Assessment of insect diversity in various urban landscapes.

Candice R. Grant

Supervisor: Dr. A. R. Westwood

A thesis submitted in partial fulfillment of the Honours Thesis (BIOL 41111/6) Course

Department of Biology

University of Winnipeg

2008

Abstract

Urban development is steadily growing across Canada. As landscapes are converted from naturalized areas into suburban enclaves, specific habitats of arthropod groups are being altered or lost. The resulting homogenized environment may favour adaptable native species, unwanted invasive/exotic generalist species or reduced populations of endemic insects. The objectives of this study were to determine the level of insect diversity present in three different land use areas within the City of Winnipeg and to study the relationship between insect diversity and the degree of urban forest development. It is predicted that increased mature urban forest canopy and increased shrub and tree diversity leads to an increase in insect abundance and diversity of herbivorous insect taxa. Conversely, the abundance of insect families not dependent on diverse plant populations will be unaffected by urban forest development. Nocturnal flying insects were trapped in specific land-use areas with varying degrees of urban forest development. Inventories were completed for tree and shrub vegetation in trapping areas. Alpha (α) and Beta (β) diversity measures were used to explore the variation of vegetation and insect abundance within neighborhoods and between land-use areas respectively. Trichoptera (caddisflies) abundance was not linked to tree or shrub diversity or structure in 2005 and 2006, whereas the plant dependent insect taxa such as Lepidoptera (moths) showed a numerical response to increased urban forest structure, but not a significant species response in 2005. The outcome of this study may assist urban planners to ameliorate harmful effects of urbanization by incorporating insect taxa responsiveness into future designs of urban development.

Acknowledgements

I would like to thank the following people for their assistance in making this project a success. To my supervisor Dr. Richard Westwood who has been a wonderful mentor and support throughout the process of this project. To my committee members Marianne Hardy and Nancy Loadman who have provided very much needed advice and encouragement. To the gracious individuals who allowed me to wander around on their property without mistaking me for a burglar; John and Deborah Sinclair, Don and Margarite Wood, Susan Earl, Andy Park, Dave Rannard, Glen Kozuska, Jim Hale, Manitoba Hydro and Akins Building Consultants. To the "CFIR Gophers" Lindsay Dedock, Stephanie Janz, Foster Karcha and Alana Westwood who helped collect vegetation data as well as Amanda Dumont and Kris Watts who exhibited immense patience while pinning the moth specimens. To my family and friends who faithfully listen to the rantings and meltdowns of this project. Finally I would like to thank my wonderful son who even in his youthful age has been a source of support always showing an interest in what mommy was doing with her bugs and who has also given me the strength to persevere in my pursuit of academic knowledge.

Table of Contents

Abstract……..**ii**

Acknowledgments…….....**iii**

Table of Contents……**iv**

List of Figures……..**v**

Introduction ……..**1**
Urban Ecosystems ....…….....**1**
Tree and Shrub Dependant Insect Taxa ……..**3**
Non-Tree Dependant Insect Taxa……....**4**

Research Objectives……..**7**

Methods and Materials……..**8**
Field Data Collection……....**8**
Laboratory Specimen Preparation and Identification Methodology……...**11**
Measurement of Vegetation and Structure……**12**

Statistical Analysis……...**12**
Diversity Indices ..……**12**
Simpson's index (*D*)……..**13**
Shannon index of Diversity (*H*)...……**14**
Shannon Evenness……**14**
Rank/Abundance……...**15**
Rarefaction……**15**
Log Alpha Series index……**16**
Cluster Analysis……**16**
Analysis of Variance (ANOVA)……...**17**
Chi-Square Test (χ^2)..……..……..**18**

Results……**19**

Discussion……**26**

Conclusions……**31**

References……...**32**

Appendix A……**36**
Appendix B……...**37**
Appendix C……..**38**

List of Figures, Tables and Appendices

Figure 1: Three study areas- level of tree canopy cover…….**8**

Figure 2: Wards Ultra Violet Bucket ® trap……...**9**

Figure 3: Canopy closure with the number of Lepidoptera individuals per treatment area……..**22**

Figure 4: Jaccard cluster analysis dendrogram of similarity coefficients for Noctuidae species in 2005……**24**

Figure 5: Cluster analysis of trap sites……...**25**

Table 1: Neighbourhood comparison of dbh, tree height and canopy closure……..**19**

Table 2: Tree and Shrub alpha diversity comparison between neighborhoods (boulevards and front yards)……....**20**

Table 3: Comparison of adult Trichoptera Families -mean individuals per neighbourhood…….**20**

Table 4: Comparison of adult Lepidoptera Families - mean individuals per site 2005…….**21**

Table 5: Noctuidae alpha diversity comparison between neighbourhoods 2005……...**22**

Table 6: Jaccard index coefficient of similarity matrix for beta diversity for Noctuidae species of 2005…….**23**

Appendix A: Number of individual tree and shrubs by neighborhood in 2007……..**36**

Appendix B: Summary statistics (± SEM) for front yard/boulevard tree and shrub species 2007…….**37**

Appendix C: Summary of Noctuidae species per trap site of neighborhoods 2005..……..**38**

Introduction

Urban Ecosystems

Urban development is the single most globally destructive human activity causing the greatest amount of habitat loss and species extinction in North America (McKinney, 2002; 2006; Christie and Hochuli, 2005). McKinney (2006) estimated that approximately 50 % of the population in the United States lives in suburban areas with 30% living within metropolitan centers. As a result, urbanized areas now cover over 5% of the earth's land surface (McKinney, 2002). It is estimated that within the next 30 years more than 50% of the global population will be concentrated in cities as a result of growth rates and migration from rural areas (Hansen *et al*., 2004; Shochat *et al*., 2006). With this rapid movement of people to cities it is expected that the total developed land base will increase from 5.2 to 9.2% in the United States alone (McKinney, 2006). As of 2001, Canadians are leaving rural areas such that four out of five people now live within metropolitan areas (Gurin, 2003; Statistics Canada, 2006). Despite the influx of people into urban centers, Canada's population growth rate has not matched the rate of urban development which has doubled (Gurin, 2003).

Urban growth and development has been shown to affect ecosystems through the conversion of land, resource consumption, habitat alteration and change in species composition (Alberti *et al*., 2003). Automotive use coupled with other human industrial activities have radically altered the earth's carbon cycle, as well as releasing into the environment vast quantities of heavy metals and trace elements (Alberti *et al*., 2003). Industrial and urban development is responsible for modifying urban habitats to such an extent that native species can no longer survive in these environments (McKinney, 2006). In highly urbanized centers native insect species are replaced with naturally occurring generalists or exotic invasive species (McKinney, 2002; Robinson, 2005). For example, this replacement process transforms unique ecosystems containing distinctive arthropod assemblages into homogenized landscapes only suitable for a few species that are adaptable to urban and suburban conditions. As a result of growing community

homogenization, landscapes will no longer be unique in structure and the overall global arthropod diversity may significantly be compromised (McKinney, 2002; 2006).

Until recently little ecological research has been conducted in urban settings, primarily because researchers in the past were interested in studying their subjects in the absence of humans (Blair and Launer, 1997; Botkin and Beveridge, 1997; McIntyre *et al*., 2000; Helden and Leather, 2004). Ecologists are now beginning to recognize the importance of urban ecosystems with more research being conducted in this field (McIntyre *et al*, 2000; Zanette *et al*., 2005). Researchers are interested in how urban development changes habitat structure thereby understanding its impact on arthropod diversity (McIntyre *et al*, 2000). With the imposing threat of global species decline, it is important now more than ever, for researchers to start examining threats to plant and animal diversity in urban areas. Knowing the number and taxonomic distribution of species within urban habitats is a necessary starting point for understanding the complex relationship between arthropod compositions and urban ecosystems (Carlton *et al*., 2004). Species richness estimates also provide foundations which serve the needs of policy makers and conservationists to make decisions about area preservation within degraded and exploited urban areas (Carlton *et al*., 2004). By completing such studies, cities can begin to focus efforts on reducing local impacts thereby improving urban environments which will ultimately aide in conserving urban arthropod diversity (Botkin and Beveridge, 1997).

The conversion of natural habitat to anthropogenic land use has many unknown effects on resident arthropod assemblages (McIntyre *et al*., 2001). Speculation about arthropod response to habitat structure has been studied and it is thought that different types of urbanization will relate to differences in species composition (McIntyre et al., 2001). While numerous insects and other arthropods are able to colonize and reproduce in disturbed and man-made environments (Frankie and Ehler, 1978) anthropogenic land use has been found to negatively affect certain arthropod species (McGeoch and Chown, 1997; Zapparoli, 1997; Gibbs and Stanton, 2001; McIntyre *et al*., 2000; McIntyre, 2000; McKinney, 2002; 2006; Christie and Hochuli, 2005; McFrederick and LeBuhn, 2006; Posa and Sodhi, 2006). Arthropod species diversity has

been found to decline from rural to urban areas, often along distance gradients (Blair and Launer, 1997; Denys and Schmidt, 1998; Gibbs and Stanton, 2001; Hansen *et al*., 2004). It can be postulated that urban communities with a high degree of tree cover and plant species diversity may be better environments to support diverse insect populations than those communities low in vegetative diversity and natural structure.

Tree and Shrub Dependant Insect Taxa

Lepidoptera are closely linked to plant communities. Though there are many studies done on Lepidoptera in natural ecosystems little is known about their occurrence in urbanized habitats (Winiarska, 2004). Certain Lepidoptera species show a decline from rural to adjacent urban areas (McGeoch and Chown, 1997). There have been no studies that investigate moths and their ecological requirements and habitats in Winnipeg. Insects are compact, abundant and easy to handle and collect, therefore may be useful as indicators of habitat quality compared to other less abundant invertebrate groups (McIntyre 2000; McIntyre *et al*., 2001). Also, because they are abundant, researchers are able to collect larger sample sizes creating higher statistical power (McIntyre 2000; McIntyre *et al*., 2000, 2001). More than 90% of known Lepidoptera species are moths, the majority of which are nocturnal; therefore, their response to light provides a convenient method of sampling (Janzen, 1988; Young, 1997; Ricketts *et al*., 2001; Abang and Karim, 2005; Brehm and Axmacher, 2006). Light traps have been used to collect insects for more that 50 years (Brehm and Axmacher, 2006). The advantage of light traps is that researchers can operate traps during the night without having to be present at the trap site (Covell, 1984) and the abundance of moths collected by light traps provides good estimates of population sizes (Yela and Holyoak, 1997; Raimondo *et al*., 2004).

Moth larvae are plant feeders that depend on vegetation to complete metamorphosis (Bland, 1978; Covell, 1984; Milne, 2000; Triplehorn and Johnson, 2005; Pedigo and Rice, 2006). Larval stages feed on the leaves, flowers, seeds, stems and trunks of trees (Young, 1997; Dover and Rowlingson, 2005). Some

moth species spend their entire life in proximity to their particular plant food source while others use dispersion or migration to facilitate resource requirement (Young, 1997). Moth assemblages are also closely linked to the ecological characteristics of vegetative hosts (Kitching *et al*., 2000).

Many moths are polyphagous, feeding on a variety of plant food while others are monophagous, having only a single food plant (Young, 1997). Adult moths use trees for diurnal resting spots (Blair and Launer, 1997; Young, 1997) and protective habitats (Dix and Baxendale, 1998). Adult and larval stages have adapted cryptic coloration patterns and behaviours to act as bark or twig mimics of tree species they inhabit to avoid predation (Young, 1997) and as such these species are sensitive to the loss of vegetation (Summerville and Crist, 2002; Abang and Karim, 2005; Posa and Sodhi, 2006). Moth diversity is also significantly correlated to tree diversity (Janzen, 1988; McGeoch and Chown, 1997; Kitching *et al*., 2000; Summerville and Crist, 2002; Brehm *et al*., 2003; Wickramasinghe *et al*., 2003; Abang and Karim, 2005). Urban trees also provide adults with daytime resting sites, oviposition sites (Blair and Launer, 1997) and nectar sources (Dover and Rowlingson, 2005) as well as providing protection against predators (Young, 1997; Dix and Baxendale, 1998). Therefore, the survival of many Lepidoptera species has been found to be closely dependant on the presence of host trees (Blair and Launer, 1997; Young, 1997; Posa and Sodhi, 2006).

Non-Tree Dependant Insect Taxa

There are many terrestrial and freshwater aquatic insect taxa that are not directly linked to the presence of tree cover in their habitats, but are found to be dependant on other structural habitat requirements or resources. Insect orders such as Hemiptera, Hymenoptera and Coleoptera may contain phytophagous species that are dependant on herbaceous flora and grass species for food or nectar resources rather than tree hosts (Chudzicka, 1990; Helden and Leather, 2004; Zanette *et al*, 2005). Zanette *et al*., (2005) found that bee and wasp richness was maintained in the city of Belo Horizonte in south-eastern Brazil by the presence of ornamental garden plants and natural herbaceous vegetation in vacant

lots. Sufficient nectar sources were providing colonies with enough sustenance to continue dwelling in these more urbanized areas of the city (Zanette *et al*., 2005). McFrederick and LeBuhn (2006) noted that urban parks played a vital role by enhancing bee diversity when they contained a stratified plant community which provided greater nectar resource choices (McFrederick and LeBuhn, 2006).

Some studies in urban areas reveal that Hymenoptera families such as Formicidae (ants), Vespidae (wasps) and Apidae (bumble and honey bees) rely on nesting sites to support a thriving colony rather than food abundance (Folgarait, 1998; McIntyre *et al*., 2001; Gibb and Hochuli, 2002; Zanette *et al*., 2005). Zanette *et al*., (2005) found that roofs, walls and ceilings within core areas of the city of Belo Horizonte provided cavity-dwelling species with microhabitats suitable for nesting sites allowing these groups to flourish within the city (Zanette *et al*., 2005). Peridomestic sites contain building surfaces and substrates for nesting sites coupled with natural and ornamental plant food resources in backyards or gardens sustain nuisance pests like wasps, hornets, ticks, mosquitoes, biting flies, spiders and scorpions (Robinson, 2005). Invasive species such as the Argentine ant *Linepithema humile*, have displaced entire assemblages of insects in regions of the southern United States especially in urban areas (Bolger *et al*., 2000; Holway, 2005; McKinney, 2006; Holway and Suarez, 2006). Irrigation and sewer systems (common features of urban environments) give these ants a steady supply of water, a vital requirement for the sustainability of established colonies (Holway and Suarez, 2006).

Many insect species are not dependent on vegetative composition for food or shelter. Their transient lifestyle within urban habitats is based upon prey abundance because they are parasitic, predatory or are carrion feeders. Chudzicka (1990) found that in sites where the abundance of phytophagous species was high, zoophagous insects were observed to be in greater numbers indicating that these were prime hunting areas sufficiently stocked with prey. Gibbs and Stanton (2001) observed that patterns of carrion beetle communities depended on bird and small animal density within urban vegetative fragments. They found that carrion beetle abundance was higher in fragments with higher bird and small animal populations resulting in greater carcass availability especially in urban areas (Gibb and Stanton, 2001).

The majority of evidence surrounding the origin of aquatic insects seems to favour the hypothesis that terrestrial insects living within the moist leaf litter areas of pond-like environments became secondarily adapted to aquatic habitats (Merritt and Cummins, 1978). Even though aquatic insects may have originated from terrestrial ancestors, their survival and success depends on the ability of their immature stages to exploit freshwater environments (Merritt and Cummins, 1978). Few aquatic insects have adapted to a completely submerged lifecycle and most will spend a period of time in the terrestrial environment especially as adults (Merritt and Cummins, 1978).

Freshwater aquatic insect taxa are not directly dependent on tree species for lifecycle requirements. As such vascular and nonvascular hydrophytic plants, periphyton/attached algae or filamentous (macroscopic) algae are examples of vegetative food and shelter resources that aquatic insects such as Trichoptera, Coleoptera, Ephemeroptera and Hemipteran species utilize (Merritt and Cummins, 1978). Some aquatic species are detritivores, feeding on decaying plant stem and leaf litter or organic material (Merritt and Cummins, 1978). Other species within insect orders such as Plecoptera, Coleoptera, Hemiptera or Odonata have either adults or juveniles which are carnivorous, feeding on other insects, invertebrates or small vertebrates (fish) of freshwater communities (Merritt and Cummins, 1978). There is no evident requirement for aquatic insects to successfully colonize an area with high canopy tree cover, thus they should be unaffected by the degree of tree cover in areas surrounding aquatic habitats.

Research Objectives

Three research objectives where addressed in this study:

1. Is urban tree and shrub composition similar in industrial and naturalized residential areas within the city of Winnipeg?

2. Are mature forest canopy and increased shrub and tree diversity linked to an increase in herbivorous insect abundance and diversity?

3. Is the presence of non-plant dependent insect taxa affected by the level and diversity of mature urban forest canopy and shrubs?

Methods and Materials

Field Data Collection

The determination of levels of urbanization intensity within the City of Winnipeg was based on aerial photographs of the city and land zoning classification. Urbanized intensity categories were developed based on McIntyre *et al*., (2001). Three levels of urbanization were identified in south western Winnipeg. These included an industrial area with minimal vegetation and natural structure (Fort Garry), a newly created residential development with some green space and limited natural structure (Lindenwoods) and a well established residential neighbourhood (River Heights) with significant plant diversity and structure (Figure 1).

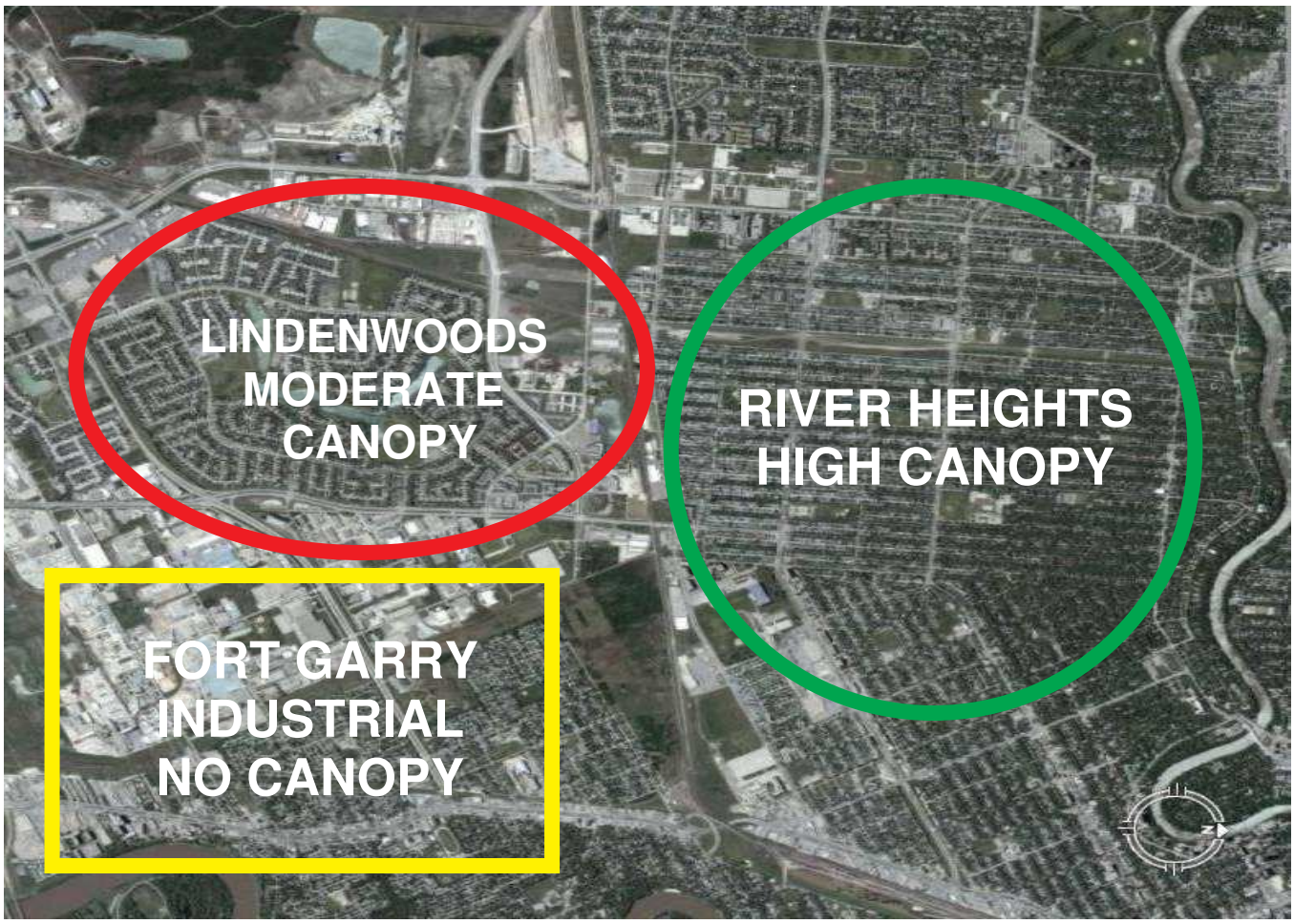

Figure 1: Three study areas- level of tree canopy cover.

Candidate study areas were also chosen on the basis of connectivity between each area, such that they occupied the same general area of the city as well as having similar topographic relief. Within each of the three urban land-use areas a series of light traps were established to capture nocturnally active flying insects. Each urban area was selected to be sufficient in size to minimize the movement of taxa from adjacent areas to the center of study areas (Janzen, 1988; Young, 1997; Ricketts *et al*., 2001; Abang and Karim, 2005; Brehm and Axmacher, 2006).

Light traps are a widely recognized sampling device to measure taxon richness and diversity of nocturnal insects (Janzen, 1988; Young, 1997; Ricketts *et al*., 2001; Abang and Karim, 2005; Brehm and Axmacher, 2006). Light traps were used as the sampling tool as they have been used in other studies to assess the diversity and abundance of nocturnally active insects and require minimal maintenance and logistical support (Covell, 1984; Yela and Holyoak, 1997; Brehm and Axmacher, 2006). Locations of traps were determined by access to electrical outlets and the need to locate trapping sites toward the interior of each test area to lower the influence of edge effects. Trap sites were at least 500 meters apart to lower interference (or bias) between the traps. Trap location was also influenced by the degree of security available at the site and the ease of access. Traps could not be accessible or visible to the general public because of potential vandalism or theft. Traps sites were also assessed according to level of safety for the researcher as I would be frequenting these areas late at night.

Figure 2: Wards Ultra Violet Bucket® trap

Nine Wards Ultra Violet Bucket® traps (Figure 2) were operated (with two back up traps in case of technical malfunctions) providing three traps per neighbourhood with land-use type designated as the treatment. Traps were designated as replicates within each treatment. One industrial area, one new residential

neighbourhood and one mature residential neighbourhood acted as the treatments. Nine traps proved to be the maximum number that could be operated based on the time required to activate traps at night and ensure morning collection. Traps were operated at least once per week from May 30 to September 19, 2005 and from May 16 to August 25, 2006. There were 21 sample days in 2005 and 17 in 2006. The actual collection day was based on weather conditions, for example rain would damage the ultraviolet lamp inside the traps as well as the specimens. Thus traps were only operated on rain free nights.

On average it took 90 minutes to activate the traps in the evening and 90 minutes to empty them in the morning. Each trap was operated for approximately12 hours during each collection night. Traps consisted of a 20 litre pail, an inverted funnel inside and an ultraviolet light with four vertical baffles to direct flying insects into the inverted cone and into the bucket (Figure 2.) Each bucket component of the trap contained a piece of Vapona® insecticide. Vapona® is an organophosphorus fumigant insecticide contained in a plasticized strip and is typically used in buildings as an insect killing agent. Vapona® was chosen as the killing agent because it is easy to handle and did not require a permit for use. When handling pieces of Vapona®, disposable gloves were used while assembling and disassembling the traps. The Vapona® pieces were placed in Ziploc® baggies until they were used again on the next collection night. Cardboard egg cartons were placed over the Vapona® strip within the bucket section to provide a surface where insects could rest until the killing agent took affect (Covell, 1984). Cartons help prevent damage to specimens when they bump into each other causing damage (scales falling off the wings, loss of legs or antennae), which would affect the accuracy of identification (Covell, 1984). Insects are caught in a passive manner by the trap with the vertical vanes acting as points of interception of adults as they fly around the light (Covell, 1984). The vanes direct the adults down towards the funnel into the collection container where they come in contact with the Vapona® vapour. At this point the funnel acts as a physical barrier to prevent the majority of insects from escaping. Traps were plugged into a 120 volt electrical outlet. The period (in hours) each trap operated each night was recorded. In the morning, specimens

where removed from the trap and placed in Petri dishes for transport to the laboratory. Petri dishes were stored at -15° C until specimens could be removed sorted and identified.

Laboratory Specimen Preparation and Identification Methodology

Frozen samples were removed from the freezer and allowed to defrost and dry out for two to three days to prevent fungal growth. Using a dissecting microscope, specimens were separated according to insect order and returned to Petri dishes which were placed in large Ziploc® plastic bags and stored until spreading and identification to a lower taxonomical unit could occur at a later date. Due to the time restriction of this project only the Orders Lepidoptera and Trichoptera were identified to family, genus or species level. Once identification commenced Petri dishes with Lepidoptera specimens were removed from the bags, opened and placed in a relaxing jar containing an anti-mould chemical (Phenol) with high humidity to relax the muscles and joints of the moths for easier spreading and mounting (Covell, 1984). Lepidoptera specimens were kept in the relaxing jar for 1-3 days to allow the relaxing effect to take place (Covell, 1984). Once the specimens were relaxed, they were taken out of the jar and spread on a pinning block. With the wings spread, identification was easier to complete without actually handling the specimens extensively (Covell, 1984). Once the specimens were successfully spread they were labelled indicating the date and site information. Lepidoptera specimens from 2005 were identified to species using Handfield (1999) and Covell (1984). Trichoptera specimens for 2005 and 2006 were separated according to family using Merritt and Cummins (1978) with individuals of the families Hydroptilidae, Leptoceridae, Limnephilidae, Phryganeidae and Polycentropodidae counted. The number of individuals in family Hydropsychidae was estimated by using a sub-sampling technique due to the multitude of individuals for some trap nights. If the Petri dish was one-quarter full or less, all individuals were counted. If the Petri dish was more than one-quarter full the contents were placed onto a sub-sampling grid sheet consisting of 36 x 36 squares (each square 4cm x 4cm). Using a random number table created in

Microsoft Excel® 2003, one square was chosen and all individuals were counted and multiplied by the total number of squares covered.

Measurement of Vegetation and Structure

Inventories of trees and shrub species were conducted on boulevards and for front yards of homes in each of the treatments during May of 2007. Inventories included the tree and shrub species, height, diameter at breast height (dbh) for trees, and degree of canopy closure over streets surrounding the trap sites. Height and dbh for front yard tree and shrub species were estimated due to access restriction on private property. However for trees and shrubs on public property (boulevards), dbh was determined by using dbh measuring tape at 1.4 meters from base of tree. Height was measured using a Suunto® Clinometer. Clinometer readings from the base and apex of the tree were recorded and then calculated using the following formula:

$$H=L*(\% \text{ of base} + \% \text{ of Tree Apex})/100$$

Where H is Height in meters and L is meters away from tree. A Spherical Densiometer was used to determine the forest overstory density. The Densiometer was held level approximately 35-40 cm from the body so that the operator's head was just outside of the grid area. The corners of 24 square grids were counted for canopy openings. The total count of canopy openings was then multiplied by 1.04 to obtain the percent of overhead areas not occupied by canopy. The difference between the percent not occupied by canopy and 100 is the estimate of overstory density in percent.

Statistical Analysis

Diversity Indices

Despite the variation within applied ecology, diversity from its earliest form has been and remains an integral component of the discipline (Magurran, 1988). Ecologists define species diversity based on two aspects, the numbers of species in the community and the relative abundance of species (Magurran,

1988; Molles, 1999). As such these factors are fundamental to measuring diversity. Many types of diversity indices take both of these factors into consideration; however, diversity measures differ in the relative weighting they may give to species evenness and species richness (Magurran, 1988; Molles, 1999). These indices are also called heterogeneity indices because they take into account both evenness and species richness; however, evenness can be isolated and analyzed on its own (Magurran, 1988). Ecological diversity is studied as two major levels based on community scale (Magurran, 1988). Species diversity or Alpha (α) diversity measures the relative abundance of species at an individual site level (Magurran, 1988). Ecosystem diversity or Beta (β) diversity measures the change in composition between two or more habitats with respect to species variety and abundance (Magurran, 1988).

Simpson's Index (D)

The Simpson's index is an important heterogeneity index which is weighted towards the abundance of the commonest species rather than providing a simple measure of the species richness (Magurran, 1988). As a dominance measure, the Simpson's index gives the probability that any two individuals drawn at random from an infinitely large community will belong to different species (Magurran, 1988). This index can be calculated using the equation (Magurran, 1988):

$$D = \Sigma \{n_i (n_i - 1)/N (N-1)\}$$

Where n_i is the number of individuals in the ith species and N is the total number of individuals (Magurran, 1988). Simpson's index is usually expressed as 1- D or 1/ D hence as D increases diversity of the community decreases (Magurran, 1988). The compositional data of yard and boulevard vegetation was used to calculate the Simpson's index for the comparison of Alpha diversity between the three neighbourhoods. The Simpson's index was also calculated for the 2005 Noctuidae species to compare the proportional abundance of Lepidoptera species between the treatment areas.

Shannon Index of Diversity (H)

The Shannon index is a diversity measure based on the proportional abundance of species within a community (Magurran, 1988). It has been found to be a useful method of comparing the diversity of different habitats especially when a number of replicates have been sampled (Magurran, 1988). It assumes that individuals are randomly sampled from an infinite population and that all species are represented within that sample (Magurran, 1988). The index is calculated by using the following formula (Magurran, 1988):

$$H' = -\Sigma\, p_i \ln p_i$$

In this calculation the quantity p_i is the proportion of individuals found in the *i*th species (Magurran, 1988). Values resulting from this equation usually fall between 1.5 and 3.5 with higher values representing higher species diversity (Magurran, 1988). This index is more sensitive to rare species within the community than does the Simpson's Index (Magurran, 1988). The compositional data of yard and boulevard vegetation was used to calculate the Shannon index of Alpha diversity for the comparison of the three treatment areas.

Shannon Evenness

Although the Shannon index of diversity takes into account the evenness of the abundance of species there is a way to calculate equitability of species as a separate measure of evenness (Magurran, 1988). As with the Shannon index, this evenness index assumes that all species in the community are accounted for in the same sample and is calculated using the following formula (Magurran, 1988):

$$E = H' / H_{max} = H' / \ln S$$

Values of *E* fall between 0 and 1.0 where zero indicates complete dominance of one species and 1.0 represents a situation where all species are equally abundant (Magurran, 1988). The compositional data of yard and boulevard vegetation as well as the 2005 Noctuidae species were used to calculate the Shannon

Evenness index to compare the Alpha diversity evenness of the vegetative and Lepidoptera among the three treatment areas.

Rank/Abundance

Relative abundance and diversity of species within a community can be represented in visual form by plotting the relative abundance of species against their rank abundance (Magurran, 1988; Molles, 1999). The abundance of each species can be plotted on a logarithmic scale against the species rank, from the most abundant to the least abundant, to produce a regression line (Magurran, 1988). The slope of the regression line can then be used as a measure of evenness where a value of zero indicates a situation in which all species are represented evenly within the community (Magurran, 1988). The slope of the regression line was calculated for the 2005 Noctuidae species as a comparison of Alpha diversity between the land-use areas of the study.

Rarefaction

Within a study area the species density may not be equal between sites due to the mobility of individuals (Magurran, 1988). This leads to an unequal number of species increasing with sample size and sample effort of collection devices (Magurran, 1988). To account for this difference of abundance, species richness can be compared between sites by "rarefying" the larger sample values down to the least effective site (Magurran, 2004). A Rarefaction curve is accomplished by calculating the number of species expected in each sample if all the samples were of a standard size by using the following formula (Magurran, 1988):

$$E(S) = \Sigma \{1-[(N-N_i / n) / (\mathrm{N}/n)]\}$$

Where $E(S)$ is the expected number of species; n is the standardized sample size; N is the total number of individuals recorded; N_i is the number of individuals in the ith species (Magurran, 1988). Two main assumptions of rarefaction are that samples need to have the same type of collection technique and that

individuals are randomly dispersed (Magurran, 2004). A major criticism of rarefaction is that it leads to a loss of information because the number of species and their relative abundance is known before the calculation although after the curve is produced all that remains is the expected number of species per sample (Magurran, 1988). A rarefaction curve was generated using the identified 2005 Noctuidae species and the rarified species richness values were used to determine the Alpha diversity of Lepidoptera between the treatment areas.

Log Alpha Series Index

The Log Alpha Series is an index which mathematically describes the relationship between the number of species and the number of individuals in those species (Magurran, 1988). The index may be obtained from the equation (Magurran, 1988):

$$\alpha = N\,(1\text{-}x)/\,x$$

Where α is an index of diversity; N is the total number of individuals; x is estimated from an iterative solution (Magurran, 1988). The Log Alpha Series index is considered a useful diversity index because it has good discriminatory abilities and is relatively unaffected by either rare species or common ones (Magurran, 1988). The identified 2005 Noctuidae species were used to calculate the Log Alpha Series index to determine the Alpha diversity among the three study areas.

Cluster Analysis

Along with identifying the dynamics of a particular habitat, ecologists sometimes wish to ascertain how species numbers and identities differ between communities (Magurran, 1988). Beta (β) diversity or differential diversity is a measure of how different (or similar) a range of habitats or samples are in terms of the variety (and abundance) of species found within them or as simply a comparison of species compositions between different communities (Magurran, 1988). A simple mathematical equation that measures the similarity of pairs of sites is the community coefficient of Jaccard or Jaccard index

(Magurran, 1988). It is based on the presence-absence relationship between the number of species common to two areas (or communities) and the total number of species within both areas (Magurran, 1988). Therefore the coefficient expresses the ratio of the common species to all the species and is calculated using the following formula (Magurran, 1988):

$$C_j = j/ (a + b - j)$$

Where *j* is the number of species found in both sites and *a* is the number of species in site A with *b* the number of species in site B (Magurran, 1988). The value of 1 represents a situation in which there is complete similarity between two sites and zero indicates sites that are dissimilar because they have no species in common (Magurran, 1988). Since several sites were involved in this investigation cluster analysis was used to demonstrate the β diversity of the collection sites. Cluster analysis starts with a matrix exhibiting the similarities between each pair of sites (Magurran, 1988). The two most similar sites of the matrix are combined to form a single cluster with successive clustering of similar sites following to form a dendrogram for visual inspection (Magurran, 1988). The Jaccard index and cluster analysis were calculated for the 2005 Noctuidae species using the Systat statistical program (Systat, 2004). This was followed by a dendrogram which displayed the similarities between the three treatment areas of this study using the same software (Systat, 2004).

Analysis of Variance (ANOVA)

Analysis of variance or ANOVA is a parametric statistical test to determine whether two or more groups have the same mean (Dytham, 2002). The basic assumptions of the ANOVA test is that the data is continuous, approximately normally distributed and that the variances of the data sets are homogeneous (Dytham, 2002). The null hypothesis of this particular test is that the sets of data have the same mean (Dytham, 2002). A one-way ANOVA with a significance level set at $P \leq 0.05$ (SPSS, 2001) was used to compare means between neighbourhood dbh, height and canopy closure of trees; the number of species, Simpson's index, Shannon's index, Shannon Evenness index between treatment vegetation including

boulevards and front yards; comparison of adult Trichoptera families for both 2005 and 2006; comparison of adult Lepidoptera families including the family Noctuidae; number of individuals, number of species, Log Alpha Series index, Shannon Evenness, Simpson's index, slope of regression line for Rank/Abundance plots and Rarefaction of Noctuidae species of 2005. If the ANOVA test was significant a post hoc analysis was performed using the Tukey Honestly significant difference (HSD) test (SPSS, 2001).

Chi-Square Test (χ^2)

The Chi-Square test or the Chi-Square goodness of fit test is a non-parametric test which determines if there are significant differences between two or more sets of frequencies (Dytham, 2002). The underlying assumptions of this particular test is that individuals are independent, that individuals belong to only one category, and that the test is nonparametric or there is not an assumption about the shape of the underlying distribution. A Chi-Square test was used to determine the significance between the numbers of unique species of the Noctuidae family of the 2005 collection between treatments.

Results

Trees and shrubs found on boulevards and in front yards in the three treatment areas were counted and categorized according to site (Appendix A). The total numbers of individuals per tree or shrub species within each land-use area were further summarized by the mean dbh and height of each species and also according to presence on the boulevard or front yards (Appendix B).

Comparison of the three treatment areas with respect to tree dbh, height and canopy closure revealed significant differences between all three parameters (Table 1). River Heights had the greatest number of individual tree species followed by Lindenwoods and Fort Garry respectively, with canopy closure being highest in River Heights and least in Fort Garry. Dbh and height did not exhibit the same trend between the three land-use areas; dbh was greatest in River Heights however in the Fort Garry sites, trees had a larger mean dbh than Lindenwoods. The average height of trees was also found to be greater in Fort Garry than River Heights and Lindenwoods having the smallest trees.

Table 1: Neighbourhood comparison of dbh, tree height and canopy closure.

Neighborhood	Dbh (cm)	Height (m)	Canopy Closure (%)
River Heights n=2903	35.8 ± 0.7c[1]	5.3 ± 0.1b	86.5 ± 4.1c
Lindenwoods n=1364	18.7 ± 0.4a	3.0 ± 0.1a	22.0 ± 1.1b
Fort Garry Industrial n=82	24.8 ± 10.3b	6.3 ± 2.5b	4.4 ± 0.4a
	$F_{2, 15}$ = 12.41	$F_{2, 15}$=5.03	$F_{2, 37}$ = 71.04
	$P<$ 0.001	P = 0.021	$P<$ 0.001

[1] Means in the same column followed by a different letter are significantly different (ANOVA,Tukey's HSD, $P < 0.05$).

There was a significant difference in the vegetative composition of boulevard and front yard tree species between neighbourhoods including differences in Shannon's index, Shannon Evenness and Simpson's index values (Table 2). Of the three areas, River Heights had higher tree and shrub diversity and also had the largest number of species when compared to Lindenwoods and Fort Garry, respectively.

Table 2: Tree and shrub alpha diversity comparison between neighbourhoods (boulevards and front yards).

Neighborhood	Number of Species	Shannon H	Shannon Evenness	Simpsons (1/D)
River Heights	33 ± 1.86b[1]	2.71 ± 0.04b	0.73 ± 0.01b	10.69 ± 0.66b
Lindenwoods	29 ± 2.65b	2.65 ± 0.58b	0.72 ± 0.02b	10.66 ± 1.11b
Fort Garry Industrial	6 ± 0.88a	1.50 ± 0.12a	0.41 ± 0.03a	4.62 ± 0.67a
	$F_{2,6} = 57.34$	$F_{2,6} = 76.38$	$F_{2,6} = 76.77$	$F_{2,6} = 17.30$
	$P < 0.001$	$P < 0.001$	$P < 0.001$	$P = 0.003$

[1] Means in the same column followed by a different letter are significantly different (ANOVA,Tukey's HSD, $P < 0.05$).

There was no significant difference in the mean number of individuals per trap site for Trichoptera families in 2005, however the mean number of individuals in the family Polycentropodidae was significantly different between the neighbourhoods in 2006 (Table 3). The total number of individuals for both collection years was significantly different between treatment areas in 2006 but not in 2005.

Table 3: Comparison of adult Trichoptera families – mean individuals per neighbourhood.

	Family	River Heights	Lindenwoods	Fort Garry Industrial		
2005	Hydropsychidae	2143	4356	14231	$F_{2,6} = 3.70$	*P = 0.090*
	Leptoceridae	30	41	42	$F_{2,6} = 0.59$	*P = 0.584*
	Phryganeidae	2	8	7	$F_{2,6} = 1.11$	*P = 0.390*
	Polycentropodidae	19	25	73	$F_{2,6} = 1.97$	*P = 0.220*
	Limnephilidae	8	18	39	$F_{2,6} = 2.85$	*P = 0.135*
	Hydroptilidae[2]	0	2	0		
2006	Hydropsychidae	2380	2450	9818	$F_{2,6} = 4.06$	*P = 0.077*
	Leptoceridae	61	47	27	$F_{2,6} = 1.43$	*P = 0.310*
	Phryganeidae	13	19	13	$F_{2,6} = 0.68$	*P = 0.541*
	Polycentropodidae	2a[1]	7b	12c	$F_{2,6} = 27.04$	*P = 0.001*
	Limnephilidae	11	11	13	$F_{2,6} = 0.05$	*P = 0.952*
	Hydroptilidae	2	27	1	$F_{2,6} = 3.93$	*P = 0.081*
Totals	2005	6607	13349	43174	$F_{2,6} = 3.72$	*P = 0.089*
	2006	7408a	7681a	29652b	$F_{2,6} = 8.49$	*P = 0.018*

[1] Means in the same row followed by a different letter are significantly different (ANOVA,Tukey's HSD, $P < 0.05$).

[2] Insufficient sample size for analysis.

The mean number of individuals of Lepidoptera families collected per site in 2005 is shown in Table 4. The family Tortricidae was the only Lepidoptera family with significant differences in the number of individuals collected between the treatment areas. The overall total of individuals by families was significantly different between the neighbourhoods in 2005.

Table 4: Comparison of adult Lepidoptera families - mean individuals per neighbourhood 2005.

Family	River Heights	Lindenwoods	Fort Garry Industrial		
Geometridae	12 ± 4.81	14 ± 2.33	4 ± 1.45	$F_{2,6} = 3.01$	$P = 0.124$
Geometridae (unknown)	17 ± 6.57ab1	27 ± 4.98b	3 ± 1.67a	$F_{2,6} = 6.21$	$P = 0.035$
Arctiidae	4 ± 2.02	3 ± 1.15	1± 0.88	$F_{2,6} = 0.70$	$P = 0.535$
Noctuidae	102 ± 11.92	164 ± 33.84	53 ± 24.88	$F_{2,6} = 4.90$	$P = 0.055$
Noctuidae (unknown)	12 ± 4.04	26 ± 5.67	16 ± 8.84	$F_{2,6} = 1.31$	$P = 0.336$
Notodontidae	1 ± 0.33	4 ± 0.88	2 ± 1.86	$F_{2,6} = 1.62$	$P = 0.275$
Sphingidae[2]	0	2	0		
Pyralidae	36 ± 10.21	47 ± 11.37	44 ± 18.58	$F_{2,6} = 0.17$	$P = 0.850$
Tortricidae	458 ± 76.37a	87 ± 2.08b	44 ± 8.51c	$F_{2,6} = 65.57$	$P < 0.001$
Micro Lepidoptera	161 ± 41.42	134 ± 19.66	101 ± 14.95	$F_{2,6} = 1.17$	$P = 0.373$
2005 Totals	700.67b	343.33a	215a	$F_{2,6} = 11.15$	$P = 0.010$

[1] Means in the same row followed by a different letter are significantly different (ANOVA,Tukey's HSD, $P < 0.05$).
[2] Insufficient Sample size for analysis.

The total number of Lepidoptera families and the % canopy closure within each land-use area showed a similar trend by each neighbourhood (Figure 3). River Heights has the largest number of individuals as well as the greatest % canopy closure followed by Lindenwoods and the Fort Garry area.

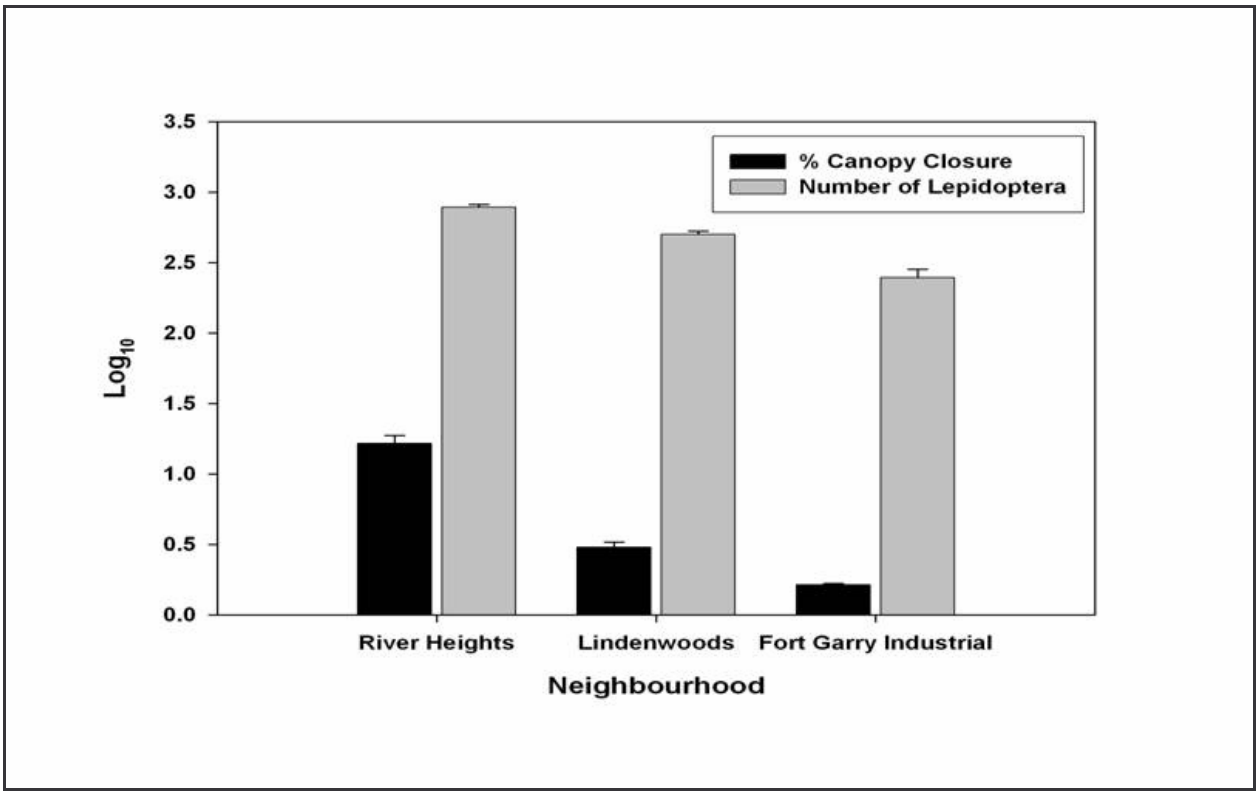

Figure 3: Canopy closure with the number of Lepidoptera individuals per treatment area.

The number of individuals collected in the nine traps sites for the Lepidoptera family Noctuidae is summarized in Appendix C. The Log Alpha Series, Shannon Evenness, Simpson's index, Rank Log Abundance and Rarified Species Richness indices are shown in Table 5. There was no significant difference within the indices between neighbourhoods (Table 5).

Table 5: Noctuidae alpha diversity comparison between neighbourhoods 2005.

	Log Series alpha	Shannon Evenness	Simpson (1/D)	Slope of Line Rank Log Abundance	Rarified Species Richness	Number of Unique spp.
River Heights	14.53 ± 1.74	0.78 ± 0.09	14.60 ± 3.23	– 0.0387 ± 0.004	13 ± 0.70	12
LindenWoods	19.83 ± 1.39	0.87 ± 0.02	19.83 ± 1.25	– 0.0267 ± 0.002	14.4 ± 0.12	19
Fort Garry Ind.	17.87 ± 1.73	0..93 ± 0.04	23.33 ± 2.40	– 0.0347 ± 0.005	14.2 ± 0.60	11
	$F_{2,6} = 2.71$	$F_{2,6} = 2.01$	$F_{2,6} = 3.26$	$F_{2,6} = 2.09$	$F_{2,6} = 1.99$	$\chi 2 = 2.7$, $df = 2$
	$P = 0.145$	$P = 0.214$	$P = 0.110$	$P = 0.204$	$P = 0.218$	$P = 0.257$

Jaccard coefficients for shared species for Noctuidae per trap sites assessing Beta diversity is shown in Table 6 and the cluster analysis dendrogram in Figure 4. The results of the Jaccard index comparisons show that River Heights and Lindenwoods share approximately 42% of the total species compliment, while River Heights and Fort Garry Industrial share 28% of the species similarity and Lindenwoods and Fort Garry share 27% of Noctuidae species.

Table 6: Jaccard index coefficient of similarity matrix for beta diversity for Noctuidae species of 2005 (traps 1-3 = River Heights, 4-6 = Lindenwoods, 7-9 = Fort Garry Industrial).

	1	2	3	4	5	6	7	8	9
1	1	0.41	0.5	0.50	0.32	0.38	0.30	0.27	0.34
2	0.41	1	0.37	0.49	0.42	0.44	0.20	0.30	0.38
3	0.50	0.37	1	0.41	0.38	0.37	0.16	0.24	0.35
4	0.50	0.49	0.41	1	0.43	0.41	0.16	0.29	0.34
5	0.32	0.42	0.38	0.43	1	0.58	0.14	0.26	0.39
6	0.38	0.44	0.37	0.41	0.58	1	0.20	0.26	0.43
7	0.30	0.20	0.16	0.16	0.14	0.20	1	0.27	0.22
8	0.27	0.30	0.24	0.29	0.26	0.26	0.27	1	0.36
9	0.34	0.38	0.35	0.34	0.39	0.43	0.22	0.36	1

0= no sharing of species, 1= completely shared species

The dendrogram of the Jaccard cluster analysis (Figure 4) clustered trap sites 1-3 in River Heights with site 4 in Lindenwoods; Fort Garry site 7 and 8; Lindenwoods site 6 and Fort Garry site 9. Lindenwoods site 5 did not appear to be clustered with any other site, thus probably had some unique species. Clustering of sites with respect to location is shown in Figure 5.

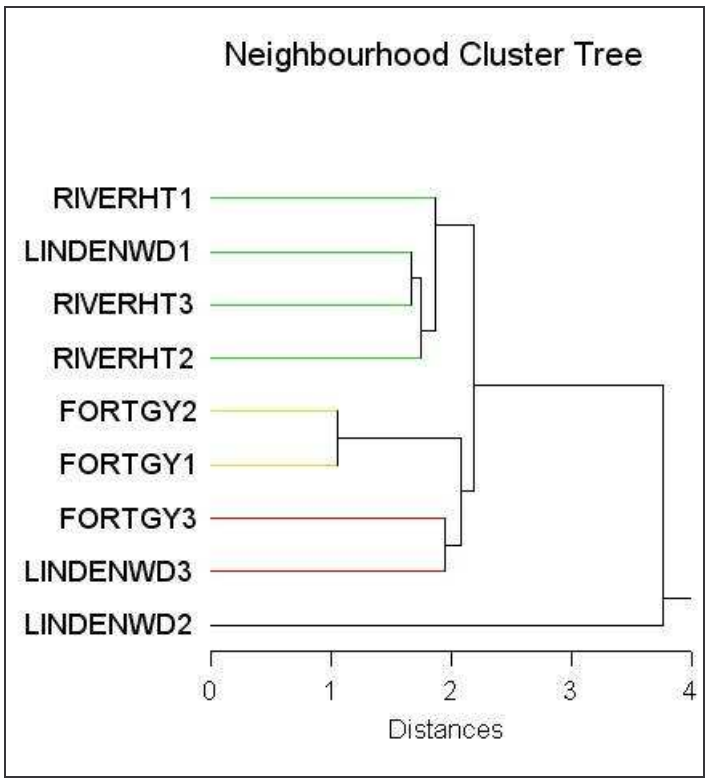

Figure 4: Jaccard cluster analysis dendrogram of similarity coefficients for Noctuidae species in 2005

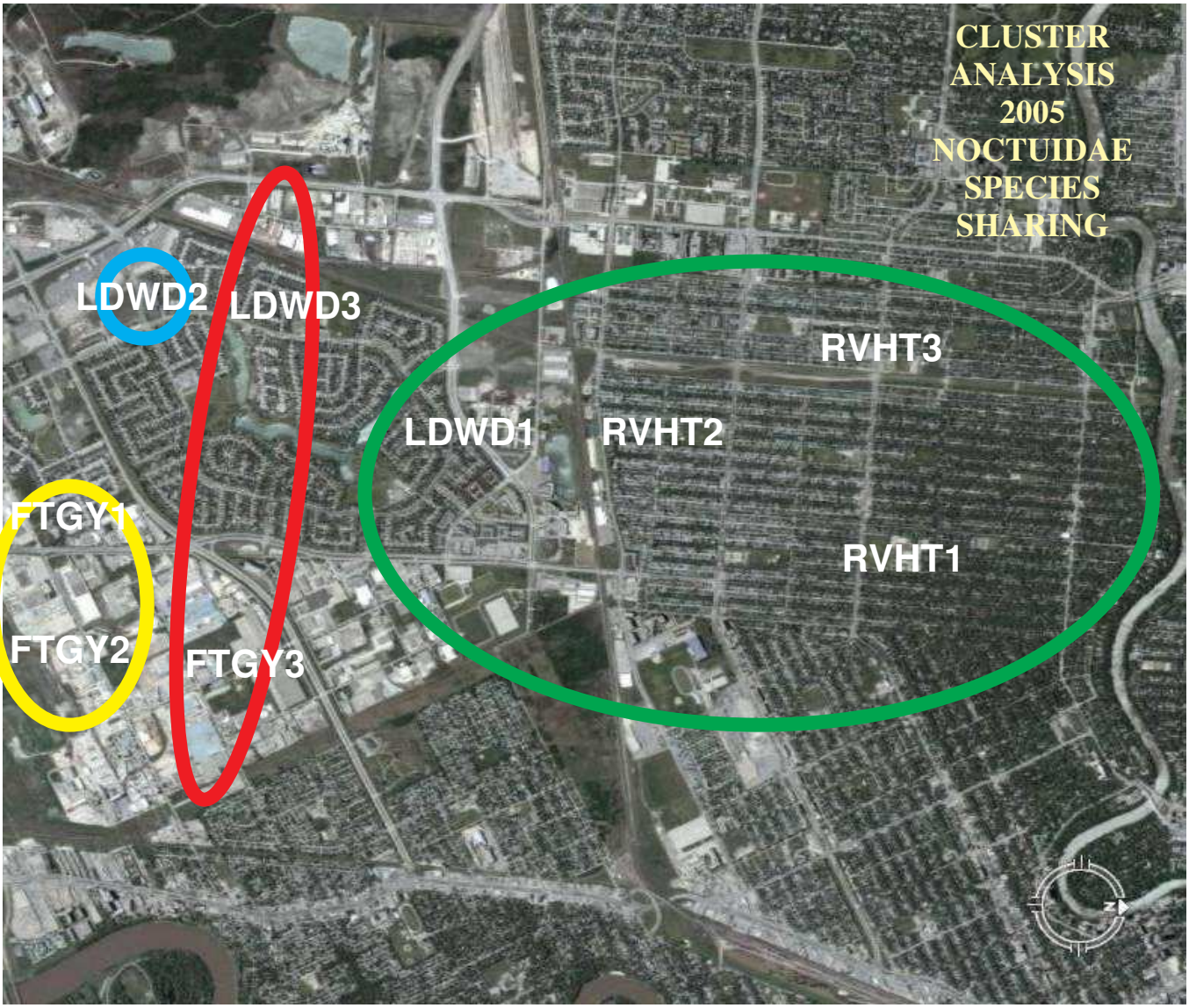

Figure 5: Cluster analysis of trap sites.

Discussion

As expected there was a significant difference in the many variables measured in relation to tree and shrub diversity and canopy cover between treatment areas. River Heights was the most diverse area, both in terms of tree and shrub species and the relative number of trees and shrubs in the vicinity of the insect traps. The expected correlation between trap sites and plant diversity was not reflected for most of the families of moths collected in 2005. The highest number of moths collected occurred in River Heights but this was mostly driven by one family, the Tortricidae, the members of which were very abundant in River Heights but scarce in the remaining two areas. Many of the Tortricidae are tree feeders, thus their presence could be linked to the increased diversity and biomass in River Heights. Within the Family Noctuidae there was not a strong correlation between moth species diversity and abundance and tree and shrub diversity.

There are several other reasons to expect that River Heights should have higher levels of moth diversity. For example, the richness-energy hypothesis suggests that regions with greater energy availability are able to sustain populations of more insect species (Kerr *et al*., 1998). Energy limits species distribution because in low energy regions fewer organisms are able to maintain viable populations because of the persistently large demands on their metabolic processes as well as the ability to forage and reproduce successfully at the same time (Kerr *et al*., 1998). Dependence on external thermal conditions, rather than direct reliance on food abundance or other ecological factors may provide the major limit to diversity in the temperate or colder regions of North America (Kerr *et al*., 1998). Potential evapotranspiration (PET) or the amount of moisture that would evaporate from a saturated surface has been found to be a good predictor of species richness patterns of birds, mammals, amphibians, insects and reptiles in temperate North America (Kerr *et al*., 1998). PET is a measure of heat which can strongly affect animal's energy budgets in high to mid-latitudes (Kerr *et al*., 1998). Kerr *et al*., (1998) found that in Canada, the richness of Lepidoptera is greatest in southern Ontario and in British Columbia which happen to be the warmest parts of the country and also correspond to areas with the highest PET values.

Winnipeg with surrounding less diverse biomes (agriculture and prairie areas) has a moisture index (IM) of -12, indicating moisture stress, where as in a city such as Toronto, with a large temperate deciduous urban forest, the IM value is +35 (Scott, 1995). It could also be expected that if tree and shrub diversity where not influencing Lepidoptera diversity in River Heights, that moth energy requirements could be better met as the closed canopy forest would increase moisture levels in the atmosphere and soil and thus lessen metabolic pressures on such a taxa. It is well documented that many insect taxa are susceptible to desiccation in one or more developmental stages (Triplehorn and Johnson, 2005) and higher PET values could have occurred in River Heights. Unfortunately PET rates were not measured in this study.

The amount of water that a stand of trees can transpire varies according to species, the quantity of foliage, soil water availability and the amount of solar energy evaporating water from the leaves (Kimmins, 2004). Species of trees such as elm, basswood, poplar and birch have high leaf area and leaf biomass and as such, areas containing these types of trees transpire large amounts of moisture into the environment and lower the impact of desiccating levels of solar energy (Kimmins, 2004). Since River Heights had a greater number of trees in the vicinity of traps versus Lindenwoods and Fort Garry, this area may have had the most amount of potential transpiration energy emission. Lepidoptera are poikilothermic meaning their body temperature rises and falls with environmental temperature (Triplehorn & Johnson, 2005). It could be hypothesized that River Heights with its significant urban forest canopy would provide more optimal conditions for insect survival (less impact of desiccating conditions) than either Lindenwoods or Fort Garry, but trapping results do not support this idea.

The availability of breeding sites for many Lepidoptera species would be highest in River Heights as minimal tree biomass and canopy closure in Lindenwoods and Fort Garry would limit potential breeding areas. While the Fort Garry industrial park does have occasional large trees they are positioned too far apart and too few in number to provide significant moth habitat. Fort Garry Industrial Park is also characterized by considerable amounts of pavement, with building units abutting the city property roadway limiting the amount of boulevard property where trees can be situated. Fort Garry trap sites

would probably receive very high levels of solar energy, having correspondingly high moisture deficits which could be predicted on energy theory to be less conducive to increased moth diversity.

It appears that neither tree and shrub diversity or microclimate had a large impact on the distribution and abundance of moth species between treatment areas. There are other factors including impact of wind, migration or movement distances of adult moths at night or perhaps structural differences in the vicinity of the traps that may have influenced captures. These factors were not studied but may be important. Despite the fact that River Heights had significantly higher levels of tree and shrub diversity the amount of plant species available may still have been too small to support more Noctuidae moth species in comparison to the other treatment areas.

When examining the Trichoptera (a taxa that should be less influenced by the presence of an urban forest and high tree and shrub diversity) the results are more in keeping with the hypothesis that there should be little difference in the diversity of Trichoptera between trap sites. Comparison of the mean individuals of Trichoptera per family of 2005 and 2006 reveals only a significant difference between treatments for the family Polycentropodidae in 2006. The largest numbers of Hydropsychidae were found in Fort Garry. Species within the Hydropsychidae are called the net-spinning caddisflies consisting of 151 North American species making it one of the largest families of caddisflies (Triplehorn and Johnson, 2005). Larvae of this family are usually found in parts of streams where the current is strongest (Triplehorn and Johnson, 2005). They are confined to running water because the current is essential for both respiration and operation of food capture nets which they construct (Merritt and Cummins, 1978). Large ditches that run east/west parallel to Bishop Grandin Boulevard (adjacent to the Fort Garry trap areas) have several areas that retain runoff and rainwater throughout the summer. Certain sections of the ditches also run into retention ponds of a newly developed housing community south of Bishop Grandin Boulevard and southeast of Scurfield Boulevard (also adjacent to Fort Garry industrial area). Adults of Trichoptera are generally weak fliers (Triplehorn and Johnson, 2005) therefore if species are developing in the ditches then it follows that the abundance of individuals would be greater in the Fort Garry area and in

Lindenwoods because of the proximity of these neighbourhoods to the eclosion sites. Also if the industrial area is acting as a heat island due to the reflective/absorbent nature of the pavement and infrastructure for solar heat (McIntyre, 2000; 2001) maybe this group is taking advantage of the higher daytime temperatures to meet metabolic requirements during the quiescent time of the day.

While streams have higher oxygen concentration due to the turbulent action of running water than do either ponds or lakes (Merritt and Cummins, 1978), deeper ponds (retention ponds) can also be highly oxygenated such that species of Hydropsychidae and the other Trichoptera families may occupy these bodies of water as well. There are a number of retention ponds in Lindenwoods and near the Fort Garry industrial area. The Red River east of Pembina Highway is also located adjacent to the three trap sites in the industrial park. The fast moving river water could provide an ideal development site for Trichoptera families such as Hydropsychidae making them more abundant in Fort Garry than the other two treatment areas.

Of the other five Trichoptera families collected in 2005 and 2006, four families have larvae that are found in slower moving or standing water habitats (Merritt and Cummins, 1978). Hydroptilidae (micro-caddisflies) is a large group of 263 North American species with larvae typically preferring small lakes (Triplehorn and Johnson, 2005). Limnephilidae or the Northern caddisflies are a large family as well, consisting of 239 species in North America having a northern distribution with larvae surviving in stagnant ponds and slower moving streams (Triplehorn and Johnson, 2005). Leptoceridae or the long horned caddisflies consists of 112 North American species with larvae that can live in a variety of water bodies, where as the family Phryganeidae or the large caddisflies typically have larvae which can survive in marshes and lakes (Triplehorn and Johnson, 2005). The Polycentropodidae are known as the trumpet-net or tent-making caddisflies and the larvae of this group are generalist when it comes to habitats because they can survive in numerous types of aquatic niches (Triplehorn and Johnson, 2005). Most larvae of Trichoptera species subsist on a wide range of food types, including algae and diatoms, microorganisms and decaying matter. Thus as long as these food types are accessible to larvae they can persist in various

aquatic environments (Merritt and Cummins, 1978). Further sampling and assessment of running and standing water bodies within and around Fort Garry and Lindenwoods may provide information regarding which taxa are actually breeding in these areas. It appears that the Trichoptera were ubiquitous throughout the treatment areas and that tree cover probably had little influence on their distribution as predicted.

Conclusion

1. Hypothesis 1: Vegetation structure and diversity were significantly different between the treatment areas.

2. Hypothesis 2: Lepidoptera abundance at the family level was greatest in mature urban forest neighbourhood (River Heights); however species diversity in the Family Noctuidae was unaffected by the degree of urban forest development in 2005.

3. Hypothesis 3: Trichoptera abundance was unaffected by the presence of urban forest. The presence of water may be an important factor influencing Trichoptera abundance. Analysis of water bodies within the three treatment areas is required to investigate a potential link.

4. There may be an impression that a large mature urban forest provides residents with a more diversified natural environment however, this may be misleading as insect diversity may be similar to industrialized environments in large cities. This may also be reflective of other animal taxa. More surveys are needed to verify that this is true.

References

Abang, F. and Karim, C. 2005. ***Diversity of Macromoths (Lepidoptera: Heterocera) in the Poring Hill Dipterocarp Forest, Sabah, Borneo***. Journal of Asia-Pacific Entomology 8(1): 69-79.

Alberti, M., Marzluff, J.M., Shulenberger, E., Bradley, G., Ryan, C., and Zumbrunnen, C. December 2003. ***Integrating Humans into Ecology: Opportunities and Challenges for Studying Urban Ecosystems***. BioScience 53: No.12.

Bland, R.G. 1978. ***How to know the insects, third edition.*** WCB McGraw Hill. Boston, Massachusetts, U.S.A. Pg 259.

Blair, R.B. and Launer, A.E. 1997. ***Butterfly Diversity and Human Land Use: Species Assemblages Along an Urban Gradient***. Biological conservation 80: 113-125.

Bolger, D.T., Suarez, A.V., Crooks, K.R., Morrison, S.A., and Case, T.J. 2000. ***Arthropods in Urban Habitat Fragments in Southern California: Area, Age and Edge Effects***. Ecological Applications 10 (4): 1230-1248.

Botkin, D.B., and Beveridge, C.E., 1997. ***Cities as Environments***. Urban Ecosystems 1: 3-19.

Brehm, G., Homeier, J., and Fiedler, K. 2003. ***Beta diversity of geometrid moths (Lepidoptera: Geometridae) in an Andean montane rainforest***. Diversity and Distribution 9: 351-366.

Brehm, G. and Axmacher, J.C. 2006. ***A Comparison of Manual and Automatic Moth Sampling Methods (Lepidoptera: Arctiidae, Geometridae) in a Rain Forest in Costa Rica.*** Environmental Entomology 35 (3): 757-764.

Carlton, C., Dean, M., and Tishechkin, A. 2004. ***Diversity of Two Beetle Taxa at a Western Amazonian Locality (Coleoptera: Histeridae; Staphylinidae, Pslaphinae.)*** The Coleopterists Bulletin 58(2):163-170.

Christie F.J., and Hochuli, D.F. 2005. ***Elevated Levels of Herbivory in Urban Landscapes: Are Declines in Tree Health More Than an Edge Effect?*** Ecology and Society 10(1): 10.

Covell, C.V. Jr. 1984. ***A Field Guide to the Moths of Eastern North America***. Boston Massachusetts: Houghton Mifflin Company. Pg 9-20.

Chudzicka, E. 1990. ***Impact of the structure of urban green and of environment pollution on arthropods***. Fragmenta Faunistica 34: 17-35.

Denys, C. and Schmidt, H. 1998. ***Insect communities on experimental mugwort (Artemisia vulgaris L.) plots along an urban gradient***. Oecologia 113: 269-277.

Dix, M., and Baxendale, F. 1998. ***Arthropods on Pine Foliage in Urban Landscapes***. Journal of Entomological Science 33(1): 113-120.

Dover, J.W., and Rowlingson, B. 2005. ***The western jewel butterfly (Hypochrysops halyaetus): factors affecting adult butterfly distribution within native Banksia bushland in an urban setting***. Biological Conservation 122: 599-609.

Dytham, Calvin. 2002.***Choosing and Using Statistics: A Biologist's Guide, Second Edition.*** Blackwell Publishing Company. MA. USA. Pg 68, 96.

Folgarait, P.J. 1998. ***Ant biodiversity and its relationship to ecosystem functioning: a review***. Biodiversity and Conservation 7: 1221-1244.

Frankie, G.W., and Ehler, L.E. 1978. ***Ecology of Insects in Urban Environments***. Annual Review of Entomology 23: 367-387.

Gibb, H., and Hochuli, D. 2002. ***Habitat fragmentation in an urban environment: large and small fragments support different arthropod assemblages***. Biological Conservation 106: 91-100.

Gibbs, J.P. and Stanton, E.J. 2001. ***Habitat Fragmentation and Arthropod Community Change: Carrion Beetles, Phoretic Mites and Flies***. Ecological Applications 11(3): 79-85.

Gurin, D. 2003. ***Understanding Sprawl, a Citizens Guide***. Vancouver B.C.: The David Suzuki Foundation. Pg 1,

Handfield, Louis. 1999. ***Le Guide Des Papillion Du Quebec***. Broquet Inc. Quebec.

Hansen, A.J., Knight, R.L., Marzluff, J.M., Powell, S., Brown, K., Gude, P.H., and Jones, K. 2004. ***Effects of Exurban Development on Biodiversity: Patterns, Mechanisms, and Research Needs***. Ecological Applications15 (6): 1893-1905.

Helden, A.J., and Leather, S.R. 2004. ***Biodiversity on urban roundabouts-Hemiptera, management and species-area relationship***. Basic and Applied Ecology 5: 367-377.

Holway, D.A. 2005. ***Edge effects of an invasive species across a natural ecological boundary***. Biological Conservation 121: 561-567.

Holway, D.A., and Suaruz, A.V. 2006. ***Homogenization of ant communities in Mediterranean California: The effects of urbanization and invasion***. Biological Conservation 127: 319-326.

Janzen, d. H. 1988. ***Ecological Characterization of a Costa Rican Dry Forest Caterpillar Fauna***. BIOTROPICA 20(2): 120-135.

Kerr, j., Vincint, R., and Currie, D. 1998. ***Lepidopteran richness patterns in North America***. Ecoscience 5: 448-453.

Kimmins, J.P. 2004. ***Forest Ecology, A Foundation for Sustainable Forest Management and Environmental Ethics in Forestry*** (third edition). Prentice Hall. Upper Saddle River, New Jersey. Pg 266-267.

Kitching, R.L., Or, A.G., Thalib, L., Mitchell, H., Hopkins, M.S., and Graham, A.W. 2000. ***Moth Assemblages as Indicators of Environmental Quality in Remnants of Upland Australian Rain Forest***. Journal of Applied Ecology 37: 284-297.

Magurran, A.E. 1988. ***Ecological Diversity and its Measurement***. Princton University Press. New Jersey, U.S.A. Pg1-50.

Magurran, A.E. 2004. ***MeasuringBiological Diversity***. Blackwell Publishing Limited. Massachusetts, U.S.A. Pg 144.

McFrederick, Q.S., and LeBuhn, G. 2006. ***Are urban parks refuges for bumble bees Bombus spp. (Hymenoptera: Apidae)?*** Biological Conservation 129: 372-382.

McGeoch, M.A. and Chown, S.L. 1997. ***Impact of urbanization on a gall-inhabiting Lepidoptera assemblage: the importance of reserves in urban areas***. Biodiversity and Conservation 6: 979-993.

McIntyre, N.E., Knowles-Yanez, K., and Hope, D. 2000. ***Urban ecology as an interdisciplinary field: differences in the use of "urban" between the social and natural sciences***. Urban Ecosystems 4: 5-24.

McIntyre N.E. 2000. ***Ecology of Urban Arthropods: A Review and a Call to Action***. Ann. Entomol. Soc. Am. 93.4: 825-835.

McIntyre, N.E. Rango, J., Fagan, W.F., and Faeth, S.H. 2001. ***Ground arthropod community structure in a heterogeneous urban environment***. Landscape and Urban Planning 52: 257-274.

McKinney, M.L. October 2002. ***Urbanization, Biodiversity, and Conservation***. BioScience 10(52): 124-135.

McKinney, M.L. 2006. ***Urbanization as a major cause of biotic homogenization***. Biological Conservation 127: 247-260.

Merritt, R., and Cummins, K. 1978. ***An Introduction to the Aquatic Insects of North America***. Kendall/Hunt Publishing Company. Dubuque, Iowa. Pg 30-31, 37.

Milne, L and M. 2000. ***National Audubon Society Field Guide to North American Insects and Spiders.*** Chanticleer Press Inc. New York. Pg 697.

Molles, M.C. 1999. ***Ecology: Concepts and Applications***. WCB/McGraw-Hill. New York. Pg 306-307.

Pedigo, L.P. and Rice M.E. 2006. ***Entomology and Pest Management, Fifth Edition.*** Pearson Prentice Hall. Upper Saddle River, New Jersey. Pg 122.

Posa, M.C., and Sodhi, N.S. 2006. ***Effects of anthropogenic land use on forest birds and butterflies in Subic Bay, Philippines***. Biological Conservation 129: 256-270.

Raimondo, S., Strazanac, J.S., and Butler, L. 2004. ***Comparison of Sampling Techniques Used in Studying Lepidoptera Population Dynamics***. Entomological Society of America 2(33): 418-425.

Ricketts, T.H., Daily, G.C., Ehrlich, P.R., and Fay, J.P. 2001. ***Countryside Biogeography of Moths in a Fragmented Landscape: Biodiversity in Native and Agricultural Habitats***. Conservation Biology 2(15): 378-388.

Robinson, W.H. 2005. ***Urban Insects and Arachnids: A Handbook of Urban Entomology***. Cambridge University Press: England. Pg 3-11.

Scott, J. 1995. ***Canada's Vegetation, A world perspective***. McGill-Queen's University Press. Montreal & Kingston, Ontario, Canada. Pg 22.

Shochat, E., Warren, P.S., Faeth, S.H., McIntyre, N.E., and Hope, D. April 2006. ***From patterns to emerging processes in mechanistic urban ecology***. Trends in Ecology and Evolution 4(21): 356-364.

SPSS. 2001. SPSS for Window, Release 11.0.1 ©. SPSS Inc. Chicago, Illinois, USA 60606.

Statistics Canada. June, 2006. World Wide Web <http://www41.statcan.ca/3119/ceb3119_002_e.htm>. Accessed 28 February, 2007.

Summerville, K. S., and Crist, T. O. 2002. ***Effects of Timber Harvest on Forest Lepidoptera: Community, Guild, and Species Responses***. Ecological Applications 12(3): 820-835.

Systat. 2004. Systat for Windows. Version 11.0 ©. Systat Software, Inc. Point Richmond, California, USA 92804-2028.

Triplehorn, C.A., and Johnson, N.F. 2005. ***Borror and Delong's Introduction to the Study of Insects (seventh edition)***. Thomson Brooks/Cole. Belmont California. Pg 30, 46, 558-569.

Wickramasinghe, L.P., Harris, S., Jones, G., and Jennings, N.V. 2003. ***Abundance and species Richness of Nocturnal Insects on Organic and Conventional Farms: Effects of Agriculture Intensification on Bat Foraging***. Conservation Biology 5(18): 1283-1292.

Winiarska, G. 2004. ***Butterflies and moths (Lepidoptera) in urban habitats: the moths of Warsaw.III. Noctuoidea (second part): Notodontidae, Arctiidae, Lymantriidae***. Fragmenta Faunistica 47: 121-126.

Yela J.L. and Holyoak, M. 1997. ***Effects of Moonlight and Meterorological Factors on Light and Bait Trap Catches of Noctuid Moths (Lepidoptera: Noctuidae)***. Environmental Entomology 6(26): 1283-1290.

Young, M. 1997. ***The Natural History of Moths***. University Press. Cambridge England. Pg 6, 11, 57-59, 110-114, 181-184.

Zanette, L.R.S., Martins, R.P., and Ribeiro, S.P. 2005. ***Effects of urbanization on Neotropical wasp and bee assemblages in a Brazilian metropolis***. Landscape and Urban Planning 71: 105-121.

Zapparoli, M. 1997. ***Urban development and insect biodiversity of the Rome area, Italy***. Landscape and Urban Planning 38: 77-86.

Appendix A: Number of individual tree and shrubs by neighbourhood in 2007.

		River Heights			LindenWoods			Fort Garry Industrial		
Scientific Name	Commmon Name	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9
Ulmus americana	Elm	197	87	231	4	2	–	3	8	–
Fraxinus sp.	Ash	34	30	43	65	108	–	–	–	1
Tilia Americana	Basswood	12	2	21	1	23	–	13	–	2
Populus sp.	Aspen/Poplar	9	5	17	9	27	2	2	–	–
Spiraea sp.	Meadowsweet	6	25	92	6	55	25	–	–	–
Populus deltoides	Cottonwood	2	1	2	7	1	–	–	–	2
Rosa sp.	Rose	5	12	28	9	21	20	–	–	–
Prunus sp.	Choke Cherry	17	27	36	4	15	–	–	–	–
Thuja sp.	Cedar	215	203	676	166	450	43	–	–	–
Juniperus sp.	Juniper	110	77	290	65	275	36	–	–	–
Aster sp.	Aster	149	54	208	72	106	–	–	–	–
Quercus macrocarpa	Oak	22	29	12	–	–	–	13	–	–
Cornus sp.	Dogwood	16	5	63	8	58	22	–	–	–
Caragana arborrescens	Siberian Pea Tree	351	22	231	3	17	12	–	–	–
Malus sp.	Apple	7	1	9	2	13	1	–	–	–
Acer sp.	Maple	203	16	99	16	13	2	–	–	–
Picea sp.	Spruce	120	71	134	75	154	7	18	9	6
Ribes sp.	Gooseberry/Current	115	17	56	32	158	10	–	–	–
Lonicera sp.	Honeysuckle	66	25	108	15	69	28	–	–	–
Syringa vulgaris	Lilac	173	93	301	28	73	13	–	–	–
Pinus sp.	Pine	31	19	88	51	192	6	–	3	–
Rubus sp.	Raspberry	7	–	–	–	–	–	–	–	–
Viburnum trilobum	Cranberry	1	–	4	–	–	–	–	–	–
Betula sp.	Birch	5	10	29	7	17	2	–	–	–
Philadelphus sp.	Mock Orange	51	1	12	–	5	–	–	–	–
Salix sp.	Willow	–	1	9	1	14	3	1	–	3
Prunus virginiana	Shubert Choke Cherry	4	1	3	48	50	23	–	–	–
Amalanchier sp.	Saskatoon	2	40	54	–	7	–	–	–	–
Prunus sp.	Cherry	9	6	21	2	11	1	3	3	4
Elaeagnus angustifolia	Russian Olive	–	–	6	–	2	1	–	–	–
Larix sp.	Larch	6	–	4	–	–	2	–	–	–
Castanea sp.	Chestnut	–	–	–	–	–	–	–	–	–
Potentilla sp.	Cinquefoil	23	–	–	2	60	27	–	–	–
Dicentra sp.	Bleeding Heart	1	–	–	–	5	2	–	–	–
Aesculus glabra	Ohio buckeye	30	–	–	1	12	7	–	–	–
Gymnocladus dioicus	Kentucky Coffeetree	2	–	8	1	2	–	–	–	–
Sorbus americana	Mountain Ash	30	–	12	–	9	4	–	–	–
Alnus sp.	Alder	–	1	–	–	5	–	–	–	–
Ulmus pumila	Siberian Elm	29	1	14	–	1	1	–	–	–
Abies sp.	Fir	–	–	2	1	–	–	–	–	–

Appendix B: Summary statistics (± SEM) for front yard/boulevard tree and shrub species 2007.

	River Heights			LindenWoods			Fort Garry Industrial		
Front Yard Tree Species	*n*	Dbh (cm)	Height (m)	*n*	Dbh (cm)	Height (m)	*n*	Dbh (cm)	Height (m)
Ulmus americana	236	51.8 ± 1.9	17.1 ± 0.4	6	10.0 ± 3.2	3.6 ± 1.9	1	40.0	10.0
Fraxinus sp.	101	17.5 ± 1.8	6.6 ± 0.5	38	13.4 ± 1.3	5.0 ± 0.6	–	–	–
Tilia Americana	32	30.2 ± 4.9	11.3 ± 1.0	18	18.1 ± 2.1	7.3 ± 0.7	–	–	–
Populus sp.	30	24.0 ± 3.9	11.2 ± 1.5	38	32.7 ± 2.4	12.0 ± 0.8	1	25.0	6.0
Populus deltoides	5	92.0 ± 10.2	23.4 ± 1.9	2	42.5 ± 7.5	12.5 ± 2.5	–	–	–
Rosa sp.	45	10.0	1.5 ± 0.1	50	–	1.0 ± 0.1	–	–	–
Prunus (Choke Cherry)	80	15.9 ± 1.6	5.8 ± 0.4	19	12.3 ± 1.6	4.9 ± 0.5	–	–	–
Aster sp.	411	–	1.4	178	–	1.2 ± 0.1	–	–	–
Quercus marcrocarpa	62	38.2 ± 2.4	14.8 ± 0.4	16	–	–	–	–	–
Malus sp.	17	19.4 ± 2.2	5.7 ± 1.0	31	15.5 ± 2.1	6.3 ± 0.9	–	–	–
Acer sp.	317	26.4 ± 2.5	4.5 ± 0.3	229	19.3 ± 2.6	4.6 ± 0.9	–	–	–
Picea sp.	325	29.2 ± 1.1	13.9 ± 0.4	114	19.2 ± 0.7	6.3 ± 0.3	17	27.4 ± 4.3	7.4 ± 0.9
Syringa vulgaris	566	6.9 ± 1.5	2.7 ± 0.1	114	12.0 ± 3.0	1.9 ± 0.1	–	–	–
Pinus sp.	138	11.8 ± 1.6	2.7 ± 0.3	249	19.6 ± 4.1	1.9 ± 0.1	–	–	–
Betula sp.	44	21.6 ± 2.2	11.7 ± 0.8	22	15.5 ± 2.2	9.5 ± 1.9	–	–	–
Salix sp.	9	14.7 ± 7.9	3.9 ± 1.7	18	23.5 ± 8.8	3.0 ± 0.7	1	15.0	6.0
Prunus virginiana	8	4.3 ± 0.9	3.6 ± 0.8	47	16.2 ± 1.2	6.6 ± 0.4	–	–	–
Prunus sp. (Cherry)	37	13.7 ± 1.5	5.8 ± 0.5	14	15.4 ± 1.9	4.6 ± 0.7	5	12.4 ± 8.5	3.5 ± 0.6
Elaeagnus angustifolia	6	21.2 ± 14.8	7.2 ± 3.6	3	21.0 ± 4.9	8.7 ± 1.9	–	–	–
Larix sp.	10	9.0 ± 1.8	3.4 ± 1.1	2	12.0	2.0 ± 1.0	–	–	–
Castanea sp.	1	–	1.0	–	–	–	–	–	–
Aesculus glabra	33	–	1.0	20	–	0.9 ± 0.1	–	–	–
Gymnoclades dioicus	10	9.3 ± 1.6	4.7 ± 1.1	3	17.7 ± 7.2	5.5 ± 1.3	–	–	–
Sorbus americana	42	35.8 ± 20.1	2.6 ± 0.6	13	8.3 ± 1.4	3.3 ± 0.5	–	–	–
Alnus sp.	1	–	1.5	5	–	2.0	–	–	–
Ulmus pumila	44	–	1.4 ± 0.1	2	18.0	6.5 ± 5.5	–	–	–
Abies sp.	2	45.0 ± 5.0	19.0 ± 1.0	1	3.0	1.0	–	–	–
Boulevard Tree Species									
Ulmus americana	279	56.1 ± 12.4	17.1 ± 9.7	–	–	–	10	40.6 ± 7.9	10.3 ± 3.8
Fraxinus sp.	6	30.6 ± 8.0	13.2 ± 2.2	135	20.7 ± 3.6	8.4 ± 1.2	1	17.0	5.0
Tilia Americana	3	47.2 ± 23.1	15.2 ± 2.3	6	17.7 ± 6.6	6.2 ± 1.8	15	19.3 ± 3.2	4.8 ± 0.5
Populus sp.	1	43.0	13.8	–	–	–	1	15.0	6.0
Populus deltoides	–	–	–	–	–	–	2	35.0 ± 7.1	6.5 ± 0.7
Quercus marcrocarpa	1	58.0	13.5	–	–	–	7	30.0	6.5
Acer sp.	1	53.1	12.9	–	–	–	–	–	–
Picea sp.	–	–	–	7	17.0 ± 5.7	7.8 ± 7.7	10	28.0 ± 7.5	6.9 ± 1.5
Betula sp.	–	–	–	4	16.9 ± 4.7	7.3 ± 0.6	–	–	–
Salix sp.	–	–	–	–	–	–	3	16.7 ± 7.6	4.3 ± 1.5
Prunus sp. (Cherry)	–	–	–	–	–	–	5	12.2 ± 4.3	3.3 ± 0.6
Prunus virginiana	–	–	–	74	18.5 ± 6.5	7.2 ± 1.3	–	–	–
Front Yard Shrub Species									
Spiraea sp.	123	4.3 ± 1.2	1.3 ± 0.8	86	3.0 ± 2.8	1.1 ± 1.0	–	–	–
Thuja sp.	1094	11.3 ± 7.9	3.8 ± 3.7	659	10.9 ± 4.6	2.7 ± 2.4	2	4.0	1.5
Juniperus sp.	477	4.5 ± 2.1	0.5 ± 0.4	376	–	0.6 ± 0.4	–	–	–
Cornus sp.	84	12.8 ± 7.5	2.4 ± 1.9	88	–	1.8 ± 1.1	–	–	–
Caragana arborrescens	604	12.0	1.8 ± 0.8	32	10.0 ± 4.4	1.0 ± 0.6	–	–	–
Ribes sp.	188	–	0.9 ± 0.6	200	12.0	1.0 ± 0.2	–	–	–
Lonicera sp.	199	–	2.0 ± 1.1	112	–	1.6 ± 2.0	–	–	–
Rubus sp.	7	–	1.0	–	–	–	–	–	–
Viburnum trilobum	5	–	1.1 ± 0.2	–	–	–	–	–	–
Philadelphus sp.	64	5.0	2.3 ± 2.7	5	–	1.8 ± 0.7	–	–	–
Amalanchier sp.	96	–	1.1 ± 0.6	7	–	0.8 ± 0.6	–	–	–
Potentilla sp.	23	–	1.5	89	–	1.0 ± 0.4	–	–	–
Dicentra sp.	1	–	2.5	7	–	1.1 ± 0.7	–	–	–

Appendix C: Summary of Noctuidae species per trap site of neighbourhoods 2005.

				River Heights			LindenWoods			Fort Garry Industrial		
Super Family	Family	*Genus*	*Species*	1	2	3	4	5	6	7	8	9
Noctuoidea	Noctuidae	*Abagrotis*	*alternata*	–	–	–	–	2	–	–	–	–
Noctuoidea	Noctuidae	*Abagrotis*	*hermina*	–	–	–	–	1	–	–	–	–
Noctuoidea	Noctuidae	*Abagrotis*	*cupida*	–	–	–	1	1	1	–	–	–
Noctuoidea	Noctuidae	*Abagrotis*	*trigona*	1	–	–	–	–	–	–	–	–
Noctuoidea	Noctuidae	*Acronicta*	*fragilis*	–	–	–	–	–	1	–	–	–
Noctuoidea	Noctuidae	*Acronicta*	*grisea*	–	–	–	–	1	–	–	–	–
Noctuoidea	Noctuidae	*Aletia*	*oxygala*	–	1	–	2	2	2	–	2	1
Noctuoidea	Noctuidae	*Amphipoea*	*americana*	3	–	2	1	1	1	–	–	–
Noctuoidea	Noctuidae	*Amphipyra*	*glabella*	–	–	–	–	–	1	–	–	–
Noctuoidea	Noctuidae	*Amphipoea*	*velata*	–	–	2	–	–	–	–	–	–
Noctuoidea	Noctuidae	*Amphipyra*	*pyramidoides*	3	8	2	4	4	1	–	–	–
Noctuoidea	Noctuidae	*Anagrapha*	*falcifera*	–	1	–	–	2	2	–	2	3
Noctuoidea	Noctuidae	*Apamea*	*alia*	–	–	–	–	–	–	–	–	1
Noctuoidea	Noctuidae	*Apamea*	*amputatrix*	1	1	–	2	–	7	1	1	4
Noctuoidea	Noctuidae	*Apamea*	*cogitata*	–	1	–	–	1	1	2	–	–
Noctuoidea	Noctuidae	*Apamea*	*lateritia*	1	–	–	–	–	1	3	–	–
Noctuoidea	Noctuidae	*Apamea*	*devastator*	3	8	12	11	38	17	3	–	14
Noctuoidea	Noctuidae	*Apamea*	*helva*	–	–	–	–	2	–	–	–	–
Noctuoidea	Noctuidae	*Apamea*	*inficita*	–	–	–	–	–	1	–	–	–
Noctuoidea	Noctuidae	*Apamea*	*lignicolora*	–	–	–	–	2	1	–	–	1
Noctuoidea	Noctuidae	*Apamea*	*nigrior*	–	–	–	–	1	–	–	–	–
Noctuoidea	Noctuidae	*Apamea*	*niveivenosa*	1	4	1	1	5	–	1	2	2
Noctuoidea	Noctuidae	*Apamea*	*ophiogramma*	–	–	1	3	14	–	–	–	–
Noctuoidea	Noctuidae	*Apamea*	*sordens*	–	1	–	–	–	–	–	–	–
Noctuoidea	Noctuidae	*Autographa*	*precationis*	4	4	7	2	4	9	–	1	1
Noctuoidea	Noctuidae	*Caenurgina*	*erechtea*	–	–	–	–	1	–	–	–	–
Noctuoidea	Noctuidae	*Catocala*	*grynea*	–	–	–	–	2	2	–	–	–
Noctuoidea	Noctuidae	*Catocala*	*lineella*	–	2	–	–	–	–	–	–	–
Noctuoidea	Noctuidae	*Catocala*	*parta*	–	–	–	1	–	–	–	–	–
Noctuoidea	Noctuidae	*Catocala*	*unijuga*	–	–	1	–	–	–	–	–	–
Noctuoidea	Noctuidae	*Chortodes*	*defecta*	–	–	–	1	–	–	–	–	–
Noctuoidea	Noctuidae	*Cosmia*	*calmi*	–	6	–	1	–	–	–	–	–
Noctuoidea	Noctuidae	*Cryptocala*	*acadiensis*	–	–	–	–	2	1	–	–	1
Noctuoidea	Noctuidae	*Diachrysia*	*aereiodes*	1	–	–	1	–	–	–	–	–
Noctuoidea	Noctuidae	*Diachrysia*	*balluca*	–	–	–	–	–	–	–	1	–
Noctuoidea	Noctuidae	*Discestra*	*trifolii*	–	1	–	2	2	–	–	4	–
Noctuoidea	Noctuidae	*Euruis*	*astricta*	–	1	–	–	–	–	–	–	–
Noctuoidea	Noctuidae	*Euxoa*	*declarata*	–	–	–	2	–	–	–	–	–
Noctuoidea	Noctuidae	*Euxoa*	*divergens*	–	–	–	–	–	–	–	–	1
Noctuoidea	Noctuidae	*Euxoa*	*fumalis*	–	–	–	–	1	–	–	–	–
Noctuoidea	Noctuidae	*Euxoa*	*obeliscoides*	–	–	–	–	5	1	–	–	–
Noctuoidea	Noctuidae	*Euxoa*	*scandens*	3	1	1	–	6	1	–	–	2
Noctuoidea	Noctuidae	*Feltia*	*jaculifera*	–	–	3	3	4	4	–	3	9
Noctuoidea	Noctuidae	*Feltia*	*tricosa*	–	1	–	2	10	7	–	3	1
Noctuoidea	Noctuidae	*Feltia*	*herilis*	3	5	4	5	12	4	–	1	4
Noctuoidea	Noctuidae	*Galgula*	*partita*	–	1	–	2	–	–	–	–	1
Noctuoidea	Noctuidae	*Graphiphora*	*augur*	–	1	1	6	3	3	–	–	1
Noctuoidea	Noctuidae	*Heliothis*	*phloxiphagy*	–	–	–	–	–	–	1	–	–
Noctuoidea	Noctuidae	*Homohadena*	*bagistriga*	–	–	–	–	–	–	–	1	–
Noctuoidea	Noctuidae	*Hyppa*	*xylinoides*	–	1	–	–	1	–	–	–	–
Noctuoidea	Noctuidae	*Idia*	*aemula*	2	–	4	8	3	2	–	–	–
Noctuoidea	Noctuidae	*Idia*	*americalis*	2	16	11	9	6	6	–	3	4
Noctuoidea	Noctuidae	*Idia*	*majoralis*	1	1	–	4	–	4	–	–	–
Noctuoidea	Noctuidae	*Ipimorpha*	*pleonectusa*	–	–	–	1	–	–	–	–	1
Noctuoidea	Noctuidae	*Lacanobia*	*atlantica*	–	–	–	–	2	1	–	–	–
Noctuoidea	Noctuidae	*Laconobia*	*radix*	–	–	–	–	1	–	–	–	–

Appendix C: Summary of Noctuidae species per trap site of neighbourhoods 2005 continued.

				River Heights			LindenWoods			Fort Garry Industrial		
Super Family	Family	*Genus*	*Species*	1	2	3	4	5	6	7	8	9
Noctuoidea	Noctuidae	*Lacinipolia*	*lorea*	2	3	3	4	5	5	–	–	2
Noctuoidea	Noctuidae	*Lacinipolia*	*olivacea*	–	–	–	–	2	1	–	1	2
Noctuoidea	Noctuidae	*Lacinipolia*	*renigera*	5	9	11	8	9	4	–	3	2
Noctuoidea	Noctuidae	*Leucania*	*lapidaria*	–	–	–	–	1	–	–	–	–
Noctuoidea	Noctuidae	*Leucania*	*multilinea*	–	–	–	–	2	2	1	1	5
Noctuoidea	Noctuidae	*Macrochilo*	*hypocritalis*	–	–	–	–	–	–	–	–	2
Noctuoidea	Noctuidae	*Megalographa*	*biloba*	–	1	–	–	–	–	–	–	–
Noctuoidea	Noctuidae	*Melanchra*	*picta*	–	–	–	–	1	–	–	–	1
Noctuoidea	Noctuidae	*Nephelodes*	*minians*	1	6	11	4	4	14	1	–	5
Noctuoidea	Noctuidae	*Noctua*	*pronuba*	–	1	1	–	3	2	–	–	2
Noctuoidea	Noctuidae	*Oligea*	*fractilinea*	–	–	–	–	–	–	1	1	–
Noctuoidea	Noctuidae	*Oligia*	*subjuncta*	–	–	–	–	–	–	–	–	1
Noctuoidea	Noctuidae	*Orthodes*	*crenulata*	2	–	1	–	2	2	–	–	4
Noctuoidea	Noctuidae	*Orthodes*	*cynica*	–	1	–	–	–	–	–	–	–
Noctuoidea	Noctuidae	*Orthosia*	*revicta*	–	–	–	–	–	1	–	–	–
Noctuoidea	Noctuidae	*Palthis*	*angulalis*	–	1	–	–	–	1	–	–	–
Noctuoidea	Noctuidae	*Papaipema*	*leucostigma*	1	–	–	1	–	–	–	–	–
Noctuoidea	Noctuidae	*Paradiarsia*	*littoralis*	–	–	–	–	–	–	–	–	1
Noctuoidea	Noctuidae	*Peridroma*	*saucia*	–	2	–	2	2	2	–	–	–
Noctuoidea	Noctuidae	*Phalaenophana*	*pyramusalis*	–	–	1	–	–	–	–	–	–
Noctuoidea	Noctuidae	*Phlogophora*	*periculosa*	–	2	–	–	4	1	–	–	–
Noctuoidea	Noctuidae	*Plusia*	*contexta*	–	–	–	–	–	–	–	–	2
Noctuoidea	Noctuidae	*Polia*	*nimbosa*	1	1	–	1	2	–	–	–	–
Noctuoidea	Noctuidae	*Pseudaletia*	*unipuncta*	7	5	3	7	14	2	1	1	5
Noctuoidea	Noctuidae	*Pseudostrotia*	*carneola*	1	3	6	3	3	1	–	–	1
Noctuoidea	Noctuidae	*Pseudohermonassa*	*tenuicula*	–	–	–	1	2	1	–	–	–
Noctuoidea	Noctuidae	*Pyrrhia*	*exprimens*	1	–	–	–	–	–	1	1	1
Noctuoidea	Noctuidae	*Scoliopteryx*	*libatrix*	–	–	–	–	–	–	–	–	1
Noctuoidea	Noctuidae	*Spaelotis*	*clandestina*	2	2	1	1	1	3	3	–	7
Noctuoidea	Noctuidae	*Syngrapha*	*alias*	–	–	1	–	–	–	–	–	–
Noctuoidea	Noctuidae	*Surira*	*bicolorago*	–	–	–	–	–	–	–	–	1
Noctuoidea	Noctuidae	*Trichoplusia*	*ni*	–	–	1	–	–	–	–	–	–
Noctuoidea	Noctuidae	*Xestia*	*c-nigrum*	–	–	–	3	2	–	–	–	–
Noctuoidea	Noctuidae	*Xestia*	*normanina*	–	–	–	–	1	–	–	–	–
Noctuoidea	Noctuidae	*Xestia*	*smithii*	24	10	16	20	28	5	2	2	5
Noctuoidea	Noctuidae	*Zale*	*minerea*	–	–	2	–	–	–	–	–	–
Noctuoidea	Noctuidae	*Zanclognatha*	*jacchusalis*	2	3	1	2	2	–	–	2	–