Effect of drainage ditches on Brachycera (Diptera) diversity in a southern Quebec peatland

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Abstract—Canadian peatlands are subject to disturbance and destruction, and drainage for agriculture is responsible for 85% of this degradation. Few studies have explicitly addressed the effects of habitat degradation on arthropod diversity in Nearctic peatlands. Because higher Diptera (Brachycera) in peatlands are diverse, are an important component of food webs, and exhibit a wide range of ecological requirements, we examined species richness, abundance, and community composition of Brachycera across transects at 1, 6, and 11 m from a collector drainage ditch in Johnville Bog and Forest Park, Quebec. In total, 1453 Brachycera were collected, representing 24 families and 166 species. Species diversity (based on Simpson's diversity index) and rarefaction-estimated species richness were higher at 6 and 11 m than at 1 m from the ditch, probably because of the homogeneous moss cover and moister conditions at greater distance from the ditch. Species composition also differed between 1 m and other distances, based on cluster analysis, multiresponse permutation procedures analysis, and the presence of five predaceous species that were significant indicator species 1 m from the drainage ditch. Our results suggest that anthropogenic degradation of hydrological conditions may be responsible for the low species richness and high dominance of a few species currently seen at the ditch margin.

Résumé—Les tourbières canadiennes sont sujettes aux perturbations et à la destruction, et le drainage pour l'agriculture est responsable de 85 % de cette dégradation. Parce que les brachycères des tourbières sont diversifiés, constituent une importante proportion de des réseaux trophiques, et exige une multitude de différents habitats; la richesse en espèces, l'abondance et la composition en espèces ont été déterminées le long de transects perpendiculaires à un canal de drainage à 1, 6 et 11 m dans le Parc Écoforestier de Johnville, Québec. Un total de 1453 brachycères a été récolté représentant 24 familles et 166 espèces. La diversité (indices Simpson) et la richesse en espèces estimée (raréfaction) étaient plus élevées à 6 et 11 m qu'à 1 m; cela est probablement dû au couvert de mousse homogène et aux conditions plus humides à une plus grande distance du canal. La composition en espèces différait aussi entre 1 m et les autres distances, basé sur l'analyse par regroupements, MRPP, et les cinq espèces significativement associées (espèces indicatrices) à 1 m du canal de drainage. Ces résultats suggèrent que les perturbations anthropiques des conditions hydrologiques sont responsables de la faible richesse en espèces et de la dominance élevée de quelques espèces aux abords du canal de drainage.

Introduction

Many terrestrial habitats are subject to severe disturbances that can modify these ecosystems significantly; peatlands (bogs and fens) are one such habitat. In fens (minerotrophic peatlands), ground water, generally associated with high pH and high levels of nutrients (Kolka and Thompson 2006), is the dominant source of water. Fen vegetation is dominated by herbaceous plants, bryophytes (mostly brown mosses), shrubs, and trees. *Sphagnum* L. (Sphagnaceae) mosses are rare or absent when the pH is high (Payette 2001). Bogs (ombrotrophic peatlands) receive all water and nutrients from precipitation, with no contribution from upland water flow (Payette 2001), and thus organisms living in bogs must be adapted to harsh environmental conditions such as acidity and nutrient

Received 30 June 2009. Accepted 30 September 2009.

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doi: 10.4039/n09-062

deficiency. Decomposition is slow because waterlogging results in low oxygen availability (Moore 2002). Bogs are the most extensive peatland type in southern Canada and cover approximately 12% of the landmass. It is estimated that 20 million hectares of peatland in Canada have been lost since 1800 and degradation has affected millions of others. The damage is attributable mostly to agriculture, urbanization, forestry, and peat mining, with drainage for agricultural purposes accounting for 85% of the loss (Government of Canada 1991). The considerable extent of bogs and their wide range of specialized biota make them a valuable natural ecosystem with diverse and unique microhabitats that are important for maintaining regional biodiversity (Moore 2002).

The high water table and associated anoxic conditions are among the primary factors controlling ecosystem productivity in peatlands, especially tree growth and organic-matter decomposition (Reinikainen *et al.* 1984). The water-table drawdown following the excavation of drainage ditches leads to changes in physical and chemical processes within the peat (Holden *et al.* 2004); this leads in turn to gradual changes in plant composition and accompanying changes in substrate quality (Latter and Howson 1978). An increase in the area dominated by trees and a decrease in *Sphagnum* cover result from the drier conditions and lower light levels (Laine *et al.* 1995). Although the vegetative dynamics of these changes have been well studied and the effects of peatland drainage on the soil mesofauna have been investigated in some studies (Silvan *et al.* 2000; Laiho *et al.* 2001), very little is known about the consequences of drainage for terrestrial invertebrates on the exposed substrate. Schikora (1994) found changes in the terrestrial spider fauna in a north German bog 22 years after progressive draining. Shade-tolerant spider species replaced light-tolerant species as the dominant group.

Many bog insects are adapted to specific environmental conditions and can be obligatory associates or characteristic of bogs (Spitzer and Danks 2006). Many insects have a high rate of population increase and a short generation time, characteristics that lead to a rapid response to anthropogenic disturbances (Kim 1993). Despite these characteristics, many higher insect taxa are currently underused as indicators of environmental health. One group that deserves consideration is the higher Diptera (Brachycera) (Keiper *et al.* 2002).

Diptera are among the most diverse groups of organisms, with about 124 000 described species (Brown 2001). They can be an important component of the diet of waterfowl and wetland birds, as well as fish, amphibians, reptiles, and mammals (Murkin and Batt 1987), and thus biomass of adult Diptera may have significant ecological effects on higher trophic levels. Faunistic studies in a variety of Holarctic peatlands have demonstrated that Diptera are diverse and abundant (*e.g.*, Blades and Marshall 1994). Previous studies have addressed selected taxa, including Chironomidae (Wrubleski 1987), biting flies (Lewis 1987), Empididae (Barták and Roháček 1999), Dolichopodidae (Rampazzi 2002), Sphaeroceridae (Marshall 1994), and multiple other acalyptrate families (Roháček and Máca 1982; Roháček *et al.* 1998). Blades and Marshall (1994) identified between 62 and 106 species of acalyptrate Diptera in each of four peatland sites in southern Ontario, based on pan-trap sampling. Using multiple collecting techniques we inventoried more than 138 species of Acalyptratae in Johnville Bog, a peatland in southern Quebec (A. Grégoire Taillefer and T.A. Wheeler, unpublished data).

Beyond basic faunistic studies, there have been few quantitative ecological studies of Brachycera in peatlands. Habitat selection by Brachycera is determined, in part, by a wide diversity of feeding and breeding habits among phytophagous, saprophagous, predaceous, and parasitic groups; thus, it is reasonable to predict that the Diptera community will be influenced by habitat modification and the accompanying changes in plant composition and substrate quality. As noted previously, anthropogenically induced drainage is a frequent habitat disturbance in peatlands, including Johnville Bog.

In this study we examined species richness, abundance, and community composition of

https://doi.org/10.4039/n09-062 Published online by Cambridge University Press

Brachycera at different distances from a collector drainage ditch in Johnville Bog. The principal objective was to determine the influence of drainage ditches on the diversity of Brachycera in this bog. The tested hypothesis was that strong edge effects would be found along the ditch, with some species avoiding or only present on the edge and with diversity increasing with distance from the ditch.

Materials and methods

Study site

The study area was in Johnville Bog and Forest Park (approximately 45°20′N, 71°44′W) in southern Quebec, Canada. The park has an area of 224 ha and protects 85 ha of bog. Prior to human alteration of the site, drainage from the bog was limited by the steep ridges of an esker. The bog is surrounded by agricultural lands and forest and, in response to agricultural demand, drainage ditches were dug between 1979 and 1980 (C. Cloutier, personal communication). The water in the collector ditch flows from south to north.

At 1 m from the ditch the moss cover is discontinuous, bare peat is visible, the substrate is dry, and the vegetation is almost entirely paper birch, *Betula papyrifera* Marsh. (Betulaceae), and tamarack, *Larix laricina* (Du Roi) K. Koch (Pinaceae). The nonbryophyte vegetation at 6 and 11 m is dominated by *Carex* L. (Cyperaceae), Labrador tea, *Ledum groenlandicum* Oeder. (Ericaceae), and tamarack. At 11 m the substrate is more humid and the moss cover more homogeneous.

Specimen collection and preparation

Four parallel transects, 10 m from one another, were established perpendicular to the ditch: T1 (45°20′45.1″N, 71°44′11.2″W), T2 (45°20′45.2″N, 71°44′11.3″W), T3 (45°20′45.4″N, 71°44′11.3″W), and T4 (45°20′46.0″N, 71°44′11.3″W). Three yellow pan traps (4 cm deep, 12 cm in diameter) were placed along each transect at 1, 6, and 11 m west of the ditch. Pan traps were placed in the substrate with their upper rim flush with the ground surface and filled with salt water and a drop of liquid detergent as a wetting agent. Traps were emptied weekly from 15 June to 20 August 2005.

Diptera were preserved in 70% ethanol and subsequently dried using hexamethyldisilazane prior to mounting. All specimens were deposited in the Lyman Entomological Museum (McGill University, Ste-Anne-de-Bellevue, Quebec). All specimens, except those in the family Phoridae (which was excluded), were identified to named species when possible, or to morphospecies. In all analyses, morphospecies were treated as equivalent to named species.

Statistical analysis

Observed abundances, log-transformed abundances, and species richness of Brachycera were tested with a two-way analysis of variance (ANOVA) for both treatment (distance) and site (T1−T4) using Minitab 15.

Rarefaction was used to estimate expected species richness using ECOSIM 7.0 (Gotelli and Entsminger 2001), with 1000 randomizations for each curve and species richness as the diversity index. Rarefied species estimates were calculated for each distance standardized at 365 individuals to allow for comparison, based on all species collected at each distance. A nonparametric estimator of species richness, abundance-based coverage (ACE), was calculated with EstimateS version 7.5 (Colwell 2005). This value extrapolates the number of species at the entire site and at the three distances that might have been detected with ideal sampling based on the rare species (≤ 10 individuals). In addition to the species-richness estimators, Simpson's diversity index was calculated as a measure of dominance (Magurran 2004) using EstimateS. Pairwise similarities of species composition were also compared using the Bray−Curtis index (Legendre and Legendre 1998) provided by EstimateS. Pooled data for all four replicates of pan traps at each distance were used in these analyses.

Compositional differences among Brachycera species at the three distances were examined using cluster analysis (based upon Bray−Curtis distance and group average as a

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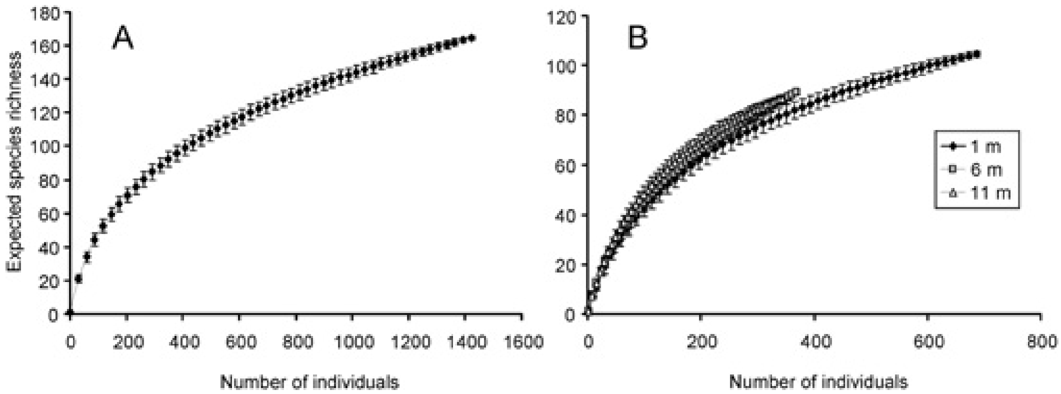
Fig. 1. Rarefaction estimates of expected species richness (mean ± 1 SD) of Brachycera for all specimens pooled (A) and separately at three distances from a drainage ditch (B) in Johnville Bog, Quebec.



linkage method) and multiresponse permutation procedures (MRPP) were performed using the program PC-ORD version 4.36 (McCune and Mefford 2005). Relative species abundance was log-transformed (Log(x + 1)) prior to analyses to reduce the influence of the most numerous species. Species represented by only one or two specimens were excluded from analyses to reduce the possibility of including nonresident species. A Sorenson distance metric was applied to each MRPP in a similar fashion to the cluster analysis.

To determine whether any Brachycera species were significantly associated with a particular distance, indicator-species analysis (Dufrêne and Legendre 1997) was performed on log-transformed (Log(x + 1)) abundance of species using the program PC-ORD version 4.36. Only species with an indicator value (IndVal) ≥ 50, with 10 or more individuals, and with a significant P value (≤ 0.05) assessed with Monte Carlo randomizations based on 1000 permutations were considered as indicators.

Results

In total, 1453 Brachycera were collected, representing 24 families and 166 species (80 named species, 86 morphospecies) (Appendix A). Many of the species were collected in low numbers: 39.2% were represented by only one specimen and 12.0% were doubletons. The rarefaction curve for all distances pooled did not reach an asymptote (Fig. 1A), and the ACE estimated that 265 species were present at the whole site. The most abundant species were *Gymnopternus frequens* Loew (Dolichopodidae) (12.9% of all specimens), *Paramyia nitens* (Loew) (Milichiidae) (5.5%), and a species of *Cordilura* (*Achaetella*) Fallén (Scathophagidae) (5.4%).

Raw species richness and abundance were higher at 1 m than at 6 or 11 m from the ditch (Table 1). When the relative numbers of specimens were compared between trap replicates, 177.5 ± 66.2 (mean ± SD) individuals were collected at 1 m, while 94.0 ± 22.3 individuals were collected at 6 m and 91.6 ± 58.5 individuals at 11 m. The minimum species richness estimated by ACE was 155.4, 143.1, and 120.1 at 1, 6, and 11 m, respectively (Table 1). The ANOVA showed significant differences between the three distances for the log-transformed abundances only ($F_{1,3}$ = 8.05, P = 0.02).

Rarefaction curves for all three distances (standardized to 365 individuals) revealed significant differences in species accumulation (Fig. 1B). The standard deviations at 365 individuals overlapped at 6 and 11 m, indicating that species richness did not differ between these two distances, but did differ at 1 m. Based on rarefaction estimates, species richness was expected to be highest at 6 and 11 m, and did not differ between these two distances, and lowest at 1 m (Table 1). The higher raw species richness, lower rarefaction

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Fig. 2. Dendrogram based on a cluster analysis using Bray−Curtis indices of similarity of Brachycera assemblages in four trap replicates (T1−T4) at three distances from a drainage ditch (1, 6, and 11 m) in Johnville Bog, Quebec.

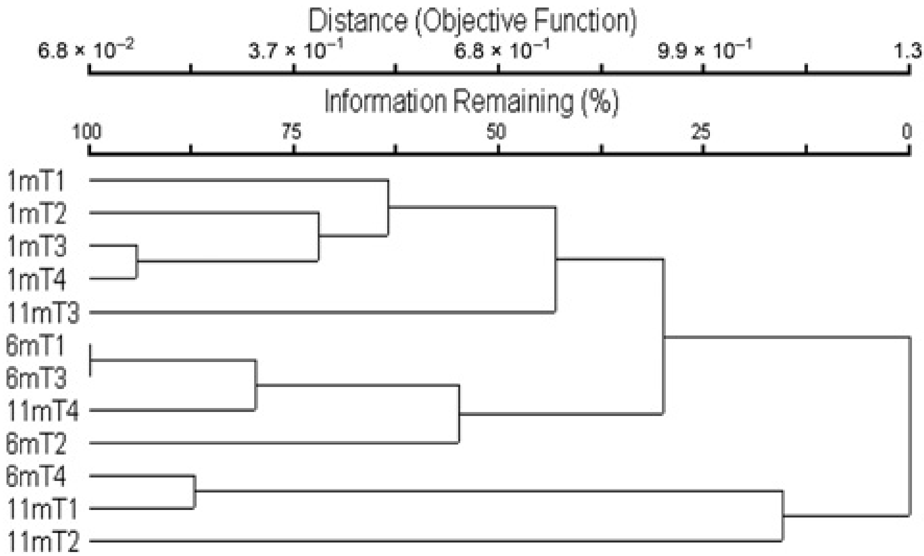

Table 1. Measures of diversity of Brachycera collected at three distances from a drainage ditch in Johnville Bog, Quebec.

Distance (m)	*n*	S_{obs}	Singletons	ACE	S_{est}	Simpson's diversity index
1	710	106	39	155.4	82.1 ± 3.4	16.14
6	376	90	43	143.1	88.7 ± 1.0	25.5
11	367	89	33	120.1	88.8 ± 0.4	30.06

Note: *n* is the number of individuals collected; S_{obs} is raw species richness; "singletons" is the number of species represented by a single specimen; ACE is the abundance-based coverage estimator of species richness; and S_{est} is the rarefaction estimate of species richness (standardized at 365 individuals).

estimate, and lower Simpson's diversity index at 1 m (Table 1) indicate that one or a few species accounted for a large proportion of specimens collected.

Species composition evaluated by cluster analysis (Fig. 2) and MRPP showed similar assemblages of Brachycera species at 6 and 11 m (P = 0.3). In contrast, assemblages at 1 m showed significant differences from those at both 6 m (P = 0.008) and 11 m (P = 0.009). Pairwise similarities with the Bray−Curtis index yielded similar results, with higher values between 6 and 11 m (0.58) than between 1 and 6 m (0.40) or 1 and 11 m (0.41). In the indicator species analysis, five species showed a significant association with distance: a species of *Platypalpus* Macquart (Empididae) (IndVal = 89, P = 0.008); *Dolichopus nigricornis* Meigen (Dolichopodidae) (IndVal = 57, P = 0.037); *Gymnopternus frequens* (IndVal = 54, P = 0.005); *Gymnopternus opacus* Loew (IndVal = 58, P = 0.013); and an unidentified species of *Gymnopternus* Loew (IndVal = 54, P = 0.036), all being closely associated with 1 m.

Discussion

Although raw species richness and the number of specimens collected were both highest near the drainage ditch, rarefaction-estimated species richness and species diversity (based on Simpson's diversity index) were higher at 6 and 11 m. The increase in species

https://doi.org/10.4039/n09-062 Published online by Cambridge University Press

diversity and decrease in dominance with increasing distance from the ditch suggest a wider range of microhabitats and variation in habitat properties. The more homogeneous moss cover, higher moisture levels, and accompanying changes in vegetation at 6 and 11 m could affect the species diversity and abundance of Brachycera.

In accordance with the hypothesis, greater distance from the ditch did allow higher species diversity and a different species assemblage at the study site. The dissimilarity in species composition shown by cluster analysis, MRPP, and Bray−Curtis indices may be explained by biological factors and variation in habitat properties such as substrate quality. The biology of the indicator species associated with the 1 m distance suggests that the substrate characteristics at this site differ from those at the others; the larvae and adults of all five indicator species are predators of invertebrates in the substrate (Cumming and Cooper 1993; Ulrich 2005; Cumming and Sinclair 2009). The drier conditions may have a positive effect on the amount of prey living in decaying material. The greater oxygen availability within the upper peat layer (Silins and Rothwell 1999) accelerates the decomposition of organic matter by aerobic microbes (Vasander and Laiho 1995). Consequent changes in plant composition from *Sphagnum* mosses, sedges, and shrubs to foliage and fine roots (Laiho *et al.* 2003) may increase the material available for saprophagous arthropods, which in turn may support the predaceous species as prey items become more abundant. Silvan *et al.* (2000) and Laiho *et al.* (2001) found changes in abundance and composition of the soil fauna following drainage, with the number of invertebrates positively correlated with the lower water table. As in our study, their results suggest that conditions following drainage were more suitable for litter-dwellers and nutrient-recycling organisms.

Drainage of peatlands to improve agricultural land has negative effects on many wetland faunal species (reptiles, birds, amphibians, mammals, fishes). Biodiversity is primarily affected by habitat loss and the presence of pollutants in drainage water (Leighton 1991), but a subset of the total species pool is capable of colonizing the altered habitat. This favours some species and causes compensatory shifts in abundance (Brown *et al.* 2001). *Gymnopternus frequens* and *Platypalpus* sp. may have colonized the ditch border earlier, outcompeted other species from the same feeding guild, and increased in abundance, leading to the accompanying decrease in overall diversity. Biodiversity does not remain uniform across environmental boundaries. At the local scale for small organisms, natural edges do not seem to influence invertebrate diversity in the same way as man-made edges. A study conducted across a natural edge between riparian and saltbush habitats showed that changes in invertebrate diversity were not coincident with the edge (Dangerfield *et al.* 2003). Horvath *et al.* (2000) and Mathe (2006) found that species richness of assemblages of Curculionidae, Carabidae (Coleoptera), and Araneae (Arachnida) along a forest−meadow transect was significantly higher at the forest edge than in the forest interior. In contrast, man-made boundaries seem to have a negative impact on invertebrate biodiversity, as was found in this study. Baldissera *et al.* (2004) found that species richness of web spiders increased at 250 m into a forest compared with open pasture, forest edge, and 50 m into a forest. A study of the effects of roads in continuous forest on soil macroinvertebrates showed that abundance and richness were reduced up to 100 m into the forest (Haskell 2001).

With increasing interest in peatland conservation and restoration, it is important to measure biodiversity appropriately. The results of this study suggest that ditches do not represent the real surface patterns and characteristics found in natural ecosystems. This has implications for decisions concerning where sampling should be done in an altered peatland. However, when drainage ditches are blocked during restoration processes (Rochefort 2000; Rochefort *et al.* 2003; van Duinen *et al.* 2003) to rewet the site, the conditions generated by water loss should disappear, leading to changes in species diversity and homogenization of species distribution within the site.

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In this study, only samples collected from a single peatland were considered; nevertheless, the results suggest a significant effect of drainage on species composition and diversity of Brachycera associated with the exposed substrate on a small spatial scale at Johnville Bog. Anthropogenic degradation of the hydrological conditions (*i.e.*, constant water loss at the ditch borders) seems to be responsible for the currently low species richness and high dominance of a few species. A lower water table induced by ditching is a key factor causing a variety of changes in peatland functions, such as carbon-sink capacity, soil thermal properties (Laiho 2006), plant heterogeneity (Coulson *et al.* 1990), and emergence of insects (Coulson and Butterfield 1985). It is expected that changing substrate properties following drainage have a major impact on food sources for indicator species. Further studies should be conducted to determine the generality of these results, whether drainage has a significant impact on the entire terrestrial peatland community, and the amount of time needed after restoration to regain levels of diversity and composition similar to those in the undisturbed ecosystem.

Acknowledgements

We thank the Johnville Woodland Conservation Corporation for permission to collect at the study site, and J. Savage and J. Kuchta (Bishop's University) for help with sampling. Funding was provided by a Natural Sciences and Engineering Research Council of Canada (NSERC) Undergraduate Student Research Award to A.G.T. and a NSERC Discovery Grant to T.A.W.

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Appendix A

Table A1. Brachycera collected from pan traps at three distances from a drainage ditch in Johnville Bog, Quebec, with the name of the taxon, number of specimens collected at each distance (1, 6, and 11 m), and total number of specimens collected.

Family	Species	Number of specimens			
		1 m	6 m	11 m	Total
Lower Brachycera					
Stratiomyidae	*Odontomyia (Odontomyiina)* Meigen sp.	0	0	1	1
Rhagionidae	*Rhagio mystaceus* (Macquart)	0	0	2	2
Tabanidae	*Hybomitra* Enderlein sp.	0	1	0	1
	Hybomitra minuscula (Hine)	0	0	1	1
Asilidae	*Asilus* (s.l.) L. sp. 1	1	1	0	2
	Asilus (s.l.) sp. 2	1	0	0	1
	Laphria Meigen sp. 1	1	2	5	8
	Laphria sp. 2	1	1	3	5
	Cyrtopogon falto Walker	7	6	5	18
	Cyrtopogon vulneratus Melander	0	9	2	11
Empididae	*Euhybus* Coquillett sp. 1	2	6	4	12
	Euhybus sp. 2	0	1	0	1
	Euhybus sp. 3	1	1	0	2
	Rhamphomyia Meigen sp. 1	0	1	0	1
	Rhamphomyia sp. 2	0	1	0	1
	Rhamphomyia sp. 3	0	0	1	1
	Drapetis (*Drapetis*) Meigen sp.	1	0	0	1
	Hilara Meigen sp.	1	0	0	1
	Hybos reversus Walker	8	13	5	26
	Platypalpus Macquart sp.	61	0	3	64
Dolichopodidae	*Condylostylus flavipes* (Aldrich)	0	1	0	1
	Condylostylus patibulatus (Say)	1	5	8	14
	Chrysotus Meigen spp.	4	17	8	29
	Sciapus tener (Loew)	0	1	0	1
	Telmaturgus parvus (Van Duzee)	6	5	2	13
	Medetera vittata Van Duzee	2	0	0	2
	Dolichopus blandus Van Duzee	0	1	1	2
	Dolichopus brevimanus Loew	0	2	5	7
	Dolichopus cuprinus Wiedemann	4	1	1	6
	Dolichopus genualis (Van Duzee)	1	2	3	6
	Dolichopus gladius Van Duzee	0	3	0	3
	Dolichopus gratus Loew	1	2	3	6
	Dolichopus incisuralis Loew	2	0	0	2
	Dolichopus nigricornis Meigen	14	3	4	21
	Dolichopus packardi Van Duzee	3	3	2	8
	Dolichopus sincerus Melander	4	4	1	9
	Dolichopus ?socius Loew ♀♀	10	4	3	17
	Dolichopus Latreille sp. 1	2	0	0	2
	Dolichopus sp. 2	0	1	0	1
	Dolichopus sp. 3	1	0	0	1
	Gymnopternus frequens Loew	147	19	21	187
	Gymnopternus humilis Loew	0	0	1	1
	Gymnopternus nigribarbus Loew	0	0	1	1
	Gymnopternus opacus Loew	36	7	4	47

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Table A1. (*continued*).

Family	Species	Number of specimens 1 m	6 m	11 m	Total
	Gymnopternus scotias Loew	4	0	0	4
	Gymnopternus subulatus Loew	6	1	3	10
	Gymnopternus Loew sp.	31	5	7	43
Aschiza					
Syrphidae	*Heringia* Rondani sp.	1	0	0	1
	Lejota Rondani sp.	1	0	0	1
	Melanostoma Schiner sp.	0	1	0	1
	Sericomyia Meigen sp. 1	0	0	1	1
	Sericomyia sp. 2	0	1	0	1
	Sphaerophoria Lepeletier and Serville sp.	0	0	1	1
Pipunculidae	*Pipunculus* Latreille sp.	1	0	0	1
Acalyptratae					
Lauxaniidae	*Homoneura sheldoni* (Coquillett)	0	1	2	3
	Lauxania shewelli Pérusse and Wheeler	2	0	0	2
	Minettia lupulina (Fabricius)	6	2	2	10
Sciomyzidae	*Pherbellia* Robineau-Desvoidy sp.	2	0	0	2
	Tetanocera valida (Loew)	6	0	2	8
	Tetanocera plebeja Loew	1	0	1	2
Agromyzidae	*Liriomyza* Mik sp.	1	0	0	1
Milichiidae	*Paramyia nitens* (Loew)	25	7	48	80
Chloropidae	*Dasyopa* Malloch sp.	0	1	0	1
	Thaumatomyia pulla (Adams)	1	13	16	30
	Tricimba Lioy sp. 1	4	0	1	5
	Tricimba sp. 2	1	0	0	1
	Tricimba trisulcata (Adams)	0	0	1	1
Heleomyzidae	*Allophyla laevis* Loew	3	0	0	3
	Suillia apicalis (Loew)	1	0	0	1
	Suillia loewi (Garrett)	4	1	0	5
	Suillia barberi (Darlington)	1	0	0	1
Sphaeroceridae	*Spelobia brevipteryx* Marshall	2	0	3	5
	Pullimosina dahli (Duda)	7	6	5	18
	Minilimosina parva (Malloch)	5	0	2	7
Drosophilidae	*Scaptomyza pallida* (Zetterstedt)	2	4	1	7
	Scaptomyza graminum (Fallén)	0	0	1	1
	Drosophila Fallén sp. 1	1	0	0	1
	Drosophila sp. 2	0	0	1	1
	Drosophila sp. 3	0	0	1	1
	Drosophila sp. 4	0	1	0	1
Diastatidae	*Diastata* Meigen sp. 1	0	1	0	1
	Diastata sp. 2	0	0	1	1
Ephydridae	*Scatella* Robineau-Desvoidy sp.	1	0	0	1
Calyptratae					
Scathophagidae	*Cordilura* (*Achaetella*) Fallén sp.	16	51	12	79
	Cordilura (*Cordilurina*) sp.	4	0	1	5
	Cordilura (*Cordilura*) sp. 1	12	14	10	36
	Cordilura (*Cordilura*) sp. 2	0	1	0	1
	Cordilura (*Cordilura*) sp. 3	0	1	0	1
	Cordilura (*Cordilura*) sp. 4	0	1	0	1
	Bucephalina Malloch sp.	0	1	1	2
	Neochirosia Malloch sp.	2	2	0	4

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Table A1. (*continued*).

Family	Species	Number of specimens			
		1 m	6 m	11 m	Total
Anthomyiidae	Anthomyiidae sp. 1	1	0	0	1
	Anthomyiidae sp. 2	1	0	0	1
	Anthomyiidae sp. 3	3	0	0	3
	Anthomyiidae sp. 4	1	0	0	1
	Anthomyiidae sp. 5	0	0	2	2
	Anthomyiidae sp. 6	9	5	4	18
	Anthomyiidae sp. 7	1	2	0	3
	Anthomyiidae sp. 8	1	0	0	1
	Anthomyiidae sp. 9	7	29	12	48
	Hylemya Robineau-Desvoidy sp.	5	0	0	5
Fanniidae	*Fannia* Robineau-Desvoidy sp.	1	1	0	2
Muscidae	*Coenosia* (*Limosia*) *triseta* Stein	0	1	0	1
	Coenosia (*Limosia*) Meigen sp. 1	1	2	0	3
	Coenosia (*Limosia*) sp. 2	0	0	1	1
	Coenosia (*Oplogaster*) *laeta* Huckett	8	1	1	10
	Coenosia (*Oplogaster*) *octopunctata* (Zett.)	2	2	0	4
	Muscina assimilis (Fallén)	5	0	0	5
	Muscina pascuorum (Meigen)	1	1	3	5
	Eudasyphora cyanicolor setosa Loew	4	1	2	7
	Spilogona Schnabl sp. 1	1	0	0	1
	Spilogona sp. 2	1	0	4	5
	Spilogona sp. 3	1	0	0	1
	Musca autumnalis DeGeer	0	1	3	4
	Mydaea discimana Malloch	2	3	4	9
	Mydaea obscurella Malloch	2	0	0	2
	Mydaea occidentalis Malloch	3	0	0	3
	Mydaea urbana (Meigen)	21	2	3	26
	Phaonia apicata Johannsen	6	0	2	8
	Phaonia bysia (Walker)	4	0	1	5
	Phaonia serva Fallén	3	2	2	7
	Phaonia ?soccata (Walker)	5	2	0	7
	Phaonia Robineau-Desvoidy sp. 1	0	1	0	1
	Phaonia sp. 2	1	0	0	1
	Phaonia sp. 3	0	1	0	1
	Helina aldrichi Snyder	25	16	11	52
	Helina obscurata (Meigen)	3	0	0	3
	Helina pectinata (Johannsen)	0	0	1	1
	Helina troene (Walker)	5	0	1	6
	Helina Robineau-Desvoidy sp. 1	1	0	0	1
	Helina sp. 2	0	1	1	2
	Helina sp. 3	1	0	0	1
	Helina sp. 4	0	0	1	1
	Hydrotaea militaris (Meigen)	0	2	0	2
	Morellia podagrica (Loew)	0	1	0	1
Calliphoridae	*Pollenia pediculata* Macquart	3	1	6	10
	Pollenia rudis Fabricius	0	1	0	1
	Pollenia vagabunda Meigen	0	1	0	1
	Calliphora terraenovae Macquart	1	0	0	1

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Table A1. (*concluded*).

Family	Species	Number of specimens 1 m	6 m	11 m	Total
	Cynomya cadaverina Robineau-Desvoidy	9	0	0	9
	Phormia regina (Meigen)	16	0	0	16
	Lucilia illustris (Meigen)	0	0	2	2
Sarcophagidae	*Boettcheria bisetosa* Parker	4	0	0	4
	Boettcheria cimbicis (Townsend)	17	17	19	53
	Boettcheria latisterna Parker	8	6	9	23
	Helicobia rapax Coquillett	0	0	2	2
	Ravinia acerba (Walker)	8	8	8	24
	Ravinia querula (Walker)	4	0	0	4
	Ravinia stimulans Walker	0	1	1	2
	Sarcophaga Meigen spp.	9	2	2	13
	Sarcophaga (*Robineauella*) *nearctica* Parker	2	0	0	2
	Sarcophaga (*Bercaeopsis*) *sarraceniae* Riley	0	0	1	1
	Sarcophaga subvicina Rohdendorf	3	1	3	7
Tachinidae	*Archytas* Jaennicke sp.	0	0	4	4
	Admontia Brauer and Bergenstamm sp.	2	4	1	7
	Arctophyto Townsend sp.	0	2	1	3
	Blepharomyia Brauer and Bergenstamm sp.	0	1	2	3
	Eucelatoria Townsend sp.	9	5	4	18
	Lixophaga Townsend sp.	0	4	1	5
	Neomintho Brauer and Bergenstamm sp.	0	0	1	1
	Opsomeigenia Townsend sp.	1	2	11	14
	Paradidyma Brauer and Bergenstamm sp.	1	0	0	1
	Ptilodexia Brauer and Bergenstamm sp.	0	1	0	1
	Tachinidae sp. 1	0	1	0	1
	Tachinidae sp. 2	0	0	6	6
	Tachinidae sp. 3	0	1	0	1
Total Brachycera		710	376	367	1453

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