profiles were missing for some lakes sampled in 2015 so late-summer profile data was collected by the MNRF. Some lakes have been defined as "warm-thin" lakes (Table 2.2), due to the technical presence of a thermocline yet a lack of a cold hypolimnion (e.g. the average volume-weighted hypolimnetic temperature for Mouse Lake is 12.7 ºC) and may be as thin as a single metre-thick stratum (Quinlan, unpublished data).

Surficial lake sediments were processed at 0.5 cm resolution for the top (1-2 cm) of each sediment core. The sediment samples were subsampled (5-15 g wet mass) and digested in 10% potassium hydroxide solution (KOH). The sediments in KOH were heated at 75ºC and stirred using an over-head stirrer for 5 minutes. Sediments were subsequently washed through nested 212µm and 106µm mesh sieves with DH_2O. Retained residues were then washed with 95% ethanol and placed in a flat-bottomed dish. Using a stereo-microscope at 30–40× magnification, sub-fossil dipteran head capsules were mounted on glass microscope slides in Entellan. Genus and species level identifications were made using a compound microscope at 400–1000× magnification.

2.2.2 Numerical analyses

Did the relationship between limnological conditions and volume weighted hypolimnetic oxygen change over time?

We compared the relationship between different limnological gradients with VWHO using the 52 lakes sampled in AP in 2015 to the 80 lakes in Muskoka-Haliburton in 1991 (Quinlan and Smol). All variables were $\log_{10}$ transformed to normality for both datasets, except for DOC, SO_4^{2-}, pH, and VWHO. Since the sample size for Muskoka-Haliburton was larger, we restricted the comparison for the ranges in variables (e.g. TP, TN, SA) that were consistent between the two studies. We first calculated Pearson correlation coefficients between each limnological variable and VWHO for both AP and Muskoka-Haliburton studies. Second, we tested the differences between VWHO correlations for Algonquin Park and Muskoka-Haliburton using the cocor v.1.1-3 package (Diedenhofen and Musch 2015) in RStudio v.1.1.456 (RStudio Team 2016) which uses Fischer *z*-transformation to test the statistical similarity of correlation coefficients (Diedenhofn and Musch 2015).

Did the response of indicator dipteran taxa to VWHO change over time?

We used a redundancy analysis (RDA) to identify important environmental gradients affecting present-day dipteran assemblages using CANOCO v.4.5 (ter Braak and Smilauer 2002). Significance testing included backwards elimination and forward selection with 999 Monte Carlo permutations.

Huisman-Olff-Fresco (HOF) hierarchical modelling (Huisman et al. 1993) was to associate species presence data with VWHO conducted in R using eHOF package v.1.8 (Jansen and Oksanen 2017). The original five model outputs ranged in complexity from flat to skewed

unimodal and have been used to assess the shape of the relationship between taxa and the environmental gradient of interest. The extended HOF modelling package (eHOF) includes two additional bimodal response curves (Jansen and Oksanen 2013). Interpretations of these bimodal response curves may be limited for higher level taxonomic classifications which include different species and species types in the same taxonomic group. Dipteran autoecological responses for Algonquin Park were compared with those from Muskoka-Haliburton (Quinlan and Smol 2001) to determine if dipterans are displaying similar relationships with VWHO 30 years later. eHOF models were generated for taxa which occurred in at least 10 lakes in both datasets where 21 taxa met this criterion.

Can inference models be used to relate present day subfossil assemblages and VWHO?

We used present-day subfossil dipteran assemblages and VWHO measurements to calibrate multiple inference models. The best models were chosen based on the lowest root-mean squared error of prediction (RMSEP). Additionally, the dipteran data from Algonquin Park was combined with that from Muskoka-Haliburton to assess the performance of a more general south-central Ontario model. Five primary approaches were used in developing the dipteran-based VWHO inference models: partial-least squares (PLS), weighted-averaging (WA), weighted-averaging partial-least squares (WA-PLS), and the modern analogue technique (MAT). All transfer functions were developed using C2 (Juggins 2007). The analogue v.0.17-3 package (Simpson and Oksanen 2019) in R was used to determine the appropriate number of analogues to select when using the modern analogue technique (MAT). MAT is a transfer method which determines a set of modern analogues based on the similarity in community structure with the fossil sample to be reconstructed (Jackson and Williams 2004). Analogue similarity was assessed

using chord distance, and the number of analogues (k) was selected based on the model with the lowest root-mean squared error of prediction (RMSEP).

The selected inference models for Algonquin Park, Muskoka-Haliburton (Quinlan & Smol 2001), and the combined model (Algonquin Park and Muskoka-Haliburton) were tested on a stratigraphic subfossil Dipteran assemblages from Dickson Lake (Favot et al. 2019), which is located within Algonquin Park, to determine the similarity of VWHO inferences using these different dipteran-based inference models.

2.3 Results

Did the relationship between limnological conditions and volume weighted hypolimnetic oxygen change over time?

We used data from a previous study of the Muskoka-Haliburton area to represent past limnological conditions to assess whether there have been any notable changes in the region after 30 years. Approximately one third of limnological variables were statistically significantly correlated with VWHO for Algonquin Park lakes (p-value < 0.05). Contrastingly, 75% of the limnological variables in the Muskoka-Haliburton lake set (Quinlan and Smol 2001) were significantly correlated with VWHO ($p < 0.05$) (Table 2.3). When comparing the correlation coefficients between Muskoka-Haliburton and Algonquin Park, 37.5% of correlations were significantly different (Table 2.4), notably, DOC-VWHO, TN-VWHO and TP-VWHO. In Algonquin Park, the correlation coefficients between VWHO and DOC, TN, and TP were all near zero values, and in Muskoka-Haliburton the coefficients ranged from -0.57 to -0.68. Both lake sets produced significant, positive correlations for the lake morphological variables surface area – SA, mean depth – Z_{mean}, and maximum depth – Z_{max} with VWHO (Table 2.3).

Did the response of indicator dipteran taxa to VWHO change over time?

Seventy-one dipteran taxa were identified from surficial sediments to high taxonomic resolution (species/species group). Forty-seven taxa were found in at least two lakes with at least a 2% relative abundance. *Procladius* was the most common occurring taxon, occurring in 89% of lakes (Table 2.5). The highest dipteran diversity (*Simpson's D* = 0.96) was observed for Cedar Lake and the lowest dipteran diversity ($D = 0.73$) was found in Lake La Muir (Table 2.6) which was dominated by *Microspectra contracta* with a 48% relative abundance (Table 2.5).

Redundancy analysis (RDA) of subfossil dipteran assemblages and environmental gradients indicated volume-weighted hypolimnetic oxygen (VWHO) and maximum depth (Z_{max}) to be significant gradients ($p < 0.05$) associated with RDA axis 1, and axis 2, respectively (Figure 2.3). When including only significant gradients, the first two axes explained 12.27% of the total variation in dipteran assemblages, with RDA axis 1 accounting for 10.34%. The lakes with high VWHO and deep Z_{max} had the lowest RDA axis 1 scores and include Louisa, Cedar, Ralph Bice, Lavieille, and Kiosk (Figure 2.4). Mouse, Tea, Little Joe, Dickson, and Clydegale had the highest RDA axis 1 scores, associated with shallow, low oxygen lakes. Lakes with intermediate Z_{max} and moderate to high VWHO included Joe, Harry, McKaskill, Welcome, Rosebary, Shirley and Whitefish lakes, and these were located in the centre of the RDA ordination. Dipteran taxa associated with high VWHO and large Z_{max} include *Micropsectra contracta*, *Sergentia coracina*, *Heterotrissocladius marcidus*, *Parakiefferiella nigra*, *Sergentia longiventris*, *Micropsectra insignilobus*, *Paracladius*, and *Heterotrissocladius maeaeri*. Conversely, *Chaoborus*, *Procladius*, *Stempellinella/Zavrelia*, *Chironomus*, and *Cladopelma lateralis* were associated with shallower lakes and low VWHO. Taxa found close to the origin of

the RDA included *Stictochironomus rosenschoeldi*, *Corynoneura* type a, *Psectrocladius sordidellus*, and *Tanytarsus lugens*.

The most common autoecological response curves produced in eHOF for Algonquin Park lakes were of type 7, where 48% of 21 taxa showed significant bimodal responses (Table 2.8). Three of the Algonquin Park taxa, and five of the Muskoka-Haliburton taxa had no significant response (model I) to VWHO (Table 2.9). Of the taxa with no relationship to VWHO, only *Synorthocladius* shared a flat-line model I response curve in both datasets. Similarly, *Cladotanytarsus mancus*, *Chaoborus*, *Heterotrissocladius*, *Micropsectra*, and *Sergentia* shared significant response types in both datasets (Table 2.8 and Table 2.9). Although *Chironomus* showed different response types in Algonquin Park compared to Muskoka-Haliburton, the first optimum is the same between datasets (0.2 mg O_2 L^{-1}). The fitted HOF responses for *Heterotrissocladius* (Figure 2.5), *Micropsectra* (Figure 2.6), *Sergentia* (Figure 2.7), *Chironomus* (Figure 2.8), and *Chaoborus* (Figure 2.9) were plotted for both locations to demonstrate their use as VWHO indicators.

Can inference models be used to relate present day subfossil assemblages and VWHO?

We found three inference models that similarly predicted VWHO. For the Algonquin Park lakes, a one component partial-least squares (PLS1) dipteran-VWHO inference model had the best predictive performance (RMSEP = 1.7 mg O_2 L^{-1}) (Table 2.10, Figure 2.10). Of the models which combined dipteran data from Algonquin Park with Muskoka-Haliburton (Quinlan and Smol 2001), there were two models which produced the lowest RMSEP of 1.9 mg O_2 L^{-1}. The best models included a two-component weighted-averaging partial-least squares (WA-PLS C2) model and a modern analogue technique (MAT) model with $k = 6$ (Table 2.11). The WA-PLS C2

model was selected as the best combined model (Figure 2.11) as, while it had comparable RMSEP values, it had substantively lower maximum jackknifed bias (compared to the one-component WA-PLS model and the WMAT and MAT models (2.0 vs 2.8, 2.9, 2.8 mg O_2 L^{-1}, respectively).

We found general agreement in VWHO trends over time when extrapolating our three inference models to VWHO reconstructions for Dickson Lake (Favot et al. 2019) (Figure 2.12). However, there were differences in magnitude. The combined model displayed greater VWHO variability and often produced lower VWHO values than the Muskoka-Haliburton and Algonquin Park models. However, for an individual interval, VWHO estimates are similar between models and differences between model estimates often did not exceed the lowest model RMSEP of 1.7 mg O_2 L^{-1} (from the Algonquin Park inference model).

2.4 Discussion

We used data from a previous Muskoka-Haliburton study (Quinlan and Smol 2001) to represent past conditions and found that the associations between limnological variables and VWHO changed over time. Strong negative associations were observed for DOC, TP, and TN with VWHO in 1991, however, present-day associations for these variables with VWHO were non-significant. Significant associations between lake morphometric variables and VWHO remained consistently positive over time, which reflects well-established relationships between lake size and lake oxygen. Despite the changes in associations between limnological conditions and VWHO, dipteran indicators continued to respond similarly to oxygen gradients over time. Since VWHO was a significant gradient affecting Algonquin Park dipteran assemblages, these

assemblages were used in association with present-day VWHO measurements to calibrate multiple VWHO predictive models with similar predictive performance.

Did the relationship between limnological conditions and volume weighted hypolimnetic oxygen change over time?

For the present-day Algonquin Park study, we found significant positive relationships between SA, Z_{mean} and Z_{max}, and VWHO, such that larger deeper lakes have higher VWHO in Algonquin Park. We did not detect significant relationships between water chemistry (e.g. DOC, pH, nutrients) and VWHO. Conversely, the earlier Muskoka-Haliburton study found similar positive significant relationships between lake size and VWHO such that larger deeper lakes have higher VWHO, however, in contrast we found significant negative relationships for TN, TP, DOC. Therefore, VWHO values in Muskoka-Haliburton were lower in lakes with higher TP, TN and DOC concentrations, but this was not the case for Algonquin Park. We found that over time, the relationships between VWHO and TN, TP and DOC have significantly changed.

The lack of significant relationships between VWHO, DOC and nutrients in the 2015 Algonquin Park dataset compared to the 1991 Muskoka-Haliburton dataset may be because of the ongoing limnological changes that have occurred in the region during the previous 30+ years. There have been long-term declines in phosphorus export from watersheds into lakes (Dillon & Molot 2005; Eimers et al. 2009), with associated declines in lake total phosphorus and cholorphyll *a* (Palmer and Yan 2013a). Crossman et al. (2016) suggests that observed long-term declines of total phosphorus in lakes in this region may be due to long-term recovery from wetland disturbances arising from road construction that occurred in the 1970s, however this would not be the case in many Algonquin Park lake watersheds where there are no roads. In contrast, Algonquin Park lakes would be more vulnerable to ecologically substantive calcium

declines (i.e. negative effects on zooplankton communities) compared to Muskoka-Haliburton lakes (Reid & Watmough 2013).

There have also been long-term increases in DOC in lakes in this region (Palmer and Yan 2013a), possibly due to climate-change associated increases in runoff (Watmough et al. 2005), coupled with recovery from acidification, resulting in greater DOC watershed export into lakes. This 'lake brownification' would decrease primary production in lakes due to decreased water transparency that are decoupled from changes in nutrients (Hessen et al. 2017, Leach et al. 2019), with possible consequences on oxygen depletion. As this region has also continued to warm in the last few decades, this would also lead to increased summer hypolimnetic oxygen depletion unconnected to changes in DOC or nutrients due to a longer stratification period and a shorter period of spring mixing (Stasko et al. 2012).

The effects of these limnological changes (e.g. declines in TP, increases in DOC, warmer climate, Ca declines), their resultant ecosystem effects (e.g. algal, zooplankton & fish productivity), and consequences on hypolimnetic oxygen (both declines and increases in oxygen depletion may result) occurring simultaneously in south-central Ontario lakes, with possible synergistic and antagonistic interactions, makes it difficult to predict their cumulative effects on summer hypolimnetic oxygen concentrations, and makes it difficult to pinpoint specific changes as possible drivers of the present-day lack of correlation between VWHO and DOC and nutrients across a regional dataset of lakes. Nelligan et al. (2019) noted that long-term VWHO changes in six south-central Ontario lakes were a function of multiple drivers including changes in regional climate, primary productivity and water transparency, however their study design did not permit an analysis of how correlations of VWHO with other limnological gradients changed over time. Consequently, due to the scope of data of this study we did not explore these VWHO correlation

differences further, however, these results emphasized the need to test dipteran responses to VWHO gradients in both the Muskoka-Haliburton (Quinlan & Smol 2010) and this present study to determine if these datasets could be merged into a larger combined inference model.

There is a clear relationship between morphological features and VWHO, as these associations were strongly positive for both lake sets. These findings were further supported by the selection of Z_{max} as a significant gradient influencing dipteran assemblages in the present study and in Quinlan and Smol (2001) likely because deep lakes will have higher VWHO due to the much larger volume of water entrained in the thicker hypolimnion, producing a 'dilution' effect of the biological and chemical oxygen demand of organic material settling into the hypolimnion. Additionally, deep lakes will have proportionally greater habitat that is cold and where chironomid diets are dominated by saprobic sources, favoured by profundal taxa, compared to shallow warm surface waters with higher algal productivity and macrophyte or hard substrate habitat, favoured by littoral taxa.

Did the response of indicator dipteran taxa to VWHO change over time?

The RDA showed that the distribution of dipteran taxa in Algonquin Park based on VWHO and lake depth is reflective of ecological preferences of dipteran taxa in other published research. Taxa which were found in association with high VWHO and deep Z_{max}, *Micropsectra*, *Heterotrissocladius*, *Parakiefferiella nigra*, and *Paracladius* have been formerly reported in similar habitats (Little and Smol 2001; Korhola et al 2000; Nazarova et al. 2011). However, *Sergentia coracina*, often considered a mesotrophic taxon with moderate oxygen requirements (Quinlan et al. 1998; Jyväsjärvi et al. 2013) was associated with high VWHO and deep Z_{max} in this present study (Figure 2.7). This finding is similar to that of Little and Smol (2001) who

found *Sergentia* to have the second highest RDA axis 1 score and postulated that this discrepancy may have been due to a lack of mesotrophic lake samples, which is an important consideration for this study as Algonquin Park lakes are primarily oligotrophic (with low levels of phosphorus), and yet have numerous lakes with anoxia and hypoxic hypolimnia. *Sergentia coracina* is a profundal taxon, showing preference for deep water (Frossard 2013; Korhola et al. 2000). The taxa most representative of low VWHO and shallow Z_{max} in Algonquin Park was *Chaoborus*. In lakes which contain fish, *Chaoborus* presence is an indicator of an anoxic hypolimnion or an anoxic bottom stratum (Quinlan and Smol 2010) as these conditions are inhospitable to fish and provide daytime refuge for chaoborids (Dawidowicz et al. 1990). Likewise, the low VWHO taxa *Cladopelma*, *Chironomus*, and *Procladius* have been found to have high tolerance to prolonged anoxia (Quinlan et al. 1998) and as such are often found in oxygen-depleted environments (Little and Smol 2001; Jyväsjärvi et al. 2013).

Autoecological response curves generated through eHOF modelling produced VWHO optima which generally agreed with RDA results. The taxa associated with higher VWHO conditions in the RDA, primarily *Heterotrissocladius*, and *Micropsectra*, had correspondingly high VWHO optima (Table 2.8). VWHO was found to be explain a significant amount of variation in dipteran assemblages in both Algonquin Park and Muskoka-Haliburton lakes (Quinlan and Smol 2001), however, individual taxon responses varied between studies. Given the changes that have occurred in the region over the last few decades, including declines in sulphate and increases in pH and DOC with recovery from acidification, and declines in lake TP (Palmer and Yan 2013b) the differences in dipteran-VWHO relationship between the two studies may have been due to changes in non-oxygen variables that influenced dipteran ecology. Indicators for calculating the Benthic Quality Index (BQI) (Wiederholm 1976),

Heterotrissocladius, *Micropsectra* and *Sergentia*, showed the same model response types with similar optima between the two studies. The BQI assigns indicator values to taxa based on observed associations with lake trophic status (Sæther 1979). *Heterotrissocladius* is often found in oligotrophic to ultra-oligotrophic systems (Sæther 1979) and eHOF analysis for *Heterotrissocladius* in Algonquin Park resulted in the highest taxon-VWHO optimum of 25.1 mg O_2 L^{-1}. Although a VWHO optimum of 25.1 O_2 L^{-1} is higher than any measured VWHO value in the study lakes, this number reflects the monotonic pattern of increase for *Heterotrissocladius* as the response curve approaches the upper end of the observed VWHO gradient; this number is the model estimate from an eHOF model type 7 fit that minimizes the model AIC. *Chironomus* have also been used as indicators of highly eutrophic conditions with low oxygen (Wiederholm 1976; Sæther 1979), however, the model response type of *Chironomus* differed between Algonquin Park and Muskoka-Haliburton. Despite the difference in model type, the first optimum for both models occur at 0.2 mg O_2 L^{-1} which supports the use of *Chironomus* as indicators of eutrophic conditions and severe anoxia. Since *Chaoborus* use anoxic hypolimnia and sediments to escape fish predation (Gosselin and Hare 2003), the presence of *Chaoborus* can be used as a low VWHO indicator in fish lakes (Quinlan and Smol 2010). *Chaoborus* showed the same model type responses in Algonquin Park and Muskoka-Haliburton (Figure 2.9) with VWHO optima less than 2 mg O_2 L^{-1}. The eHOF results for *Heterotrissocladius*, and *Micropsectra* are often associated with oligotrophic conditions with minimal oxygen depletion (Meriläinen and Hamina 1993; Sæther 1979) and previous studies have noted declining abundances of these taxa in association with declining oxygen levels (Brodersen and Quinlan 2006). Taxon responses to VWHO for *Heterotrissocladius* and *Micropsectra* were similar for Algonquin Park and Muskoka-Haliburton, supporting their use as ecological indicators of high VWHO.

Can inference models be used to relate present day subfossil assemblages and VWHO?

Merging taxa into higher taxonomic groups, following Quinlan and Smol (2001) enabled comparisons between the two studies, however, this may have also complicated the resulting eHOF outputs. Chironomid identification has advanced since Quinlan and Smol (2001) allowing for identification to lower taxonomic levels (species/species group) whereas the previous study identified chironomids to genus/genus group. This is an important consideration if different species within the same genus display differing affinities toward VWHO. Without knowing which species are significantly contributing to the genus level identifications for Quinlan and Smol (2001) it is not possible to determine whether the genus groups used to compare taxa between Algonquin Park and Muskoka-Haliburton were formed by the same species ratios. Additionally, merging species into genus-level groups may also be responsible for bimodal eHOF response curves, like those observed for the genus group *Micropsectra*. In the present, Algonquin Park study, *Micropsectra* contains three species with significant eHOF optima, *Micropsectra contracta* (8.5 mg O_2 L^{-1}), *Micropsectra insignilobus* (1.9 – 9.4 mg O_2 L^{-1}), and *Micropsectra radialis* (0.7 mg O_2 L^{-1}). The combination of these three unimodal species responses may have resulted in the bimodal response for the *Micropsectra* genus in the combined-dataset inference model (Figure 2.6).

The dipteran-VWHO models performed similarly on a test dataset for Dickson Lake, however, it is not possible to determine which model best represented the Dickson Lake VWHO trends without past VWHO measurements. An important consideration here is the difference in taxonomic resolution between models, where the Algonquin Park model identified chironomids to a finer taxonomic resolution, such that the Muskoka-Haliburton and combined models had more taxa at the supra-species level. For chironomid taxa with differing VWHO preferences, the

merging of taxa to a lower resolution may add statistical noise to the predictions. However, since all models generated similar VWHO trends the noise added may not be substantive enough to warrant concern. For studies which seek to identify chironomids to species level (e.g. the test set from Favot et al. 2019), the new Algonquin Park model may be preferable as information may be lost in the merging process. However, despite the lower predictive performance of the combined model, it may be more generally applied to the southern-Ontario region as it is representative of a larger geographical region and greater limnological variability, as it includes more productive mesotrophic lakes and lakes whose watersheds include metasedimentary bedrock.

Although associations between different limnological variables and VWHO have changed over time, dipteran communities have been robust to these changes. This indicates that dipteran communities in south-central Ontario are relatively insensitive to changing environmental conditions unless they directly influence VWHO concentrations. This dipteran-VWHO relationship enabled us to establish multiple predictive models which can be used as a tool for determining baseline VWHO values which have not been defined for many Algonquin Park lakes.

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2.6 Figures and Tables

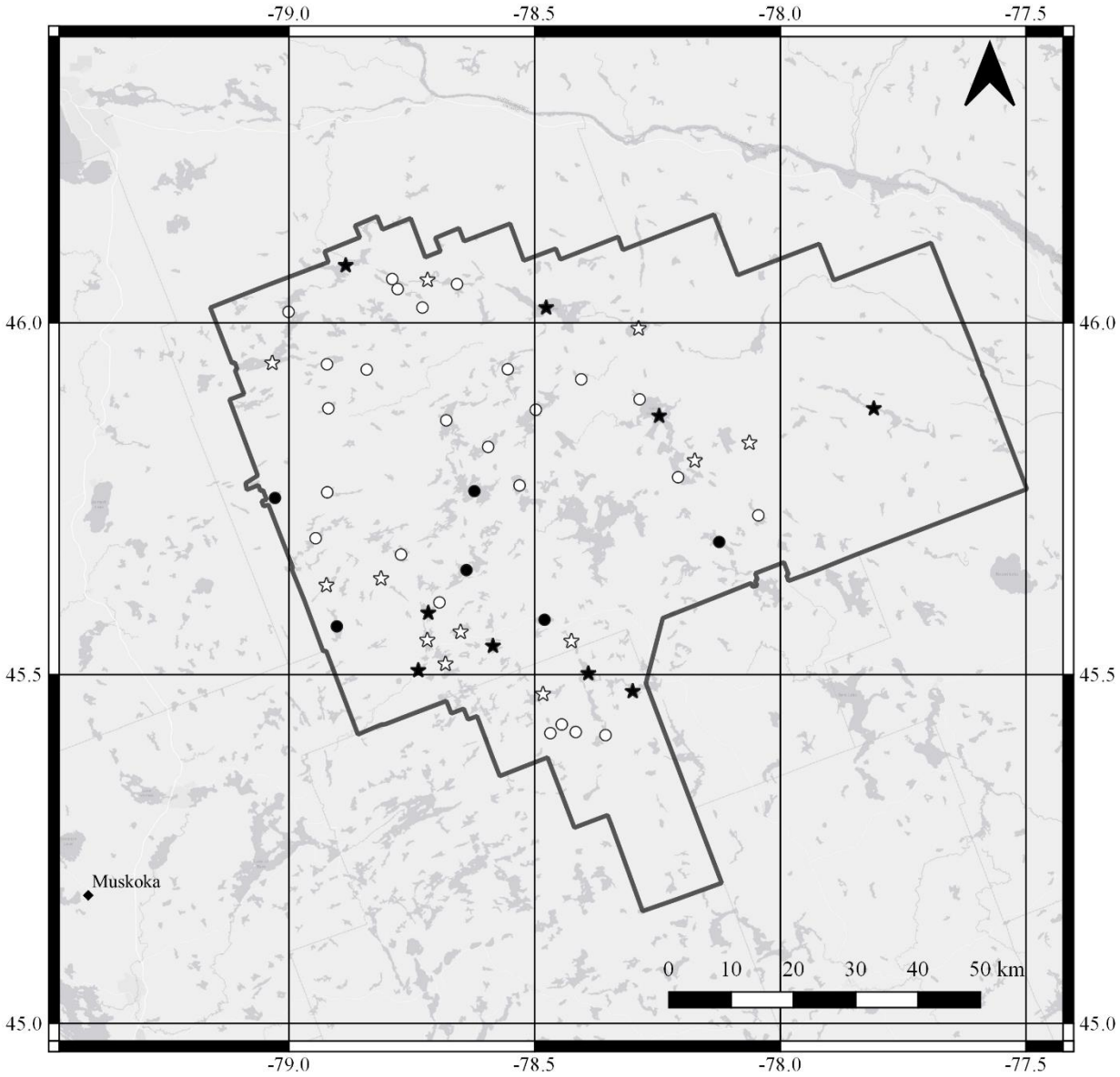

Figure 2.1 Map of study lakes (n = 52) showing Algonquin Park boundary where stars represent study lakes with cottages, and circles represent study lakes without cottages. White markers indicate lakes with natural hydrology and black markers indicate the presence of a dam at the outlet.

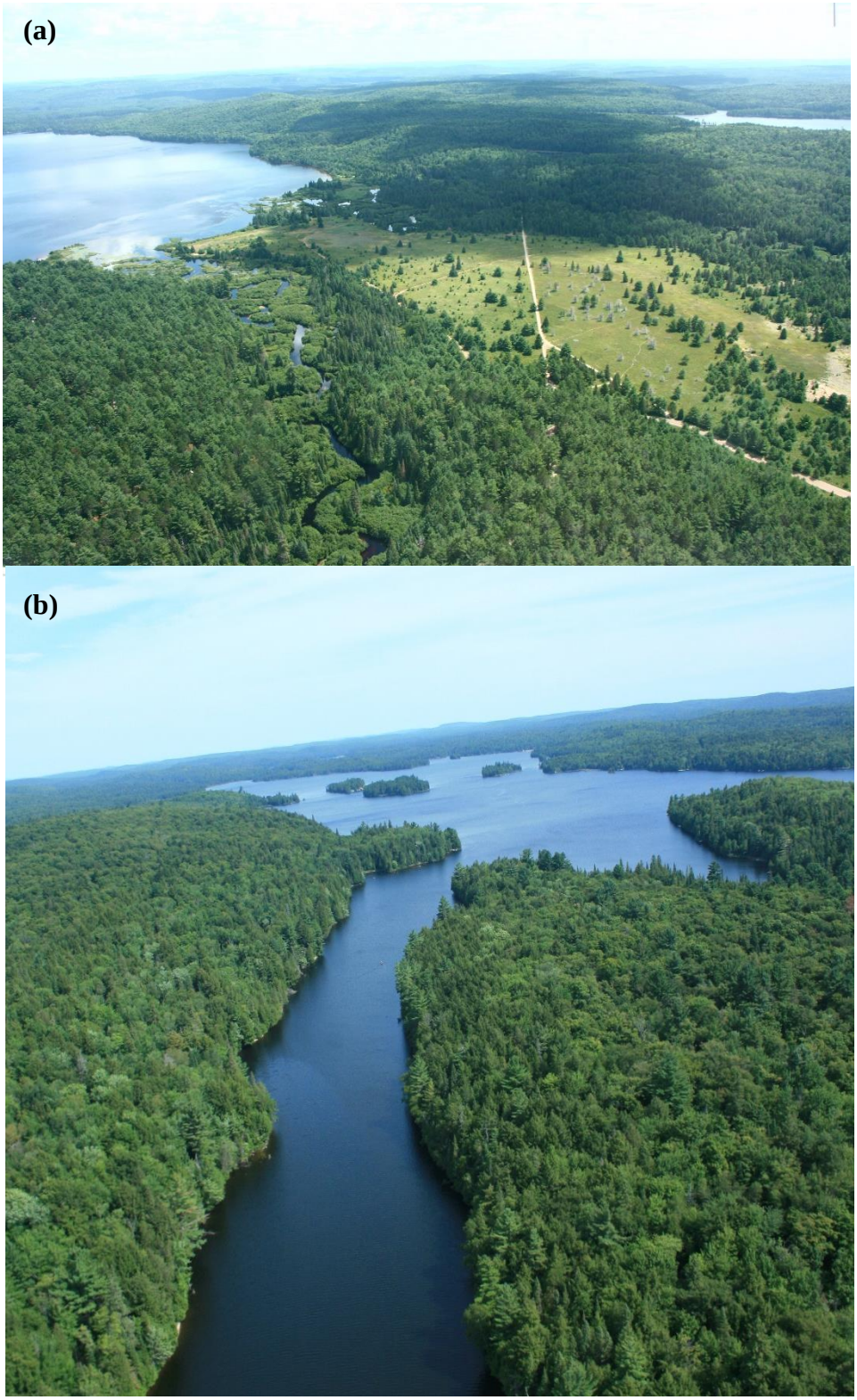

Figure 2.2 Two study lakes (a) Lake of Two Rivers, and (b) Joe Lake, Algonquin Park. Photos courtesy of Patrick Moldowan.

Table 2.1 Location and maximum depth of study lakes in Algonquin Park, Ontario.

Lake	Latitude (ºN)	Longitude (ºW)	Z_{max} (m)
Big Trout	45.76139	78.62250	33.1
Biggar	45.94139	78.92250	32.9
Birchcliffe	45.93389	78.84167	9.3
Brule	45.63694	78.81250	26.7
Burnt Island	45.64917	78.63861	36.9
Burntroot	45.86194	78.67972	24.6
Cache	45.54083	78.58472	34.4
Canoe	45.54917	78.71833	43.0
Catfish	45.93444	78.55444	22.9
Cauchon	46.06056	78.71778	43.6
Cedar	46.02139	78.47639	58.6
Clydegale	45.41361	78.35556	12.3
Dickson	45.78111	78.20778	18.6
Farncomb	45.89167	78.28611	17.0
Galeairy	45.47611	78.30028	22.9
Gibson	45.87889	78.91972	16.0
Grand	45.87861	77.80944	42.5
Harry	45.42889	78.44472	24.4
Hogan	45.87694	78.49750	38.5
Joe	45.58806	78.71639	25.8
Kioshkokwi (Kiosk)	46.08111	78.88444	47.5
La Muir	45.82417	78.59444	44.1
Lake of two Rivers	45.57833	78.47972	40.5
Lavieille	45.86806	78.24639	51.9
Little Cauchon	46.05472	78.65778	50.3
Little Crooked	45.82778	78.18889	8.8
Little Dickson	45.80472	78.17389	25.9
Little Joe	45.60306	78.69361	14.5
Louisa	45.47222	78.48278	62.8
Manitou	46.01556	79.00083	38.6
McCraney	45.56889	78.90250	65.3
McIntosh	45.67111	78.77194	31.3
McKaskill	45.72694	78.04444	20.9
Merchant	45.76944	78.53056	34.9
Mink	46.06194	78.78972	45.9
Mouse	46.02167	78.72833	8.7
North Branch	45.83000	78.06278	12.0
North Tea	45.94306	79.03389	45.9
Philip	45.92000	78.40500	16.4

Table 2.1 *(Continued)*

Lake	Latitude (ºN)	Longitude (ºW)	Z_{max}(m)
Radiant	45.99194	78.28833	36.6
Rain	45.62750	78.92361	26.9
Ralph Bice	45.69444	78.94556	55.2
Rence	45.41639	78.46778	8.2
Rock	45.50167	78.39056	34.3
Rosebary	45.75972	78.92194	18.9
Shirley	45.68917	78.12417	27.4
Smoke	45.51528	78.68139	56.4
Source	45.56083	78.65056	42.7
Tea	45.50611	78.73667	15.8
Tim	45.75167	79.02833	22.3
Waterclear	46.04778	78.77861	22.7
Welcome	45.41806	78.41611	24.3
Whitefish	45.54778	78.42500	28.4

Table 2.2 An example of a "warm-thin" hypolimnion for Mouse Lake, Algonquin Park. Temperature and oxygen profiles show that the thermocline is in the 3-4 m stratum, and the warm and thin hypolimnion spans 6 – 8 m, with a bottom temperature of 11.5 oC.

Depth (m)	Temperature (ºC)	Dissolved Oxygen (mg O_2 L^{-1})
0.5	20.8	7.3
1	20.8	7.4
2	20.8	7.3
3	20.8	7.4
4	17.6	2.5
5	14.6	1.5
6	13	0.7
7	12	0.4
8	11.5	0.2

Table 2.3 Correlations between environmental variables and VWHO for (a) Algonquin Park lakes from the present study, and (b) Muskoka-Haliburton lakes from Quinlan and Smol (2001). All variables were log10 transformed for both datasets except DOC, SO4, pH, and VWHO. Gradients of TP, TN, and SA from Quinlan and Smol (2001) were truncated to reflect the length of the gradients for the present study before correlations were calculated.

Algonquin Park			**Muskoka-Haliburton**		
Environmental variable	**Correlation coefficient**	***p*-value**	**Environmental variable**	**Correlation coefficient**	***p*-value**
DOC	-0.05	0.742	DOC	-0.57	<0.0001
SO_4	0.21	0.142	SO_4	0.22	0.054
pH	0.23	0.098	pH	-0.09	0.423
TN	0.04	0.781	TN	-0.68	<0.0001
TP	-0.01	0.984	TP	-0.67	< 0.0001
SA	0.56	<0.0001	SA	0.48	< 0.0001
Z_{mean}	0.8	<0.0001	Z_{mean}	0.79	< 0.0001
Z_{max}	0.85	<0.0001	Z_{max}	0.81	< 0.0001

Table 2.4 Correlation comparisons based on observed correlations between environmental variables and VWHO presented in Table 2.3. Where z is calculated using a Fischer z-transformation and used to test the statistical difference between correlations. Sample sizes are displayed for (a) Algonquin Park lakes (n_a) and (b) Muskoka-Haliburton lakes (n_b). All variables were log10 transformed for both datasets except DOC, SO4, pH, and VWHO. TP, TN and SA for Quinlan and Smol (2001) were adjusted to reflect the length of the gradients for the present study before correlations were calculated.

Environmental variable	$\mathbf{n_a}$	$\mathbf{n_b}$	***Z***	***p*-value**
DOC	52	80	3.25	0.001
SO_4	52	80	0.05	0.958
pH	52	80	1.79	0.733
TN	52	72	4.65	<0.0001
TP	52	65	4.31	<0.0001
SA	52	69	0.56	0.573
Z_{mean}	52	80	0.22	0.825
Z_{max}	52	80	1.01	0.314

Table 2.5 Taxa with greater than 2% relative abundance in at least 2 lakes, ordered by decreasing number of observed occurrences for Algonquin Park lakes, Ontario. Relative abundance represents an average percentage calculated from the lakes where the taxon occurred.

Taxon	Occurrences (#)	Relative abundance (%)
Procladius	33	20.97
Heterotrissocladius marcidus	32	27.78
Sergentia coracina	32	18.39
Tanytarsus pallidicornis	32	20.69
Tanytarsus lugens	31	13.89
Micropsectra contracta	29	47.96
Chaoborus	28	35.20
Chironomus anthracinus	27	20.00
Dicrotendipes nervosus	27	8.86
Paratanytarsus	27	7.41
Tanytarsus chinyensis	26	6.93
Thienemannimyia	26	8.51
Ablabesmyia	25	10.58
Psectrocladius sordidellus	24	10.64
Tanytarsus lactescens	24	6.73
Heterotrissocladius grimshawi	22	9.26
Stempellinella/Zavrelia	22	8.51
Micropsectra insignilobus	21	15.00
Synorthocladius	20	6.38
Corynoneura edwardsi	18	7.34
Stempellina	18	8.16
Chaetocladius piger	17	15.19
Cladopelma lateralis	17	7.41
Micropsectra radialis	17	8.16
Constempellina/Thienemmanniola	16	5.06
Cladotanytarsus mancus	15	4.60
Heterotrissocladius maeaeri	13	15.50
Polypedilum nubeculosum	13	2.33
Glyptotendipes pallens	12	4.21
Micropsectra pallidula	12	5.61
Corynoneura carriana	10	6.40
Chironomus plumosus	9	3.20
Corynoneura type a	9	6.38
Parakiefferiella nigra	9	9.09
Sergentia longiventris	9	4.60
Cladopelma laccophila	8	3.30
Labrundinia	8	12.64
Microtendipes pedellus	8	3.70
Cryptochironomus	7	6.86

Table 2.5 *(Continued)*

Taxon	Occurrences (#)	Relative abundance (%)
Stictochironomus rosenschoeldi	7	5.61
Rheotanytarsus	6	3.41
Tanytarsus undifferentiated	6	6.90
Cricotopus bicinctus	4	6.38
Parachironomus varus	4	4.26
Paratendipes albimanus	3	5.06
Telopelopia	3	3.16
Paracladius	2	4.44

Table 2.6 Dipteran species richness and diversity measures from surficial sediments of study lakes in Algonquin Park, Ontario.

Lake	S	Simpson	Hill's N2
Big Trout	26	0.94	16.71
Burnt Island	32	0.93	14.29
Catfish	34	0.90	10.28
Cauchon	35	0.95	20.74
Cedar	43	0.96	26.16
Clydegale	20	0.84	6.17
Dickson	19	0.86	7.28
Farncomb	28	0.85	6.64
Galeairy	26	0.93	14.45
Gibson	25	0.93	13.69
Grand	36	0.95	20.31
Harry	30	0.94	17.92
Joe	38	0.94	16.05
Kioshkokwi	22	0.94	16.27
La Muir	19	0.73	3.73
Lake of Two Rivers	17	0.86	7.08
Lavieille	23	0.94	18.06
Little Cauchon	33	0.94	16.09
Little Dickson	24	0.93	14.99
Little Joe	17	0.89	8.83
Louisa	18	0.91	10.82
Manitou	28	0.94	17.02
McKaskill	20	0.92	11.81
Merchant	26	0.90	10.38
Mouse	20	0.89	9.43
North Tea	20	0.91	11.71
Philip	21	0.94	15.89
Radiant	28	0.95	20.89
Rain	34	0.93	14.72

Table 2.6 *(Continued)*			
Lake	**S**	**Simpson**	**Hill's N2**
Ralph Bice	17	0.87	7.71
Rock	19	0.89	9.51
Rose	34	0.95	18.84
Shirley	36	0.94	17.22
Source	22	0.91	10.80
Tea	26	0.88	8.34
Welcome	21	0.92	12.44
Whitefish	17	0.91	11.16

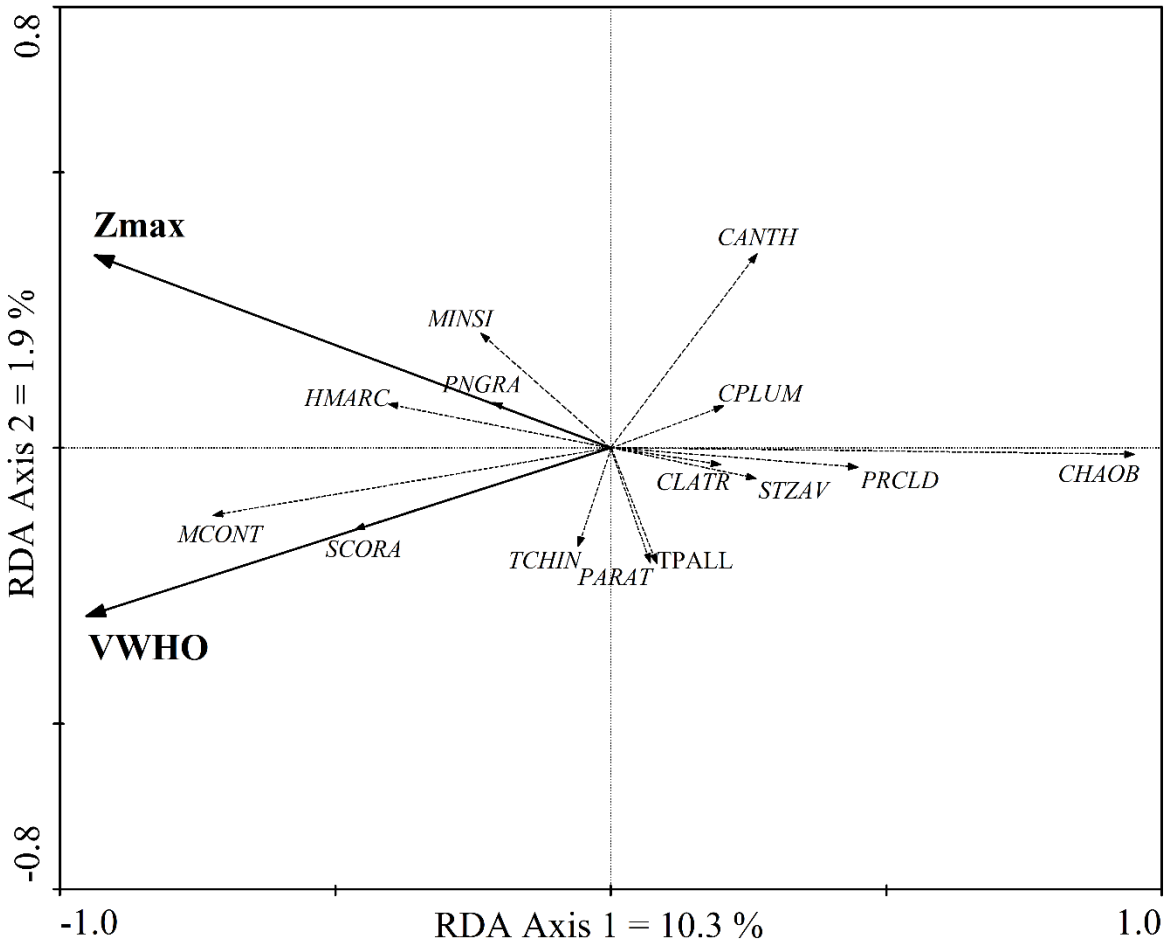

Figure 2.3 Redundancy analysis (RDA) of present-day Algonquin Park dipteran assemblages constrained to significant environmental gradients, VWHO and Z_{max}. For visual representation purposes, taxa which did not have at least one axis score >= 0.3 were excluded from the RDA. The taxon codes for the taxa presented in the RDA are listed in Table 2.7.

Table 2.7 Dipteran taxon codes for RDA taxa.

Code	Taxon
CHAOB	*Chaoborus*
CANTH	*Chironomus anthracinus*
CPLUM	*Chironomus plumosus*
CLATR	*Cladopelma lateralis*
HMARC	*Heterotrissocladius marcidus*
MCONT	*Micropsectra contracta*
MINSI	*Micropsectra insignilobus*
PARAT	*Paratanytarsus*
PNGRA	*Parakiefferiella nigra*
PRCLD	*Procladius*
SCORA	*Sergentia coracina*
STZAV	*Stempellinella/Zavrelia*
TCHIN	*Tanytarsus chinyensis*
TPALL	*Tanytarsus pallidicornis*

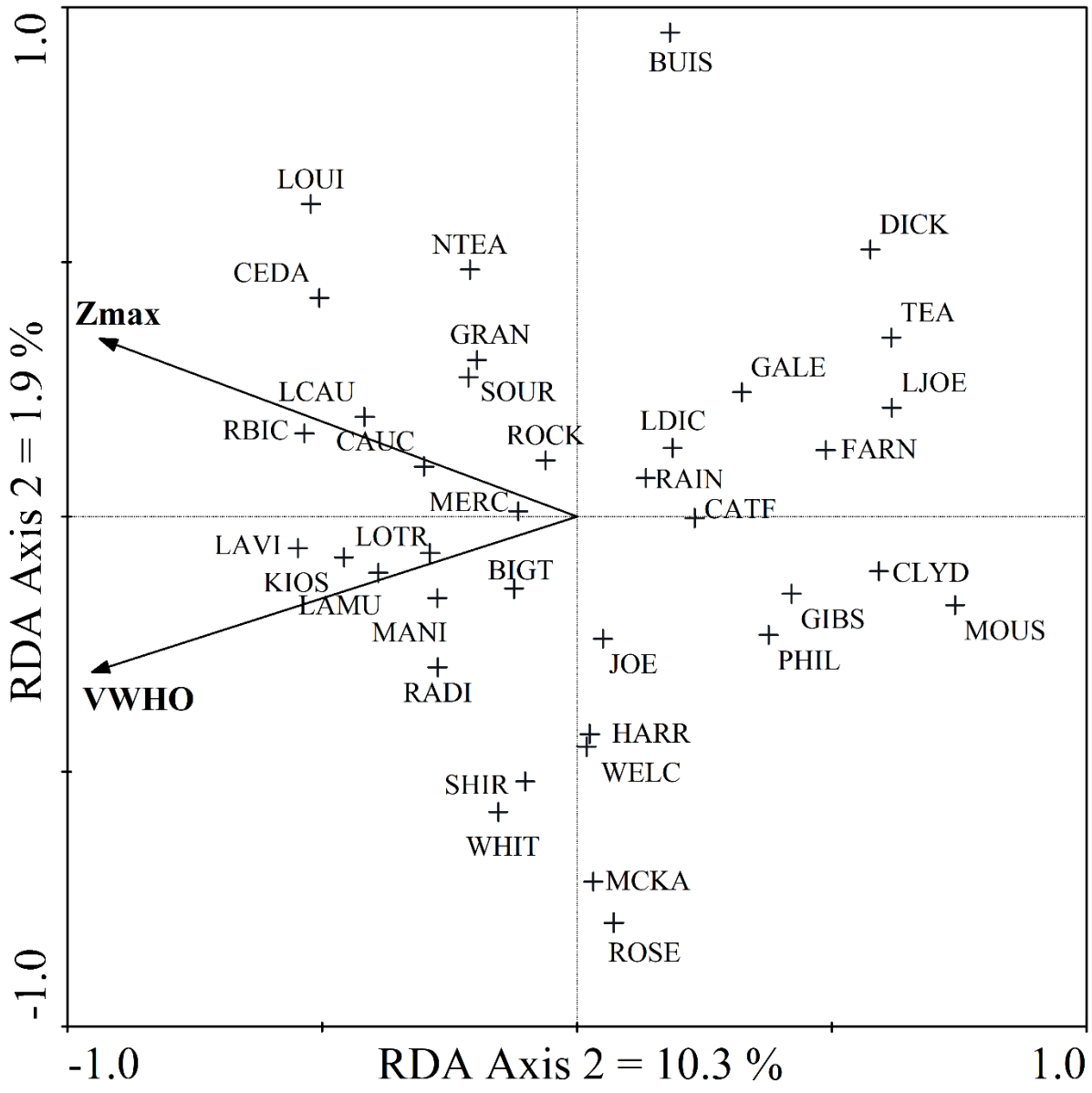

Figure 2.4 Redundancy analysis (RDA) of Algonquin Park lakes constrained to significant environmental gradients, VWHO and Z_{max}.

Table 2.8 VWHO eHOF optima (mg L^{-1} O_2) for dipterans in Algonquin Park lakes. Model type 1 is no significant taxon response along the gradient; model types 2 and 3 are monotone sigmoid responses; model type 4 is a symmetrical unimodal response; model type 5 is a skewed unimodal response; and model types 6 and 7 are unimodal models with two optima (Jansen and Oksanen 2013).

Taxon	Model type	Optimum 1	Optimum 2
Chironomus	2	0.2	-
Cladopelma	5	0.8	-
Cladotanytarsus mancus	4	7.2	-
Corynoneura/Thienemanniella	6	3.2	7.6
Cricotopus/Orthocladius/Paratrichocladius	1	-	-
Chaoborus	5	1.1	-
Dicrotendipes	6	3.8	9.4
Glyptotendipes	6	0.7	8.2
Heterotrissocladius	7	5.3	25.1
Micropsectra	7	0.2	9.4
Pentaneurini	7	3.4	7
Polypedilum	1	-	-
Procladius	7	0.2	5.1
Psectrocladius (Psectrocladius)	7	3.3	9.4
Sergentia	5	5.8	-
Stempellinella/Zavrelia	7	0.2	3.7
Stempellina	3	7.7	-
Synorthocladius	1	-	-
Tanytarsus chinyensis	4	6.3	-
Tanytarsus lugens	7	0.2	7.1
Tanytarsus s. lat/Tanytarsus undifferentiated	5	6.8	-

Table 2.9 VWHO eHOF optima (mg L^{-1} O_2) for dipterans in Muskoka-Haliburton lakes.

Taxon	Model type	Optimum 1	Optimum 2
Chironomus	6	0.2	10.8
Cladopelma	1	-	-
Cladotanytarsus mancus	4	3	-
Corynoneura/Thienemanniella	3	7	-
Cricotopus/Orthocladius/Paratrichocladius	2	0.2	-
Chaoborus	5	2.5	-
Dicrotendipes	5	0.9	-
Glyptotendipes	4	0.6	-
Heterotrissocladius	7	4.5	10.1
Micropsectra	7	0.2	7.4
Pentaneurini	4	2.9	-
Polypedilum	2	0.2	-

Table 2.9 *(Continued)*

Taxon	Model type	Optimum 1	Optimum 2
Procladius	2	0.2	-
Psectrocladius (Psectrocladius)	1	-	-
Sergentia	5	4	-
Stempellinella/Zavrelia	6	1.3	5.4
Stempellina	4	5.3	-
Synorthocladius	1	-	-
Tanytarsus chinyensis	1	-	-
Tanytarsus lugens	1	-	-
Tanytarsus s. lat/Tanytarsus undifferentiated	6	2.3	8.3

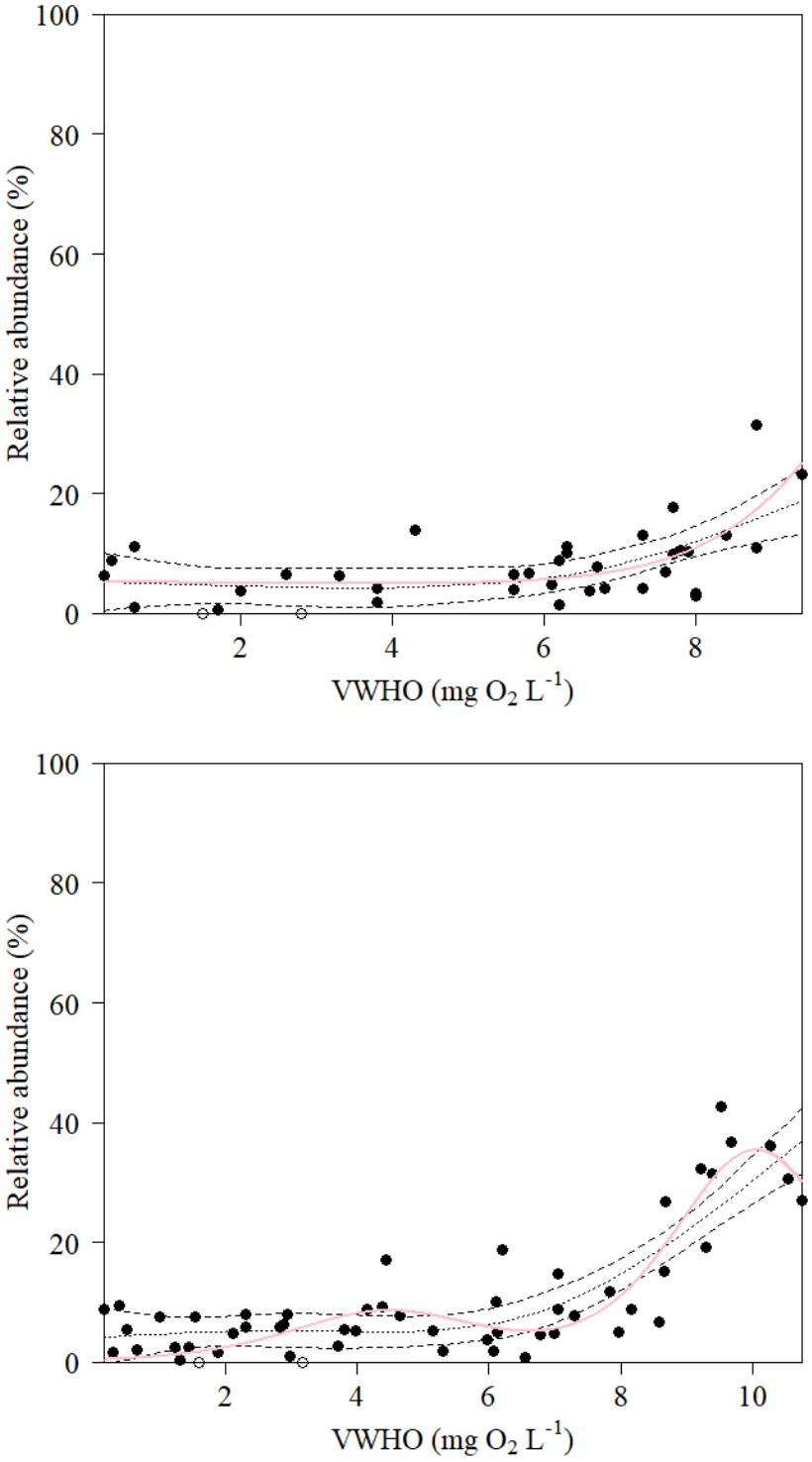

Figure 2.5 eHOF plots for *Heterotrissocladius* from (a) Algonquin Park and (b) Muskoka-Haliburton, Ontario. Solid lines show the shape of the resulting eHOF curve, and dashed lines show the GAM confidence intervals.

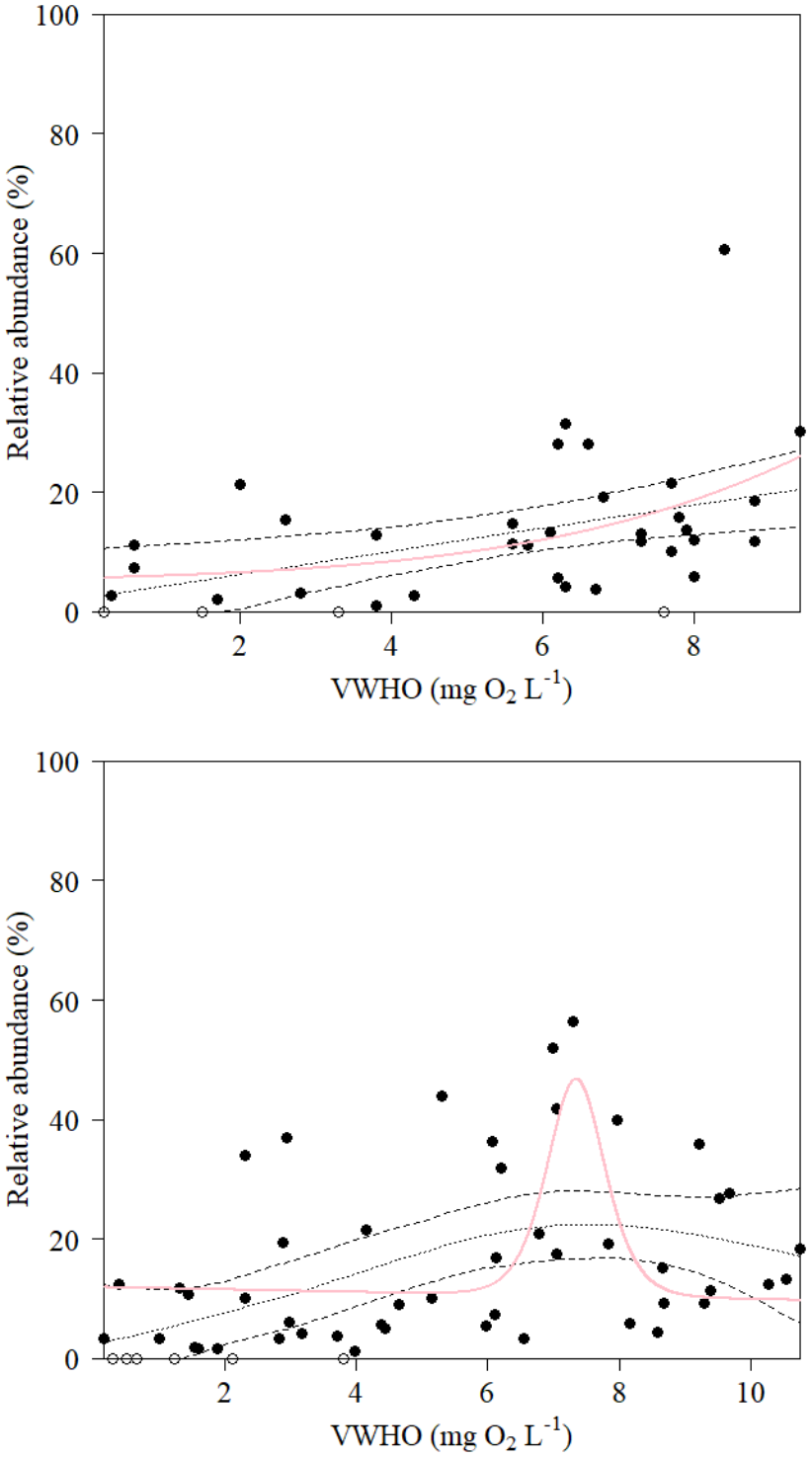

Figure 2.6 eHOF plots for *Micropsectra* from (a) Algonquin Park and (b) Muskoka-Haliburton, Ontario. Solid lines show the shape of the resulting eHOF curve, and dashed lines show the GAM confidence intervals.

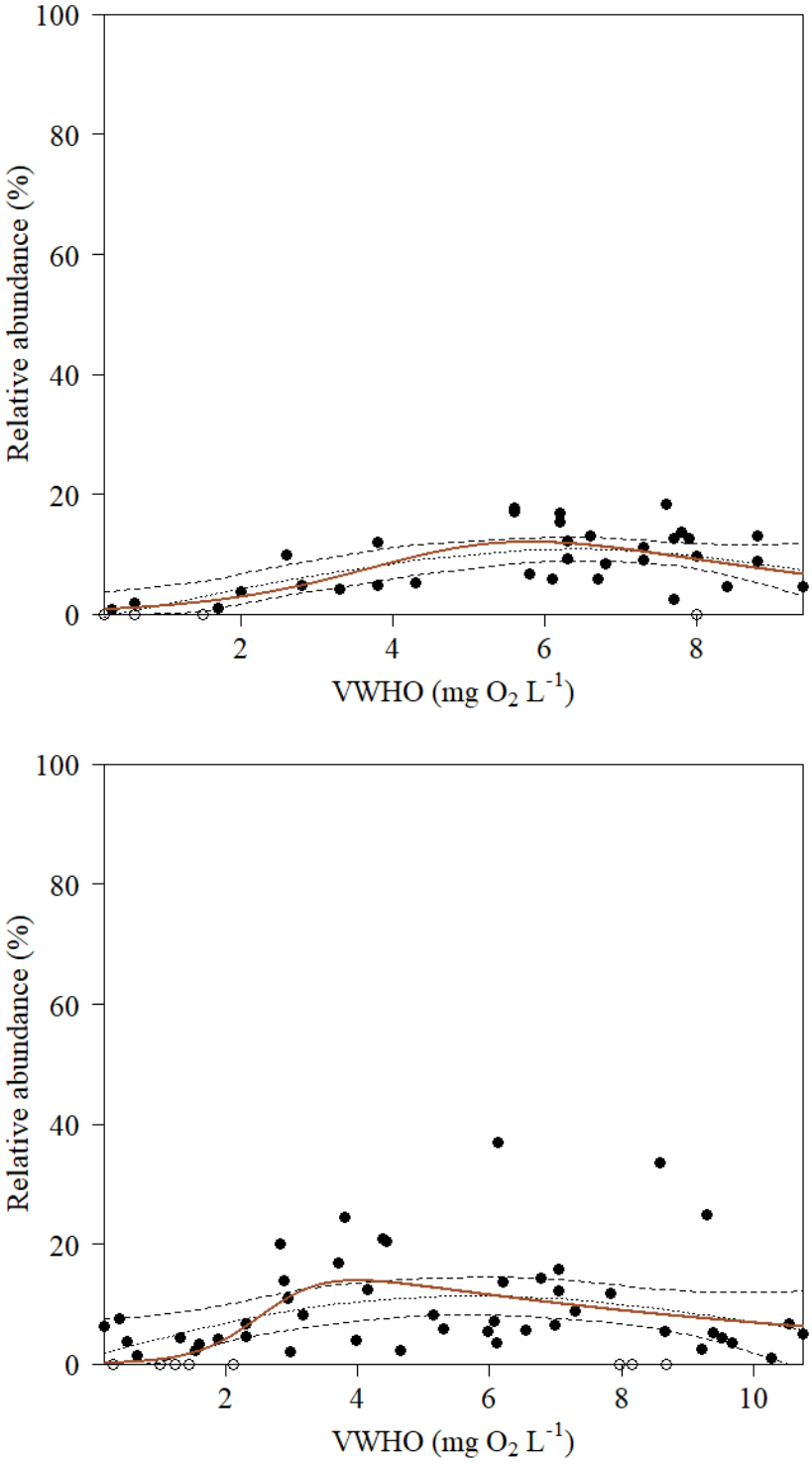

Figure 2.7 eHOF plots for *Sergentia* from (a) Algonquin Park and (b) Muskoka-Haliburton, Ontario. Solid lines show the shape of the resulting eHOF curve, and dashed lines show the GAM confidence intervals.

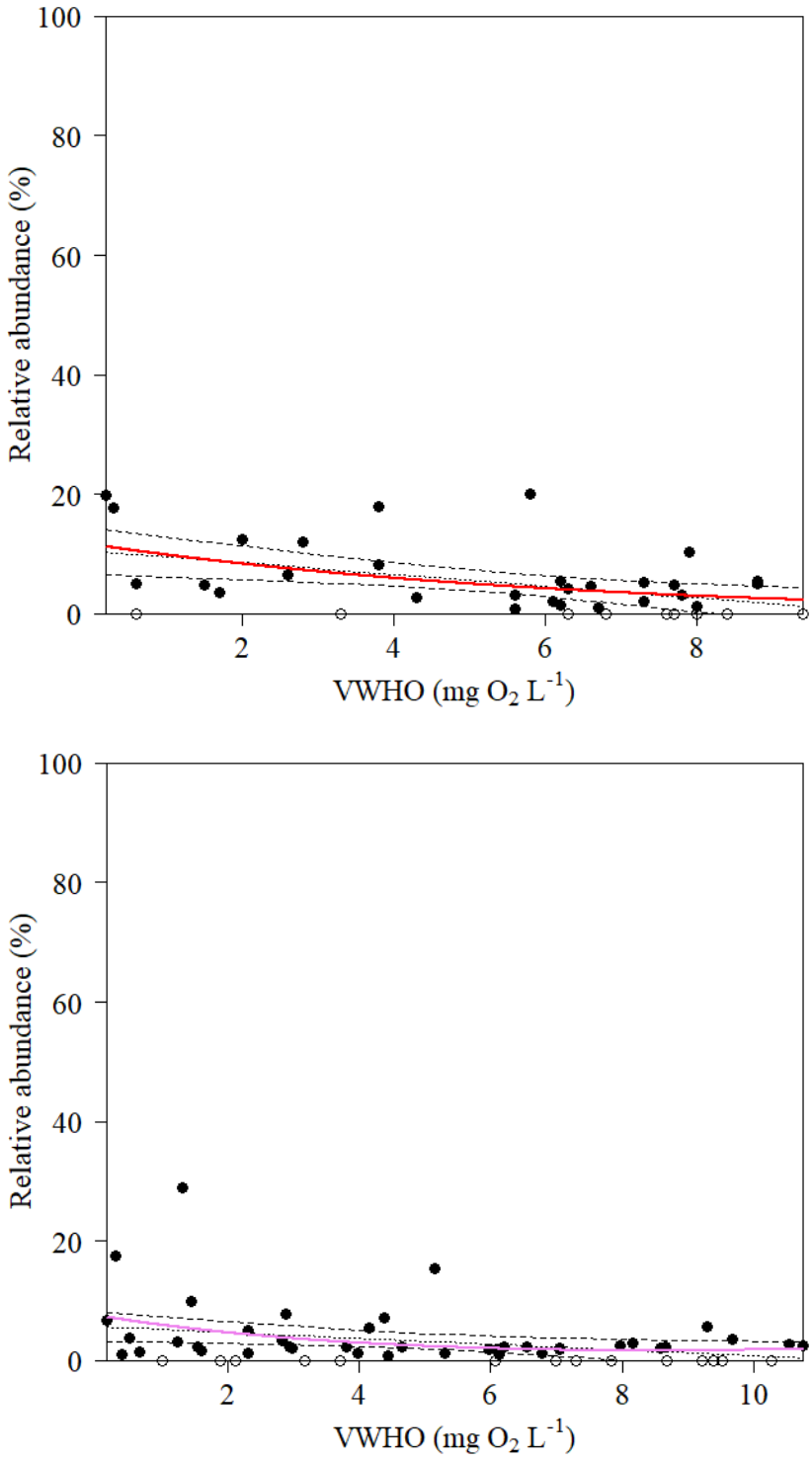

Figure 2.8 eHOF plots for *Chironomus* from (a) Algonquin Park and (b) Muskoka-Haliburton, Ontario. Solid lines show the shape of the resulting eHOF curve, and dashed lines show the GAM confidence intervals.

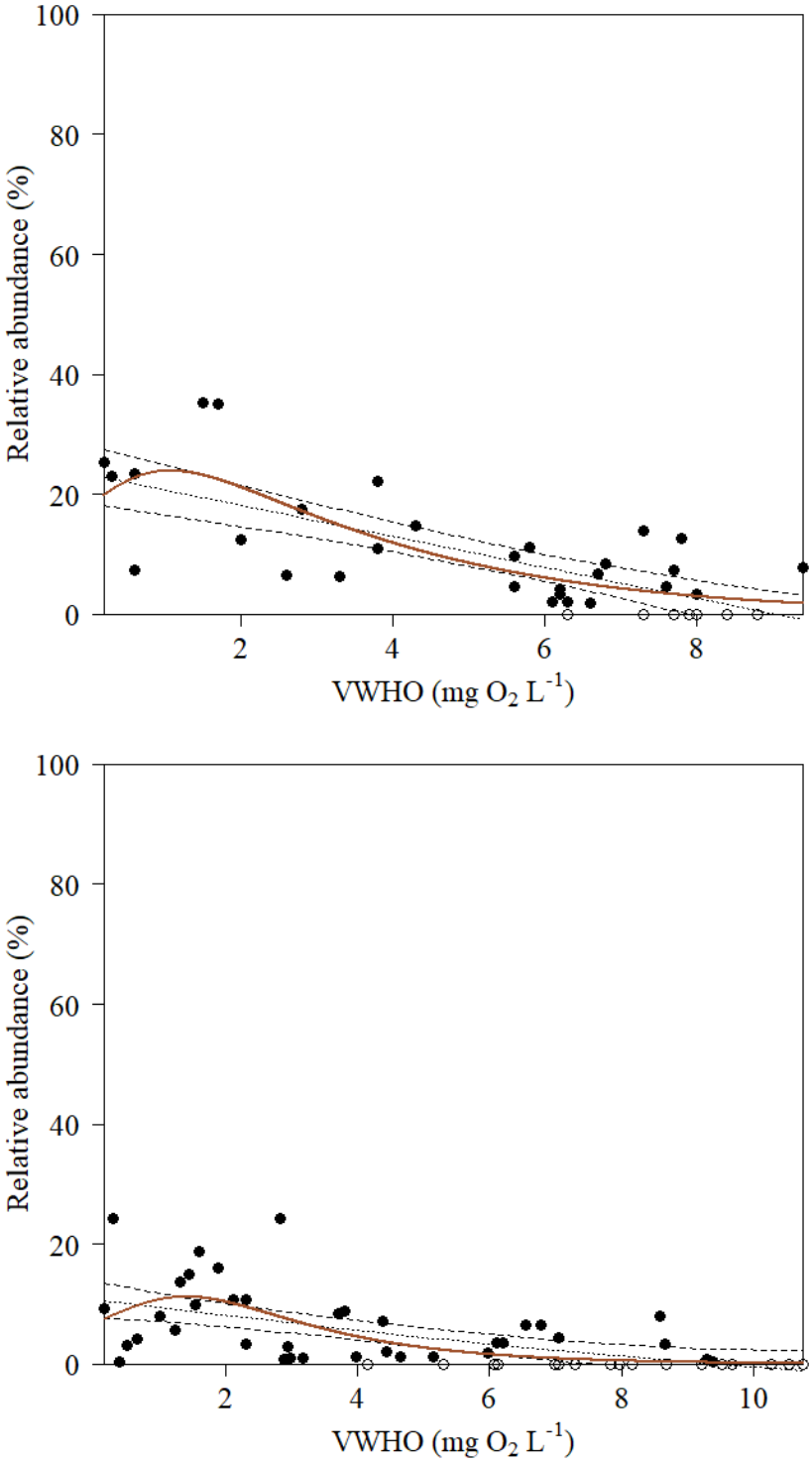

Figure 2.9 eHOF plots for *Chaoborus* from (a) Algonquin Park and (b) Muskoka-Haliburton, Ontario. Solid lines show the shape of the resulting eHOF curve, and dashed lines show the GAM confidence intervals.

Table 2.10 Model statistics for Algonquin Park dipteran-VWHO inferences.

Model	Component / deshrinking	r^2	RMSE	Max bias	r^2_{jack}	RMSEP	Max bias jack
WA	Inverse	0.77	1.3	2.2	0.41	2.1	3.9
WA	Classical	0.77	1.5	1.8	0.42	2.1	3.5
WA	Inverse tolerance	0.51	1.9	3.4	9×10^{-4}	3.0	5.6
WA	Classical tolerance	0.51	2.6	4.0	4×10^{-4}	3.6	7.9
WA-PLS	Component 1	0.77	1.3	2.2	0.41	2.1	3.9
WA-PLS	Component 2	0.89	0.9	1.2	0.38	2.1	3.9
WA-PLS	Component 3	0.94	0.6	0.7	0.30	2.4	3.9
WA-PLS	Component 4	0.97	0.5	0.4	0.28	2.5	4.0
WA-PLS	Component 5	0.98	0.4	0.4	0.25	2.6	4.1
PLS	Component 1	0.73	1.4	1.9	0.59	1.7	2.7
PLS	Component 2	0.86	1.0	1.2	0.44	2.1	2.8
PLS	Component 3	0.92	0.7	0.8	0.35	2.4	3.2
PLS	Component 4	0.95	0.6	0.6	0.31	2.5	3.3
PLS	Component 5	0.97	0.5	0.4	0.30	2.7	3.4
MAT	-	0.33	2.2	4.2	0.30	2.2	4.2
WMAT	-	0.33	2.2	4.2	0.30	2.2	4.2

Table 2.11 Statistics for the combined (Algonquin Park and Muskoka-Haliburton) dipteran-VWHO inference models.

Model	Component / deshrinking	r^2	RMSE	Max bias	r^2_{jack}	RMSEP	Max bias jack
WA	Inverse	0.65	1.8	2.2	0.57	2.0	2.6
WA	Classical	0.65	2.2	1.5	0.57	2.3	1.4
WA	Inverse tolerance	0.65	1.7	1.9	0.55	2.0	2.3
WA	Classical tolerance	0.65	2.2	1.5	0.55	2.3	1.6
WA-PLS	Component 1	0.65	1.8	2.1	0.57	2.0	2.6
WA-PLS	Component 2	0.74	1.5	1.3	0.58	1.9	2.0
WA-PLS	Component 3	0.79	1.4	1.7	0.57	2.0	2.3
WA-PLS	Component 4	0.81	1.3	1.7	0.54	2.1	2.4
WA-PLS	Component 5	0.83	1.2	1.3	0.5	2.2	2.1
PLS	Component 1	0.60	1.9	2.4	0.55	2.0	2.7
PLS	Component 2	0.70	1.6	2.0	0.55	2.0	2.6
PLS	Component 3	0.75	1.5	1.4	0.53	2.1	2.1
PLS	Component 4	0.78	1.4	1.7	0.48	2.2	2.2
PLS	Component 5	0.79	1.3	1.5	0.47	2.3	2.2
MAT	-	0.60	1.9	2.9	0.60	1.9	2.9
WMAT	-	0.60	1.9	2.8	0.60	1.9	2.8

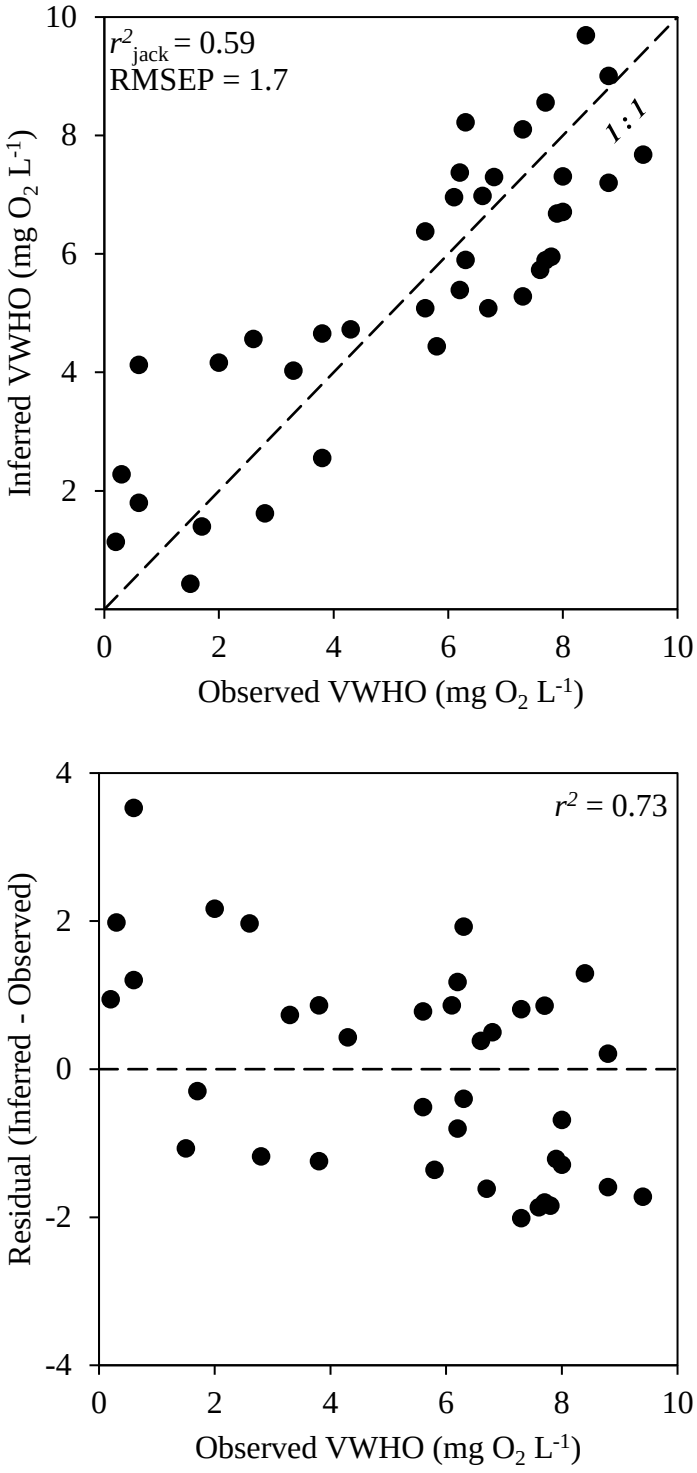

Figure 2.10 PLS model for Algonquin Park showing (a) predictive performance and (b) residuals.

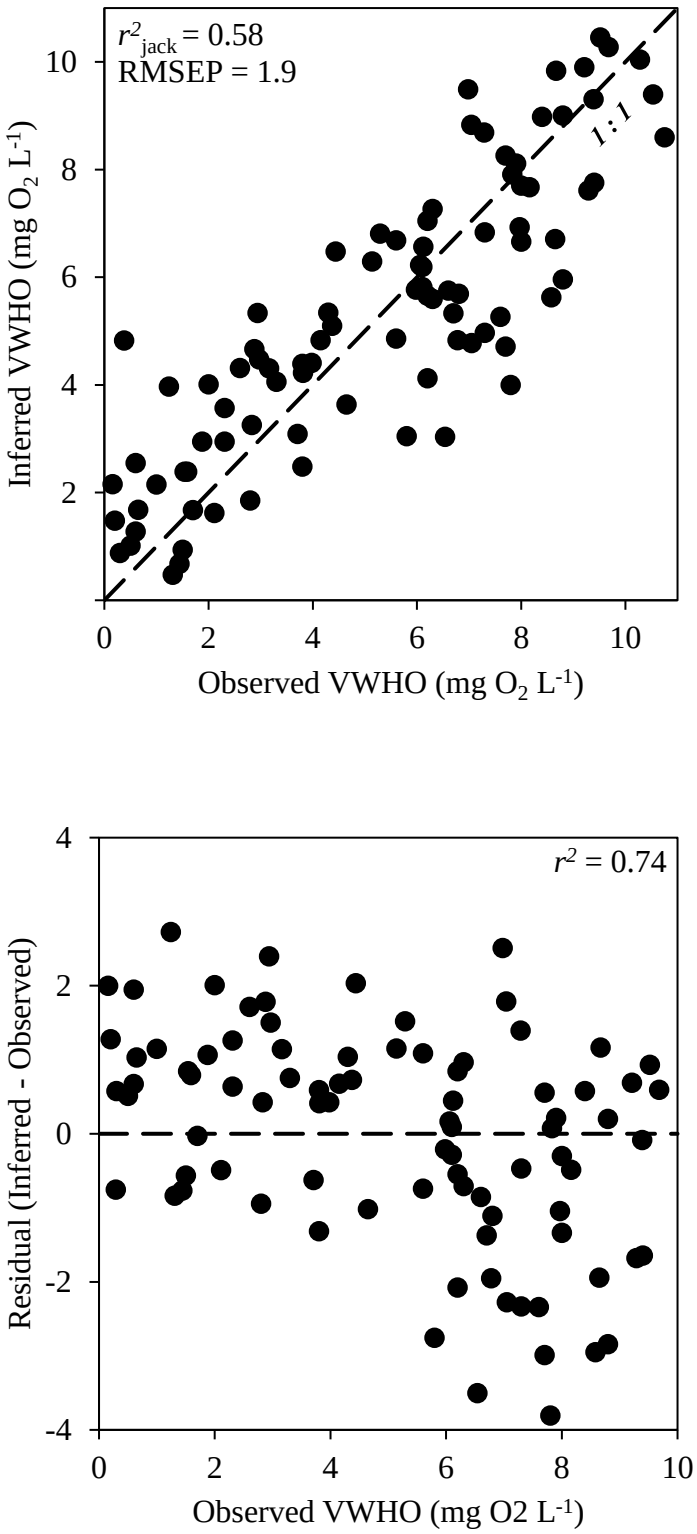

Figure 2.11 WA-PLS C2 model for Algonquin Park and Muskoka-Haliburton showing (a) predictive performance and (b) residuals.

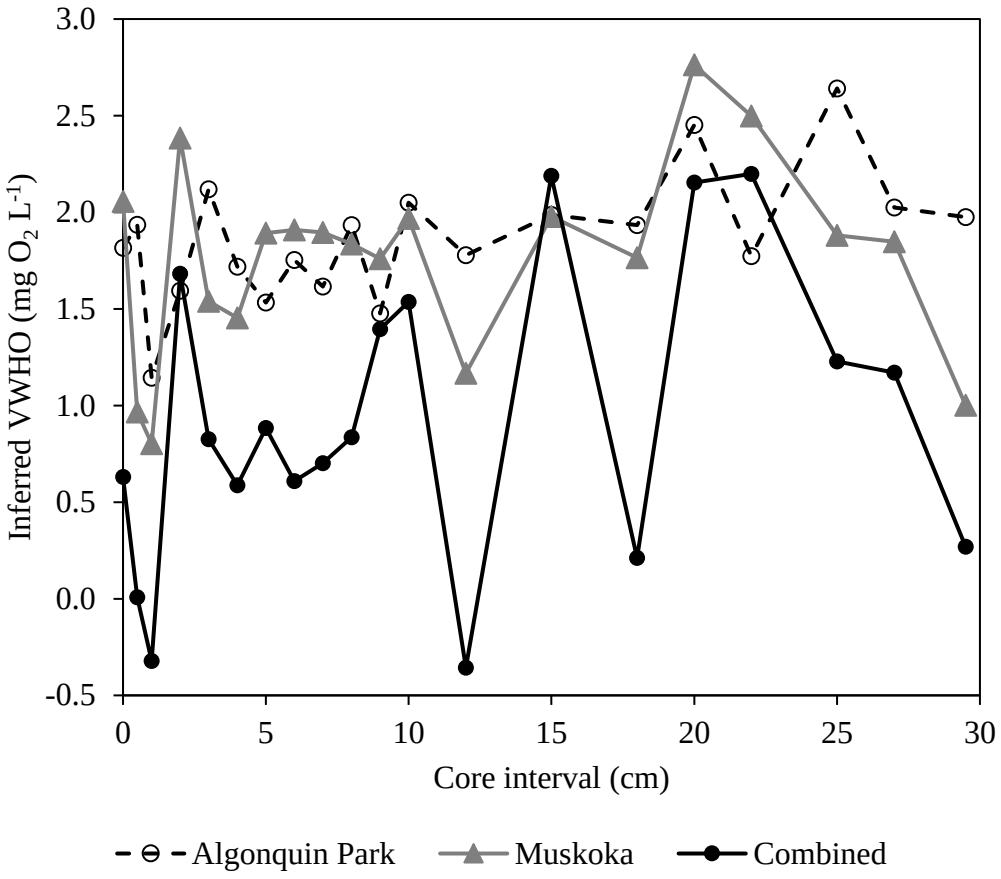

Figure 2.12 Paleolimnological reconstructions of VWHO for Dickson Lake, Algonquin Park using three inference models (a) Algonquin Park (b) Muskoka-Haliburton and (c) Algonquin Park plus Muskoka-Haliburton (combined model). Reconstructions were performed using down-core dipteran identifications from Favot et al. (2019).

Chapter 3: A top-bottom paleolimnological approach for assessing change in volume-weighted hypolimnetic oxygen (VWHO) in Algonquin Park lakes

3.1 Introduction

Dillon and Rigler (1975) stressed the need for lake managers to enforce regulations which include more than just the lake area and associated shoreline. This is an important consideration as all anthropogenic activities which occur in the terrestrial environment upstream from lakes have the potential to drastically alter the downstream aquatic environment (Hornung and Reynolds 1995). Cultural eutrophication is one such example, whereby anthropogenic nutrient inputs alter the trophic status of a lake (Smith 1998). Anthropogenic nutrient inputs may include point sources from factories and commercial enterprises; however, more often, nutrient loading is diffuse, originating from activities involving shoreline development (Lee 1973) and agriculture (Heathwaite et al. 2005). Cultural eutrophication is a primary concern to lake managers as noxious algal blooms can occur which pose risks to human health while simultaneously having detrimental ecosystem effects (Moore et al. 2008). Phosphorus concentrations are frequently considered during assessments of lake health as phosphorus is the limiting nutrient in aquatic environments (Correll 1999) and increasing phosphorus has frequently been attributed as the cause to increases in algal productivity (Carpenter 2008).

Paleolimnological studies have attempted to observe the association between inferred phosphorus changes overtime and shoreline developments. Moos and Ginn (2016) attributed shoreline development (cottages and resorts) to a 2.6 $\mu g\ L^{-1}$ increase in diatom-inferred phosphorus in Musselman lake on the Oak Ridges Moraine in Ontario. Similarly, other studies

have associated increasing phosphorus levels with increased shoreline cottage-use and the transition from cottages to residences (Sawyers et al. 2016; Campbell and Chow-Fraser 2018; Brenden et al. 2018). Interestingly, long-term monitoring of Big Platte Lake in Michigan showed a disproportionately low reduction in lake phosphorus concentrations, despite eliminating 95% of the point source inputs, suggesting that internal loading and shoreline developments were largely contributing to total phosphorus budgets (Canale et al. 2004).

In south-central Ontario lakes, widespread declines in TP concentrations have been observed in lakes with and without cottages since the 1980s. These declines have been attributed, in part, to reduced catchment TP input, as annual stream TP exports have decreased by 16-89% (Eimers et al. 2009). Crossman et al. (2015) suggested the TP declines have occurred as the environment recovered from disturbance and returned to the natural baseline conditions which existed in the years prior to the establishment of the monitoring program.

Since monitoring programs are rare, and often do not span long enough timeframes when available, the baseline condition of a lake is often unknown (Frey 1988). However, knowledge of baseline conditions is important for effective lake management and in establishing appropriate remediation targets (Smol 1992). Lake sediment cores, when processed stratigraphically during down-core paleolimnological analysis, can capture the natural variability of the system which can assist in setting baseline conditions (Smol 2008). Since down-core analysis is a time-consuming procedure which prevents researchers from analyzing more than a few lakes in parallel, a top-bottom approach can be used to assess long-term change in more lakes that cover a larger regional geographical scale. A top-bottom paleolimnological approach uses the uppermost sediment from a sediment core to represent present-day conditions and subsequently makes comparisons with the bottom layer of sediment which represents a pre-disturbance

condition (Cumming et al. 1992). The depth of sediment required to capture the pre-disturbance condition in south-central Ontario should be below 15 – 20 cm as these depths have been determined to represent pre-disturbance conditions through isotope dating procedures (^{210}Pb) (Evans and Dillon 1982; Evans et al. 1986).

The objective of this chapter was to reconstruct pre-disturbance VWHO conditions for lakes in Algonquin Park, Ontario, and determine if anthropogenic nutrient inputs from shoreline cottages influenced patterns of VWHO change. Changes in dipteran assemblages were examined for shifts in indicator taxa since pre-disturbance conditions (circa 1850 CE), and the change in inferred VWHO was assessed to determine whether overall regional VWHO has declined over time. Finally, a causal model was developed to quantify the total estimated effect of private cottages on the change in VWHO overtime. Specifically, our research questions were: (1) Have dipteran assemblages changed over time? (2) Has VWHO changed over time? (3) Has cottage development influenced VWHO?

3.2 Methods

3.2.1 Field sampling and laboratory methods

Lake sediment cores were collected from 54 lakes in Algonquin Park using a Glew (1989) gravity corer with an inner core tube diameter of 7.62 cm and extruded the same day with a Glew (1988) extruder. Sediment subsamples were processed for subfossil dipteran assemblages following methods in Quinlan & Smol (2001). Subfossil dipteran assemblages were sifted, identified and enumerated from surficial sediments (0.0-0.05 cm and 0.5-1.0 cm sediment core depth), representing present-day conditions, and ‘bottom’ sediments (two 0.5 cm intervals from bottom of sediment core), representing pre-disturbance conditions. All bottom sediments

occurred below 16 cm below the sediment surface, and as such, are assumed to represent pre-disturbance conditions (< 1850 CE), as 15-20 cm sediment depth is representative of the pre-1850 period (DeSellas et al. 2011). Sediments were re-subsampled for dipteran remains if initial processing did not generate 50 enumerated dipteran remains. Top-bottom comparisons of assemblages were possible from 31 Algonquin Park lakes (Figure 3.1) where > 50 dipteran remains were identified from both top and bottom sediments; of these 31 lakes, private cottages are established along the shorelines of 14 lakes, while 17 lakes had no shoreline cottage development and as such are considered 'reference' lakes in the context of cottage influence on long-term changes of lake water quality and ecological condition.

3.2.2 Statistical methods

Have dipteran assemblages changed over time?

We assessed the similarity of dipteran communities in the present samples compared to the fossil assemblages using analysis of similarity (ANOSIM) using adonis in the vegan 2.5-5 package (Oksanen 2018) in RStudio v.1.1.456 (RStudio Team 2016) to assess the similarity of dipteran communities in the present samples compared to the fossil assemblages. ANOSIM is a non-parametric test which uses a ranked dissimilarity matrix to compare groups; for this dataset, the test was run on a Bray-Curtis distance matrix. The test statistic, *R*, ranges from -1 to 1 where the null hypothesis specifies that the differences within a group are equal to the differences between groups, which would result in an *R* statistic of zero. Significance testing was achieved using 999 permutations to obtain corresponding *p*-values. Subsequently, the vegan package in R was used to calculate a similarity percentage (SIMPER) to identify the taxa with the greatest contributions

to the average Bray-Curtis dissimilarities for each group, where the groups were assigned based on the sediment intervals (top and bottom).

The change in dipteran communities over time was more broadly observed by constraining top and bottom assemblages to the environmental variables significantly affecting present-day dipteran communities. VWHO and Z_{max} were used to constrain a redundancy analysis (RDA) as they were found to be the significant environmental gradients affecting dipteran distributions (see Chapter 2). Historic samples (from the bottom sediment intervals) were plotted passively to observe inferred changes in dipteran assemblages over time.

Has VWHO changed over time?

We used the inference model based on 37 Algonquin Park lakes from Chapter 2 to reconstruct the historic (ca 1850 CE) VWHO values to compare them with present-day VWHO (2015) values. Although we have measured VWHO for present-day lakes, we inferred these values to include the model bias incorporated in the bottom samples. To determine if present VWHO concentrations were significantly different from historic VWHO, a binomial test was used as it produces more accurate *p*-values compared to parametric *t*-tests. The binomial test requires that samples are independent, however, the lakes are highly connected across the landscape, where it is possible that changes in a lake upstream could affect downstream lakes. Spatial autocorrelation analysis using Moran's *I* was conducted in R to test the assumption of independence between samples.

Has cottage development influenced VWHO over time?

We developed a causal inference model to assess the effect of private cottages on the change in inferred VWHO (dVWHO) using causal graphical models in Python (Python Software

Foundation 2019). Causal inference modelling is similar to structural equation modelling (SEM) and path analysis, however it does not have linear dependencies and can include both quantitative and categorical variables (Pearl 2009a). The causal model was used to identify possible confounders which introduce bias when estimating the effect of cottage presence on dVWHO. Researchers may try to control for as many variables as possible to produce unconfounded results, however, this approach can effectively control for the variable of interest (Pearl and Mackenzie 2018). Mathematical methods may be used to identify confounders based on counterfactuals; however, the same results may be achieved using a more 'user-friendly' approach by way of causal modelling and the backdoor adjustment (Pearl 1995). The variables with confounding influence were controlled for in ordinary least squares (OLS) regression. Lastly, a difference-in-differences analysis was conducted in Python (Python Software Foundation 2019) as a method capable of measuring the effect of a change that occurs at a particular point of time (Doudchenko and Imbens 2016). In this case that change is the establishment of cottages on lakes. A difference in differences model is akin to a 2x2 contingency table where the cells of the table represent different expected values (Table 3.1; Table 3.2).This model assumes that, once the difference between the control and treatment group are taken into account, they *would* undergo change similarly from the past to the present (the parallel assumption). Meaning, if a difference is observed from the past to the present, then this difference is attributed to the causal effect (ψ) cottages must have had on lakes (Figure 3.2).

3.2.3 An introduction to causal inference

Causal inference was used to determine the effect of cottages on dVWHO using a causal model, developed based on *a priori* assumptions of lake dynamics (Figure 3.3) associated with lake

trophic status and hypolimnetic oxygen. Causal inference was used to determine the effect of private cottage presence on lake VWHO levels. Due to a combination of practical and environmental concerns related to observational studies and natural experiment, lake-scale manipulations were not possible. To overcome this, a class of methods from the field of causal inference were used which can estimate the effect that cottages would have on lake VWHO if a randomized controlled trial could have been performed (Rosenbaum and Rubin 1983). Causal inference is capable of making an unbiased estimate of the treatment effect by exploiting the difference of the expected observed value of data from that data's expected counterfactual values (Equation 3.1).

$$\psi_i = \mathbb{E}[y_i|X_i, do(T = \text{Test})] - \mathbb{E}[y_i|X_i, do(T = \text{Control})]$$

Equation 3.1. The principal equation for causal inference. ψ_i denotes the individual treatment effect. The first term $\mathbb{E}[y_i|X_i, do(T = \text{Test})]$ is the *expected* value for y_i for observation X_i if X_i were given the test condition. The second term $\mathbb{E}[y_i|X_i, do(T = \text{Control})]$ is the *expected* value for y_i for observation X_i if X_i were given the control condition.

Equation 3.1 is only capable of obtaining an unbiased estimate of the individual treatment effect (ψ_i) if four assumptions are met, the stable unit treatment value assumption, consistency assumption, assumption of ignorability and the overlap assumption (Rosenbaum and Rubin 1983).

Assumption 3.1. The stable unit treatment value assumption states that the potential outcomes $y_i|X_i, do(T = test)$ and $y_i|X_i, do(T = control)$ do not depend or vary on any other X_i being a part of the control group or the test group (Rosenbaum and Rubin 1983). Alternatively stated, y_i must be independent of, and must not vary on any other data treatment assignments.

Assumption 3.2. The consistency assumption states that the expected value of y given $do(T = t_i)$ is equal to what would be observed if y happened to have $T = t_i$ (Rosenbaum and Rubin 1983; Pearl 2009b). More concretely, $[y_i|T = t_i] = [y_i|do(T = t_i)]$.

Assumption 3.3. The ignorability assumption or the 'no unmeasured confounder' assumption states that after applying necessary covariates *X* there are no confounders between the treatment variable and the target variable *y* (Rosenbaum and Rubin 1983; Pearl 2017).

In practice, the ignorability assumption is the most difficult to prove, however it is required to make the individual treatment effect identifiable (Rosenbaum and Rubin 1983; Pearl 2017). Due to our domain knowledge about how VWHO can be affected (formalized by the causal diagram shown in Figure 3.3) we can be quite certain that there does not exist any significant *unknown* confounders between our treatment variable (cottages) and our variable of interest (dVWHO).

Assumption 3.4. The overlap assumption states that for any observation X_i the probability of X_i being a part of the treatment group or the control group is neither 0% nor 100% (Crump et al. 2009). Stated plainly, observing X_i in either the treatment group or the control group must be *possible*. Stated precisely, $0 < P(T = t_i \mid X_i) < 1$.

3.2.4 Development of a causal diagram and computing validation adjustment sets

To control for confounder bias we need to find a validation adjustment set. To do this a causal diagram was constructed that describes the data generating process at any given time. A proper causal diagram is both directed and acyclic, a directed acyclic graph (Pearl 2009b; Rubin 2005). The arrow heads indicate the direction of causation between related variables; the model assumes all information flows from the tail of the arrow through the arrowhead (Pearl 2009a). Therefore, all arrows must emanate from variables which *cause* a change in the variables being pointed to;

this is the reason why bidirectional arrows or cycles are impossible. If a variable (A) is suspected to affect another variable (B), either directly, or through a mediator, then an arrow would connect A to B. This can be done even if the mediator through which A affects B is unknown. Additionally, if an arrow connects two variables, C and B, for the sake of the causal diagram, it is not necessary for the effect of C on B to be a non-zero number. Following the creation of a diagram which includes all known causal, and all suspected causal relationships between the variables of interest, a validation adjustment set can be determined. Validation adjustment sets can be identified (if any such sets exist) using the backdoor adjustment criterion (Pearl 2009b; Rubin 2005). The backdoor adjustment finds which variables (if any) block all backdoor paths between cottages and the change in volume-weighted hypolimnetic oxygen levels (dVWHO) (Figure 3.3).

The rationale used to draw causal relationships is presented for each association below.

(1) Dams → Depth, dVWHO

Hydrological dams constructed at the outlet of lakes leads to lake deepening, which can increase maximum lake depth. Dam construction may also impact dVWHO through depth mediated processes, or through an unknown mediator.

(2) Depth (Z_{max}) → VWHO, dVWHO, VWHO Historic, Cottage

Max depth affects VWHO directly as deeper lakes have larger hypolimnetic volumes than shallow lakes in the same region and at an equivalent trophic state will have higher VWHO (Charlton 1980). Similarly, the influence of maximum lake depth would have impacted historic VWHO values as well as the change in VWHO, since deeper lakes are often more robust to environmental changes. The inclusion of historic VWHO in the causal model is important as it directly relates to the resulting change in VWHO, the

variable of interest. The effect of other morphometric factors (e.g. lake surface area, and mean depth) were not included as they were highly correlated with maximum lake depth. Additionally, since increasing maximum depth was observed to be positively correlated with the presence of cottages, this relationship was included in the causal diagram with an arrow from depth to cottages.

(3) Cottage → P, DOC, dVWHO

Cottage developments may increase phosphorus (P) loading from anthropogenic sources (Powers et al. 2016; Sawyers et al. 2016; Campbell and Chow-Fraser 2018; Brenden et al. 2018). Similarly, anthropogenic activities may increase organic contaminant loads (Rowett et al. 2016) and disturb the terrestrial landscape increasing DOC export from runoff. Since there is the potential for cottages to affect dVWHO through an unknown mediator, this causal relationship was also included.

(4) VWHO Historic → Fe, dVWHO

Hypolimnetic oxygen concentrations affect iron (Fe) solubility (Schaller et al. 1997) and a clear relationship exists between the two measures of VWHO since dVWHO is calculated using VWHO historic.

(5) Fe → P

Fe may influence P as redox reactions govern whether P may be present in the water column or become bound in Fe-P compounds and precipitate out of the water column (Nürnberg et al. 2013; Molot et al. 2014). Consequently, high Fe concentrations may suppress the availability of P.

(6) P → Autochthonous DOC, DOC

P is the limiting nutrient in most lakes and is frequently positively correlated with chlorophyll *a* (chl *a*) (Schindler 1974; Dillon and Rigler 1975). Increased productivity (increased chl *a*) subsequently results in an increase in autochthonous organic matter (represented by dissolved organic carbon, DOC) (Imai et al. 2001).

(7) Allochthonous DOC → DOC, True Colour, P

The DOC in the lakes presented here likely contained DOC derived from allochthonous sources, as Dillon and Molot (1997) indicated that the watershed in south-central Ontario lakes is largely responsible for observed lake water DOC. The humic carbon compounds in DOC impart colour to filtered water samples (Cuthbert and Del Giorgio 1992) which can be observed in measurements of true colour. P can be transported to lakes through export of P-bound to allochthonous DOC.

(8) DOC → dVWHO

Heterotrophic decomposition of DOC in the water column consumes oxygen (Linsey and Lasenby 1985) and can contribute to oxygen depletion.

The only required covariate found was maximum depth (Z_{max}) and all the valid adjustments sets can increase the precision the change in hypolimnetic oxygen levels can be estimated (Table 3.3).

3.3 Results

Have dipteran assemblages changed over time?

ANOSIM results indicated significant differences in dipteran assemblages when comparing present-day and fossil assemblages ($R = 0.038$, $p = 0.007$). However, as the *R*-statistic is near 0, this signifies that the difference between intervals is quite small and is likely due to shifting

relative abundances rather than replacement of taxa since pre-disturbance conditions circa 1850 CE. Specifically, increasing abundances of *Chaoborus*, *Chironomus anthracinus*, and *Procladius* were consistently observed for lakes which experienced significant reductions in VWHO. These abundance shifts were often coupled with declining relative abundances of *Micropsectra*, namely *Micropsectra contracta* and *Micropsectra insignilobus*. These findings were consistent with the results from SIMPER which identified these taxa as having the greatest contributions to the Bray-Curtis dissimilarity between top and bottom sediment intervals (Table 3.4). Conversely, the lakes which experienced significant increases in VWHO showed the opposite trend. Notably, *Micropsectra contracta* increased by 25% in Lake La Muir since ca 1850 CE while anoxic indicators *Procladius* and *Chironomus anthracinus* declined and disappeared, respectively.

The RDA constrained to present-day VWHO and Z_{max} gradients showed dipteran assemblage changes primarily occurred along RDA Axis 2, associated with the Z_{max} gradient. The greatest shifts in lake community compositions in the positive direction along RDA Axis 2 were observed for lakes which have had dams constructed, namely, Burnt Island, Tea, Grand, and Cedar (Figure 3.4).

Has VWHO changed over time?

Despite the connectivity between the study lakes in Algonquin Park, spatial autocorrelation analyses did not indicate a significant spatial effect on VWHO, enabling the use of statistical tests which assume sample independence. Overall, changes in inferred VWHO did not show a significant pattern of decrease over time (binomial test, *successes* = 18, $n = 31$, $p = 0.47$), where successes in this case was the number of lakes which experienced a negative dVWHO. Ten lakes experienced changes in VWHO greater than the inference model RMSEP (± 1.7 mg O_2 L^{-1})

where three of those lakes showed significant increases, and seven showed significant decreases. The magnitude of VWHO change was larger in lakes with natural hydrology, and all significant increases in VWHO were observed for these lakes which have been unaltered by dams (Figure 3.5).

Has cottage development influenced VWHO over time?

The total effect of cottages on the change in inferred VWHO was not significant (*OLS regression*; $r = 0.32$, $R^2_{adjusted} = -0.054$, $p = 0.58$). Similarly, the difference-in-differences analysis identified no significant effect of cottage presence on the change in VWHO (*OLS regression*; $\varphi = 0.57$, $p = 0.65$). Causal modelling identified depth as a confounder of the effect of cottages on VWHO, therefore, subsequent analyses controlled for depth to observe the total un-confounded effect of cottages on VWHO. However, power analysis indicated that the effect size (f^2) would have to be 0.2 ($R^2 \approx 17\%$) to detect the effect with a power of 80% at the present sample size of 31 (Figure 3.6).

3.4 Discussion

We found that Algonquin Park dipteran communities have experienced slight significant changes since the industrial revolution. In this study of 31 paired top-bottom lake sediment samples, taxa-specific relative abundances have changed over time but there was a lack of observed taxon turnover and compositional shift. There was no overall trend in dipteran-inferred VWHO change over time, however 32% of study lakes experienced inferred VWHO changes with magnitudes greater than the inference model RMSEP (1.7 mg O2 L^{-1}). Similarly, there was no marked

difference in responses between lakes with private cottages and those without. Despite greater potential phosphorus sources from cottages, cottage lakes were not more susceptible to VWHO declines than reference lakes.

Have dipteran assemblages changed over time?

Dipteran assemblages shifted in relative abundances along VWHO and Z_{max} gradients. However, the lack of taxon turnover suggested that limnological conditions did not abruptly or drastically change over the ca 1850 CE to 2015 time period. Taxa which have previously been found in association with higher VWHO concentrations such as *Micropsectra*, and *Heterotrissocladius* (Little and Smol 2001; Quinlan and Smol 2001) generally increased in abundance for lakes with increased VWHO over time. Simultaneously, taxa associated with low VWHO such as *Chironomus*, *Procladius*, and *Chaoborus* (Quinlan and Smol 2001; Quinlan and Smol 2010) generally decreased in abundance as VWHO increased. Despite the large increase in RDA Axis 2 (increasing Z_{max}) scores for Burnt Island over time, the dipteran communities in this lake shifted to include more low oxygen indicators with increases of 6% and 12% observed for *Chaoborus* and *Chironomus anthracinus*, respectively. This may be due to increases in the strength of stratification as a result of lake deepening which would have prevented oxygen replenishment to the hypolimnion.

Has VWHO changed over time?

VWHO change was not consistent across Algonquin Park lakes, there were significant increases and significant decreases, and the VWHO in some lakes remained relatively constant over time. The variation in inferred VWHO change may have been influenced by multiple factors which interact across multiple spatial and time scales. For example, the declines in VWHO observed for

shallow lakes, Clydegale, Farncomb, and Catfish may be due to the sensitivity of shallow stratified lakes, with thinner hypolimnetic volumes, to shifting environmental conditions. Climate change in this region has resulted in increased air temperatures (Favot et al. 2019) which can warm surface water temperatures, strengthening stratification and increasing microbial activity in the hypolimnion (Granéli 1978), leading to VWHO declines. Surprisingly, some of the larger lakes in this study, Source, La Muir, and McKaskill experienced significant increases in VWHO. Significant VWHO increases in large lakes may have been influenced by the overall reduction in catchment TP export observed in south-central Ontario (Eimers et al. 2009). Precipitation has increased in the Algonquin Park region over the last 100 years (Favot et al. 2019) which would reduce lake water residence times in hydrologically connected lakes due to increased inflow from the watershed. Reduced water residence times may further reduce TP concentrations and subsequently reduce primary productivity (Paerl et al. 1998), leading to increased VWHO due to declines in oxygen depletion. Additionally, reduced water residence times may also reduce the effects and strength of stratification (Paerl et al. 1998; Paerl 2006) which may enhance whole lake mixing, and oxygen replenishment, increasing VWHO. In general, lakes with dams at the outlet experienced smaller magnitude changes in VWHO compared to lakes with natural hydrology (Figure 3.5), which may be attributed to a substantive change of lake water residence times due to lake deepening, such that these lakes had different trajectories of VWHO change associated with processes that are related to water residence time.

Has cottage development influenced VWHO over time?

Cottages were not found to be significantly reducing VWHO concentrations in Algonquin Park lakes. These findings are interesting as cottages in Algonquin Park are estimated to contribute approximately 30% of total phosphorus inputs (OMNR 2013b). Additionally, most private

cottage septic systems in Algonquin Park have been established within 15 m from shorelines, where many contribute to surface runoff (OMNR 2013). Septic effluent is highly concentrated with phosphorus (Gilliom and Patmont 1983) which can enter nearby waterbodies and cause algal blooms (Lapointe et al. 2017). However, soil attenuation can substantially reduce mobile phosphorus concentrations through sorption processes (Macintosh 2011; Sawhney and Starr 1977) until the soil becomes concentrated beyond the capacity for sorption to continue. However, Sawhney and Starr (1977) diverted effluent from a high phosphorus soil trench over a six-month period and noted a substantive decrease in soil phosphorus (10-20%), which promoted site recovery, allowing for future soil phosphorus attenuation to occur following the redirection of effluent. Given that six months without effluent input to the high phosphorus soil trench was sufficient to reduce soil phosphorus, a similar effect may be observed in Algonquin Park during the off-season. Sorption regeneration during the off-season may then result in reduced phosphorus loading to nearby lakes from Algonquin Park cottages. Nearby study sites in south-central Ontario showed significant losses of soil calcium (Ca) as a result of reduced pH due to acidic deposition (Watmough and Dillon 2004). Acidic soils may further impact lake phosphorus concentrations due to increased inputs of aluminum (Al) which contributes to phosphorus immobilization due to Al-sorption (Huser and Ryding 2005). Therefore, catchment mediated processes may impact Algonquin Park lakes in ways which reduce the effects of private cottage nutrient inputs.

Similar cottage impact assessments have shown no (or minimal) associations between cottage use and lake oxygen/water quality (Hall and Smol 1996; Quinlan and Smol 2002; Clerk et al. 2001; Thienpont et al. 2008). These findings may be due, in part, to the sparse nature of shoreline cottages combined with preferential establishment of cottages along the shorelines of

larger lakes. Although similar findings have been reported, the sample size in this present study is likely not large enough to detect the effect of cottages on lake trophic status. Power analysis indicated that a sample size between 400 to 450 would be required to detect the effect 75-80% of the time ($f^2 = 0.15$). Since the effect size of cottages on VWHO is small, the present sample size of 31 is unlikely to identify a statistically significant effect. These results are further complicated by the declines in TP observed for south-central Ontario as it is possible that the decline in TP export from watersheds to lakes may negate some of the increase in anthropogenic TP from cottages.

Previously established dipteran indicator taxa responded predictably in association with changes in VWHO in this study of Algonquin Park lakes. This further supports the use of *Micropsectra*, and *Heterotrissocladius* as high VWHO indicators and *Chironomus*, *Procladius*, and *Chaoborus* as low VWHO indicators in south-central Ontario. Since we established historic (ca 1850 CE) dipteran assemblages which were previously unknown, future monitoring of select Algonquin Park lakes can use these assemblages as a baseline for comparison. Although we did not find VWHO changes to be consistent across the landscape, there were some lakes which dropped below 7 mg O_2 L^{-1} which is below the VWHO requirement for lake trout which are both ecologically and recreationally important. Lake managers may elect to increase monitoring of late summer oxygen for select lakes or implement new strategies for increasing VWHO before continuing with fish stocking programs. While cottages were not found to be significantly influencing VWHO changes, this lack of effect could be attributed to catchment-mediated processes which counteract the cottage effect. It is therefore possible that this effect may become more apparent under different catchment conditions.

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3.6 Figures and Tables

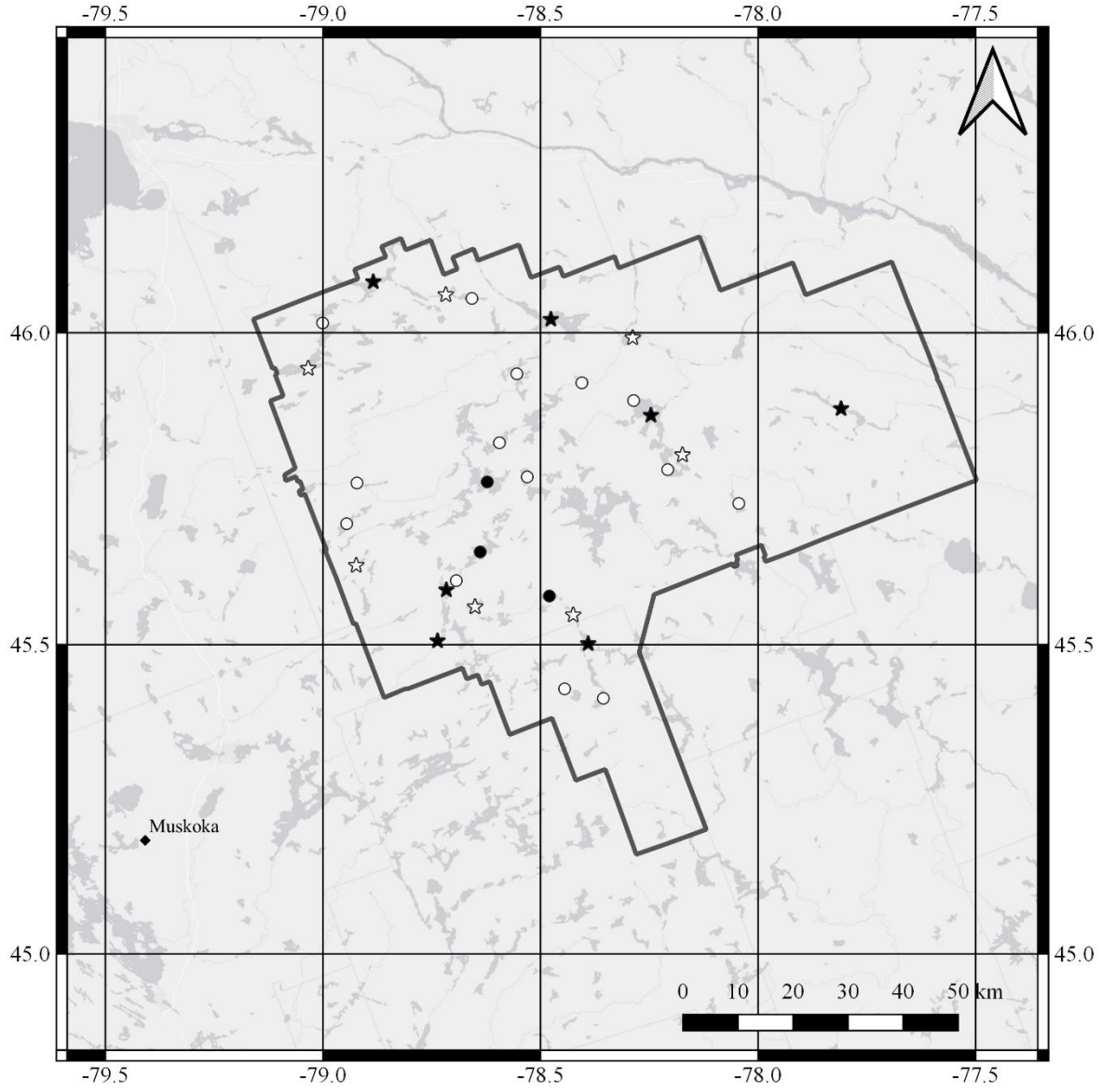

Figure 3.1 Map of top-bottom study lakes (n = 31) showing Algonquin Park boundary where stars represent cottage lakes, and circles represent lakes without cottages. White markers indicate natural hydrology lakes and black markers indicate the presence of a dam at the outlet.

Table 3.1 Schematic table describing the design of a difference in differences model. Cell D is the cell of interesting. The difference in differences model estimates the observed values in each cell.

	Pre-Cottage O_2 Levels	**Post-Cottage O_2 Levels**
No Cottages (Control)	A	B
Cottages Presence (Test)	C	*D

Table 3.2 Detailed schematic table describing the design of a difference in differences model. Each cell shows which equation is used to estimate the observed values in each cell. *Denotes the variable (ψ) that is the causal estimate that cottages have on lakes.

	Pre-Cottage O_2 Levels	**Post-Cottage O_2 Levels**
No Cottages (Control)	b	$b + t$
Cottages Presence (Test)	$b + m$	$b + m + t + \psi^*$

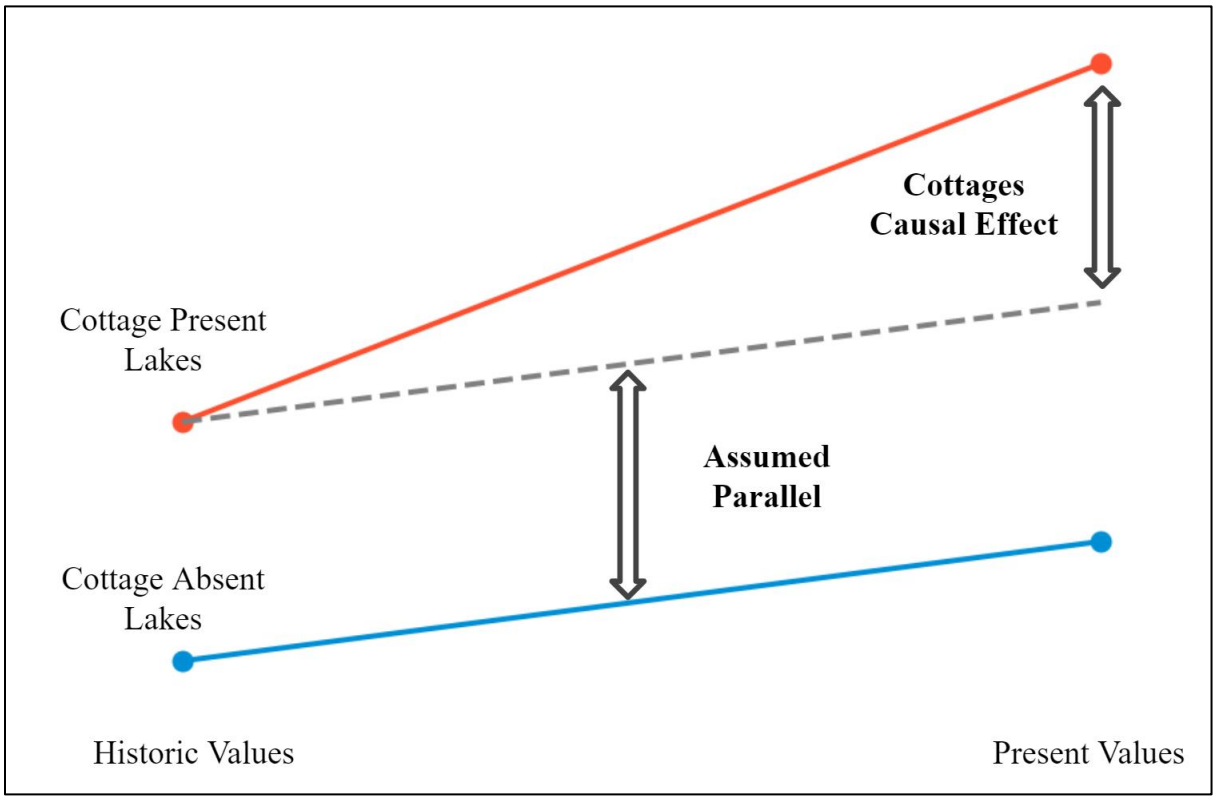

Figure 3.2 Visualization of a causal difference-in-differences model.

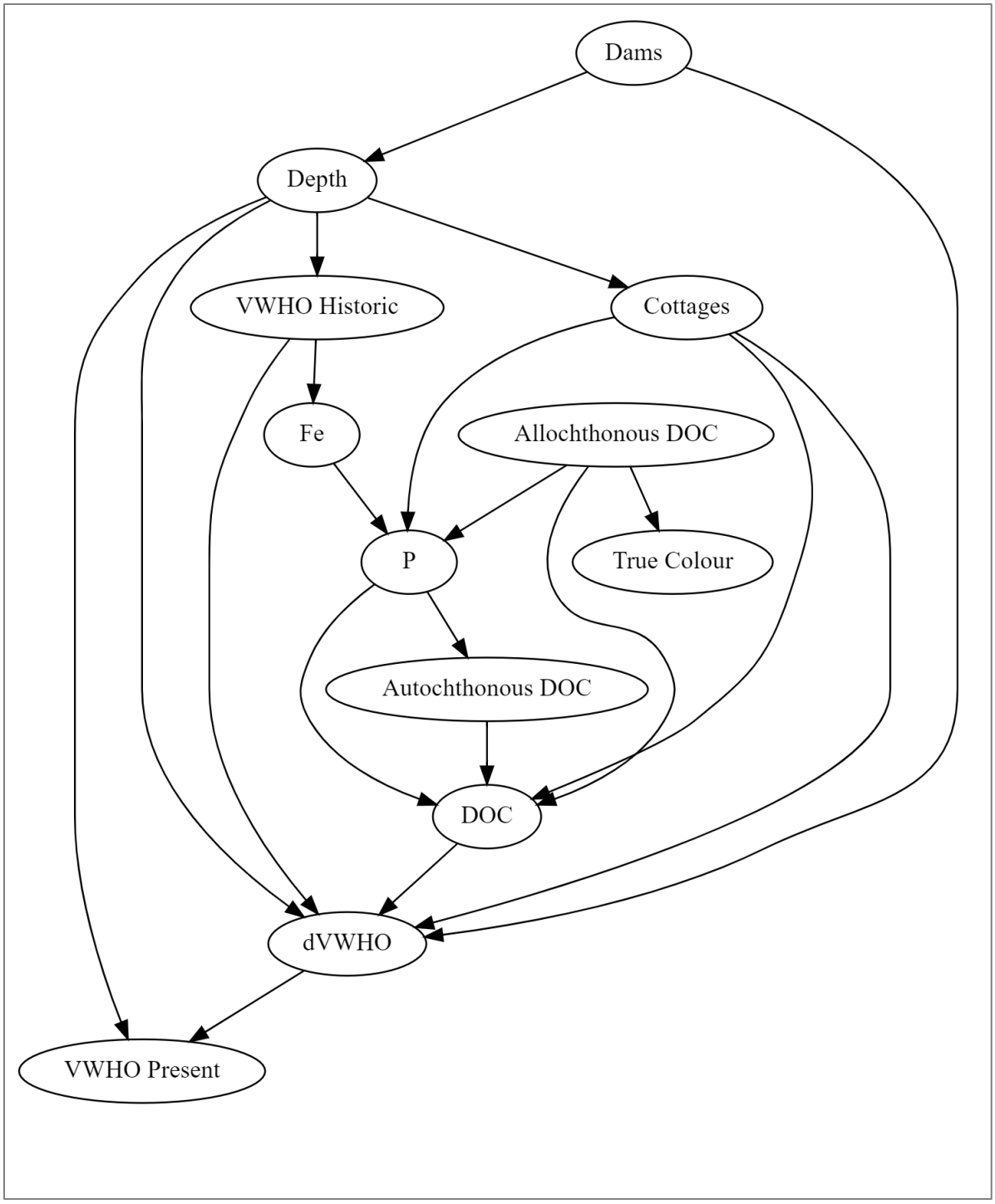

Figure 3.3 A causal diagram describing the data generating process. The associations illustrated here were based on *a priori* associations of limnological variables with VWHO. Arrows describe the direction and potential existence of an effect from one variable to another. The creation of a causal diagram is required for computing valid adjustment sets.
The change in inferred VWHO (ΔVWHO) is represented by dVWHO.

Table 3.3 List of valid adjustment sets for identifying the causal effect between cottages and the change in VWHO.

Covariate Names	Causal Diagram Names
Maximum Depth	Depth
Maximum Depth, Dams, Iron	Depth, Dams, Fe
Maximum Depth, True Colour, VWHO Historic	Depth, True Colour, VWHO Historic
Maximum Depth, Iron	Depth, Fe
Maximum Depth, Allochthonous DOC, Iron	Depth, Allochthonous DOC, Fe
Maximum Depth, Iron, True Colour	Depth, Fe, True Colour
Maximum Depth, Dams	Depth, Dams
Maximum Depth, Dams, True Colour	Depth, Dams, True Colour
Maximum Depth, Dams, Iron, True Colour	Depth, Dams, Fe, True Colour
Maximum Depth, Allochthonous DOC, Dams, Iron, True Colour	Depth, Allochthonous DOC, Dams, Fe, True Colour
Maximum Depth, VWHO Historic	Depth, VWHO Historic
Maximum Depth, Allochthonous DOC	Depth, Allochthonous DOC
Maximum Depth, Allochthonous DOC, VWHO Historic	Depth, Allochthonous DOC, VWHO Historic
Maximum Depth, Allochthonous DOC, Iron, VWHO Historic	Depth, Allochthonous DOC, Fe, VWHO Historic
Maximum Depth, Allochthonous DOC, Dams	Depth, Allochthonous DOC, Dams
Maximum Depth, Allochthonous DOC, Dams, VWHO Historic	Depth, Allochthonous DOC, Dams, VWHO Historic
Maximum Depth, Dams, Iron, VWHO Historic	Depth, Dams, Fe, VWHO Historic
Maximum Depth, Allochthonous DOC, Dams, Iron, VWHO Historic	Depth, Allochthonous DOC, Dams, Fe, VWHO Historic
Maximum Depth, Allochthonous DOC, Iron, True Colour	Depth, Allochthonous DOC, Fe, True Colour
Maximum Depth, Iron, VWHO Historic	Depth, Fe, VWHO Historic
Maximum Depth, Iron, True Colour, VWHO Historic	Depth, Fe, True Colour, VWHO Historic
Maximum Depth, Allochthonous DOC, True Colour	Depth, Allochthonous DOC, True Colour
Maximum Depth, Allochthonous DOC, Dams, True Colour,	Depth, Allochthonous DOC, Dams, True Colour,
Maximum Depth, Dams, VWHO Historic	Depth, Dams, VWHO Historic
Maximum Depth, True Colour	Depth, True Colour
Maximum Depth, Dams, True Colour, VWHO Historic	Depth, Dams, True Colour, VWHO Historic
Maximum Depth, Allochthonous DOC, Dams, True Colour, VWHO Historic	Depth, Allochthonous DOC, Dams, True Colour, VWHO Historic
Maximum Depth, Dams, Iron, True Colour, VWHO Historic	Depth, Dams, Fe, True Colour, VWHO Historic
Maximum Depth, Allochthonous DOC, Dams, Iron	Depth, Allochthonous DOC, Dams, Fe

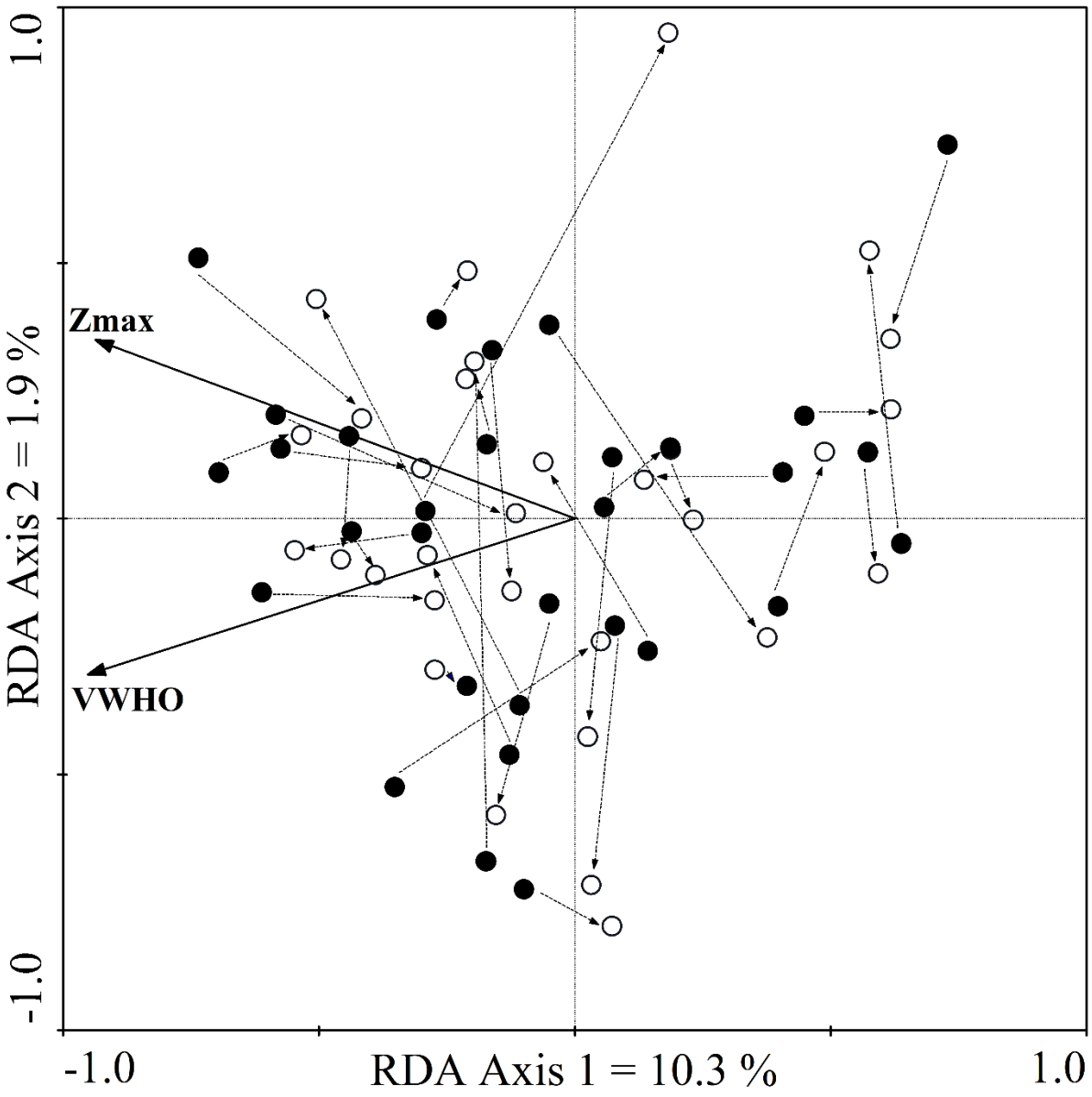

Figure 3.4 Redundancy analysis (RDA) of present-day (hollow circles) dipteran assemblages constrained to significant environmental gradients, VWHO and Z_{max}. Historic (pre-disturbance) assemblages were plotted passively (black circles) and dashed arrows indicate the direction of change for individual lakes.

Table 3.4 SIMPER results of taxa with the largest contribution to BC dissimilarity between top and bottom dipteran assemblages.

Taxon	Average relative abundance (%)		Contribution	Cumulative contribution
	Historic	Present		
Chaoborus	8.9	8.2	0.045	0.045
Micropsectra contracta	8.0	9.0	0.042	0.087
Chironomus anthracinus	4.7	5.0	0.038	0.125
Sergentia coracina	9.4	7.8	0.033	0.158
Micropsectra insignilobus	3.7	3.0	0.033	0.191
Procladius	6.5	6.5	0.030	0.221
Tanytarsus undifferentiated	2.7	0.7	0.030	0.251

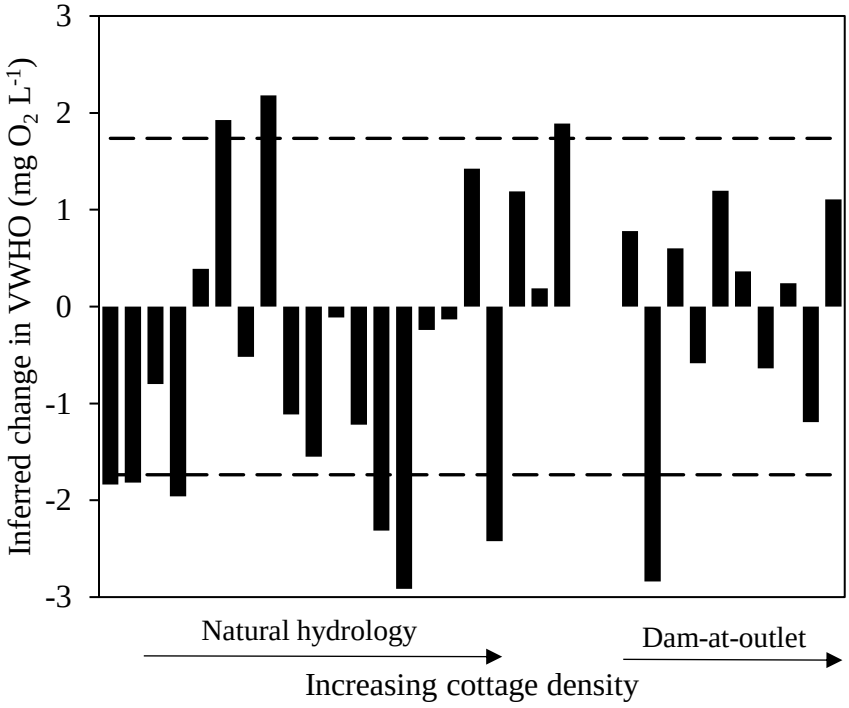

Figure 3.5 Inferred change in VWHO (mg O_2 L^{-1}) for natural hydrology and dammed lakes, ordered along an increasing cottage density gradient. Inferred changes which exceed the dashed lines (prediction error of VWHO inference model in Chapter 2; RMSEP = 1.7 mg O_2 L^{-1}) are considered significant.

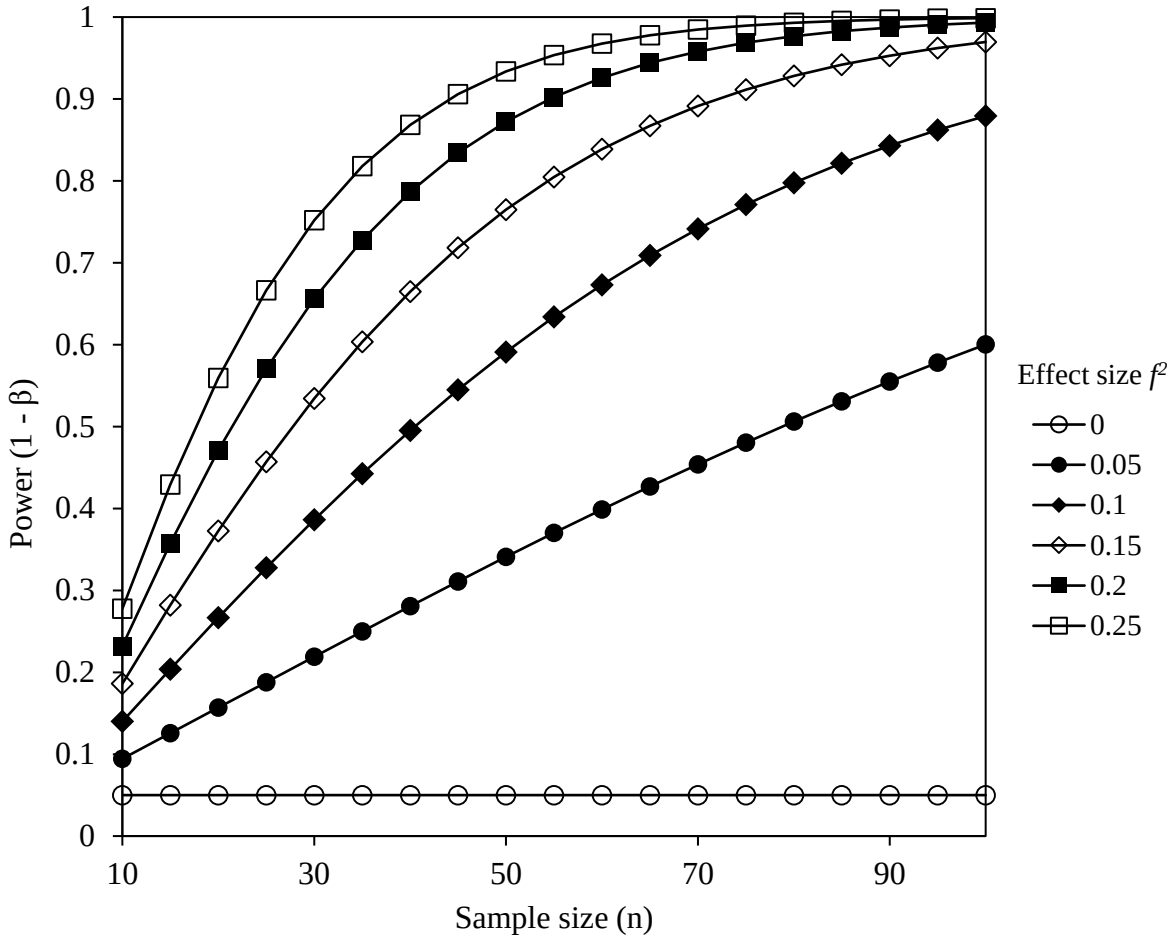

Figure 3.6 Results of pre-hoc power analysis for regression analysis.

4.0 Conclusion

Here we assessed how Algonquin Park lakes have responded over time under the influence of multiple environmental stressors with a special focus on the impact of private cottages. We established baseline (ca 1850 CE) dipteran communities and VWHO concentrations where historic lake data was previously unavailable for these study lakes. These baselines were compared with present-day conditions to find that the lakes in Algonquin Park experienced some changes which were not consistent across the landscape.

Dipteran distributions in Algonquin Park are significantly influenced by VWHO and Z_{max} gradients, which reflects previous findings for Muskoka-Haliburton lakes. Limnological relationships with VWHO were significantly different for DOC, TP and TN in Algonquin Park compared with Muskoka-Haliburton. However, despite these differences, important dipteran indicators showed similar responses to VWHO between the studies, indicating that dipteran communities may be demonstrating an insensitivity to changing limnological dynamics which do not directly affect VWHO (i.e. despite other limnological changes, VWHO remains the primary variable influencing dipteran ecology). Overall, observed dipteran distributions and VWHO optima agree with previously defined autoecology.

The newly developed Algonquin Park dipteran -VWHO inference model can be used in future studies to establish baseline VWHO conditions for Algonquin Park lakes. The model can assist lake managers when setting remediation targets based on baseline VWHO values. Similarly, the combined model for south-central Ontario may be a useful tool for lower resolution dipteran identifications (genus group), however, merging chironomid species into genus-level groupings should be done cautiously, as merging may add complication to analyses of chironomid responses due to intra-taxon differences in ecological preferences.

There was no overall trend in inferred VWHO change over time and dipteran inferred VWHO change was not significant for most lakes. Increases in inferred VWHO reflected increasing abundances of high VWHO indicator taxa while decreases in inferred VWHO were reflected by increasing abundances of low VWHO indicator taxa. Similarly, lakes with cottages did not experience greater VWHO declines compared to reference lakes despite the potential increase in allochthonous P from anthropogenic sources. These findings are similar to previous research in the region which suggest that the declining P export from surrounding catchments may counteract increasing anthropogenic P loading.

The variability of the direction and magnitude of VWHO responses exemplifies the complexity encountered when trying to establish patterns and mechanisms of environmental change where multiple stressors may be interacting in unpredictable ways.

Although VWHO did not consistently decrease across the landscape over time, some lake-specific VWHO declines resulted in present-VWHO levels which are now lower than 7 mg O_2 L^{-1} required for sustaining summer lake trout populations. The current management plans for VWHO in Algonquin Park are primarily based on maintaining low external P inputs, however, we demonstrated that there is no present-day association between P and VWHO for these lakes. Therefore, a new strategy which addresses the cause for VWHO decline in Algonquin Park may be required for appropriate VWHO regulation. Unfortunately, it is unclear what is driving the variable VWHO changes, and they are likely due to multiple stressors which may be difficult to control for. Future work could incorporate important catchment variables related to P export to determine how the results might change if P export were to increase. Lastly, related studies should aim to do a power analysis before conducting fieldwork to determine a more appropriate sample size.

Appendices

Appendix A: Raw data

Table A. 1 Raw dipteran count data for tops (T-) and bottoms (B-). Lake codes listed in A.3.

Taxon	T-BIGT	T-BIGG	T-BIRC	T-BONI
Ablabesmyia	1	0	0	2
Abiskomyia	0	0	0	0
Acalcarella	0	0	0	1
Chaetocladius dentiforceps	0	0	0	0
Chaetocladius piger	2	2	0	0
Chaoborus	1	0	1	5
***Chironomini* larvula**	0	0	0	0
Chironomus anthracinus	2.5	3	1.5	1
Chironomus plumosus	0	0	0	0
Cladopelma laccophila	0	0	0	1
Cladopelma lateralis	0	0	0	8
Cladotanytarsus mancus	0	0	0	0
Conchapelopia	0	0	0	0
Constempellina/Thienemmanniola	0	0	0	0
Corynoneura arctica	0	2	0	0
Corynoneura carriana	0	0	0	0
Corynoneura coronata	0	0	0	0
Corynoneura edwardsi	0	1	2	0
Corynoneura lobata	0	1	0	0
***Corynoneura* type A**	0	0	0	0
Cricotopus bicinctus	0	0	0	0
Cricotopus cylindraceus	0	1	0	0
Cricotopus intersectus	0	0	0	0
Cricotopus laricomalis	0	0	0	0
Cricotopus sylvestris	0	0	0	0
***Cricotopus* type C**	0	0	0	0
***Cricotopus* type P**	0	0	0	0
Cricotopus trifascia	0	0	0	0
Cricotopus trifasciatus	0	1	0	0
Cryptochironomus	0	0	1	0
Cryptotendipes	0	1	0	0
Derotanypus	0	1	0	1
Dicrotendipes nervosus	0	0	2.5	2
Dicrotendipes notatus	0	1	0	0
Doncricotopus	0	0	0	0

Table A.1 *(Continued)*

Taxon	T-BIGT	T-BIGG	T-BIRC	T-BONI
Einfeldia pagana	0	0	0	0
Endochironomus impar	0	0	0	2
Eukiefferiella devonica	0	0	0	0
Eukiefferiella claripennis	0	0	0	0
Eukiefferiella fittkaui	0	0	0	0
Georthocladius	0	0	0	0
Gillotia	0	0	0	0
Glyptotendipes barbipes	0	0	0	0
Glyptotendipes pallens	2	1	0	0
Harnischia	0	0	0	0
Hayesomyia	0	0	0	0
Heterotrissocladius grimshawi	0	0	0	0
Heterotrissocladius maeaeri	1	2	0	0
Heterotrissocladius marcidus	1	0	0	0
Hudsonimyia	0	0	0	0
Labrundinia	0	0	0	0
Larsia	0	0	0	0
Lauterborniella	0	0	0	0
Lipiniella	0	0	0	0
Metriocnemus fuscipes	0	0	0	0
Microchironomus	0	0	0	0
Micropsectra contracta	4	0	0	0
Micropsectra insignilobus	5	0	0	2
Micropsectra pallidula	3	0	0	1
Micropsectra radialis	2	1	0	7
***Micropsectra* type A**	1	0	0	0
Microtendipes pedellus	0	0	0	1
Microtendipes rydalensis	0	0	0	0
Monopelopia	1	1	0	1
Nanocladius branchicolus	0	0	0	0
Natarsia	0	0	0	0
Neozavrelia	0	1	0	1
Pagastiella	0	0	0	0
Parachaetocladius	0	0	0	1
Parachironomus varus	1	1	0	2
Paracladius	0	0	0	0
Paracladopelma	0	0	0	0
Paracricotopus	0	0	0	0
Parakiefferiella bathophila	0	0	0	0

Table A.1 *(Continued)*

Taxon	T-BIGT	T-BIGG	T-BIRC	T-BONI
Parakiefferiella nigra	0	0	0	0
Parakiefferiella tiquetra	0	0	0	0
Paralauterborniella	0	0	0	0
Paramerina	0	0	0	0
Parametriocnemus paraphaenocladius	0	0	0	0
Paratanytarsus	2	1	0	3
Paratendipes albimanus	0	0	0	0
Parorthocladius	0	0	0	0
Pentaneurella	0	0	0	0
Phaenopsectra flavipes	0	0	0	0
Polypedilum nubeculosum	0	0	0	2.5
Polypedilum nubifer	0	0	0	1
Procladius	1	0	3	13
***Propsilocerus* type N**	0	0	0	0
Protanypus	0	0	0	0
Psectrocladius barbatipes	2	0	0	1
Psectrocladius calcaratus	0	0	0	1
Psectrocladius flavus	0	0	0	1
Psectrocladius psilopterus	0	0	0	0
Psectrocladius septentrionalis	0	0	0	0
Psectrocladius sordidellus	0	0	0	2
Psectrotanypus	0	0	0	0
Pseudochironomus	0	0	0	0
Rheocricotopus chalybeatus	0	0	0	0
Rheopelopia	0	0	0	0
Rheotanytarsus	1	0	0	1
Sergentia coracina	6	0	0	1
Sergentia longiventris	1	1	0	0
Smittia/Parasmittia	0	0	0	0
Stempellina	0	3	4	0
Stempellinella/Zavrelia	0	0	0	2
Stenochironomus	0	0	0	0
Stictochironomus rosenschoeldi	3	0	0	0
***Stictochironomus* type B**	0	0	0	0
Symposiocladius	0	0	0	0
Synorthocladius	1	0	0	2
Tanypus	0	0	0	0
Tanytarsus chinyensis	1	0	3.5	5
Tanytarsus glabrescens	0	2	0	0

Table A.1 *(Continued)*

Taxon	T-BIGT	T-BIGG	T-BIRC	T-BONI
Tanytarsus gracilentus	0	0	0	0
Tanytarsus lactescens	0	0	1	0
Tanytarsus lugens	1	0	1.5	4
Tanytarsus mendax	1	0	0	1
Tanytarsinia	0	0	0	0
Tanytarsus pallidicornis	6	3	1	16
Telmatopelopia	0	0	0	0
Telopelopia	0	1	0	0
Thienemanniella clavicornis	0	0	0	0
Thienemannimyia	0	1	1	0
Tribelos	0	0	0	0
Trissocladius	0	0	0	0
Xenochironomus	0	0	0	0
Zalutschia/Zalutschiola	0	0	0	0
Zavreliella	0	0	0	1
Zavrelimyia	0	0	0	1

Taxon	T-BRUL	T-BUIS	T-BURN	T-CATF
Ablabesmyia	0	1	0	3
Abiskomyia	0	0	0	0
Acalcarella	0	0	0	0
Chaetocladius dentiforceps	2	2	0	0
Chaetocladius piger	1.5	5	0	3
Chaoborus	1	10	6	21
***Chironomini* larvula**	0	0	0	0
Chironomus anthracinus	0	9	1.5	16
Chironomus plumosus	0	1	0	1
Cladopelma laccophila	0	0	0	1
Cladopelma lateralis	0	0	0	1
Cladotanytarsus mancus	0	0	0	0.5
Conchapelopia	0	0	0	1
Constempellina/Thienemmanniola	0	1	1.5	1
Corynoneura arctica	0	0	0	0
Corynoneura carriana	0	0	0	0
Corynoneura coronata	0	0	0	0
Corynoneura edwardsi	0	2	0	1
Corynoneura lobata	0	0	0	0
***Corynoneura* type A**	0	1	0	0
Cricotopus bicinctus	0	0	0	0
Cricotopus cylindraceus	0	0	0	1

Table A.1 *(Continued)*

Taxon	T-BRUL	T-BUIS	T-BURN	T-CATF
Cricotopus intersectus	0	0	0	0
Cricotopus laricomalis	0	0	0	0
Cricotopus sylvestris	0	0	0	0
***Cricotopus* type C**	1	0	0	0
***Cricotopus* type P**	0	0	0	0
Cricotopus trifascia	0	0	0	0
Cricotopus trifasciatus	0	0	0	0
Cryptochironomus	0	0	1	0
Cryptotendipes	0	0	0	0
Derotanypus	0	0	0	0
Dicrotendipes nervosus	1	2	2.5	2
Dicrotendipes notatus	0	0	0	0
Doncricotopus	0	0	0	0
Einfeldia pagana	0	0	0	0
Endochironomus impar	0	0	0	0
Eukiefferiella devonica	0	0	0	0
Eukiefferiella claripennis	0	0	0	0
Eukiefferiella fittkaui	0	0	0	0
Georthocladius	0	1	0	0
Gillotia	0	0	0	0
Glyptotendipes barbipes	0	1	0	0
Glyptotendipes pallens	0	0	1	1
Harnischia	0	0	0	0
Hayesomyia	0	0	0	0
Heterotrissocladius grimshawi	0	0	0	1
Heterotrissocladius maeaeri	0	2	0	1
Heterotrissocladius marcidus	0	1	1	2
Hudsonimyia	0	0	0	0
Labrundinia	0	0	0	0
Larsia	0	0	0	0
Lauterborniella	0	0	0	0
Lipiniella	0	0	0	0
Metriocnemus fuscipes	0	0	0	0
Microchironomus	0	0	0	0
Micropsectra contracta	0	2	0	0
Micropsectra insignilobus	3	12	0	1
Micropsectra pallidula	0	1	0	0
Micropsectra radialis	0	2	0	0
***Micropsectra* type A**	0	0	0	0

Table A.1 *(Continued)*

Taxon	T-BRUL	T-BUIS	T-BURN	T-CATF
Microtendipes pedellus	0	0	0	0
Microtendipes rydalensis	0	0	0	0
Monopelopia	0	0	0	0
Nanocladius branchicolus	0	0	0	1
Natarsia	0	0	0	0
Neozavrelia	0	0	0	0
Pagastiella	0	0	0	0
Parachaetocladius	0	0	0	0
Parachironomus varus	0	0	0	0
Paracladius	0	0	0	0
Paracladopelma	0	0	0	0
Paracricotopus	0	0	0	0
Parakiefferiella bathophila	0	0	0	0
Parakiefferiella nigra	0	0	0	0
Parakiefferiella tiquetra	0	0	0	0
Paralauterborniella	0	0	0	0
Paramerina	0	0	0	0
Parametriocnemus paraphaenocladius	0	0	0	0
Paratanytarsus	1	0	0	4
Paratendipes albimanus	0	0	0	0
Parorthocladius	0	0	0	0
Pentaneurella	0	0	0	1
Phaenopsectra flavipes	0	0	0	0
Polypedilum nubeculosum	0	0	0	0
Polypedilum nubifer	0	0	0	0
Procladius	0	2	5	8
***Propsilocerus* type N**	0	0	0	1
Protanypus	0	0	0	0
Psectrocladius barbatipes	0	0	0	0
Psectrocladius calcaratus	0	0	0	0
Psectrocladius flavus	0	0	0	0
Psectrocladius psilopterus	0	0	0	0
Psectrocladius septentrionalis	0	0	0	0
Psectrocladius sordidellus	0	1	0	2
Psectrotanypus	0	0	0	0
Pseudochironomus	0	0	0	1
Rheocricotopus chalybeatus	0	0	0	0
Rheopelopia	0	0	0	0
Rheotanytarsus	0	1	0	0

Table A.1 *(Continued)*

Taxon	T-BRUL	T-BUIS	T-BURN	T-CATF
Sergentia coracina	0	2	0	3.5
Sergentia longiventris	0	1	0	1
Smittia/Parasmittia	0	0	0	0
Stempellina	0	1	0	0
Stempellinella/Zavrelia	0	1	0	0
Stenochironomus	0	0	0	0
Stictochironomus rosenschoeldi	0	1	0	1
***Stictochironomus* type B**	0	0	0	0
Symposiocladius	0	0	0	0
Synorthocladius	0	3	0	0
Tanypus	0	0	0	0
Tanytarsus chinyensis	2	1	1	0
Tanytarsus glabrescens	0	0	0	0
Tanytarsus gracilentus	0	0	0	0
Tanytarsus lactescens	0	0	0	0
Tanytarsus lugens	0	1	0	1
Tanytarsus mendax	0	1	0	0
Tanytarsinia	0	0	0	2
Tanytarsus pallidicornis	2	6	1	5
Telmatopelopia	0	0	0	0
Telopelopia	0	0	0	3
Thienemanniella clavicornis	0	0	0	0
Thienemannimyia	0	2	1	1
Tribelos	0	0	0	0
Trissocladius	1	0	0	0
Xenochironomus	0	0	0	0
Zalutschia/Zalutschiola	0	0	0	0
Zavreliella	0	0	0	1
Zavrelimyia	0	0	0	0

Taxon	T-CAUC	T-CEDA	T-CLYD	T-DICK
Ablabesmyia	4	3.5	1	1
Abiskomyia	0	1	0	0
Acalcarella	0	0	0	0
Chaetocladius dentiforceps	0	1	0	0
Chaetocladius piger	2	2	0	0
Chaoborus	0	3	22	16
***Chironomini* larvula**	0	0	0	0
Chironomus anthracinus	4	1	2	12.5
Chironomus plumosus	0	0	1	0

Table A.1 *(Continued)*

Taxon	T-CAUC	T-CEDA	T-CLYD	T-DICK
Cladopelma laccophila	0	0	1	0
Cladopelma lateralis	0	1.5	2	0
Cladotanytarsus mancus	1.5	1	0	1
Conchapelopia	0	0	0	0
Constempellina/Thienemmanniola	1	0	1.5	3
Corynoneura arctica	0	0	0	0
Corynoneura carriana	1	0	0	0
Corynoneura coronata	0	0	0	0
Corynoneura edwardsi	2	2	0	1
Corynoneura lobata	0	0	0	0
***Corynoneura* type A**	0	0	0	0
Cricotopus bicinctus	0	0	1	0
Cricotopus cylindraceus	1.5	0	0	0
Cricotopus intersectus	0	0	0	1
Cricotopus laricomalis	0	0	0	0
Cricotopus sylvestris	0	1	0	0
***Cricotopus* type C**	0.5	2	0	0
***Cricotopus* type P**	0	0	0	0
Cricotopus trifascia	0	0	0	0
Cricotopus trifasciatus	0	0	0	0
Cryptochironomus	0	1	0	0
Cryptotendipes	1	0	3	0
Derotanypus	0	0	0	0
Dicrotendipes nervosus	2	1	2	1
Dicrotendipes notatus	0	0	0	0
Doncricotopus	0	1	0	0
Einfeldia pagana	0	0	0	0
Endochironomus impar	1	0	0	0
Eukiefferiella devonica	0	1	0	0
Eukiefferiella claripennis	0	0	0	0
Eukiefferiella fittkaui	0	1.5	0	0
Georthocladius	0	0	0	0
Gillotia	0	1	0	0
Glyptotendipes barbipes	0	0	0	0
Glyptotendipes pallens	0	1	0	0
Harnischia	0	0	2	0
Hayesomyia	0	0	0	0
Heterotrissocladius grimshawi	1	0	0	1
Heterotrissocladius maeaeri	1	0.5	0	0

Table A.1 *(Continued)*

Taxon	T-CAUC	T-CEDA	T-CLYD	T-DICK
Heterotrissocladius marcidus	8	2.5	0	3
Hudsonimyia	0	0	0	0
Labrundinia	0	1	0	0
Larsia	0	0	0	0
Lauterborniella	0	0	0	0
Lipiniella	0	0	0	0
Metriocnemus fuscipes	0	0	0	0
Microchironomus	0	0	0	0
Micropsectra contracta	4	5.5	0	0
Micropsectra insignilobus	3	3	0	0
Micropsectra pallidula	2	2	0	0
Micropsectra radialis	1	0	0	0
***Micropsectra* type A**	0	0	0	0
Microtendipes pedellus	1	0	0	0
Microtendipes rydalensis	0	0	0	0
Monopelopia	0	0	0	0
Nanocladius branchicolus	0	0	0	0
Natarsia	0	0	0	0
Neozavrelia	0	0	0	0
Pagastiella	0	0	0	0
Parachaetocladius	0	0	0	0
Parachironomus varus	0	0	0	0
Paracladius	0	0	0	0
Paracladopelma	1	0	0	0
Paracricotopus	0	0	0	0
Parakiefferiella bathophila	0	0	0	0
Parakiefferiella nigra	0.5	8	0	0
Parakiefferiella tiquetra	0	0	0	0
Paralauterborniella	0	0	0	0
Paramerina	0	1	0	0
Parametriocnemus paraphaenocladius	1	0	0	0
Paratanytarsus	2	0	0	3
Paratendipes albimanus	0	1	2	0
Parorthocladius	0	1	0	0
Pentaneurella	0	0	0	0
Phaenopsectra flavipes	0	1.5	0	0
Polypedilum nubeculosum	0	0	1	1
Polypedilum nubifer	0	0	0	0
Procladius	1	1	9	9

Table A.1 *(Continued)*

Taxon	T-CAUC	T-CEDA	T-CLYD	T-DICK
***Propsilocerus* type N**	0	0	0	0
Protanypus	0	0	0	0
Psectrocladius barbatipes	0	0	0	0
Psectrocladius calcaratus	0	0	0	0
Psectrocladius flavus	0	0	0	0
Psectrocladius psilopterus	0	0	0	0
Psectrocladius septentrionalis	0	0	0	0
Psectrocladius sordidellus	5.5	1.5	3	0
Psectrotanypus	0	0	0	0
Pseudochironomus	0	0	0	0
Rheocricotopus chalybeatus	0	0	0	0
Rheopelopia	0	1	0	0
Rheotanytarsus	0	3	0	0
Sergentia coracina	7.5	6.5	0	0
Sergentia longiventris	1	2	0	0
Smittia/Parasmittia	1	0	0	0
Stempellina	0	1.5	0	0
Stempellinella/Zavrelia	0	0	1	3
Stenochironomus	0	0	0	0
Stictochironomus rosenschoeldi	0	0	0	0
***Stictochironomus* type B**	0	1.5	0	0
Symposiocladius	0	0	0	0
Synorthocladius	2	1.5	0	1
Tanypus	0	0	0	0
Tanytarsus chinyensis	2	0	1	0
Tanytarsus glabrescens	0	0	0	0
Tanytarsus gracilentus	0	0	0	0
Tanytarsus lactescens	4	1	2	1
Tanytarsus lugens	2	6	1	1.5
Tanytarsus mendax	0	0	0	0
Tanytarsinia	1	4	0	0
Tanytarsus pallidicornis	2	2	0	1
Telmatopelopia	0	0	0	0
Telopelopia	0	0	0	0
Thienemanniella clavicornis	0	0	0	0
Thienemannimyia	0	2	4	2
Tribelos	0	0	0	0
Trissocladius	0	0	0	0
Xenochironomus	0	0	0	0

Table A.1 *(Continued)*

Taxon	T-CAUC	T-CEDA	T-CLYD	T-DICK
Zalutschia/Zalutschiola	0	0	0	0
Zavreliella	0	0	0	0
Zavrelimyia	0	0	0	0
Taxon	**T-FARN**	**T-GALE**	**T-GIBS**	**T-GRAN**
Ablabesmyia	7	1	0	10
Abiskomyia	0	0	0	0
Acalcarella	0	0	0	0
Chaetocladius dentiforceps	0	0	0	0
Chaetocladius piger	0	0	1	1.5
Chaoborus	35	6	11	2
***Chironomini* larvula**	0	0	0	0
Chironomus anthracinus	2	5	5.5	2
Chironomus plumosus	1.5	1	2	0
Cladopelma laccophila	0	3	1	0
Cladopelma lateralis	4	1	2	1
Cladotanytarsus mancus	0	0	1	3.5
Conchapelopia	0	0	0	1
Constempellina/Thienemmanniola	1	0	0	0
Corynoneura arctica	1	0	0	0
Corynoneura carriana	0	0	4	0
Corynoneura coronata	0	0	0	0
Corynoneura edwardsi	1	0	0	0
Corynoneura lobata	1	0	0	1
***Corynoneura* type A**	1	0	0	0
Cricotopus bicinctus	0	0	1	0
Cricotopus cylindraceus	1	0	0	0.5
Cricotopus intersectus	0	0	0	0
Cricotopus laricomalis	0	0	0	0
Cricotopus sylvestris	0	0	0	0
***Cricotopus* type C**	2	0	1	0
***Cricotopus* type P**	0	0	0	0
Cricotopus trifascia	0	0	0	0
Cricotopus trifasciatus	0	0	0	0
Cryptochironomus	0	0	0	2
Cryptotendipes	0	0	0	0
Derotanypus	0	0	0	0
Dicrotendipes nervosus	0	6	5	6
Dicrotendipes notatus	0	0	1	0
Doncricotopus	0	0	0	0

Table A.1 *(Continued)*

Taxon	T-FARN	T-GALE	T-GIBS	T-GRAN
Einfeldia pagana	0	0	0	0
Endochironomus impar	0	0	0	0
Eukiefferiella devonica	0	0	0	0
Eukiefferiella claripennis	0	0	0	0
Eukiefferiella fittkaui	0	0	0	0
Georthocladius	0	0	0	0
Gillotia	0	0	0	0
Glyptotendipes barbipes	0	0	1	0
Glyptotendipes pallens	0	0	0	0
Harnischia	0	0	0	0
Hayesomyia	0	1	0	0
Heterotrissocladius grimshawi	0	1	0	1
Heterotrissocladius maeaeri	0	0	0	1
Heterotrissocladius marcidus	0.5	5	0	2.5
Hudsonimyia	0	0	0	0
Labrundinia	2	0	0	1
Larsia	0	0	0	0
Lauterborniella	0	0	0	0
Lipiniella	0	0	0	0
Metriocnemus fuscipes	0	0	0	0
Microchironomus	0	1	0	0
Micropsectra contracta	0	4	0	9
Micropsectra insignilobus	0	3	0	1.5
Micropsectra pallidula	1	3	0	0
Micropsectra radialis	1	4	2	2
***Micropsectra* type A**	0	0	0	0
Microtendipes pedellus	0	0	0	0
Microtendipes rydalensis	0	0	0	0
Monopelopia	0	2	0	0
Nanocladius branchicolus	0	0	0	0
Natarsia	0	0	0	0
Neozavrelia	0	0	0	1
Pagastiella	0	0	0	0
Parachaetocladius	0	0	0	0
Parachironomus varus	0	0	0	0
Paracladius	0	0	0	0
Paracladopelma	0	0	0	0
Paracricotopus	0	0	0	0
Parakiefferiella bathophila	0	0	1	0

Table A.1 *(Continued)*

Taxon	T-FARN	T-GALE	T-GIBS	T-GRAN
Parakiefferiella nigra	0	0	0	1.5
Parakiefferiella tiquetra	0	0	0	0
Paralauterborniella	0	0	0	0
Paramerina	0	0	0	0
Parametriocnemus paraphaenocladius	0	0	0	0
Paratanytarsus	5	0	2	0
Paratendipes albimanus	0	0	0	0
Parorthocladius	0	0	0	0
Pentaneurella	0	1	0	0
Phaenopsectra flavipes	0	0	0	0.5
Polypedilum nubeculosum	1	0	0	2
Polypedilum nubifer	0	0	0	1
Procladius	9	14	6	3
***Propsilocerus* type N**	0	0	0	0
Protanypus	0	0	0	0
Psectrocladius barbatipes	0	0	0	0
Psectrocladius calcaratus	0	0	0	1.5
Psectrocladius flavus	0	0	0	0
Psectrocladius psilopterus	0	0	1	0
Psectrocladius septentrionalis	0	0	0	0
Psectrocladius sordidellus	4.5	2	0	6
Psectrotanypus	0	1	0	0
Pseudochironomus	0	0	0	0
Rheocricotopus chalybeatus	0	0	0	0
Rheopelopia	0	0	0	0
Rheotanytarsus	0	0	0	2
Sergentia coracina	1	9	3	5.5
Sergentia longiventris	0	0	0	0
Smittia/Parasmittia	0	0	0	0
Stempellina	0	0	2	1
Stempellinella/Zavrelia	4	1	2	1
Stenochironomus	0	0	0	0
Stictochironomus rosenschoeldi	0	2	0	0
***Stictochironomus* type B**	0	0	0	0
Symposiocladius	0	0	0	0
Synorthocladius	5.5	3	3	1
Tanypus	0	0	0	0
Tanytarsus chinyensis	1	0	0	2
Tanytarsus glabrescens	0	0	0	0

Table A.1 *(Continued)*

Taxon	T-FARN	T-GALE	T-GIBS	T-GRAN
Tanytarsus gracilentus	0	0	0	0
Tanytarsus lactescens	4	0	1	4.5
Tanytarsus lugens	0	2	1	6
Tanytarsus mendax	0	0	0	0
Tanytarsinia	1	0	0	4.5
Tanytarsus pallidicornis	1	9	2	2
Telmatopelopia	0	0	0	0
Telopelopia	0	0	0	0
Thienemanniella clavicornis	0	0	0	0
Thienemannimyia	0	0	0	0
Tribelos	0	0	0	0
Trissocladius	0	0	0	0
Xenochironomus	0	0	0	0
Zalutschia/Zalutschiola	0	0	0	0
Zavreliella	1	0	0	0
Zavrelimyia	0	0	0	0
Taxon	**T-HARR**	**T-HOGA**	**T-JOE**	**T-KIOS**
Ablabesmyia	4	0	0	2
Abiskomyia	0	0	0	0
Acalcarella	0	0	0	0
Chaetocladius dentiforceps	0	0	0	0
Chaetocladius piger	2	1	6	0
Chaoborus	3	0	6	0
***Chironomini* larvula**	0	0	0	0
Chironomus anthracinus	1	3	1	2.5
Chironomus plumosus	0	0	0	0
Cladopelma laccophila	1	1	0	0
Cladopelma lateralis	0	0	2	3.5
Cladotanytarsus mancus	2	2	1	0
Conchapelopia	0	0	0	0
Constempellina/Thienemmanniola	2	0	0	0
Corynoneura arctica	0	1	0	0
Corynoneura carriana	1	0	0	0
Corynoneura coronata	0	0	0	0
Corynoneura edwardsi	0	0	0	0
Corynoneura lobata	0	0	0	0
***Corynoneura* type A**	1	0	2	0
Cricotopus bicinctus	3	0	0	0
Cricotopus cylindraceus	0	0	1	1

Table A.1 *(Continued)*

Taxon	T-HARR	T-HOGA	T-JOE	T-KIOS
Cricotopus intersectus	0	0	0	0
Cricotopus laricomalis	0	0	0	0
Cricotopus sylvestris	0	0	0	0
***Cricotopus* type C**	0	0	0	0
***Cricotopus* type P**	0	0	0	0
Cricotopus trifascia	0	0	2.5	0
Cricotopus trifasciatus	0	0	0	0
Cryptochironomus	0	1	0	0
Cryptotendipes	0	0	0	0
Derotanypus	0	0	0	0
Dicrotendipes nervosus	0	1	7	3.5
Dicrotendipes notatus	0	0	1	0
Doncricotopus	0	0	0	0
Einfeldia pagana	0	0	0	0
Endochironomus impar	0	0	0	0
Eukiefferiella devonica	0	0	0	0
Eukiefferiella claripennis	0	0	0	0
Eukiefferiella fittkaui	0	0	0	0
Georthocladius	0	0	0	0
Gillotia	0	0	0	0
Glyptotendipes barbipes	0	0	0	1
Glyptotendipes pallens	1	0	1	1
Harnischia	0	0	0	0
Hayesomyia	0	0	0	0
Heterotrissocladius grimshawi	0	0	2	2
Heterotrissocladius maeaeri	0	0	0	0
Heterotrissocladius marcidus	1	1	3	3.5
Hudsonimyia	0	0	0	0
Labrundinia	0	0	0	0
Larsia	0	0	0	0
Lauterborniella	0	0	0	0
Lipiniella	0	0	0	0
Metriocnemus fuscipes	0	0	0	0
Microchironomus	0	0	0	0
Micropsectra contracta	2	3	14	6
Micropsectra insignilobus	0	1	4	0
Micropsectra pallidula	2	0	0	0
Micropsectra radialis	0	1	0	0
***Micropsectra* type A**	0	0	1	0

Table A.1 *(Continued)*

Taxon	T-HARR	T-HOGA	T-JOE	T-KIOS
Monopelopia	0	0	0	0
Nanocladius branchicolus	0	0	0	0
Natarsia	0	0	1	0
Neozavrelia	0	0	1	0
Pagastiella	0	0	0	0
Parachaetocladius	0	0	0	0
Parachironomus varus	0	0	3	0
Paracladius	0	0	0	0
Paracladopelma	0	0	0	0
Paracricotopus	0	0	0	0
Parakiefferiella bathophila	0	1	0	0
Parakiefferiella nigra	0	2	0	0
Parakiefferiella tiquetra	0	0	0	0
Paralauterborniella	0	0	0	0
Paramerina	0	0	0	0
Parametriocnemus paraphaenocladius	0	0	0	0
Paratanytarsus	4	0	2	1
Paratendipes albimanus	0	0	0	0
Parorthocladius	0	0	0	0
Pentaneurella	0	0	0	0
Phaenopsectra flavipes	0	0	1	0
Polypedilum nubeculosum	1	0	3	1
Polypedilum nubifer	0	0	0	0
Procladius	4	1	8	3
***Propsilocerus* type N**	0	0	0	0
Protanypus	0	0	0	0
Psectrocladius barbatipes	0	0	1	0
Psectrocladius calcaratus	1	0	0	0
Psectrocladius flavus	0	0	0	0
Psectrocladius psilopterus	2	0	1	0
Psectrocladius septentrionalis	0	0	0	0
Psectrocladius sordidellus	0	1	1	2.5
Psectrotanypus	0	0	0	0
Pseudochironomus	0	0	0	0
Rheocricotopus chalybeatus	0	0	0	0
Rheopelopia	0	0	0	0
Rheotanytarsus	0	0	0	0
Sergentia coracina	11	4	21	4.5
Sergentia longiventris	1	0	1	0

Table A.1 *(Continued)*

Taxon	T-HARR	T-HOGA	T-JOE	T-KIOS
Stempellinella/Zavrelia	4	0	8.5	1
Stenochironomus	0	0	0	0
Stictochironomus rosenschoeldi	0	0	0	1
***Stictochironomus* type B**	0	0	0	0
Symposiocladius	0	0	0	0
Synorthocladius	0	1	4	0
Tanypus	0	0	1	0
Tanytarsus chinyensis	3	1	2	3.5
Tanytarsus glabrescens	0	0	0	0
Tanytarsus gracilentus	0	0	0	0
Tanytarsus lactescens	3	0	2	1
Tanytarsus lugens	2	3	3	1
Tanytarsus mendax	0	0	0	0
Tanytarsinia	0	0	0	0
Tanytarsus pallidicornis	2	2	3	2
Telmatopelopia	0	0	0	0
Telopelopia	0	0	4	0
Thienemanniella clavicornis	0	0	0	0
Thienemannimyia	1	2	2	3
Tribelos	0	0	0	0
Trissocladius	0	0	0	0
Xenochironomus	1	0	0	0
Zalutschia/Zalutschiola	0	0	0	0
Zavreliella	1	0	0	0
Zavrelimyia	0	0	0	0

Taxon	T-LAMU	T-LOTR	T-LAVI	T-LCAU
Ablabesmyia	0	1	0	0
Abiskomyia	0	0	0	0
Acalcarella	0	0	0	0
Chaetocladius dentiforceps	0	0	0	0
Chaetocladius piger	0	0	3	0
Chaoborus	0	2	5	0
***Chironomini* larvula**	0	0	0	0
Chironomus anthracinus	0	0	0	3.5
Chironomus plumosus	0	0	0	1
Cladopelma laccophila	0	1	0	0
Cladopelma lateralis	0	0	0	0
Cladotanytarsus mancus	1	0	0	2
Conchapelopia	0	0	0	0

Table A.1 *(Continued)*

Taxon	T-LAMU	T-LOTR	T-LAVI	T-LCAU
Corynoneura arctica	0	0	0	0
Corynoneura carriana	1	0	2	0
Corynoneura coronata	0	0	0	0
Corynoneura edwardsi	0	0	2	1
Corynoneura lobata	0	0	0	0
***Corynoneura* type A**	0	0	0	1
Cricotopus bicinctus	0	0	0	0
Cricotopus cylindraceus	0	0	0	0
Cricotopus intersectus	0	0	0	0
Cricotopus laricomalis	0	0	1	1
Cricotopus sylvestris	0	0	0	0
***Cricotopus* type C**	0	0	0	0
***Cricotopus* type P**	0	0	0	0
Cricotopus trifascia	0	0	0	0
Cricotopus trifasciatus	0	0	0	0
Cryptochironomus	0	0	0	0
Cryptotendipes	0	0	0	0
Derotanypus	0	0	0	0
Dicrotendipes nervosus	1	0	1	0
Dicrotendipes notatus	1	0	0	0
Doncricotopus	0	0	0	0
Einfeldia pagana	0	0	0	0
Endochironomus impar	0	0	0	0
Eukiefferiella devonica	0	0	0	0
Eukiefferiella claripennis	0	0	0	0
Eukiefferiella fittkaui	0	0	0	0
Georthocladius	0	0	0	0
Gillotia	0	0	0	0
Glyptotendipes barbipes	0	0	0	0
Glyptotendipes pallens	0	1	0	0
Harnischia	0	0	0	0
Hayesomyia	0	0	0	0
Heterotrissocladius grimshawi	1	0	5	2
Heterotrissocladius maeaeri	0	0	10	0
Heterotrissocladius marcidus	13.5	3	0	2.5
Hudsonimyia	0	0	0	0
Labrundinia	0	5.5	1	0
Larsia	0	0	0	0
Lauterborniella	0	0	0	0

Table A.1 *(Continued)*

Taxon	T-LAMU	T-LOTR	T-LAVI	T-LCAU
Microchironomus	0	0	0	0
Micropsectra contracta	53	0	19.5	1
Micropsectra insignilobus	14	0	0	3
Micropsectra pallidula	0	0	0	0
Micropsectra radialis	0	0	0	2
***Micropsectra* type A**	0	0	0	0
Microtendipes pedellus	1	0	0	0
Microtendipes rydalensis	0	0	0	0
Monopelopia	0	0	0	0
Nanocladius branchicolus	0	0	0	0
Natarsia	0	0	0	0
Neozavrelia	0	0	0	0
Pagastiella	0	0	0	0
Parachaetocladius	0	0	0	0
Parachironomus varus	0	0	0	0
Paracladius	0	0	2	0
Paracladopelma	0	0	0	0
Paracricotopus	0	0	0	0
Parakiefferiella bathophila	0	0	0	0
Parakiefferiella nigra	0	0	0	2
Parakiefferiella tiquetra	0	0	0	0
Paralauterborniella	0	0	0	0
Paramerina	0	1	0	0
Parametriocnemus paraphaenocladius	0	0	0	0
Paratanytarsus	2	1	0	1
Paratendipes albimanus	0	0	0	0
Parorthocladius	0	0	0	0
Pentaneurella	0	0	0	0
Phaenopsectra flavipes	0	0	0	0
Polypedilum nubeculosum	0	0	0	0
Polypedilum nubifer	0	1	0	0
Procladius	4	3	0	4
***Propsilocerus* type N**	0	0	0	0
Protanypus	1	0	0	0
Psectrocladius barbatipes	0	0	0	0
Psectrocladius calcaratus	0	0	0	0
Psectrocladius flavus	0	0	0	0
Psectrocladius psilopterus	0	0	0	0
Psectrocladius septentrionalis	0	0	0	0

Table A.1 *(Continued)*

Taxon	T-LAMU	T-LOTR	T-LAVI	T-LCAU
Pseudochironomus	0	0	0	0
Rheocricotopus chalybeatus	0	1	0	0
Rheopelopia	0	0	0	0
Rheotanytarsus	0	0	0	0
Sergentia coracina	5	8	3	3.5
Sergentia longiventris	0	0	0	2
Smittia/Parasmittia	0	0	0	0
Stempellina	2	1	0	1
Stempellinella/Zavrelia	0	0	0	0
Stenochironomus	0	0	0	0
Stictochironomus rosenschoeldi	0	0	0	0
***Stictochironomus* type B**	0	0	0	0
Symposiocladius	0	0	0	0
Synorthocladius	0	0	2	0
Tanypus	0	0	0	0
Tanytarsus chinyensis	1	0	0	1
Tanytarsus glabrescens	0	0	0	0
Tanytarsus gracilentus	0	0	0	1
Tanytarsus lactescens	5	0	1	1
Tanytarsus lugens	2	2	0	3
Tanytarsus mendax	0	0	0	0
Tanytarsinia	0	0	0	3
Tanytarsus pallidicornis	1	9	1	0
Telmatopelopia	0	0	0	0
Telopelopia	0	0	0	0
Thienemanniella clavicornis	0	0	0	0
Thienemannimyia	1	0	3	1
Tribelos	0	0	0	0
Trissocladius	0	0	0	0
Xenochironomus	0	0	0	0
Zalutschia/Zalutschiola	0	0	0	0
Zavreliella	0	0	0	0
Zavrelimyia	0	0	0	0

Taxon	T-LCRO	T-LDIC	T-LJOE	T-LOUI
Ablabesmyia	3	4	0	0
Abiskomyia	0	0	0	0
Acalcarella	0	0	0	0
Chaetocladius dentiforceps	0	0	0	0
Chaetocladius piger	0	1	0	6

Table A.1 *(Continued)*

Taxon	T-LCRO	T-LDIC	T-LJOE	T-LOUI
Chaoborus	8	12	4	0
***Chironomini* larvula**	0	0	0	0
Chironomus anthracinus	0	9	0	0
Chironomus plumosus	2	0	0	0
Cladopelma laccophila	0	1	0	0
Cladopelma lateralis	0.5	1.5	4	0
Cladotanytarsus mancus	4	1	0	0
Conchapelopia	0	0	0	0
Constempellina/Thienemmanniola	0	1.5	0	2
Corynoneura arctica	1	0	0	0
Corynoneura carriana	0	1	0	0
Corynoneura coronata	0	0	0	0
Corynoneura edwardsi	3	8	0	1
Corynoneura lobata	0	0	0	1
***Corynoneura* type A**	0	1	0	1
Cricotopus bicinctus	0	0	0	0
Cricotopus cylindraceus	1	0	0	0
Cricotopus intersectus	0	0	0	0
Cricotopus laricomalis	0	0	0	0
Cricotopus sylvestris	0	0	0	0
***Cricotopus* type C**	0	0	0	0
***Cricotopus* type P**	0	0	0	0
Cricotopus trifascia	0	0	0	0
Cricotopus trifasciatus	0	0	0	0
Cryptochironomus	0	0	2.5	1
Cryptotendipes	0	0	0	0
Derotanypus	0	0	0	0
Dicrotendipes nervosus	4	2	0	3.5
Dicrotendipes notatus	0	1	1	0
Doncricotopus	0	0	0	0
Einfeldia pagana	0	0	0	0
Endochironomus impar	0	0	0	0
Eukiefferiella devonica	0	0	0	0
Eukiefferiella claripennis	0	0	0	0
Eukiefferiella fittkaui	0	0	0	0
Georthocladius	0	0	0	0
Gillotia	0	0	0	0
Glyptotendipes barbipes	0	0	4	0
Glyptotendipes pallens	1	0	2	0

Table A.1 *(Continued)*

Taxon	T-LCRO	T-LDIC	T-LJOE	T-LOUI
Heterotrissocladius grimshawi	0.5	2	5	0
Heterotrissocladius maeaeri	0	0	0	0
Heterotrissocladius marcidus	0	0	1	7
Hudsonimyia	0	0	0	0
Labrundinia	0	0	1	0
Larsia	1	0	0	0
Lauterborniella	0	0	0	0
Lipiniella	0	0	0	0
Metriocnemus fuscipes	0	0	0	0
Microchironomus	0	0	0	0
Micropsectra contracta	0	9	1	3
Micropsectra insignilobus	0	1	2	0
Micropsectra pallidula	0	1	0	0
Micropsectra radialis	0	3	1	1
***Micropsectra* type A**	0	0	0	0
Microtendipes pedellus	0	0	2	0
Microtendipes rydalensis	0	0	0	0
Monopelopia	0	0	0	0
Nanocladius branchicolus	0	0	0	0
Natarsia	0	0	0	0
Neozavrelia	0	0	0	0
Pagastiella	1	0	0	0
Parachaetocladius	0	0	0	0
Parachironomus varus	1.5	0	0	0
Paracladius	0	0	0	0
Paracladopelma	0	0	0	0
Paracricotopus	0	0	0	0
Parakiefferiella bathophila	0	1	1	0
Parakiefferiella nigra	0	0	0	0
Parakiefferiella tiquetra	0	0	0	0
Paralauterborniella	0	0	0	0
Paramerina	0	0	0	0
Parametriocnemus paraphaenocladius	0	0	0	0
Paratanytarsus	4	4	1	1
Paratendipes albimanus	0	0	0	2
Parorthocladius	0	0	0	0
Pentaneurella	0	0	0	0
Phaenopsectra flavipes	0	0	0	0
Polypedilum nubeculosum	1	1	0	0

Table A.1 *(Continued)*

Taxon	T-LCRO	T-LDIC	T-LJOE	T-LOUI
***Propsilocerus* type N**	0	0	0	0
Protanypus	0	0	0	0
Psectrocladius barbatipes	0	0	0	0
Psectrocladius calcaratus	0	0	1	0
Psectrocladius flavus	0	0	0	0
Psectrocladius psilopterus	1	0	0	0
Psectrocladius septentrionalis	0	0	0	0
Psectrocladius sordidellus	2.5	3	1	0
Psectrotanypus	0	0	0	0
Pseudochironomus	0	0	0	0
Rheocricotopus chalybeatus	0	0	0	0
Rheopelopia	0	0	0	0
Rheotanytarsus	0	0	0	0
Sergentia coracina	0	13	1	4
Sergentia longiventris	0	0	0	1
Smittia/Parasmittia	0	0	0	0
Stempellina	0	2	3	0
Stempellinella/Zavrelia	1	0	0	1
Stenochironomus	0	0	0	0
Stictochironomus rosenschoeldi	0	0	0	0
***Stictochironomus* type B**	0	0	0	0
Symposiocladius	0	0	0	0
Synorthocladius	6	4	0	2
Tanypus	0	0	0	0
Tanytarsus chinyensis	3	1	0	1
Tanytarsus glabrescens	0	0	0	0
Tanytarsus gracilentus	0	0	0	0
Tanytarsus lactescens	3	3	1	0
Tanytarsus lugens	1	1	7.5	0
Tanytarsus mendax	0	0	0	0
Tanytarsinia	2	0	0	0
Tanytarsus pallidicornis	4	2	1	0
Telmatopelopia	0	0	0	0
Telopelopia	0	1	0	0
Thienemanniella clavicornis	0	0	0	0
Thienemannimyia	0	3	0	1
Tribelos	0	0	0	0
Trissocladius	0	0	0	0
Xenochironomus	0	0	0	0

Table A.1 *(Continued)*

Taxon	**T-LCRO**	**T-LDIC**	**T-LJOE**	**T-LOUI**
Zavrelimyia	0	1	0	0
Taxon	**T-MANI**	**T-MCIN**	**T-MCKA**	**T-MERC**
Ablabesmyia	2	0	3	7
Abiskomyia	0	0	0	0
Acalcarella	0	0	0	0
Chaetocladius dentiforceps	0	0	0	0
Chaetocladius piger	0	0	0	0
Chaoborus	6	1	4	6
***Chironomini* larvula**	0	0	0	0
Chironomus anthracinus	4	0	0	10
Chironomus plumosus	0	0	0	0
Cladopelma laccophila	0	0	1	0
Cladopelma lateralis	1	0	1	0
Cladotanytarsus mancus	1	0	1	0
Conchapelopia	0	0	0	0
Constempellina/Thienemmanniola	1	0	0	0
Corynoneura arctica	1	0	1	2
Corynoneura carriana	2	0	0	0
Corynoneura coronata	0	0	0	0
Corynoneura edwardsi	1	0	0	0
Corynoneura lobata	0	0	0	0
***Corynoneura* type A**	0	0	3	1
Cricotopus bicinctus	0	0	0	0
Cricotopus cylindraceus	0	0	1	0
Cricotopus intersectus	0	0	0	0
Cricotopus laricomalis	0	0	0	0
Cricotopus sylvestris	0	0	0	0
***Cricotopus* type C**	0	0	0	1
***Cricotopus* type P**	0	0	0	0
Cricotopus trifascia	0	0	0	0
Cricotopus trifasciatus	0	0	0	0
Cryptochironomus	0	0	0	0
Cryptotendipes	0	0	0	0
Derotanypus	0	0	0	0
Dicrotendipes nervosus	2	0	0	1
Dicrotendipes notatus	1	0	0	0
Doncricotopus	0	0	0	0
Einfeldia pagana	0	0	0	0
Endochironomus impar	0	0	0	0

Table A.1 *(Continued)*

Taxon	T-MANI	T-MCIN	T-MCKA	T-MERC
Eukiefferiella devonica	0	0	0	0
Eukiefferiella claripennis	0	0	0	0
Eukiefferiella fittkaui	0	0	0	0
Georthocladius	0	0	0	0
Gillotia	0	0	0	0
Glyptotendipes barbipes	1	1	0	0
Glyptotendipes pallens	2	0	0	1
Harnischia	0	0	0	0
Hayesomyia	0	0	0	0
Heterotrissocladius grimshawi	1	0	0	1
Heterotrissocladius maeaeri	0	0	0	1
Heterotrissocladius marcidus	7	0	2	14
Hudsonimyia	0	0	0	0
Labrundinia	0	0	0	0
Larsia	0	0	0	0
Lauterborniella	0	0	0	0
Lipiniella	0	0	0	0
Metriocnemus fuscipes	0	0	0	0
Microchironomus	0	0	0	0
Micropsectra contracta	11.5	2	9	36
Micropsectra insignilobus	4	0	0	11
Micropsectra pallidula	0	0	0	4
Micropsectra radialis	2	0	0	0
Micropsectra type A	0	0	0	0
Microtendipes pedellus	3	0	0	0
Microtendipes rydalensis	0	0	0	0
Monopelopia	0	0	0	0
Nanocladius branchicolus	0	0	0	0
Natarsia	0	0	0	0
Neozavrelia	0	0	0	0
Pagastiella	0	0	0	0
Parachaetocladius	0	0	0	0
Parachironomus varus	0	0	0	0
Paracladius	0	0	0	0
Paracladopelma	0	0	0	0
Paracricotopus	0	0	0	0
Parakiefferiella bathophila	0	0	1	0
Parakiefferiella nigra	0	0	0	0
Parakiefferiella tiquetra	0	0	0	0

Table A.1 *(Continued)*

Taxon	T-MANI	T-MCIN	T-MCKA	T-MERC
Parametriocnemus paraphaenocladius	0	0	0	0
Paratanytarsus	3	1	1	1
Paratendipes albimanus	0	0	0	0
Parorthocladius	0	0	0	0
Pentaneurella	0	0	0	0
Phaenopsectra flavipes	0	0	0	0
Polypedilum nubeculosum	0	0	0	0
Polypedilum nubifer	0	0	0	0
Procladius	6	0	0	12
***Propsilocerus* type N**	0	0	0	0
Protanypus	0	0	0	0
Psectrocladius barbatipes	0	0	0	0
Psectrocladius calcaratus	0	0	0	0
Psectrocladius flavus	0	0	0	0
Psectrocladius psilopterus	0	0	0	0
Psectrocladius septentrionalis	0	0	0	0
Psectrocladius sordidellus	1	0	0	3
Psectrotanypus	0	0	0	0
Pseudochironomus	0	0	0	0
Rheocricotopus chalybeatus	0	0	0	0
Rheopelopia	0	0	0	0
Rheotanytarsus	0	0	0	0
Sergentia coracina	2	1	4	28
Sergentia longiventris	0	0	0	0
Smittia/Parasmittia	0	0	0	0
Stempellina	0	1	0	1
Stempellinella/Zavrelia	0	1	0	1
Stenochironomus	0	0	1	0
Stictochironomus rosenschoeldi	0	0	0	1
***Stictochironomus* type B**	0	0	0	0
Symposiocladius	0	0	0	0
Synorthocladius	3	0	3	0
Tanypus	0	0	0	0
Tanytarsus chinyensis	2	1.5	1	5
Tanytarsus glabrescens	0	0	0	0
Tanytarsus gracilentus	0	0	0	0
Tanytarsus lactescens	0	0	1	0
Tanytarsus lugens	3	0	0	11
Tanytarsus mendax	0	0	0	0

Table A.1 *(Continued)*

Taxon	T-MANI	T-MCIN	T-MCKA	T-MERC
Telmatopelopia	0	0	1	0
Telopelopia	0	0	0	0
Thienemanniella clavicornis	0	0	0	0
Thienemannimyia	4	0	4	7
Tribelos	0	0	0	0
Trissocladius	0	0	0	0
Xenochironomus	0	0	0	0
Zalutschia/Zalutschiola	0	0	0	0
Zavreliella	0	0	0	1
Zavrelimyia	0	0	0	0
Taxon	**T-MINK**	**T-MOUS**	**T-NBRA**	**T-NTEA**
Ablabesmyia	1	0	2	0
Abiskomyia	0	0	0	0
Acalcarella	0	0	0	0
Chaetocladius dentiforceps	0	0	0	0
Chaetocladius piger	0	4	0	1
Chaoborus	0	23	2	5
***Chironomini* larvula**	0	0	0	0
Chironomus anthracinus	1	3	1.5	9
Chironomus plumosus	0	2	0	0
Cladopelma laccophila	0	0	0	0
Cladopelma lateralis	0	2	1.5	2
Cladotanytarsus mancus	0	0	2	0
Conchapelopia	0	0	0	0
Constempellina/Thienemmanniola	0	0	0	1
Corynoneura arctica	0	0	0	0
Corynoneura carriana	0	0	0	0
Corynoneura coronata	0	0	0	0
Corynoneura edwardsi	0	0	0	0
Corynoneura lobata	0	0	0	0
***Corynoneura* type A**	0	0	0	0
Cricotopus bicinctus	0	0	0	0
Cricotopus cylindraceus	0	0	0	0
Cricotopus intersectus	0	0	0	0
Cricotopus laricomalis	0	0	0	0
Cricotopus sylvestris	0	0	0	0
***Cricotopus* type C**	0	0	0	0
***Cricotopus* type P**	0	0	0	0
Cricotopus trifascia	0	0	0	0

Table A.1 *(Continued)*

Taxon	T-MINK	T-MOUS	T-NBRA	T-NTEA
Cricotopus trifasciatus	0	0	0	0
Cryptochironomus	0	0	0	0
Cryptotendipes	0	0	0	0
Derotanypus	0	0	0	0
Dicrotendipes nervosus	0	1	1.5	1
Dicrotendipes notatus	0	0	0	3
Doncricotopus	0	0	0	0
Einfeldia pagana	0	0	0	0
Endochironomus impar	0	0	0	0
Eukiefferiella devonica	0	0	0	0
Eukiefferiella claripennis	0	0	0	0
Eukiefferiella fittkaui	0	0	0	0
Georthocladius	0	0	0	0
Gillotia	0	0	0	0
Glyptotendipes barbipes	0	0	0	0
Glyptotendipes pallens	0	0	0	0
Harnischia	0	0	0	0
Hayesomyia	0	0	0	0
Heterotrissocladius grimshawi	0	0	0	1
Heterotrissocladius maeaeri	0	0	0	0
Heterotrissocladius marcidus	2	1	1	2
Hudsonimyia	0	0	0	0
Labrundinia	0	0	1.5	0
Larsia	0	0	0	0
Lauterborniella	0	0	0	0
Lipiniella	0	0	0	0
Metriocnemus fuscipes	1	0	0	0
Microchironomus	0	0	0	0
Micropsectra contracta	4.5	3	3	4
Micropsectra insignilobus	4	0	0	0
Micropsectra pallidula	0	0	0	1
Micropsectra radialis	0	8	0	0
***Micropsectra* type A**	0	0	0	0
Microtendipes pedellus	0	2	0	0
Microtendipes rydalensis	0	0	0	0
Monopelopia	0	0	0	0
Nanocladius branchicolus	0	0	0	0
Natarsia	0	0	0	0
Neozavrelia	0	0	0	0

Table A.1 *(Continued)*

Taxon	T-MINK	T-MOUS	T-NBRA	T-NTEA
Parachironomus varus	0	0	0	0
Paracladius	0	0	0	2
Paracladopelma	0	0	0	0
Paracricotopus	0	0	0	0
Parakiefferiella bathophila	0	0	0	0
Parakiefferiella nigra	0	0	0	0
Parakiefferiella tiquetra	0	0	0	0
Paralauterborniella	0	0	0	0
Paramerina	0	0	0	0
Parametriocnemus paraphaenocladius	0	0	0	0
Paratanytarsus	1	5	0	1
Paratendipes albimanus	1	0	0	0
Parorthocladius	0	0	0	0
Pentaneurella	0	0	0	0
Phaenopsectra flavipes	0	0	0	0
Polypedilum nubeculosum	0	0	0	0
Polypedilum nubifer	0	0	0	0
Procladius	0	14	4	2
***Propsilocerus* type N**	0	0	0	0
Protanypus	0	0	0	0
Psectrocladius barbatipes	0	0	0	0
Psectrocladius calcaratus	0	0	0	0
Psectrocladius flavus	0	0	0	0
Psectrocladius psilopterus	0	0	0	0
Psectrocladius septentrionalis	0	0	0	0
Psectrocladius sordidellus	0	0	0	0
Psectrotanypus	0	0	0	0
Pseudochironomus	0	0	0	0
Rheocricotopus chalybeatus	0	0	0	0
Rheopelopia	0	0	0	0
Rheotanytarsus	0	0	0	0
Sergentia coracina	5.5	0	0	3
Sergentia longiventris	0	0	0	0
Smittia/Parasmittia	0	0	0	0
Stempellina	1	2	0	2
Stempellinella/Zavrelia	0	3	0	0
Stenochironomus	0	0	0	0
Stictochironomus rosenschoeldi	0	0	0	0
***Stictochironomus* type B**	0	0	0	0

Table A.1 *(Continued)*

Taxon	T-MINK	T-MOUS	T-NBRA	T-NTEA
Tanypus	0	0	0	0
Tanytarsus chinyensis	0	2	0	0
Tanytarsus glabrescens	0	0	0	0
Tanytarsus gracilentus	0	0	0	0
Tanytarsus lactescens	1	4	1	0
Tanytarsus lugens	2	8	1	1
Tanytarsus mendax	0	0	0	0
Tanytarsinia	0	0	0	0
Tanytarsus pallidicornis	1	7	1	2
Telmatopelopia	0	0	0	0
Telopelopia	0	0	0	0
Thienemanniella clavicornis	0	0	0	0
Thienemannimyia	1	3	1	1
Tribelos	0	0	0	0
Trissocladius	0	0	0	0
Xenochironomus	0	0	0	0
Zalutschia/Zalutschiola	0	0	0	0
Zavreliella	0	0	0	0
Zavrelimyia	0	0	0	0
Taxon	**T-PHIL**	**T-RADI**	**T-RAIN**	**T-RBIC**
Ablabesmyia	0	3	2	2
Abiskomyia	0	0	0	0
Acalcarella	0	0	0	0
Chaetocladius dentiforceps	0	0	0	0
Chaetocladius piger	0	0	2	0
Chaoborus	3	0	17	0
***Chironomini* larvula**	0	0	0	0
Chironomus anthracinus	0	0	3	3
Chironomus plumosus	0	0	0	0
Cladopelma laccophila	0	0	0	0
Cladopelma lateralis	2	0	0	0
Cladotanytarsus mancus	0	1	0	0
Conchapelopia	0	0	0	0
Constempellina/Thienemmanniola	0	1	3.5	0
Corynoneura arctica	0	0	0	0
Corynoneura carriana	0	0	1	0
Corynoneura coronata	0	0	0	1
Corynoneura edwardsi	2	1	2	0
Corynoneura lobata	0	0	0	1

Table A.1 *(Continued)*

Taxon	T-PHIL	T-RADI	T-RAIN	T-RBIC
***Corynoneura* type A**	0	0	0	0
Cricotopus bicinctus	3	0	0	0
Cricotopus cylindraceus	0	1	0	0
Cricotopus intersectus	0	0	0	0
Cricotopus laricomalis	0	0	0	0
Cricotopus sylvestris	0	0	0	0
***Cricotopus* type C**	0	0	1	0
***Cricotopus* type P**	0	0	1	0
Cricotopus trifascia	0	0	0	0
Cricotopus trifasciatus	0	0	0	0
Cryptochironomus	1	3.5	1	0
Cryptotendipes	0	0	1	0
Derotanypus	0	1	1	0
Dicrotendipes nervosus	0	2	3	1
Dicrotendipes notatus	0	0	0	0
Doncricotopus	0	0	0	0
Einfeldia pagana	0	0	0	0
Endochironomus impar	0	0	0	0
Eukiefferiella devonica	0	0	0	0
Eukiefferiella claripennis	0	1	0	0
Eukiefferiella fittkaui	0	2	0	0
Georthocladius	0	0	0	0
Gillotia	0	0	0	0
Glyptotendipes barbipes	0	0	0	0
Glyptotendipes pallens	0	0	0	0
Harnischia	0	0	0	0
Hayesomyia	0	0	0	0
Heterotrissocladius grimshawi	1	0	1	0
Heterotrissocladius maeaeri	1	0	1	2
Heterotrissocladius marcidus	1	1.5	14	15
Hudsonimyia	0	0	0	0
Labrundinia	0	0	0	0
Larsia	0	0	0	0
Lauterborniella	0	0	0	0
Lipiniella	0	0	0	0
Metriocnemus fuscipes	0	0	0	0
Microchironomus	0	0	0	0
Micropsectra contracta	0	1	3	7
Micropsectra insignilobus	0	2	0	3

Table A.1 *(Continued)*

Taxon	T-PHIL	T-RADI	T-RAIN	T-RBIC
***Micropsectra* type A**	0	0	0	0
Microtendipes pedellus	0	1.5	0	0
Microtendipes rydalensis	0	0	0	0
Monopelopia	0	0	0	0
Nanocladius branchicolus	0	0	0	0
Natarsia	0	0	0	0
Neozavrelia	0	1	0	0
Pagastiella	0	0	0	1
Parachaetocladius	0	0	0	0
Parachironomus varus	2	0	0	0
Paracladius	0	0	0	0
Paracladopelma	0	0	1	0
Paracricotopus	0	0	0	0
Parakiefferiella bathophila	0	1	0	0
Parakiefferiella nigra	0	1.5	1	1
Parakiefferiella tiquetra	0	0	0	0
Paralauterborniella	0	0	0	0
Paramerina	0	0	0	0
Parametriocnemus paraphaenocladius	0	0	0	0
Paratanytarsus	2	1	0	0
Paratendipes albimanus	0	0	0	0
Parorthocladius	0	1	0	0
Pentaneurella	0	0	0	0
Phaenopsectra flavipes	0	0	0	0
Polypedilum nubeculosum	1	0	2	0
Polypedilum nubifer	0	0	0	0
Procladius	1	3	7	1
***Propsilocerus* type N**	0	0	0	0
Protanypus	0	0	1	0
Psectrocladius barbatipes	0	0	0	0
Psectrocladius calcaratus	0	2	0	0
Psectrocladius flavus	0	0	0	0
Psectrocladius psilopterus	0	0	1	0
Psectrocladius septentrionalis	0	0	0	0
Psectrocladius sordidellus	5	4.5	5.5	3
Psectrotanypus	0	0	0	0
Pseudochironomus	0	0	0	0
Rheocricotopus chalybeatus	0	0	0	0
Rheopelopia	0	0	0	0

Table A.1 *(Continued)*

Taxon	T-PHIL	T-RADI	T-RAIN	T-RBIC
Sergentia longiventris	0	0	0	0
Smittia/Parasmittia	0	0	0	0
Stempellina	2	0	0	0
Stempellinella/Zavrelia	4	1	1	0
Stenochironomus	0	0	0	0
Stictochironomus rosenschoeldi	0	0	0	0
***Stictochironomus* type B**	0	0	0	0
Symposiocladius	0	0	0	0
Synorthocladius	0	0	2	0
Tanypus	0	0	0	0
Tanytarsus chinyensis	1	1.5	3	0
Tanytarsus glabrescens	0	0	0	0
Tanytarsus gracilentus	0	0	0	0
Tanytarsus lactescens	2	0	2	1
Tanytarsus lugens	2	2	3	2
Tanytarsus mendax	0	0	0	0
Tanytarsinia	0	0	0	0
Tanytarsus pallidicornis	5	4	11	3
Telmatopelopia	0	0	0	0
Telopelopia	0	0	0	0
Thienemanniella clavicornis	0	0	0	0
Thienemannimyia	4	4	9	0
Tribelos	0	0	0	0
Trissocladius	0	0	0	0
Xenochironomus	0	0	0	0
Zalutschia/Zalutschiola	0	0	0	0
Zavreliella	0	0	1	0
Zavrelimyia	0	0	1	0

Taxon	T-RENC	T-ROCK	T-ROSE	T-SHIR
Ablabesmyia	0	0	2	1
Abiskomyia	0	0	0	0
Acalcarella	0	0	0	1
Chaetocladius dentiforceps	0	0	0	0
Chaetocladius piger	3	0	0	4
Chaoborus	0	6	7	20
***Chironomini* larvula**	0	0	0	0
Chironomus anthracinus	1.5	2	1	3
Chironomus plumosus	2	0	0	0
Cladopelma laccophila	1	0	0	0

Table A.1 *(Continued)*

Taxon	T-RENC	T-ROCK	T-ROSE	T-SHIR
Cladotanytarsus mancus	0	0	0	2
Conchapelopia	0	0	0	0
Constempellina/Thienemmanniola	0	0	0	4.5
Corynoneura arctica	0	0	0	0
Corynoneura carriana	0	0	0	2
Corynoneura coronata	1	0	0	0
Corynoneura edwardsi	0	0	1	2
Corynoneura lobata	0	0	0	0
***Corynoneura* type A**	0	0	0	0
Cricotopus bicinctus	0	0	0	0
Cricotopus cylindraceus	0	0	1	0
Cricotopus intersectus	0	0	0	0
Cricotopus laricomalis	0	0	0	0
Cricotopus sylvestris	0	0	0	0
***Cricotopus* type C**	0	0	0	0
***Cricotopus* type P**	0	0	0	1
Cricotopus trifascia	0	0	0	0
Cricotopus trifasciatus	0	0	0	0
Cryptochironomus	0	0	0	0
Cryptotendipes	0	0	1	0
Derotanypus	0	0	0	1
Dicrotendipes nervosus	0	0	4	3
Dicrotendipes notatus	0	0	0	0
Doncricotopus	0	0	0	0
Einfeldia pagana	0	0	0	0
Endochironomus impar	0	0	0	0
Eukiefferiella devonica	0	0	0	0
Eukiefferiella claripennis	0	0	0	0
Eukiefferiella fittkaui	0	0	0	0
Georthocladius	0	0	0	0
Gillotia	0	0	0	0
Glyptotendipes barbipes	0	0	0	0
Glyptotendipes pallens	0	0	0	1
Harnischia	0	0	0	0
Hayesomyia	0	0	0	0
Heterotrissocladius grimshawi	0	2	2	1
Heterotrissocladius maeaeri	0	0	1	0
Heterotrissocladius marcidus	1	2	5	5
Hudsonimyia	0	0	0	0

Table A.1 *(Continued)*

Taxon	T-RENC	T-ROCK	T-ROSE	T-SHIR
Lauterborniella	0	0	2	0
Lipiniella	0	0	0	0
Metriocnemus fuscipes	0	0	0	0
Microchironomus	0	0	0	0
Micropsectra contracta	1	3	2	8
Micropsectra insignilobus	0	1	1	7
Micropsectra pallidula	0	1	0	0
Micropsectra radialis	2	1	1	1
***Micropsectra* type A**	0	1	0	1
Microtendipes pedellus	0	0	0	0
Microtendipes rydalensis	0	0	0	0
Monopelopia	0	0	0	0
Nanocladius branchicolus	0	0	0	0
Natarsia	0	0	0	0
Neozavrelia	0	0	0	0
Pagastiella	0	0	0	1.5
Parachaetocladius	0	0	0	0
Parachironomus varus	0	0	1	0
Paracladius	0	0	0	0
Paracladopelma	0	0	0	0
Paracricotopus	0	0	0	1
Parakiefferiella bathophila	0	0	1	0
Parakiefferiella nigra	0	3	0	0
Parakiefferiella tiquetra	0	0	0	0
Paralauterborniella	0	0	1	0
Paramerina	1	0	0	0
Parametriocnemus paraphaenocladius	0	0	0	0
Paratanytarsus	1	2	5	5
Paratendipes albimanus	0	0	0	0
Parorthocladius	0	0	0	0
Pentaneurella	0	0	0	0
Phaenopsectra flavipes	0	0	0	0
Polypedilum nubeculosum	0	0	1	3
Polypedilum nubifer	0	0	0	0
Procladius	5	13	9	8
***Propsilocerus* type N**	0	0	0	0
Protanypus	0	0	2	2
Psectrocladius barbatipes	0	0	0	0
Psectrocladius calcaratus	0	0	0	1

Table A.1 *(Continued)*

Taxon	T-RENC	T-ROCK	T-ROSE	T-SHIR
Psectrocladius septentrionalis	0	0	0	0
Psectrocladius sordidellus	1	0	4	5
Psectrotanypus	0	0	0	0
Pseudochironomus	0	0	0	0
Rheocricotopus chalybeatus	0	0	0	0
Rheopelopia	0	0	0	0
Rheotanytarsus	0	0	2	0
Sergentia coracina	0	11	6	13
Sergentia longiventris	0	0	0	0
Smittia/Parasmittia	0	0	0	0
Stempellina	0	1	4	0
Stempellinella/Zavrelia	0	3	1	1
Stenochironomus	0	0	0	0
Stictochironomus rosenschoeldi	0	0	0	0
***Stictochironomus* type B**	0	0	0	0
Symposiocladius	0	0	0	0
Synorthocladius	0	0	1	1
Tanypus	0	0	0	0
Tanytarsus chinyensis	1	3	3	7
Tanytarsus glabrescens	0	0	0	0
Tanytarsus gracilentus	0	0	0	0
Tanytarsus lactescens	0	0	7	2
Tanytarsus lugens	3	0	4	5
Tanytarsus mendax	0	0	0	0
Tanytarsinia	0	0	0	0
Tanytarsus pallidicornis	2	4	13	13
Telmatopelopia	0	0	0	0
Telopelopia	0	0	0	0
Thienemanniella clavicornis	0	0	1	0
Thienemannimyia	1	2	5	5
Tribelos	0	0	0	1
Trissocladius	0	0	0	0
Xenochironomus	0	0	0	0
Zalutschia/Zalutschiola	0	0	0	0
Zavreliella	0	0	0	0
Zavrelimyia	0	0	0	0
Taxon	**T-SOUR**	**T-TEA**	**T-TIM**	**T-WATE**
Ablabesmyia	1	1	2	0
Abiskomyia	0	0	0	0

Table A.1 *(Continued)*

Taxon	T-SOUR	T-TEA	T-TIM	T-WATE
Chaetocladius dentiforceps	1	0	0	0
Chaetocladius piger	1	0	0	0
Chaoborus	0	26	2	0
***Chironomini* larvula**	0	0	0	0
Chironomus anthracinus	0	19	0	0
Chironomus plumosus	0	1	0	0
Cladopelma laccophila	0	0	0	0
Cladopelma lateralis	1	0	0	0
Cladotanytarsus mancus	0	0	0	0
Conchapelopia	0	0	0	0
Constempellina/Thienemmanniola	0	1	0	1
Corynoneura arctica	0	0	0	0
Corynoneura carriana	2	0	1	0
Corynoneura coronata	0	0	0	0
Corynoneura edwardsi	1	0	0	0
Corynoneura lobata	0	0	1	0
***Corynoneura* type A**	0	0	0	0
Cricotopus bicinctus	0	0	1	0
Cricotopus cylindraceus	0	0	0	0
Cricotopus intersectus	0	0	0	0
Cricotopus laricomalis	0	0	0	0
Cricotopus sylvestris	0	0	0	0
***Cricotopus* type C**	0	0	0	0
***Cricotopus* type P**	0	0	0	0
Cricotopus trifascia	0	0	0	0
Cricotopus trifasciatus	0	0	0	0
Cryptochironomus	0	0	0	0
Cryptotendipes	0	0	0	0
Derotanypus	0	0	0	0
Dicrotendipes nervosus	1	1	2	1
Dicrotendipes notatus	1	0	0	0
Doncricotopus	0	0	0	0
Einfeldia pagana	0	0	0	0
Endochironomus impar	0	0	0	0
Eukiefferiella devonica	0	0	0	0
Eukiefferiella claripennis	0	0	0	0
Eukiefferiella fittkaui	0	0	0	0
Georthocladius	0	0	0	0
Gillotia	0	0	0	0

Table A.1 *(Continued)*

Taxon	T-SOUR	T-TEA	T-TIM	T-WATE
Harnischia	0	0	0	0
Hayesomyia	0	0	0	0
Heterotrissocladius grimshawi	0	1	6	0
Heterotrissocladius maeaeri	0	2	0	1
Heterotrissocladius marcidus	6	7	2	1.5
Hudsonimyia	0	0	0	0
Labrundinia	0	0	0	1
Larsia	0	0	0	0
Lauterborniella	0	0	0	0
Lipiniella	0	0	0	0
Metriocnemus fuscipes	0	0	0	0
Microchironomus	0	0	0	0
Micropsectra contracta	11	1	1	2
Micropsectra insignilobus	3	1	3	1
Micropsectra pallidula	0	1	0	0
Micropsectra radialis	3	0	0	0
Micropsectra type A	0	0	0	0
Microtendipes pedellus	1	0	0	0
Microtendipes rydalensis	0	0	0	0
Monopelopia	0	0	0	0
Nanocladius branchicolus	0	0	0	0
Natarsia	0	0	0	0
Neozavrelia	0	0	0	0
Pagastiella	0	1	0	0
Parachaetocladius	0	0	0	0
Parachironomus varus	0	0	0	0
Paracladius	0	0	0	0
Paracladopelma	0	0	0	0
Paracricotopus	0	0	0	0
Parakiefferiella bathophila	0	0	0	1
Parakiefferiella nigra	0	0	0	0
Parakiefferiella tiquetra	0	0	0	0
Paralauterborniella	0	0	0	0
Paramerina	0	0	0	0
Parametriocnemus paraphaenocladius	0	0	0	0
Paratanytarsus	4	0	0	0
Paratendipes albimanus	0	0	0	0
Parorthocladius	0	0	0	0
Pentaneurella	0	0	0	0

Table A.1 *(Continued)*

Taxon	T-SOUR	T-TEA	T-TIM	T-WATE
Phaenopsectra flavipes	0	0	0	0
Polypedilum nubeculosum	0	0	1	1
Polypedilum nubifer	0	0	0	0
Procladius	6	17	1	1
***Propsilocerus* type N**	0	0	0	0
Protanypus	0	1	0	0
Psectrocladius barbatipes	0	0	0	0
Psectrocladius calcaratus	0	0	0	0
Psectrocladius flavus	0	0	0	0
Psectrocladius psilopterus	0	1	0	0
Psectrocladius septentrionalis	0	0	0	0
Psectrocladius sordidellus	1	2	1	0
Psectrotanypus	0	0	0	0
Pseudochironomus	0	0	0	0
Rheocricotopus chalybeatus	0	0	0	0
Rheopelopia	0	0	0	0
Rheotanytarsus	0	0	0	2
Sergentia coracina	5	1	1	1.5
Sergentia longiventris	0	0	0	0
Smittia/Parasmittia	0	0	0	0
Stempellina	0	0	0	0
Stempellinella/Zavrelia	1	2	0	1
Stenochironomus	0	0	0	0
Stictochironomus rosenschoeldi	0	0	0	0
***Stictochironomus* type B**	0	0	0	0
Symposiocladius	0	0	0	0
Synorthocladius	0	0	0	0
Tanypus	0	0	0	0
Tanytarsus chinyensis	1	2	0	0
Tanytarsus glabrescens	0	0	0	0
Tanytarsus gracilentus	0	0	0	0
Tanytarsus lactescens	1	1	0	0
Tanytarsus lugens	1	7	0	0
Tanytarsus mendax	0	0	0	0
Tanytarsinia	0	0	0	0
Tanytarsus pallidicornis	0	6	9	0
Telmatopelopia	0	0	0	0
Telopelopia	0	0	0	0
Thienemanniella clavicornis	0	0	0	0

Table A.1 *(Continued)*

Taxon	T-SOUR	T-TEA	T-TIM	T-WATE
Thienemannimyia	1	7	1	3
Tribelos	0	0	0	1
Trissocladius	0	0	0	0
Xenochironomus	0	0	0	0
Zalutschia/Zalutschiola	0	2.5	0	0
Zavreliella	0	0	0	0
Zavrelimyia	0	0	0	0
Taxon	**T-WELC**	**T-WHIT**	**B-BIGT**	**B-BONI**
Ablabesmyia	1	3	3	5
Abiskomyia	0	0	0	0
Acalcarella	0	0	0	0
Chaetocladius dentiforceps	0	0	0	0
Chaetocladius piger	0	1	0	0
Chaoborus	1	6	6	1
***Chironomini* larvula**	0	0	0	0
Chironomus anthracinus	2	1.5	4	1
Chironomus plumosus	0	0	0	0
Cladopelma laccophila	0	0	0	0
Cladopelma lateralis	0	2	0	2
Cladotanytarsus mancus	0	0	1.5	2
Conchapelopia	0	0	0	0
Constempellina/Thienemmanniola	0	0	0	0
Corynoneura arctica	0	0	2	0
Corynoneura carriana	0	0	0	0
Corynoneura coronata	0	0	0	0
Corynoneura edwardsi	1	0	0	0
Corynoneura lobata	0	0	0	0
***Corynoneura* type A**	0	0	0	0
Cricotopus bicinctus	0	0	0	0
Cricotopus cylindraceus	0	0	0	0
Cricotopus intersectus	0	0	0	0
Cricotopus laricomalis	0	0	0	0
Cricotopus sylvestris	0	0	0	0
***Cricotopus* type C**	0	0	0	0
***Cricotopus* type P**	0	0	0	0
Cricotopus trifascia	0	0	0	0
Cricotopus trifasciatus	0	0	0	0
Cryptochironomus	0	0	1	5
Cryptotendipes	0	0	0	0

Table A.1 *(Continued)*

Taxon	T-WELC	T-WHIT	B-BIGT	B-BONI
Derotanypus	0	0	0	0
Dicrotendipes nervosus	1	0	0	8.5
Dicrotendipes notatus	0	0	0	0
Doncricotopus	0	0	0	0
Einfeldia pagana	0	0	0	0
Endochironomus impar	0	0	0	0
Eukiefferiella devonica	0	0	0	0
Eukiefferiella claripennis	0	0	0	0
Eukiefferiella fittkaui	0	0	0	0
Georthocladius	0	0	0	0
Gillotia	0	0	0	0
Glyptotendipes barbipes	0	0	0	0
Glyptotendipes pallens	0	2	0	0
Harnischia	0	0	0	0
Hayesomyia	0	0	0	0
Heterotrissocladius grimshawi	1	1.5	0	0
Heterotrissocladius maeaeri	0	0	1	0
Heterotrissocladius marcidus	4	3.5	4.5	0
Hudsonimyia	0	0	1	0
Labrundinia	0	3	1	1
Larsia	0	0	0	0
Lauterborniella	1	0	0	5
Lipiniella	0	0	0	0
Metriocnemus fuscipes	0	0	0	0
Microchironomus	0	0	0	0
Micropsectra contracta	2	7.5	4	2
Micropsectra insignilobus	0	0	14	0
Micropsectra pallidula	0	0	0	0
Micropsectra radialis	0	0	0	0
***Micropsectra* type A**	0	0	0	0
Microtendipes pedellus	1	0	1	0
Microtendipes rydalensis	0	0	0	0
Monopelopia	0	0	0	0
Nanocladius branchicolus	0	0	0	0
Natarsia	0	0	0	0
Neozavrelia	0	0	0	0
Pagastiella	0	0	0	3.5
Parachaetocladius	0	0	0	0
Parachironomus varus	0	0	0	0

Table A.1 *(Continued)*

Taxon	T-WELC	T-WHIT	B-BIGT	B-BONI
Paracladius	0	0	0	0
Paracladopelma	0	0	0	0
Paracricotopus	0	0	0	0
Parakiefferiella bathophila	0	0	1	0
Parakiefferiella nigra	1	0	3	0
Parakiefferiella tiquetra	0	0	0	2
Paralauterborniella	0	0	0	0
Paramerina	0	0	0	0
Parametriocnemus paraphaenocladius	0	0	0	0
Paratanytarsus	1	1	3	6
Paratendipes albimanus	0	1	0	0
Parorthocladius	0	0	0	0
Pentaneurella	0	0	0	0
Phaenopsectra flavipes	0	0	8	0
Polypedilum nubeculosum	1	0	1	22
Polypedilum nubifer	0	0	0	0
Procladius	8	4	8	11
***Propsilocerus* type N**	0	0	0	0
Protanypus	0	0	4	0
Psectrocladius barbatipes	0	0	0	1
Psectrocladius calcaratus	0	0	0	1
Psectrocladius flavus	0	0	0	0
Psectrocladius psilopterus	0	0	0	0
Psectrocladius septentrionalis	0	0	0	0
Psectrocladius sordidellus	0	0	3.5	0
Psectrotanypus	0	0	0	0
Pseudochironomus	0	0	0	0
Rheocricotopus chalybeatus	0	0	0	0
Rheopelopia	0	0	0	0
Rheotanytarsus	0	0	0	0
Sergentia coracina	6	6.5	9	0
Sergentia longiventris	0	0	2	0
Smittia/Parasmittia	0	0	0	0
Stempellina	4	0	0	4
Stempellinella/Zavrelia	1	1	1	3
Stenochironomus	0	0	0	0
Stictochironomus rosenschoeldi	1	0	0	0
***Stictochironomus* type B**	0	0	0	0
Symposiocladius	0	0	1	0

Table A.1 *(Continued)*

Taxon	T-WELC	T-WHIT	B-BIGT	B-BONI
Synorthocladius	0	2	5	0
Tanypus	0	0	0	0
Tanytarsus chinyensis	3	0	1	3
Tanytarsus glabrescens	0	0	0	0
Tanytarsus gracilentus	0	0	0	0
Tanytarsus lactescens	0	0	3	2
Tanytarsus lugens	4	1	0	3
Tanytarsus mendax	0	0	0	0
Tanytarsinia	0	0	8	0
Tanytarsus pallidicornis	4	0	0	8
Telmatopelopia	0	0	0	0
Telopelopia	0	0	0	0
Thienemanniella clavicornis	0	0	0	0
Thienemannimyia	0	0	5	0
Tribelos	0	0	0	0
Trissocladius	0	0	0	0
Xenochironomus	0	0	0	0
Zalutschia/Zalutschiola	0	0	0	0
Zavreliella	0	0	0	4
Zavrelimyia	0	0	0	0
Taxon	**B-BUIS**	**B-CATF**	**B-CAUC**	**B-CEDA**
Ablabesmyia	3	5	5	2
Abiskomyia	0	0	0	0
Acalcarella	0	0	0	0
Chaetocladius dentiforceps	0	0	1	0
Chaetocladius piger	2	0	1	0
Chaoborus	3	17	0	1
***Chironomini* larvula**	0	0	0	1
Chironomus anthracinus	0	9	3	0
Chironomus plumosus	0	0	0	0
Cladopelma laccophila	0	0	0	0
Cladopelma lateralis	0	1	0	3
Cladotanytarsus mancus	0	0	0.5	0
Conchapelopia	0	0	0	1
Constempellina/Thienemmanniola	0	1	2	3
Corynoneura arctica	1	0	1	1
Corynoneura carriana	0	0	0	0
Corynoneura coronata	0	0	0	0
Corynoneura edwardsi	1	1	1	0

Table A.1 *(Continued)*

Taxon	B-BUIS	B-CATF	B-CAUC	B-CEDA
Corynoneura lobata	0	0	0	0
***Corynoneura* type A**	0	0	0	0
Cricotopus bicinctus	0	0	0	0
Cricotopus cylindraceus	0	0.5	0	0
Cricotopus intersectus	0	0	0	0
Cricotopus laricomalis	0	0	0	0
Cricotopus sylvestris	0	0	0	0
***Cricotopus* type C**	0	0	0	0
***Cricotopus* type P**	0	0	0	0
Cricotopus trifascia	0	0	0	0
Cricotopus trifasciatus	0	0	0	0
Cryptochironomus	1	0	0	0
Cryptotendipes	0	0	0	0
Derotanypus	0	0	0	0
Dicrotendipes nervosus	0	0	3	1
Dicrotendipes notatus	0	0	0	0
Doncricotopus	0	0	0	0
Einfeldia pagana	0	0	0	0
Endochironomus impar	0	0	0	0
Eukiefferiella devonica	0	0	0	0
Eukiefferiella claripennis	0	0	0	4
Eukiefferiella fittkaui	0	0	1	0
Georthocladius	0	0	0	0
Gillotia	0	0	0	0
Glyptotendipes barbipes	0	0	1	0
Glyptotendipes pallens	0	0	0	0
Harnischia	0	0	0	0
Hayesomyia	0	0	0	0
Heterotrissocladius grimshawi	2	1	0	0
Heterotrissocladius maeaeri	1	0	0	0
Heterotrissocladius marcidus	1	5	4	3
Hudsonimyia	0	0	0	0
Labrundinia	0	3	0	0
Larsia	0	0	0	0
Lauterborniella	0	0	0	0
Lipiniella	0	0	0	0
Metriocnemus fuscipes	0	0	0	0
Microchironomus	0	0	0	0
Micropsectra contracta	6	3	13.5	4

Table A.1 *(Continued)*

Taxon	B-BUIS	B-CATF	B-CAUC	B-CEDA
Micropsectra insignilobus	2	0	1	1
Micropsectra pallidula	1	0	0	0
Micropsectra radialis	0	0	0	1
***Micropsectra* type A**	0	0	0	0
Microtendipes pedellus	0	0	0.5	0
Microtendipes rydalensis	0	0	0	0
Monopelopia	0	0	0	0
Nanocladius branchicolus	0	0	0	0
Natarsia	0	0	0	0
Neozavrelia	0	0	0	0
Pagastiella	0	0	0	0
Parachaetocladius	0	0	0	0
Parachironomus varus	0	0	0	0
Paracladius	0	0	0	0
Paracladopelma	0	0	0	0
Paracricotopus	0	0	0	0
Parakiefferiella bathophila	0	0	1	0
Parakiefferiella nigra	3	3	3	1
Parakiefferiella tiquetra	0	1	0	0
Paralauterborniella	0	0	0	0
Paramerina	0	0	0	0
Parametriocnemus paraphaenocladius	0	0	0	0
Paratanytarsus	0	4	1	1
Paratendipes albimanus	0	0	0	0
Parorthocladius	0	0	0	0
Pentaneurella	0	0	0	0
Phaenopsectra flavipes	0	0	0	0
Polypedilum nubeculosum	0	0	2	1
Polypedilum nubifer	0	0	0	0
Procladius	3	6	2	2
***Propsilocerus* type N**	0	0	0	0
Protanypus	0	0	1	0
Psectrocladius barbatipes	0	0	0	0
Psectrocladius calcaratus	0	0	0	0
Psectrocladius flavus	0	0	0	0
Psectrocladius psilopterus	0	0	0	1
Psectrocladius septentrionalis	0	0	0	0
Psectrocladius sordidellus	0	0.5	0.5	0
Psectrotanypus	0	0	0	0

Table A.1 *(Continued)*

Taxon	B-BUIS	B-CATF	B-CAUC	B-CEDA
Pseudochironomus	0	0	0	0
Rheocricotopus chalybeatus	0	0	0	0
Rheopelopia	0	0	0	0
Rheotanytarsus	0	0	0	0
Sergentia coracina	5	7.5	12.5	2
Sergentia longiventris	0	0	0	0
Smittia/Parasmittia	0	0	0	0
Stempellina	0	1	0	0
Stempellinella/Zavrelia	0	0	5	1
Stenochironomus	0	0	0	0
Stictochironomus rosenschoeldi	0	0	1	1
***Stictochironomus* type B**	0	0	0	0
Symposiocladius	0	0	0	0
Synorthocladius	6	6.5	3	0
Tanypus	0	0	0	0
Tanytarsus chinyensis	0	1	1	0
Tanytarsus glabrescens	0	0	0	0
Tanytarsus gracilentus	0	0	0	0
Tanytarsus lactescens	1	0	0	1
Tanytarsus lugens	1	4	0	2
Tanytarsus mendax	0	0	0	0
Tanytarsinia	0	2	1	0
Tanytarsus pallidicornis	5	1	1	7
Telmatopelopia	0	0	0	0
Telopelopia	0	0	0	0
Thienemanniella clavicornis	0	0	0	0
Thienemannimyia	1	0	0	3
Tribelos	0	0	0	0
Trissocladius	0	0	0	0
Xenochironomus	0	0	0	0
Zalutschia/Zalutschiola	0	0	0	0
Zavreliella	0	0	2	0
Zavrelimyia	0	0	0	0

Taxon	B-CLYD	B-DICK	B-FARN	B-GRAN
Ablabesmyia	5	1	7	9
Abiskomyia	0	0	0	0
Acalcarella	0	0	0	0
Chaetocladius dentiforceps	0	0	0	0
Chaetocladius piger	0	0	3	0

Table A.1 *(Continued)*

Taxon	B-CLYD	B-DICK	B-FARN	B-GRAN
Chaoborus	10	22	34	1
***Chironomini* larvula**	0	0	0	0
Chironomus anthracinus	6	2	3	0
Chironomus plumosus	0	2	0	0
Cladopelma laccophila	0	1	0	0
Cladopelma lateralis	1	1	3	3.5
Cladotanytarsus mancus	0	1	0	5
Conchapelopia	0	0	0	0
Constempellina/Thienemmanniola	0	0	2	0
Corynoneura arctica	1	0	0	0
Corynoneura carriana	0	0	0	0
Corynoneura coronata	0	0	0	0
Corynoneura edwardsi	0	0	4	2
Corynoneura lobata	0	0	0	0
***Corynoneura* type A**	0	0	4	0
Cricotopus bicinctus	0	0	0	0
Cricotopus cylindraceus	0	0	0	0
Cricotopus intersectus	0	0	1	0
Cricotopus laricomalis	0	0	0	0
Cricotopus sylvestris	0	0	0	0
***Cricotopus* type C**	0	0	0	0
***Cricotopus* type P**	0	0	0	0
Cricotopus trifascia	0	0	0	0
Cricotopus trifasciatus	0	0	0	0
Cryptochironomus	0	0	1	1.5
Cryptotendipes	1	0	0	0
Derotanypus	0	0	0	0
Dicrotendipes nervosus	1	1	1	2.5
Dicrotendipes notatus	0	0	0	0
Doncricotopus	0	0	0	0
Einfeldia pagana	0	0	0	0
Endochironomus impar	0	0	0	0
Eukiefferiella devonica	0	0	0	0
Eukiefferiella claripennis	0	0	0	0
Eukiefferiella fittkaui	0	0	0	0
Georthocladius	0	0	0	0
Gillotia	0	0	0	0
Glyptotendipes barbipes	0	1	0	0
Glyptotendipes pallens	0	0	0	0

Table A.1 *(Continued)*

Taxon	B-CLYD	B-DICK	B-FARN	B-GRAN
Harnischia	0	3	0	0
Hayesomyia	2	0	0	0
Heterotrissocladius grimshawi	0	1	0.5	4
Heterotrissocladius maeaeri	0	1	0	0
Heterotrissocladius marcidus	0	8	4.5	1.5
Hudsonimyia	0	0	0	0
Labrundinia	1	1	1	1
Larsia	0	0	0	0
Lauterborniella	0	0	0	0
Lipiniella	0	0	0	0
Metriocnemus fuscipes	0	0	0	0
Microchironomus	0	0	0	0
Micropsectra contracta	0	0	4	5.5
Micropsectra insignilobus	0	0	0	0
Micropsectra pallidula	0	0	0	0
Micropsectra radialis	0	0	0	0
***Micropsectra* type A**	0	0	0	0
Microtendipes pedellus	0	0	3	0
Microtendipes rydalensis	1	0	0	0
Monopelopia	0	0	0	0
Nanocladius branchicolus	0	0	0	0
Natarsia	0	0	0	0
Neozavrelia	0	0	0	0
Pagastiella	0	0	1	0
Parachaetocladius	0	0	0	0
Parachironomus varus	0	0	0	0
Paracladius	0	0	0	0
Paracladopelma	0	0	0	0
Paracricotopus	0	0	0	0
Parakiefferiella bathophila	1	1	0	0
Parakiefferiella nigra	0	1	0	4
Parakiefferiella tiquetra	0	0	0	0
Paralauterborniella	0	0	0	0
Paramerina	0	0	0	0
Parametriocnemus paraphaenocladius	0	0	0	0
Paratanytarsus	2	1	7	1
Paratendipes albimanus	0	0	0	0
Parorthocladius	0	0	0	0
Pentaneurella	0	0	0	0

Table A.1 *(Continued)*

Taxon	B-CLYD	B-DICK	B-FARN	B-GRAN
Phaenopsectra flavipes	1	1	0	0
Polypedilum nubeculosum	0	0	3	4.5
Polypedilum nubifer	0	0	0	0
Procladius	3	12	14	4
***Propsilocerus* type N**	0	0	0	0
Protanypus	0	0	0	0
Psectrocladius barbatipes	0	0	0	0
Psectrocladius calcaratus	0	0	0	0
Psectrocladius flavus	0	0	0	0
Psectrocladius psilopterus	0	0	0	2
Psectrocladius septentrionalis	0	0	0	0
Psectrocladius sordidellus	3.5	0	0	1
Psectrotanypus	0	0	0	0
Pseudochironomus	0	0	0	0
Rheocricotopus chalybeatus	0	0	0	0
Rheopelopia	0	0	0	0
Rheotanytarsus	0	0	0	0
Sergentia coracina	0	0	6	3
Sergentia longiventris	0	0	0	0
Smittia/Parasmittia	0	0	0	0
Stempellina	0	1	1	0.5
Stempellinella/Zavrelia	1	1	5	4
Stenochironomus	0	0	0	0
Stictochironomus rosenschoeldi	0	1	0	0
***Stictochironomus* type B**	0	0	0	0
Symposiocladius	0	0	0	0.5
Synorthocladius	1	3	5.5	2
Tanypus	0	0	0	0
Tanytarsus chinyensis	2	3	3	3
Tanytarsus glabrescens	0	0	0	0
Tanytarsus gracilentus	0	0	0	0
Tanytarsus lactescens	0	3	4	2
Tanytarsus lugens	0	2	0	1.5
Tanytarsus mendax	0	0	0	0
Tanytarsinia	5	0	2	2
Tanytarsus pallidicornis	2	3	1	2
Telmatopelopia	0	0	0	0
Telopelopia	0	0	0	0
Thienemanniella clavicornis	0	0	0	0

Table A.1 *(Continued)*

Taxon	B-CLYD	B-DICK	B-FARN	B-GRAN
Thienemannimyia	2	0	0	1
Tribelos	0	0	0	0
Trissocladius	0	0	0	0
Xenochironomus	0	0	0	0
Zalutschia/Zalutschiola	0	0	0	0
Zavreliella	0	0	0	0
Zavrelimyia	0	0	0	0
Taxon	**B-HARR**	**B-JOE**	**B-KIOS**	**B-LAMU**
Ablabesmyia	4	5	3	6
Abiskomyia	0	0	0	0
Acalcarella	0	0	0	0
Chaetocladius dentiforceps	1	0	0	0
Chaetocladius piger	2	0	0	3
Chaoborus	3	9	1	5
***Chironomini* larvula**	0	0	0	0
Chironomus anthracinus	8	0	7	0
Chironomus plumosus	0	0	0	0
Cladopelma laccophila	0	0	0	0
Cladopelma lateralis	0	1	0	2
Cladotanytarsus mancus	1.5	0	1	0
Conchapelopia	3	0	0	1
Constempellina/Thienemmanniola	1	0	2	1
Corynoneura arctica	2	1	0	4
Corynoneura carriana	2	0	0	2
Corynoneura coronata	0	0	0	0
Corynoneura edwardsi	0	1	1	4
Corynoneura lobata	1	0	1	0
***Corynoneura* type A**	1	1	0	0
Cricotopus bicinctus	0	0	0	0
Cricotopus cylindraceus	0	0	0	0
Cricotopus intersectus	0	0	0	0
Cricotopus laricomalis	0	0	0	0
Cricotopus sylvestris	0	0	0	0
***Cricotopus* type C**	0	0	0	0
***Cricotopus* type P**	0	0	0	0
Cricotopus trifascia	0	0	0	0
Cricotopus trifasciatus	0	0	0	0
Cryptochironomus	1	0	1	0
Cryptotendipes	0	0	0	1

Table A.1 *(Continued)*

Taxon	B-HARR	B-JOE	B-KIOS	B-LAMU
Derotanypus	0	0	0	1
Dicrotendipes nervosus	0	1	0.5	4
Dicrotendipes notatus	0	0	0	1
Doncricotopus	0	0	0	0
Einfeldia pagana	0	0	0	0
Endochironomus impar	0	0	0	0
Eukiefferiella devonica	0	0	0	0
Eukiefferiella claripennis	0	0	0	0
Eukiefferiella fittkaui	0	0	0	0
Georthocladius	0	0	0	0
Gillotia	0	0	0	0
Glyptotendipes barbipes	0	0	0	0
Glyptotendipes pallens	0	0	0	0
Harnischia	0	0	0	0
Hayesomyia	0	0	0	0
Heterotrissocladius grimshawi	0	1	0	1
Heterotrissocladius maeaeri	2	0	0	0
Heterotrissocladius marcidus	0.5	7	4	12.5
Hudsonimyia	0	0	0	0
Labrundinia	1	1	1	0
Larsia	0	0	0	0
Lauterborniella	0	0	0	0
Lipiniella	0	0	0	0
Metriocnemus fuscipes	0	0	0	0
Microchironomus	0	0	0	0
Micropsectra contracta	1	20	7	36
Micropsectra insignilobus	0	8	3	10
Micropsectra pallidula	0	0	0	0
Micropsectra radialis	0	0	0	0
***Micropsectra* type A**	0	0	0	0
Microtendipes pedellus	0	0	0	0
Microtendipes rydalensis	0	0	0	0
Monopelopia	0	0	0	0
Nanocladius branchicolus	0	0	0	0
Natarsia	0	0	0	0
Neozavrelia	0	1	1	3
Pagastiella	0	0	0	0
Parachaetocladius	0	0	0	0
Parachironomus varus	0	1	0	0

Table A.1 *(Continued)*

Taxon	B-HARR	B-JOE	B-KIOS	B-LAMU
Paracladius	0	0	0	0
Paracladopelma	0	0	0	0
Paracricotopus	0	0	0	0
Parakiefferiella bathophila	0	0	0	1
Parakiefferiella nigra	4	0	1.5	2
Parakiefferiella tiquetra	0	0	0	0
Paralauterborniella	0	0	0	0
Paramerina	0	0	0	0
Parametriocnemus paraphaenocladius	0	0	0	0
Paratanytarsus	2	3	0	6
Paratendipes albimanus	0	0	0	0
Parorthocladius	0	0	0	0
Pentaneurella	0	0	0	0
Phaenopsectra flavipes	0	0	0	0
Polypedilum nubeculosum	0	0	3	2
Polypedilum nubifer	3	0	0	2
Procladius	12	6	0	12
***Propsilocerus* type N**	0	0	0	0
Protanypus	1	1	0	0
Psectrocladius barbatipes	0	0	0	0
Psectrocladius calcaratus	0	0	0	0
Psectrocladius flavus	0	0	0	0
Psectrocladius psilopterus	1	0	0	0
Psectrocladius septentrionalis	0	0	0	0
Psectrocladius sordidellus	1	3	0.5	3
Psectrotanypus	0	0	0	0
Pseudochironomus	0	0	0	0
Rheocricotopus chalybeatus	0	0	0	0
Rheopelopia	0	0	0	0
Rheotanytarsus	0	0	0	0
Sergentia coracina	10	27.5	6.5	12
Sergentia longiventris	0	1	0	0
Smittia/Parasmittia	0	0	0	0
Stempellina	1	0	0	0
Stempellinella/Zavrelia	3	1	0	0
Stenochironomus	0	0	0	0
Stictochironomus rosenschoeldi	0	0	0	0
***Stictochironomus* type B**	0	0	0	0
Symposiocladius	0	0	0	0

Table A.1 *(Continued)*

Taxon	B-HARR	B-JOE	B-KIOS	B-LAMU
Synorthocladius	0	1.5	0	4
Tanypus	0	0	0	0
Tanytarsus chinyensis	0	0	2	0
Tanytarsus glabrescens	0	0	0	0
Tanytarsus gracilentus	0	0	0	0
Tanytarsus lactescens	3	3	1	3
Tanytarsus lugens	1	0	2	4
Tanytarsus mendax	0	0	0	0
Tanytarsinia	2	0	0	6
Tanytarsus pallidicornis	2	4	3	1
Telmatopelopia	0	0	0	0
Telopelopia	0	0	0	0
Thienemanniella clavicornis	0	0	0	0
Thienemannimyia	0	2	2	4
Tribelos	0	0	0	0
Trissocladius	0	0	0	0
Xenochironomus	0	0	0	0
Zalutschia/Zalutschiola	0	0	0	0
Zavreliella	0	0	0	1
Zavrelimyia	0	0	0	0
Taxon	**B-LOTR**	**B-LAVI**	**B-LCAU**	**B-LCRO**
Ablabesmyia	3	5	4	3
Abiskomyia	0	0	0	0
Acalcarella	0	0	0	0
Chaetocladius dentiforceps	0	0	0	0
Chaetocladius piger	1	1	1	0
Chaoborus	7	10	0	14
***Chironomini* larvula**	0	0	0	0
Chironomus anthracinus	0	0	2	0
Chironomus plumosus	0	0	0	2
Cladopelma laccophila	0	0	0	0
Cladopelma lateralis	0	0	0	1
Cladotanytarsus mancus	0	1	0.5	1.5
Conchapelopia	0	0	0	0
Constempellina/Thienemmanniola	0	0	0	0
Corynoneura arctica	0	2	0	1
Corynoneura carriana	0	0	0	0
Corynoneura coronata	0	0	1	0
Corynoneura edwardsi	1	2	1	0

Table A.1 *(Continued)*

Taxon	B-LOTR	B-LAVI	B-LCAU	B-LCRO
Corynoneura lobata	0	0	0	2
***Corynoneura* type A**	0	0	0	0
Cricotopus bicinctus	0	0	0	0
Cricotopus cylindraceus	1	0	0	1.5
Cricotopus intersectus	0	0	0	0
Cricotopus laricomalis	0	0	0	0
Cricotopus sylvestris	0	0	0	0
***Cricotopus* type C**	0	0	0	0
***Cricotopus* type P**	0	0	0	0
Cricotopus trifascia	0	0	0	0
Cricotopus trifasciatus	0	0	0	0
Cryptochironomus	0	1.5	1	0
Cryptotendipes	0	0	0	0
Derotanypus	0	0	0	0
Dicrotendipes nervosus	0	1	2	1
Dicrotendipes notatus	0	0	0	1
Doncricotopus	0	0	0	0
Einfeldia pagana	0	0	0	0
Endochironomus impar	1	0.5	0	0
Eukiefferiella devonica	0	0	0	0
Eukiefferiella claripennis	0	0	0	0
Eukiefferiella fittkaui	0	0	0	0
Georthocladius	0	0	0	0
Gillotia	0	0	0	0
Glyptotendipes barbipes	0	0	0	0
Glyptotendipes pallens	0	0	0	3
Harnischia	0	3	0	0
Hayesomyia	0	0	0	0
Heterotrissocladius grimshawi	0	1.5	1	0
Heterotrissocladius maeaeri	0	0	0	0
Heterotrissocladius marcidus	1.5	24.5	9	0
Hudsonimyia	0	0	0	0
Labrundinia	2	0	0	0
Larsia	0	0	0	0
Lauterborniella	0	0	0	0
Lipiniella	1	0	0	0
Metriocnemus fuscipes	0	0	0	0
Microchironomus	0	0	0	0
Micropsectra contracta	3	6	7	0

Table A.1 *(Continued)*

Taxon	B-LOTR	B-LAVI	B-LCAU	B-LCRO
Micropsectra insignilobus	0	4	0.5	0
Micropsectra pallidula	0	0	0	0
Micropsectra radialis	0	0	0	0
***Micropsectra* type A**	0	0	0	0
Microtendipes pedellus	0	0	1	0
Microtendipes rydalensis	0	0	0	0
Monopelopia	0	0	0	0
Nanocladius branchicolus	0	0	0	0
Natarsia	0	0	0	0
Neozavrelia	0	0	0	0
Pagastiella	0	0	0	0
Parachaetocladius	0	0	0	0
Parachironomus varus	0	0	0	0
Paracladius	0	0	0	0
Paracladopelma	1	1	0	0
Paracricotopus	0	0	0	0
Parakiefferiella bathophila	0	0	0	0
Parakiefferiella nigra	4	6	0	0
Parakiefferiella tiquetra	0	0	0	0
Paralauterborniella	0	0	0	0
Paramerina	0	0	0	0
Parametriocnemus paraphaenocladius	0	0	0	0
Paratanytarsus	1	2	2	1
Paratendipes albimanus	0	0	0	0
Parorthocladius	0	0	0	0
Pentaneurella	0	0	0	0
Phaenopsectra flavipes	1	0	0	0
Polypedilum nubeculosum	0	0	0	0
Polypedilum nubifer	0	0	0	0
Procladius	5	1	0	3
***Propsilocerus* type N**	0	0	0	0
Protanypus	0	2	2	0
Psectrocladius barbatipes	0	0	0	0
Psectrocladius calcaratus	0	0	0	0
Psectrocladius flavus	0	0	0	0
Psectrocladius psilopterus	0	0	0	1
Psectrocladius septentrionalis	0	0	0	0
Psectrocladius sordidellus	2.5	3	0.5	1.5
Psectrotanypus	0	0	0	0

Table A.1 *(Continued)*

Taxon	**B-LOTR**	**B-LAVI**	**B-LCAU**	**B-LCRO**
Pseudochironomus	0	0	0	0
Rheocricotopus chalybeatus	0	0	0	0
Rheopelopia	0	0	0	0
Rheotanytarsus	0	0	0	0
Sergentia coracina	12	2	2.5	0
Sergentia longiventris	1	0	0	0
Smittia/Parasmittia	0	0	0	0
Stempellina	0	0.5	0	0
Stempellinella/Zavrelia	0	0	0	2
Stenochironomus	0	0	0	0
Stictochironomus rosenschoeldi	0	0	0	0
***Stictochironomus* type B**	0	0	0	0
Symposiocladius	0	0	0	1
Synorthocladius	0	2	1	6.5
Tanypus	0	0	0	0
Tanytarsus chinyensis	0	3	0	0
Tanytarsus glabrescens	0	0	0	1
Tanytarsus gracilentus	0	0	0	0
Tanytarsus lactescens	1	2	0	5
Tanytarsus lugens	0	0	0	0
Tanytarsus mendax	0	0	0	0
Tanytarsinia	0	1	2	0
Tanytarsus pallidicornis	2	5.5	0	2
Telmatopelopia	0	0	0	0
Telopelopia	0	0	0	0
Thienemanniella clavicornis	2	0	0	0
Thienemannimyia	4	1	0	0
Tribelos	0	0	0	0
Trissocladius	0	0	0	0
Xenochironomus	0	0	0	0
Zalutschia/Zalutschiola	0	0	0	0
Zavreliella	0	0	1	1
Zavrelimyia	2	0	0	0
Taxon	**B-LDICK**	**B-LJOE**	**B-MANI**	**B-MCKA**
Ablabesmyia	3	8	0	3
Abiskomyia	0	1	0	0
Acalcarella	0	0	0	0
Chaetocladius dentiforceps	0	0	0	0
Chaetocladius piger	1	2	0	0

Table A.1 *(Continued)*

Taxon	B-LDICK	B-LJOE	B-MANI	B-MCKA
Chaoborus	22	19	0	12
***Chironomini* larvula**	0	0	0	0
Chironomus anthracinus	6	18	1	1
Chironomus plumosus	0	3	0	0
Cladopelma laccophila	0	0	0	0
Cladopelma lateralis	0	13	1	2
Cladotanytarsus mancus	0	1	2	2.5
Conchapelopia	0	0	0	0
Constempellina/Thienemmanniola	0	2	0	0
Corynoneura arctica	0	1	0	1
Corynoneura carriana	0	0	0	0
Corynoneura coronata	0	0	0	0
Corynoneura edwardsi	2	4	0	0
Corynoneura lobata	5	0	0	0
***Corynoneura* type A**	1	0	1	0
Cricotopus bicinctus	0	0	0	1
Cricotopus cylindraceus	0	1.5	0	0
Cricotopus intersectus	0	0	0	0
Cricotopus laricomalis	0	0	0	0
Cricotopus sylvestris	0	0	0	0
***Cricotopus* type C**	0	0	0	0
***Cricotopus* type P**	0	0	0	0
Cricotopus trifascia	0	1	0	0
Cricotopus trifasciatus	0	0	0	0
Cryptochironomus	0	2	0	2
Cryptotendipes	0	0	0	0
Derotanypus	1	0	0	0
Dicrotendipes nervosus	4	3	0	1
Dicrotendipes notatus	0	0	0	0
Doncricotopus	0	0	0	0
Einfeldia pagana	0	0	0	0
Endochironomus impar	0	0	0	0
Eukiefferiella devonica	0	0	1	0
Eukiefferiella claripennis	0	1	0	0
Eukiefferiella fittkaui	0	0	0	0
Georthocladius	0	0	0	0
Gillotia	0	0	0	0
Glyptotendipes barbipes	0	0	0	0
Glyptotendipes pallens	0	0	1	0

Table A.1 *(Continued)*

Taxon	B-LDICK	B-LJOE	B-MANI	B-MCKA
Harnischia	0	0	0	0
Hayesomyia	0	0	0	0
Heterotrissocladius grimshawi	1.5	4	0	0
Heterotrissocladius maeaeri	3.5	1.5	0	0
Heterotrissocladius marcidus	0	1.5	4	2
Hudsonimyia	4	0	0	0
Labrundinia	0	3	0	0
Larsia	0	0	0	0
Lauterborniella	1	0	0	0
Lipiniella	0	0	0	0
Metriocnemus fuscipes	0	0	0	0
Microchironomus	0	0	0	0
Micropsectra contracta	9	2	9	9
Micropsectra insignilobus	2	0	4	2
Micropsectra pallidula	0	0	0	0
Micropsectra radialis	0	0	0	0
***Micropsectra* type A**	0	0	0	0
Microtendipes pedellus	0	2	0	0
Microtendipes rydalensis	0	2	0	0
Monopelopia	0	0	0	0
Nanocladius branchicolus	0	0	0	0
Natarsia	0	0	0	0
Neozavrelia	0	0	0	0
Pagastiella	0	1	0	0
Parachaetocladius	0	0	0	0
Parachironomus varus	0	0	0	0
Paracladius	0	0	0	0
Paracladopelma	0	1	0	0
Paracricotopus	1	0	0	0
Parakiefferiella bathophila	0	2	0	0
Parakiefferiella nigra	0	0	0	1
Parakiefferiella tiquetra	0	0	0	2
Paralauterborniella	1	0	0	0
Paramerina	0	0	0	0
Parametriocnemus paraphaenocladius	0	0	0	0
Paratanytarsus	1	3	2	0
Paratendipes albimanus	0	0	0	0
Parorthocladius	0	0	0	0
Pentaneurella	0	0	0	0

Table A.1 *(Continued)*

Taxon	B-LDICK	B-LJOE	B-MANI	B-MCKA
Phaenopsectra flavipes	0	1	0	0
Polypedilum nubeculosum	0	2	0	1
Polypedilum nubifer	0	1	1	1
Procladius	3	21	1	4
***Propsilocerus* type N**	0	0	0	0
Protanypus	0	2	0	0
Psectrocladius barbatipes	0	0	0	0
Psectrocladius calcaratus	0	0	0	0
Psectrocladius flavus	0	0	0	0
Psectrocladius psilopterus	0	3	0	0
Psectrocladius septentrionalis	0	0	0	0
Psectrocladius sordidellus	0.5	1.5	1	1
Psectrotanypus	0	0	0	0
Pseudochironomus	0	0	0	0
Rheocricotopus chalybeatus	0	0	0	0
Rheopelopia	0	0	0	0
Rheotanytarsus	0	0	0	0
Sergentia coracina	17.5	1	3.5	2
Sergentia longiventris	0	0	0	0
Smittia/Parasmittia	0	0	0	0
Stempellina	0	4	1	0
Stempellinella/Zavrelia	0	9	0	2
Stenochironomus	0	0	0	0
Stictochironomus rosenschoeldi	0	0	0	0
***Stictochironomus* type B**	0	0	0	0
Symposiocladius	0	0	0	0
Synorthocladius	2	1	2	3
Tanypus	0	0	0	0
Tanytarsus chinyensis	1	2	1	4
Tanytarsus glabrescens	0	0	0	0
Tanytarsus gracilentus	0	0	0	0
Tanytarsus lactescens	2	2	0	1
Tanytarsus lugens	1	21	0	3
Tanytarsus mendax	0	0	0	0
Tanytarsinia	0	14	1.5	4
Tanytarsus pallidicornis	4	13	1	2
Telmatopelopia	0	0	0	0
Telopelopia	0	0	0	0
Thienemanniella clavicornis	0	0	0	0

Table A.1 *(Continued)*

Taxon	B-LDICK	B-LJOE	B-MANI	B-MCKA
Thienemannimyia	2	0	1	5
Tribelos	0	0	1	0
Trissocladius	0	0	0	0
Xenochironomus	0	0	0	0
Zalutschia/Zalutschiola	0	0	0	0
Zavreliella	0	0	0	0
Zavrelimyia	0	0	0	0
Taxon	**B-MERC**	**B-NTEA**	**B-PHIL**	**B-RADI**
Ablabesmyia	8	1	4	10
Abiskomyia	0	0	0	0
Acalcarella	0	0	0	0
Chaetocladius dentiforceps	0	0	0	0
Chaetocladius piger	0	0	0	0
Chaoborus	1	2	3	0
***Chironomini* larvula**	0	0	0	0
Chironomus anthracinus	9.5	13.5	6	0
Chironomus plumosus	0	0	0	0
Cladopelma laccophila	0	0	0	0
Cladopelma lateralis	0	0	0	0
Cladotanytarsus mancus	1	1	0	0
Conchapelopia	0	0	0	0
Constempellina/Thienemmanniola	0	0	0	1
Corynoneura arctica	0	3	1	0
Corynoneura carriana	1	1	1	0
Corynoneura coronata	0	0	0	0
Corynoneura edwardsi	1	0	2	6
Corynoneura lobata	0	0	1	0
***Corynoneura* type A**	2	1	1	0
Cricotopus bicinctus	0	0	0	0
Cricotopus cylindraceus	0	0	0	1.5
Cricotopus intersectus	0	0	0	0
Cricotopus laricomalis	0	0	0	0
Cricotopus sylvestris	0	0	0	0
***Cricotopus* type C**	0	1	0	0
***Cricotopus* type P**	0	0	0	0
Cricotopus trifascia	0	0	0	0
Cricotopus trifasciatus	0	0	0	0
Cryptochironomus	0	1	1	0
Cryptotendipes	0	0	0	0

Table A.1 *(Continued)*

Taxon	B-MERC	B-NTEA	B-PHIL	B-RADI
Derotanypus	0	0	0	0
Dicrotendipes nervosus	0	2	1	2
Dicrotendipes notatus	0	0	0	0
Doncricotopus	0	0	0	0
Einfeldia pagana	0	0	0	0
Endochironomus impar	0	0	0	0
Eukiefferiella devonica	0	0	0	0
Eukiefferiella claripennis	0	0	0	0
Eukiefferiella fittkaui	0	0	0	4
Georthocladius	0	0	0	0
Gillotia	0	0	0	0
Glyptotendipes barbipes	0	0	0	0
Glyptotendipes pallens	0	0	0	1
Harnischia	0	0	0	0
Hayesomyia	0	0	0	0
Heterotrissocladius grimshawi	0.5	0	0	2.5
Heterotrissocladius maeaeri	0	0	0	0
Heterotrissocladius marcidus	11.5	2.5	2	3
Hudsonimyia	0	0	0	0
Labrundinia	0	0	1	1
Larsia	0	0	0	0
Lauterborniella	0	0	0	0
Lipiniella	0	0	0	0
Metriocnemus fuscipes	0	0	0	0
Microchironomus	0	0	0	0
Micropsectra contracta	14.5	7.5	1	1
Micropsectra insignilobus	26	2	1	3
Micropsectra pallidula	0	0	0	0
Micropsectra radialis	0	0	0	0
***Micropsectra* type A**	0	0	0	0
Microtendipes pedellus	0	0	0	1
Microtendipes rydalensis	0	1.5	0	0
Monopelopia	0	0	0	0
Nanocladius branchicolus	0	0	0	0
Natarsia	0	0	0	0
Neozavrelia	0	1	0	0
Pagastiella	0	0	0	0
Parachaetocladius	0	0	0	0
Parachironomus varus	0	1	0	2

Table A.1 *(Continued)*

Taxon	B-MERC	B-NTEA	B-PHIL	B-RADI
Paracladius	0	0	0	0
Paracladopelma	0	0	1	0
Paracricotopus	0	0	0	0
Parakiefferiella bathophila	0	0	0	0
Parakiefferiella nigra	0	1	1	6.5
Parakiefferiella tiquetra	0	0	1	0
Paralauterborniella	0	0	0	0
Paramerina	0	0	0	0
Parametriocnemus paraphaenocladius	0	0	0	0
Paratanytarsus	2	5	4	3
Paratendipes albimanus	0	0	0	1
Parorthocladius	0	0	0	0
Pentaneurella	0	0	0	0
Phaenopsectra flavipes	0	0	0	0
Polypedilum nubeculosum	0	2	2	4
Polypedilum nubifer	0	0	0	1
Procladius	1	0	1	8
***Propsilocerus* type N**	0	0	0	0
Protanypus	0.5	0	0	0
Psectrocladius barbatipes	0	0	0	0
Psectrocladius calcaratus	0	0	0	0
Psectrocladius flavus	0	0	0	0
Psectrocladius psilopterus	0	0	0	0
Psectrocladius septentrionalis	0	0	0	0
Psectrocladius sordidellus	1	0.5	1.5	3.5
Psectrotanypus	0	0	0	0
Pseudochironomus	0	0	0	0
Rheocricotopus chalybeatus	0	0	0	0
Rheopelopia	0	0	0	0
Rheotanytarsus	0	0	0	1
Sergentia coracina	25.5	7	2	2.5
Sergentia longiventris	0	0	1	0
Smittia/Parasmittia	0	0	0	0
Stempellina	0	0	0	1
Stempellinella/Zavrelia	0	1	0	5
Stenochironomus	0	0	0	0
Stictochironomus rosenschoeldi	0	0	0	0
***Stictochironomus* type B**	0	0	0	0
Symposiocladius	0	0	0	0

Table A.1 *(Continued)*

Taxon	B-MERC	B-NTEA	B-PHIL	B-RADI
Synorthocladius	0	4	1	2
Tanypus	0	0	0	0
Tanytarsus chinyensis	0	0	0	5
Tanytarsus glabrescens	0	0	0	0
Tanytarsus gracilentus	0	0	0	0
Tanytarsus lactescens	2	1	4	0
Tanytarsus lugens	2	1	0	6
Tanytarsus mendax	0	0	0	0
Tanytarsinia	1	4	3	3
Tanytarsus pallidicornis	3	1	0	5.5
Telmatopelopia	0	0	0	0
Telopelopia	0	0	0	0
Thienemanniella clavicornis	0	0	2	1
Thienemannimyia	2	0	3	0
Tribelos	0	0	0	0
Trissocladius	0	0	0	0
Xenochironomus	0	0	0	0
Zalutschia/Zalutschiola	0	0	0	0
Zavreliella	0	0	0	0
Zavrelimyia	0	0	0	0
Taxon	**B-RAIN**	**B-RBIC**	**B-RENC**	**B-ROCK**
Ablabesmyia	2	2	2	12
Abiskomyia	0	0	0	0
Acalcarella	0	0	0	0
Chaetocladius dentiforceps	0	0	0	0
Chaetocladius piger	0	3	0	0
Chaoborus	13	2	10	6
***Chironomini* larvula**	0	0	0	0
Chironomus anthracinus	4.5	0	4	3
Chironomus plumosus	0	0	0	0
Cladopelma laccophila	0	0	0	0
Cladopelma lateralis	0	0	2	1
Cladotanytarsus mancus	0	1	0	1
Conchapelopia	0	0	0	0
Constempellina/Thienemmanniola	0	0	1	3
Corynoneura arctica	0	0	0	0
Corynoneura carriana	0	0	0	0
Corynoneura coronata	0	1	0	0
Corynoneura edwardsi	0	0	0	1

Table A.1 *(Continued)*

Taxon	B-RAIN	B-RBIC	B-RENC	B-ROCK
Corynoneura lobata	0	0	0	1
***Corynoneura* type A**	0	0	0	0
Cricotopus bicinctus	0	0	0	0
Cricotopus cylindraceus	1	0	0	1
Cricotopus intersectus	0	0	0	0
Cricotopus laricomalis	0	0	0	0
Cricotopus sylvestris	0	0	0	0
***Cricotopus* type C**	0	0	1	0
***Cricotopus* type P**	0	0	0	0
Cricotopus trifascia	0	0	0	0
Cricotopus trifasciatus	0	0	0	0
Cryptochironomus	1	0	1	0
Cryptotendipes	0	0	0	0
Derotanypus	0	1	0	0
Dicrotendipes nervosus	3.5	1	0	0.5
Dicrotendipes notatus	0	0	0	0
Doncricotopus	0	0	0	0
Einfeldia pagana	0	0	0	0
Endochironomus impar	0	0	0	0
Eukiefferiella devonica	0	0	0	0
Eukiefferiella claripennis	0	0	0	0
Eukiefferiella fittkaui	0	0	0	1
Georthocladius	0	0	0	0
Gillotia	0	0	0	0
Glyptotendipes barbipes	0	0	0	0
Glyptotendipes pallens	0	0	2	0
Harnischia	2	2	0	0
Hayesomyia	0	0	0	0
Heterotrissocladius grimshawi	0	0.5	0	0
Heterotrissocladius maeaeri	1	0	0	0
Heterotrissocladius marcidus	2	36.5	2	3.5
Hudsonimyia	0	0	0	0
Labrundinia	0	0	0	2
Larsia	0	0	0	0
Lauterborniella	1	0	0	0
Lipiniella	0	0	0	0
Metriocnemus fuscipes	0	0	0	0
Microchironomus	0	0	0	0
Micropsectra contracta	1	37	2	1

Table A.1 *(Continued)*

Taxon	B-RAIN	B-RBIC	B-RENC	B-ROCK
Micropsectra insignilobus	0	27	0	0
Micropsectra pallidula	0	0	0	0
Micropsectra radialis	0	0	0	0
***Micropsectra* type A**	0	0	0	0
Microtendipes pedellus	0	0	0	0
Microtendipes rydalensis	0	0	0	0
Monopelopia	0	0	0	0
Nanocladius branchicolus	0	0	0	0
Natarsia	0	0	0	0
Neozavrelia	0	0	0	0
Pagastiella	0	0	0	0
Parachaetocladius	0	0	0	0
Parachironomus varus	0	0	0	1
Paracladius	0	0	0	0
Paracladopelma	1	2	0	0
Paracricotopus	0	0	0	0
Parakiefferiella bathophila	0	0	0	0
Parakiefferiella nigra	0	0	0	7
Parakiefferiella tiquetra	0	0	0	0
Paralauterborniella	0	0	0	0
Paramerina	0	0	0	0
Parametriocnemus paraphaenocladius	0	0	0	0
Paratanytarsus	1	0	1	4
Paratendipes albimanus	0	0	0	0
Parorthocladius	0	0	0	0
Pentaneurella	0	0	0	0
Phaenopsectra flavipes	1	0	0	0
Polypedilum nubeculosum	1	0	1	0
Polypedilum nubifer	1	0	0	0
Procladius	8	8	9	13
***Propsilocerus* type N**	0	0	0	0
Protanypus	0	3	0	1
Psectrocladius barbatipes	0	0	0	0
Psectrocladius calcaratus	0	0	0	0
Psectrocladius flavus	0	0	0	0
Psectrocladius psilopterus	0	0	0	1
Psectrocladius septentrionalis	0	0	0	0
Psectrocladius sordidellus	0.5	0	0	1
Psectrotanypus	0	0	0	0

Table A.1 *(Continued)*

Taxon	B-RAIN	B-RBIC	B-RENC	B-ROCK
Pseudochironomus	0	0	0	0
Rheocricotopus chalybeatus	0	0	0	0
Rheopelopia	0	0	0	0
Rheotanytarsus	0	0	0	0
Sergentia coracina	2.5	28.5	1	5
Sergentia longiventris	0	0	0	0
Smittia/Parasmittia	0	0	0	0
Stempellina	1	0	0	0
Stempellinella/Zavrelia	2	0	0	1
Stenochironomus	0	0	0	0
Stictochironomus rosenschoeldi	0	1	0	0
***Stictochironomus* type B**	0	0	0	0
Symposiocladius	0	0	0	0
Synorthocladius	3	1.5	0	3
Tanypus	0	0	0	0
Tanytarsus chinyensis	1	0	1	2
Tanytarsus glabrescens	0	0	0	0
Tanytarsus gracilentus	0	0	0	0
Tanytarsus lactescens	3	0	1	3
Tanytarsus lugens	2	0	3	1
Tanytarsus mendax	0	0	0	0
Tanytarsinia	4	3	0	0
Tanytarsus pallidicornis	1	13	1	1
Telmatopelopia	0	0	0	0
Telopelopia	0	0	0	0
Thienemanniella clavicornis	0	0	0	1
Thienemannimyia	1	1	5	1
Tribelos	0	0	0	0
Trissocladius	0	0	0	0
Xenochironomus	0	0	0	0
Zalutschia/Zalutschiola	0	0	0	0
Zavreliella	0	1	0	0
Zavrelimyia	0	0	0	0

Taxon	B-ROSE	B-SOUR	B-TEA	B-TIM
Ablabesmyia	4	3	0	2
Abiskomyia	0	0	0	0
Acalcarella	0	0	0	0
Chaetocladius dentiforceps	0	0	0	0
Chaetocladius piger	0	1	0	0

Table A.1 *(Continued)*

Taxon	B-ROSE	B-SOUR	B-TEA	B-TIM
Chaoborus	1	4	25	4
***Chironomini* larvula**	0	0	0	0
Chironomus anthracinus	1.5	2	14	1
Chironomus plumosus	0	0	1	1
Cladopelma laccophila	3	0	0	0
Cladopelma lateralis	0	1	0	0
Cladotanytarsus mancus	0.5	0	0.5	0
Conchapelopia	0	0	0	0
Constempellina/Thienemmanniola	1	2	0	1
Corynoneura arctica	1	0	0	2
Corynoneura carriana	1	0	0	0
Corynoneura coronata	0	0	0	0
Corynoneura edwardsi	0	0	0	1
Corynoneura lobata	0	0	0	0
***Corynoneura* type A**	1	0	0	0
Cricotopus bicinctus	0	0	0	0
Cricotopus cylindraceus	0	0	0	0
Cricotopus intersectus	0	0	0	0
Cricotopus laricomalis	0	0	0	0
Cricotopus sylvestris	0	0	0	0
***Cricotopus* type C**	0	0	0	0
***Cricotopus* type P**	0	0	0	0
Cricotopus trifascia	0	0	0	0
Cricotopus trifasciatus	0	0	0	0
Cryptochironomus	0	1	0	0
Cryptotendipes	0	0	1	0
Derotanypus	0	0	0	0
Dicrotendipes nervosus	0	2	2	0
Dicrotendipes notatus	0	0	0	0
Doncricotopus	0	0	0	0
Einfeldia pagana	0	0	0	1
Endochironomus impar	0	0	0	0
Eukiefferiella devonica	0	0	0	0
Eukiefferiella claripennis	0	0	0	0
Eukiefferiella fittkaui	0	0	0	0
Georthocladius	0	0	0	0
Gillotia	0	0	0	0
Glyptotendipes barbipes	0	0	0	0
Glyptotendipes pallens	0	1	0	0

Table A.1 *(Continued)*

Taxon	B-ROSE	B-SOUR	B-TEA	B-TIM
Harnischia	0	1	0	0
Hayesomyia	0	0	0	0
Heterotrissocladius grimshawi	3	2	1.5	0
Heterotrissocladius maeaeri	0	0	0	0
Heterotrissocladius marcidus	1	8	1.5	5
Hudsonimyia	0	0	0	0
Labrundinia	1	0	1	0
Larsia	0	0	0	0
Lauterborniella	0	0	0	0
Lipiniella	0	0	0	0
Metriocnemus fuscipes	0	0	0	0
Microchironomus	0	0	0	0
Micropsectra contracta	4	2	0	4
Micropsectra insignilobus	1	2	2	4
Micropsectra pallidula	0	0	0	0
Micropsectra radialis	0	0	0	0
***Micropsectra* type A**	0	0	0	0
Microtendipes pedellus	0	0	0	0
Microtendipes rydalensis	0	0	0	0
Monopelopia	0	0	0	0
Nanocladius branchicolus	0	0	0	0
Natarsia	0	0	0	0
Neozavrelia	2	1	1	4
Pagastiella	1	0	0	0
Parachaetocladius	0	0	0	0
Parachironomus varus	0	0	0	0
Paracladius	0	0	0	0
Paracladopelma	0	0	0	0
Paracricotopus	0	0	0	0
Parakiefferiella bathophila	1	0	0	0
Parakiefferiella nigra	1	3	0	0
Parakiefferiella tiquetra	0	0	0	0
Paralauterborniella	0	0	0	0
Paramerina	0	0	0	0
Parametriocnemus paraphaenocladius	0	0	0	0
Paratanytarsus	3	3	1	1
Paratendipes albimanus	0	0	0	0
Parorthocladius	0	0	0	0
Pentaneurella	0	0	0	0

Table A.1 *(Continued)*

Taxon	B-ROSE	B-SOUR	B-TEA	B-TIM
Phaenopsectra flavipes	3	1	0	1
Polypedilum nubeculosum	1	0	1	1
Polypedilum nubifer	3	0	0	0
Procladius	7	3	18	4
***Propsilocerus* type N**	0	0	0	0
Protanypus	0	0	1	1
Psectrocladius barbatipes	0	0	0	0
Psectrocladius calcaratus	0	0	0	0
Psectrocladius flavus	0	0	0	0
Psectrocladius psilopterus	0	0	0	0
Psectrocladius septentrionalis	0	0	0	0
Psectrocladius sordidellus	0.5	3	0.5	3
Psectrotanypus	0	0	0	0
Pseudochironomus	0	0	0	0
Rheocricotopus chalybeatus	0	0	0	0
Rheopelopia	0	0	0	0
Rheotanytarsus	0	0	0	0
Sergentia coracina	7	9	0	2
Sergentia longiventris	0	0	0	0
Smittia/Parasmittia	0	0	0	0
Stempellina	0	0	1	2
Stempellinella/Zavrelia	3	3	0	3
Stenochironomus	0	0	0	0
Stictochironomus rosenschoeldi	0	1	0	0
***Stictochironomus* type B**	0	0	0	0
Symposiocladius	0	0	0	0
Synorthocladius	0	0	0	2
Tanypus	0	0	0	0
Tanytarsus chinyensis	2	2	0	2
Tanytarsus glabrescens	0	0	0	0
Tanytarsus gracilentus	0	0	0	0
Tanytarsus lactescens	3	2	0	2
Tanytarsus lugens	0	0	2	1
Tanytarsus mendax	0	0	0	0
Tanytarsinia	1	3	5	0
Tanytarsus pallidicornis	5	1	1	3
Telmatopelopia	0	0	0	0
Telopelopia	0	0	0	0
Thienemanniella clavicornis	0	0	1	0

Table A.1 *(Continued)*

Taxon	B-ROSE	B-SOUR	B-TEA	B-TIM
Thienemannimyia	4	0	3	0
Tribelos	0	0	0	0
Trissocladius	0	0	0	0
Xenochironomus	0	0	0	0
Zalutschia/Zalutschiola	0	0	0	0
Zavreliella	1	0	0	0
Zavrelimyia	0	0	0	0

Taxon	B-WATE	B-WHIT
Ablabesmyia	1	2
Abiskomyia	0	0
Acalcarella	0	0
Chaetocladius dentiforceps	0	0
Chaetocladius piger	0	2
Chaoborus	0	9
***Chironomini* larvula**	0	0
Chironomus anthracinus	20	0
Chironomus plumosus	0	0
Cladopelma laccophila	0	0
Cladopelma lateralis	1	1
Cladotanytarsus mancus	0	0
Conchapelopia	0	0
Constempellina/Thienemmanniola	1	0
Corynoneura arctica	0	0
Corynoneura carriana	0	0
Corynoneura coronata	0	0
Corynoneura edwardsi	2	0
Corynoneura lobata	2	0
***Corynoneura* type A**	0	1
Cricotopus bicinctus	0	0
Cricotopus cylindraceus	0	0
Cricotopus intersectus	0	0
Cricotopus laricomalis	0	0
Cricotopus sylvestris	0	0
***Cricotopus* type C**	0	0
***Cricotopus* type P**	0	0
Cricotopus trifascia	0	0
Cricotopus trifasciatus	0	0
Cryptochironomus	0	0
Cryptotendipes	0	0

Table A.1 *(Continued)*

Taxon	B-WATE	B-WHIT
Derotanypus	0	0
Dicrotendipes nervosus	0	1
Dicrotendipes notatus	0	0
Doncricotopus	0	0
Einfeldia pagana	0	0
Endochironomus impar	0	0
Eukiefferiella devonica	0	0
Eukiefferiella claripennis	0	0
Eukiefferiella fittkaui	0	0
Georthocladius	0	0
Gillotia	1	0
Glyptotendipes barbipes	0	0
Glyptotendipes pallens	0	0
Harnischia	0	0
Hayesomyia	0	0
Heterotrissocladius grimshawi	0	0
Heterotrissocladius maeaeri	0	0
Heterotrissocladius marcidus	5	6
Hudsonimyia	0	0
Labrundinia	0	0
Larsia	0	0
Lauterborniella	1	0
Lipiniella	0	0
Metriocnemus fuscipes	0	0
Microchironomus	0	0
Micropsectra contracta	3	0
Micropsectra insignilobus	0	0
Micropsectra pallidula	0	0
Micropsectra radialis	0	0
***Micropsectra* type A**	0	0
Microtendipes pedellus	0	1
Microtendipes rydalensis	0	0
Monopelopia	0	0
Nanocladius branchicolus	0	0
Natarsia	0	0
Neozavrelia	0	0
Pagastiella	0	0
Parachaetocladius	0	0
Parachironomus varus	0	2

Table A.1 *(Continued)*

Taxon	B-WATE	B-WHIT
Paracladius	0	0
Paracladopelma	0	0
Paracricotopus	0	0
Parakiefferiella bathophila	0	0
Parakiefferiella nigra	2	3
Parakiefferiella tiquetra	0	0
Paralauterborniella	0	0
Paramerina	0	0
Parametriocnemus paraphaenocladius	0	0
Paratanytarsus	2	0
Paratendipes albimanus	1	0
Parorthocladius	0	0
Pentaneurella	0	0
Phaenopsectra flavipes	1	0
Polypedilum nubeculosum	0	1
Polypedilum nubifer	0	0
Procladius	3	0
***Propsilocerus* type N**	0	0
Protanypus	0	0
Psectrocladius barbatipes	0	0
Psectrocladius calcaratus	0	0
Psectrocladius flavus	0	0
Psectrocladius psilopterus	0	0
Psectrocladius septentrionalis	0	0
Psectrocladius sordidellus	2	1
Psectrotanypus	0	0
Pseudochironomus	0	0
Rheocricotopus chalybeatus	0	0
Rheopelopia	0	0
Rheotanytarsus	0	0
Sergentia coracina	7	13
Sergentia longiventris	0	0
Smittia/Parasmittia	0	0
Stempellina	0	0
Stempellinella/Zavrelia	1	2
Stenochironomus	0	0
Stictochironomus rosenschoeldi	0	1
***Stictochironomus* type B**	0	0
Symposiocladius	0	0

Table A.1 *(Continued)*

Taxon	B-WATE	B-WHIT
Synorthocladius	0	0
Tanypus	0	0
Tanytarsus chinyensis	0	2
Tanytarsus glabrescens	0	0
Tanytarsus gracilentus	0	0
Tanytarsus lactescens	1	1
Tanytarsus lugens	1	0
Tanytarsus mendax	0	0
Tanytarsinia	1	1
Tanytarsus pallidicornis	0	0
Telmatopelopia	0	0
Telopelopia	0	0
Thienemanniella clavicornis	0	0
Thienemannimyia	2	0
Tribelos	0	0
Trissocladius	0	0
Xenochironomus	0	0
Zalutschia/Zalutschiola	0	0
Zavreliella	0	0
Zavrelimyia	0	0

Table A.2 Environmental data for Algonquin Park lakes, lake codes presemted in A.3.

Lake code	Secchi Depth	Gran Alkalinity	Calcium	Chloride
T-BIGT	4.4	6.2	2.4	1.3
T-BUIS	1.9	4.3	1.7	0.2
T-CATF	3.2	5.7	2.2	3
T-CAUC	3	3.9	1.7	1.6
T-CEDA	6.1	4.4	1.9	3.7
T-CLYD	3.5	3.9	1.6	0.8
T-DICK	3.9	2.3	1.1	0.2
T-FARN	6.1	1.5	1.1	0.2
T-GRAN	5.8	5	2	1.5
T-HARR	2.9	4.6	1.8	0.2
T-JOE	3.7	7.2	2.4	0.2
T-KIOS	3	6.4	2.2	0.2
T-LAMU	4.4	3.1	1.2	0.2
T-LAVI	2.5	7.9	2.6	0.2
T-LCAU	2.9	7	2.5	0.2
T-LDIC	4.5	7.2	2.4	0.3
T-LJOE	4.6	14.7	4	0.4
T-LOTR	3.4	2.9	1.6	0.2
T-MANI	3.4	24.3	2.4	0.2
T-MCKA	2.8	7	2.3	0.2
T-MERC	2.5	7.9	2.6	0.3
T-NTEA	1.6	5.1	2	0.2
T-PHIL	3.7	6.1	2.2	0.2
T-RADI	3	5.8	2.2	0.2
T-RAIN	4.3	4.2	1.9	0.2
T-RBIC	4.4	9.1	2.9	0.2
T-ROCK	5.6	14.9	3.5	0.2
T-ROSE	4.8	6.5	2.5	0.2
T-SOUR	4	6.4	2.3	0.2
T-TEA	3.1	4.6	2	0.2
T-WHIT	3.1	2.5	1.2	0.1

Lake code	DIC	DOC	Potassium	Magnesium
T-BIGT	1.5	4.8	0.5	0.9
T-BUIS	1	5.7	0.4	0.5
T-CATF	1.1	5.7	0.4	0.7
T-CAUC	1	4.4	0.3	0.5
T-CEDA	1.2	4.7	0.4	0.6
T-CLYD	1	4.6	0.3	0.5

Table A.2 *(Continued)*

Lake code	DIC	DOC	Potassium	Magnesium
T-DICK	0.7	4	0.3	0.3
T-FARN	0.6	3.4	0.3	0.3
T-GRAN	1.3	5.4	0.4	0.6
T-HARR	1.1	5.9	0.4	0.6
T-JOE	1.7	4.8	0.4	0.7
T-KIOS	1.5	6.5	0.5	0.7
T-LAMU	0.8	3.8	0.3	0.4
T-LAVI	2	4.9	0.6	0.9
T-LCAU	1.7	5.8	0.4	0.9
T-LDIC	1.7	5.8	0.5	1.1
T-LJOE	3.7	5.8	0.6	1.5
T-LOTR	1	5.1	0.2	0.5
T-MANI	2.1	5.2	0.4	1.1
T-MCKA	1.5	4.9	0.5	0.8
T-MERC	1.8	5	0.6	1.1
T-NTEA	1.2	7.6	0.5	0.7
T-PHIL	1.5	4.9	0.5	0.7
T-RADI	1.4	6.7	0.4	0.8
T-RAIN	1.1	5.3	0.4	0.7
T-RBIC	2.3	4.2	0.5	0.9
T-ROCK	3.5	2.6	0.7	1.7
T-ROSE	1.6	4.7	0.5	0.9
T-SOUR	1.6	3.8	0.4	1
T-TEA	1.2	5	0.2	0.6
T-WHIT	0.7	6.1	0.3	0.4

Lake code	Sodium	Silicate	Sulphate	True Colour
T-BIGT	1.5	0.8	4.2	27.8
T-BUIS	0.7	1.4	2.9	28.4
T-CATF	2.6	1.7	3.6	39.2
T-CAUC	1.6	1	3.1	21.7
T-CEDA	3	1.2	3.3	18.5
T-CLYD	1.1	0.9	2.9	26
T-DICK	0.5	0.4	2.1	16.7
T-FARN	0.6	1.1	2.6	13.3
T-GRAN	1.7	1.4	3.4	29.1
T-HARR	0.8	1	3.4	37.4
T-JOE	0.9	1.8	2.9	24
T-KIOS	0.9	2.1	3.2	36.8
T-LAMU	0.6	1.2	2.7	16.5

Table A.2 *(Continued)*

Lake code	Sodium	Silicate	Sulphate	True Colour
T-LAVI	1	0.6	3.5	13.8
T-LCAU	0.9	1.8	3.5	38.9
T-LDIC	1	1.2	4.2	25.9
T-LJOE	1.4	2.4	4	29.4
T-LOTR	0.8	0.5	3.1	23.3
T-MANI	1.2	2	4.1	23.6
T-MCKA	0.9	1.8	3.4	26.4
T-MERC	1.2	1.2	4.9	23.1
T-NTEA	0.8	1.9	3	53.7
T-PHIL	0.9	1.6	3.4	26.9
T-RADI	0.9	1.5	3.2	48
T-RAIN	0.8	1.2	3.5	28.6
T-RBIC	0.9	1.8	3.7	18.3
T-ROCK	1.3	4.2	4.3	6.1
T-ROSE	0.9	0.6	4.7	21.5
T-SOUR	0.8	0.2	4.4	10.5
T-TEA	0.8	0.6	3.6	25.3
T-WHIT	0.6	0.7	2.3	38.2

Lake code	Iron	NH4/NH3	Total Nitrogen	Total Phosphorus
T-BIGT	30	12	242	4.8
T-BUIS	60	12	318	5
T-CATF	140	6	276	5.7
T-CAUC	80	10	233	4.6
T-CEDA	50	12	223	4
T-CLYD	130	14	247	5.5
T-DICK	50	20	242	4.7
T-FARN	50	8	272	3.1
T-GRAN	100	10	281	4.5
T-HARR	80	4	280	5.5
T-JOE	20	4	298	5.1
T-KIOS	50	10	299	5.6
T-LAMU	60	10	231	4.5
T-LAVI	10	6	282	4.5
T-LCAU	80	10	293	5
T-LDIC	30	6	255	5.5
T-LJOE	50	10	283	6.5
T-LOTR	70	8	243	3.9
T-MANI	40	4	262	4.9

Table A.2 *(Continued)*

Lake code	Iron	NH4/NH3	Total Nitrogen	Total Phosphorus
T-MCKA	30	12	250	6.6
T-MERC	20	12	246	4.6
T-NTEA	170	20	318	7.4
T-PHIL	30	18	253	7.5
T-RADI	120	8	305	6.2
T-RAIN	40	10	249	4.7
T-RBIC	20	8	222	4.8
T-ROCK	20	4	169	3.7
T-ROSE	20	4	223	4.8
T-SOUR	10	6	236	4.8
T-TEA	130	8	249	5.6
T-WHIT	110	14	282	5.2

Lake code	Conductivity	pH	Aluminum	Surface Area
T-BIGT	30.7	7.1	16.1	1559
T-BUIS	19.4	6.7	36.9	968
T-CATF	33.9	6.8	36.5	589
T-CAUC	24.6	6.7	20	237
T-CEDA	34.7	6.8	15.5	2549
T-CLYD	20.8	6.7	28.7	319
T-DICK	13.6	6.5	14.1	1006
T-FARN	14.6	6.4	23.2	67
T-GRAN	27.2	6.7	28.3	735
T-HARR	21.1	6.7	30.4	110
T-JOE	24.7	6.9	21.1	136
T-KIOS	24.3	6.8	39.6	1110
T-LAMU	15.3	6.5	20.7	748
T-LAVI	28.4	7	7.9	2229
T-LCAU	26.7	6.9	32.3	254
T-LDIC	29.8	6.9	8.4	120
T-LJOE	41.9	7.2	7.3	50
T-LOTR	18.6	6.6	20.6	312
T-MANI	30.1	6.9	9	1386
T-MCKA	25.3	6.9	17.4	280
T-MERC	31.8	7	9.7	455
T-NTEA	21.9	6.7	57.8	1480
T-PHIL	25	6.9	16.7	193
T-RADI	24.5	6.9	40.3	638
T-RAIN	21.8	6.8	24.6	166

Table A.2 *(Continued)*

Lake code	Conductivity	pH	Aluminum	Surface Area
T-RBIC	30.3	7	14	465
T-ROCK	41.6	7.2	2.6	510
T-ROSE	28.8	6.9	13.7	197
T-SOUR	27.4	6.9	4.3	280
T-TEA	21.9	6.7	16.7	150
T-WHIT	14.5	6.4	70.7	220
Lake code	**Mean Depth**	**Max Depth**	**Volume**	**Bottom O2**
T-BIGT	8.8	33.1	137000000	5.4
T-BUIS	10.4	36.9	100000000	1.3
T-CATF	5.7	22.9	35246613	4
T-CAUC	13	43.6	30829187	1.1
T-CEDA	13.1	58.6	346000000	8
T-CLYD	3.4	12.3	10721040	0.3
T-DICK	6.7	18.6	66927036	0.2
T-FARN	4.9	17	3249768	0.4
T-GRAN	8.3	42.5	64654948	6.1
T-HARR	10.5	24.4	11609648	3.5
T-JOE	6.7	25.8	9591287	2.1
T-KIOS	13.3	47.5	147000000	8.8
T-LAMU	11.5	44.1	85783130	7.8
T-LAVI	14.5	51.9	368000000	9.7
T-LCAU	15.3	50.3	38775832	4
T-LDIC	8.3	25.9	9883056	2.5
T-LJOE	4	14.5	1991683	1.1
T-LOTR	16.3	40.5	50994573	7
T-MANI	13.5	38.6	187000000	5
T-MCKA	6.9	20.9	19439224	0.3
T-MERC	10.4	34.9	46954722	6.9
T-NTEA	11.2	45.9	165000000	6.1
T-PHIL	6.2	16.4	12007486	3.7
T-RADI	8.8	36.6	55767595	8.3
T-RAIN	6.6	26.9	10966851	0.5
T-RBIC	18.5	55.2	86159713	8.7
T-ROCK	8	34.3	40983987	5.7
T-ROSE	7	18.9	13687649	4
T-SOUR	9.7	42.7	25961400	6.6
T-TEA	5.8	15.8	8707480	0.2
T-WHIT	7.2	28.4	15740804	7.9

Table A.2 *(Continued)*

Lake code	Present VWHO	Lake Order	Cottage (presence)	Cottage Abundance
T-BIGT	6.6	4	0	0
T-BUIS	2	3	0	0
T-CATF	3.8	5	0	0
T-CAUC	7.3	3	1	1
T-CEDA	8	6	1	10
T-CLYD	1.5	4	0	0
T-DICK	0.2	4	0	0
T-FARN	1.7	3	0	0
T-GRAN	6.1	5	1	2
T-HARR	6.2	4	0	0
T-JOE	5.6	5	1	6
T-KIOS	8.8	5	1	3
T-LAMU	8.4	4	0	0
T-LAVI	9.4	5	0	0
T-LCAU	7.9	4	1	5
T-LDIC	3.8	3	0	0
T-LJOE	0.6	3	1	1
T-LOTR	7.6	5	1	6
T-MANI	7.7	5	1	2
T-MCKA	6.8	3	0	0
T-MERC	6.2	2	0	0
T-NTEA	5.8	5	1	1
T-PHIL	3.3	4	0	0
T-RADI	8	6	1	4
T-RAIN	4.3	4	1	1
T-RBIC	8.8	3	0	0
T-ROCK	5.6	6	1	24
T-ROSE	6.7	4	0	0
T-SOUR	6.3	3	1	15
T-TEA	0.3	5	1	10
T-WHIT	7.8	5	1	9

Lake code	Cottage (V weighted)	Dam (presence/absence)	dVWHO	Historic VWHO
T-BIGT	0.00E+00	1	0.8	6.2
T-BUIS	0.00E+00	1	-2.8	7.0
T-CATF	0.00E+00	0	-1.8	4.4
T-CAUC	3.24E-08	0	-0.2	8.3
T-CEDA	2.89E-08	1	1.2	6.1
T-CLYD	0.00E+00	0	-1.8	2.2

Table A.2 *(Continued)*

Lake code	Cottage (V weighted)	Dam (presence/absence)	dVWHO	Historic VWHO
T-DICK	0.00E+00	0	-0.8	1.9
T-FARN	0.00E+00	0	-2.0	3.4
T-GRAN	3.09E-08	1	0.4	6.6
T-HARR	0.00E+00	0	0.4	5.0
T-JOE	6.26E-07	1	-1.2	7.6
T-KIOS	2.04E-08	1	-0.6	7.8
T-LAMU	0.00E+00	0	1.9	7.8
T-LAVI	0.00E+00	1	0.6	7.1
T-LCAU	1.29E-07	0	-2.4	9.1
T-LDIC	0.00E+00	0	-0.5	5.2
T-LJOE	5.02E-07	0	1.2	2.9
T-LOTR	1.18E-07	1	-0.6	6.4
T-MANI	1.07E-08	0	-2.9	8.8
T-MCKA	0.00E+00	0	2.2	5.1
T-MERC	0.00E+00	0	-1.1	8.5
T-NTEA	6.06E-09	0	-2.3	6.8
T-PHIL	0.00E+00	0	-1.5	5.6
T-RADI	7.17E-08	0	-0.1	6.8
T-RAIN	9.12E-08	0	1.4	3.3
T-RBIC	0.00E+00	0	-0.1	9.1
T-ROCK	5.86E-07	1	0.2	4.8
T-ROSE	0.00E+00	0	-1.2	6.3
T-SOUR	5.78E-07	0	1.9	6.3
T-TEA	1.15E-06	1	1.1	1.2
T-WHIT	5.72E-07	0	0.2	5.8

Table A.3 Lake codes associated with Algonqiun Park lake names.

Lake Code	Lake Name
BIGT	Big Trout
BIGG	Biggar
BIRC	Birchcliffe
BONI	Bonita
BRUL	Brule
BUIS	Burnt Island
BURN	Burntroot
CACH	Cache
CANO	Canoe
CATF	Catfish
CAUC	Cauchon
CEDA	Cedar
CLYD	Clydegale
DICK	Dickson
FARN	Farncomb
GALE	Galeairy
GIBS	Gibson
GRAN	Grand
HARR	Harry
HOGA	Hogan
JOE	Joe
KIOS	Kioshkokwi
LAMU	La Muir
LOTR	Lake of Two Rivers
LAVI	Lavieille
LCAU	Little Cauchon
LCRO	Little Crooked
LDIC	Little Dickson
LJOE	Little Joe
LOUI	Louisa
MANI	Manitou
MCCR	McCraney
MCIN	McIntosh
MCKA	McKaskill
MERC	Merchant
MINK	Mink
MOUS	Mouse
NBRA	North Branch
NTEA	North Tea
PHIL	Philip
RADI	Radiant
RAIN	Rain
RBIC	Ralph Bice

Table A.3 *(Continued)*

Lake Code	Lake Name
RENC	Rence
ROCK	Rock
ROSE	Rosebary
SHIR	Shirley
SMOK	Smoke
SOUR	Source
TEA	Tea
TIM	Tim
WATE	Waterclear
WELC	Welcome
WHIT	Whitefish

Table A.4 Normality test statistics and environmental transformations selected for RDAs.

Environmental variable	Transformation	W	P	Selected transformation
Secchi	none	0.968	0.353	
Secchi	log	0.971	0.44	
Secchi	sqrt	0.979	0.694	*
Gran alkalinity	none	0.773	3.85×10^{-6}	
Gran alkalinity	log	0.976	0.603	*
Gran alkalinity	sqrt	0.902	0.003	
Ca	none	0.892	0.002	
Ca	log	0.969	0.377	*
Ca	sqrt	0.947	0.08	
Cl	none	0.516	7.02×10^{-10}	
Cl	log	0.675	8.74×10^{-8}	*
Cl	sqrt	0.598	7.19×10^{-9}	
DIC	none	0.817	2.87×10^{-5}	
DIC	log	0.966	0.311	*
DIC	sqrt	0.906	0.004	
DOC	none	0.969	0.371	
DOC	log	0.956	0.151	
DOC	sqrt	0.971	0.445	*
K	none	0.928	0.02	
K	log	0.941	0.05	
K	sqrt	0.945	0.067	*
Mg	none	0.881	0.001	
Mg	log	0.978	0.662	*
Mg	sqrt	0.948	0.082	
Na	none	0.771	3.54×10^{-6}	
Na	log	0.931	0.023	*
Na	sqrt	0.863	3.18×10^{-4}	
SiO3	none	0.878	0.001	
SiO3	log	0.961	0.224	
SiO3	sqrt	0.965	0.286	*
SO4	none	0.971	0.447	
SO4	log	0.978	0.65	*
SO4	sqrt	0.978	0.671	
True colour	none	0.972	0.476	
True colour	log	0.947	0.079	
True colour	sqrt	0.986	0.913	*
Fe	none	0.94	0.046	

Table A.2 *(Continued)*

Environmental variable	Transformation	*W*	*P*	Selected transformation
Fe	log	0.95	0.095	
Fe	sqrt	0.971	0.43	*
NH3.NH4	none	0.903	0.004	
NH3.NH4	log	0.931	0.024	
NH3.NH4	sqrt	0.935	0.032	*
TN	none	0.979	0.698	*
TN	log	0.957	0.167	
TN	sqrt	0.971	0.438	
TP	none	0.815	2.62×10^{-5}	
TP	log	0.929	0.021	*
TP	sqrt	0.881	9.28×10^{-4}	
Conductivity	none	0.952	0.116	
Conductivity	log	0.981	0.779	*
Conductivity	sqrt	0.978	0.645	
pH	none	0.964	0.271	*
pH	log	0.964	0.268	
pH	sqrt	0.964	0.272	
Al	none	0.904	0.004	
Al	log	0.95	0.098	
Al	sqrt	0.985	0.888	*
SA	none	0.782	5.84×10^{-6}	
SA	log	0.985	0.889	*
SA	sqrt	0.916	0.008	
Zmean	none	0.956	0.149	
Zmean	log	0.977	0.631	
Zmean	sqrt	0.978	0.669	*
Zmax	none	0.964	0.272	
Zmax	log	0.969	0.371	
Zmax	sqrt	0.978	0.664	*
Volume	none	0.689	1.46×10^{-7}	
Volume	log	0.984	0.855	*
Volume	sqrt	0.888	0.001	
Bot O2	none	0.928	0.02	*
Bot O2	log	0.843	1.43×10^{-4}	
Bot O2	sqrt	0.92	0.011	
VWHO	none	0.911	0.006	*
VWHO	log	0.744	1.17×10^{-6}	
VWHO	sqrt	0.857	2.26×10^{-4}	
Cottage density	none	0.543	1.44×10^{-9}	

Table A.2 *(Continued)*

Environmental variable	Transformation	*W*	*P*	Selected transformation
Cottage density	logx+1	0.543	1.44×10^{-9}	
Cottage density	sqrt	0.693	1.7×10^{-7}	*

APPENDIX B: eHOF parameters

Table B.1 eHOF model parameters for subfossil dipteran assemblages from Algonquin Park lakes along a VWHO gradient.

Taxon	Model type	Parameters a	b	c	d	f
CHIRON	2	2.07	1.68			
CLADOP	5	2.86	2.05	2.7	100	
CLDTYM	4	-9.6	15.2	13.7		
CORYTH	6	-2.708	12.777	5.594	0.486	
CRICOR	1	4.33183				
C.TOT	5	0.593	3.416	-0.236	14.717	
DICROT	6	-1.18	6.864	4.013	0.807	
GLYPTO	6	-0.162	33.215	3.493	0.816	
HTRTRS	7	-89.22	8.635	9.966	29.836	-0.237
MICROP	7	-100	3.3063	4.6053	33.581	-0.0475
PENTAN	7	-1.952	10.366	4.772	0.441	10.418
POLYPE	1	4.99043				
PROCLD	7	-3.47	7.63	5.67	1.13	-3.41
PSECTP	7	-8.254	9.055	10.787	-0.727	8.912
SERGEN	5	0.165	2.465	4.06	8.524	
STMPLL	7	-0.9642	6.6285	4.1395	0.0111	-100
STMPLN	3	-29.98	34.17	3.57		
SYNORT	1	4.03976				
TANYCH	4	-2.82	6.79	6.1		
TANYLU	7	-5.927	9.845	8.746	-0.761	11.045
TANYSL	5	-14.361	15.667	2.411	0.738	

Table B.2 eHOF model parameters for subfossil dipteran assemblages from Muskoka-Haliburton lakes along a VWHO gradient (Quinlan and Smol 2001).

Taxon	Model type	Parameters a	b	c	d	f
CHIRON	6	2.56	2.85	-8.55	5.47	
CLADOP	1	5.94676				
CLDTYM	4	-7.15	33.25	10.83		
CORYTH	3	-8.93	10.47	2.97		
CRICOR	2	3.45	1.01			
C.TOT	5	0.95	5.754	0.995	14.939	
DICROT	5	3.27	1.003	0.739	68.221	
GLYPTO	4	-2.73	100	5.21		
HTRTRS	7	-12.196	12.742	11.529	-0.601	10.237

Table B.2 *(Continued)*

Taxon	Model type	Parameters				
		a	**b**	**c**	**d**	**f**
MICROP	7	-25.26	36.601	24.424	100	-0.224
PENTAN	4	0.167	3.494	2.007		
POLYPE	2	3.737	0.483			
PROCLD	2	2.5	1.27			
PSECTP	1	4.111				
SERGEN	5	1.21	1.51	4.97	21.44	
STMPLL	6	-0.589	21.678	3.968	0.392	
STMPLN	4	-2.54	9.35	6.59		
SYNORT	1	5.25675				
TANYCH	1	4.94951				
TANYLU	1	5.5653				
TANYSL	6	-1.089	7.51	1.771	0.591	

APPENDIX C: Code

```
# install and import
!pip install causalgraphicalmodels
!pip install bambi
!pip install arviz
!pip install git+https://github.com/statsmodels/statsmodels.git

import numpy as np
import pandas as pd

import matplotlib.pyplot as graph
import seaborn as sns
import arviz as az

from scipy import stats

from google.colab import drive

from causalgraphicalmodels import CausalGraphicalModel

import statsmodels.api as sm
import statsmodels.formula.api as smf

import pymc3 as pm
from bambi import Model as BayesModel

from IPython.display import display, Markdown


def rmse(y_true, y_pred):
    return np.sqrt(mean_squared_error(y_true, y_pred))


df = pd.read_csv('final_top_unt_env_alphacode_sppremoved.csv')


df.columns = [c.replace(' ', '_').replace('/', '_').lower() for c in df.co
lumns]
df = df.rename(columns={
    'cottage_(presence_absence)': 'is_cottage',
})

display(df.head())
print(df.info())
```

```
## CAUSAL MODEL

causal_graph = CausalGraphicalModel(
    nodes=['Depth', 'Fe', 'P', 'Cottages', 'DOC', 'dVWHO', 'VWHO Historic'
, 'VWHO Present'],
    edges=[
        ('Depth', 'Cottages'), ('Depth', 'dVWHO'), ('Depth', 'VWHO Histori
c'), ('Depth', 'VWHO Present'),
        ('Fe', 'P'),
        ('P', 'DOC'),
        ('Cottages', 'P'), ('Cottages', 'DOC'), ('Cottages', 'dVWHO'),
        ('DOC', 'dVWHO'),
        ('dVWHO', 'VWHO Present'),
        ('VWHO Historic', 'dVWHO'), ('VWHO Historic', 'Fe')
    ]
)

display(causal_graph.draw())

print('Total effect of Cottages on the change in VWHO')
display(causal_graph.get_all_backdoor_adjustment_sets('Cottages', 'dVWHO')
)
print()




# Backdoor adjustments

display(causal_graph.get_all_backdoor_adjustment_sets('Cottages', 'dVWHO')
)

target_variable = 'vwho_change'
equations = [
    f'{target_variable} ~ C(is_cottage) + max_depth',
    f'{target_variable} ~ C(is_cottage) + calcium + max_depth',
    f'{target_variable} ~ C(is_cottage) + iron + max_depth',
    f'{target_variable} ~ C(is_cottage) + calcium + iron + max_depth',
    f'{target_variable} ~ C(is_cottage) + calcium + iron + max_depth + his
toric_vwho'
]

for equation in equations:
    print('\n'*3)
```

```
    display(f'Model [{equation}]')
    model = smf.ols(equation, data).fit()

    display(model.summary())

    # Some Post Hoc Tests
    print(f'Shapiro Wilk Test p = {stats.shapiro(model.resid_pearson)[1]}'
)
    sns.distplot(model.resid_pearson, fit=stats.norm)
    graph.show()

    print('-'*60)
```

DIFFERENCE IN DIFFERENCES

```
print(data.columns)

columns_did = ['vwho', 'max_depth', 'is_cottage', 'is_present']

d_pre_no_cottage = data[data['is_cottage'] == 0][['historic_vwho', 'max_de
pth', 'is_cottage']]
d_pre_no_cottage.columns = columns_did[:3]
d_pre_no_cottage['is_present'] = 0

d_post_no_cottage = data[data['is_cottage'] == 0][['present_vwho_t', 'max_
depth', 'is_cottage']]
d_post_no_cottage.columns = columns_did[:3]
d_post_no_cottage['is_present'] = 1

d_pre_cottage = data[data['is_cottage'] == 1][['historic_vwho', 'max_depth
', 'is_cottage']]
d_pre_cottage.columns = columns_did[:3]
d_pre_cottage['is_present'] = 0

d_post_cottage = data[data['is_cottage'] == 1][['present_vwho_t', 'max_dep
th', 'is_cottage']]
d_post_cottage.columns = columns_did[:3]
d_post_cottage['is_present'] = 1

data_did = pd.concat([d_pre_no_cottage, d_post_no_cottage, d_pre_cottage,
d_post_cottage])
display(data_did.sample(5))
print(data_did.shape)

# Estimate the causal effect under difference in differences
```

```
results_did = smf.ols(
    'vwho ~ 1 + C(is_present) + C(is_cottage) + C(is_present):C(is_cottage
)',
    data=data_did
).fit()

display(results_did.summary())

graph.title(f'Shapiro = {stats.shapiro(results_did.resid_pearson)}')
sns.distplot(results_did.resid_pearson, fit=stats.norm)
graph.show()

results_did = smf.ols(
    'vwho ~ 1 + C(is_present) + C(is_cottage) + C(is_present):C(is_cottage
) + max_depth',
    data=data_did
).fit()

display(results_did.summary())

graph.title(f'Shapiro = {stats.shapiro(results_did.resid_pearson)}')
sns.distplot(results_did.resid_pearson, fit=stats.norm)
graph.show()
```