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THE SPECIES COMPOSITION AND SEASONAL DISTRIBUTION OF MOSQUITOES IN VERNAL POOLS IN SUBURBAN MONTREAL, QUEBEC

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ABSTRACT. A study was conducted in the spring and summer of 1998 to determine the invertebrate community in vernal pools on the western portion of the Island of Montreal. This paper examines the mosquitoes (Diptera: Culicidae) found in 10 pools. Fifteen species in 4 genera (*Aedes, Anopheles, Culex,* and *Ochlerotatus*) were collected and the seasonal distribution of each species was determined. *Ochlerotatus stimulans* was the most abundant species. Two peaks occurred in larval abundance, in late April and early July. Larvae were more abundant in the spring; larval density was higher later in the summer. The abundance of mosquitoes in these pools was similar to those found in remote regions of the province.

KEY WORDS Mosquitoes, vernal pools, suburban, Montreal

INTRODUCTION

Temporary or ephemeral freshwaters, defined as bodies of water that experience a recurrent dry phase of varying length and predictability (Williams 1996), have not been investigated to the same extent as permanent bodies of water. Literature pertaining to temporary waters is largely scattered (King et al. 1996) and only in the past 10–15 years have these systems begun to receive attention. Moreover, most studies have been conducted in semiarid and arid regions around the world where these temporary systems are abundant (Cole 1966, Abell 1981, McLachlan 1983, Boulton and Suter 1986, Thiery 1991, Miller 1992, Blaustein et al. 1996, Meintjes 1996). Although temporary habitats have been associated primarily with hot climates, they are also found in temperate regions such as North America and Europe where they may be as numerous as those found in semiarid and arid zones (Williams 1987).

The more common forms of ephemeral systems in Canada are vernal pools and ponds; these basins fill with water from melting snow and spring rains; retain surface water until midsummer; and are usually dry throughout late summer, autumn, and winter (Mozley 1932, Ward 1992). Studies have been conducted throughout Canada, including Manitoba (Mozley 1932, Daborn and Clifford 1974, LaBerge and Hann 1990), Alberta (Donald 1983), British Columbia (McLay 1978), Ontario (Paterson and Fernando 1969, Harper and Hynes 1970, McKee and Mackie 1981), and Quebec (Mailhot and Maire 1978; Maire et al. 1978; Maire and Aubin 1979, 1980; Tessier et al. 1981; Maire 1982; Alaire and LeClair 1988). These studies examined many different groups of invertebrates such as Cladocera, Anostraca, Mollusca, and Insecta.

Although vernal habitats have been examined in Quebec, little research has been done in suburban areas. Therefore, a study was conducted in 1998 to determine the invertebrate community in vernal pools situated on the western portion of the Island of Montreal. This paper examines the relative abundance, species composition, and seasonal distribution of 1 of the groups of invertebrates collected, the mosquitoes.

MATERIALS AND METHODS

Ten pools were selected for study on the western portion of the Island of Montreal. Pool choice was based on 2 major criteria: they had to be formed by water from snowmelt, spring rains, or both, and they were not to be connected or immediately proximal to any permanent body of water.

Six pools were situated in Ste-Anne-de-Bellevue (45°N, 73°W), 2 of which were located in the Stoneycroft Wildlife Area and 4 in the Morgan Arboretum (adjacent to the Macdonald Campus of McGill University). The remaining 4 pools were in the Village of Senneville. Pools in the same locality tended to be similar with respect to the vegetation surrounding them and the environmental conditions to which they were exposed. These pools were found in an isolated woodland area, in a wood lot near a municipal park, and in a grassy meadow. Except for 1 Senneville pool that had stones as its substrate, the substrate of all other pools was composed of organic debris such as branches, mosses, grasses, and leaves of coniferous and deciduous trees. At the beginning of the sampling season the pools approximately ranged in size from 105 to 660 m^2 and had maximum water depths that ranged from 15 to 98 cm.

Sampling was done twice weekly in the afternoon (1200–1800 h) April 9–July 23, 1998. Sampling dates for the 1st 3 wk differed among pools; sampling commenced only when pools were completely free of ice and hence certain pools were

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sampled earlier than others. After April 21, all pools were visited on the same day. Sampling continued until desiccation; pools were considered dry and no longer visited if they remained dry 1 wk after the last sampling date when water was present. In addition, desiccated pools were visited only if the total amount of rainfall for a day exceeded 20 mm. All pools were dry on the 2nd and 3rd week of June and some were replenished by rains only on the last week of that month.

A small aquarium net measuring 15 × 12.5 cm and a D-frame dip net measuring 25 × 31 cm were utilized to collect invertebrates in the pools. Both nets had a similar cross-thatching mesh pattern with apertures less than 0.25 mm wide. The larger D-frame dip net was utilized when the maximum water depth exceeded 15 cm, and conversely, the smaller net was used when the maximum water depth was less than 15 cm.

Air and water temperatures, maximum water depth, maximum length, and maximum width were recorded for each pool on each sampling date. If a pool dissociated itself into smaller pools as it dried, the parameters were measured for each of the smaller individual pools.

Because no standardized sampling techniques exist for collecting organisms in vernal pools, methods adopted in this study attempted to sample a large area of each pool without greatly diminishing the organisms found within them. A maximum of 10 1-m sweeps was made in each pool; these sweeps were performed both near the edge and middle of the pool. As pools became smaller in area, the number of sweeps decreased so as to sample one half of the surface area of a pool. During desiccation, if a pool separated itself into smaller separate pools, the number of sweeps in each smaller pool permitted sampling of one half of its surface area; the total number of sweeps for these smaller pools did not exceed 10. Because of the variation in pool sizes and sampling procedures, quantitative treatment of data is somewhat problematic.

Nets were dragged close to the bottom of each pool, ensuring the collection of organisms on the bottom and in the water column. Contents of nets were then transferred into a bucket of water; large detritus was washed to remove any organisms and discarded. Contents of the bucket were then filtered through the aquarium net to remove water, and samples were placed in labeled containers containing 80% ethanol. In the laboratory, samples were sieved in a U.S.A. Standard Sieve Series Mesh no. 35 (Humbolt Mfg. Co., Chicago, IL) to remove small detritus; this material was examined under a dissecting microscope and organisms were separated from remaining detritus and placed into vials containing 80% ethanol. Organisms were subsequently enumerated and identified to genera or species by using the keys provided by Wood et al. (1979). Many specimens early in the season were identified only to genera because early instars (1st and 2nd) were too small to be reliably identified. Pupae collected were identified only to genera because a complete species key was not available.

RESULTS

Four genera (*Aedes, Anopheles, Culex,* and *Ochlerotatus*) and a total of 15 species were collected; these included 2 *Aedes* species (*Ae. cinereus* Meigen and *Ae. vexans* (Meigen)), 1 *Anopheles* species (*An. quadrimaculatus* Say), 3 *Culex* species (*Cx. pipiens* Linnaeus, *Cx. restuans* Theobald, and *Cx. territans* Walker), and 9 *Ochlerotatus* species (*Oc. canadensis* (Theobald), *Oc. communis* (De Geer), *Oc. diantaeus* (Howard, Dyar, and Knab), *Oc. euedes* (Howard, Dyar, and Knab), *Oc. excrucians* (Walker), *Oc. intrudens* (Dyar), *Oc. provocans* (Walker), *Oc. punctor* (Kirby), and *Oc. stimulans* (Walker)). The total number of specimens collected of each species as well as the total number of larvae and pupae found are presented in Table 1. To simplify the presentation of the data, they were amalgamated into 4-wk intervals for each month. *Ochlerotatus stimulans* was the most abundant species found, whereas *Cx. territans* was the least common.

To compare the relative abundance of mosquitoes as a measure of sampling effort, the total number of specimens collected per week was converted to number of insects per dip. This number was calculated by dividing the total number of larvae collected in all pools in a given week by the total number of sampling dips in that week. Dip values (Table 2) for each week were calculated by totaling the number of collection sweeps while using the D-frame dip net; dip values obtained from collection sweeps with the smaller aquarium net were converted by dividing these values by a factor of 2.07. The small aquarium net samples 2.07 times less than the D-frame dip net. Therefore, each dip value obtained by the aquarium net needs to be divided by 2.07 to make direct comparisons with the D-frame net. Because of the rigors in sampling vernal habitats, it is difficult to calculate exactly the volume of water sampled for each sweep by either net. It has been estimated that 1 dip value approximately equates to 0.0375 m^3 or 37.5 liters. In other words, 0.0375 m^3 of water was sampled for every 1-m sweep with the D-frame dip net. As shown in Table 2, dip values were not constant throughout the entire sampling season because not all pools were visited on the same sampling dates early in the season, pool size diminished as the season progressed, and not all pools became dry at the same time.

The relative abundance and seasonal distribution of mosquitoes is presented in Figs. 1 and 2. *Culex restuans* was the most abundant mosquito collected per dip (20 insects/dip), whereas *An. quadrimaculatus* and *Oc. diantaeus* (<1 insect/dip) were the least abundant. Larval *Ochlerotatus* were collected as early as the 2nd week of April, larval *Culex* were

Table 1. Number of specimens collected per week (4 wk indicated per month) from all 10 vernal pools in suburban Montreal (1998).

	April				May				June				July			
Species	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Ochlerotatus canadensis			32	451	75	2							257	3		
Oc. communis		2	203	346	8											
Oc. diantaeus			26	163	28											
Oc. euedes			102	279	84	3										
Oc. excrucians			327	412	55											
Oc. intrudens			1	16												
Oc. provocans		136	351	276	14											
Oc. punctor			110	129												
Oc. stimulans			1,297	1,623	304	2										
Aedes cinereus													496	19		
Ae. vexans													464			
Culex pipiens					1	18	1						142	240	11	
Cx. restuans													422	526	218	
Cx. territans													1	4	1	
Anopheles quadrimaculatus												1			14	
Aedes and *Ochlerotatus*[1]		1,452	1,388	171	11	14	5					1,025	1			
Culex[1]												5	277			
Total larvae	0	1,590	3,837	3,866	580	39	6	0	0	0	0	1,031	2,060	792	244	0
Pupae			13	1,008	1,888	109	3	1					602	605	42	

[1] Specimens too small (early instars) to be identified to species.

Table 2. Total number of dips and larval density (per m^3) per week in vernal pools in suburban Montreal.

Month	Week	Dips	Larvae/m^3
April	1	0.00	0.00
	2	109.00	388.99
	3	130.15	786.17
	4	160.36	642.89
May	1	86.90	177.98
	2	69.37	14.99
	3	34.64	4.62
	4	8.70	0
June	1	10.63	0
	2	0.00	0
	3	0.00	0
	4	26.62	1,032.81
July	1	37.67	1,458.28
	2	28.78	733.84
	3	10.63	612.1
	4	0.48	0.00

seen in the 1st week of May, and larval *Anopheles* and *Aedes* were 1st collected in the last week of June. Mosquito species appeared in succession, with the majority collected only before or after pool dessication and replenishment, with the exceptions being *Oc. canadensis* and *Cx. pipiens*. Both of these species were present early and late in the season and were more abundant later in the season. Culicid larval abundance peaked twice during the sampling season; the 3rd week of April and the 1st week of July (Fig. 3). A similar pattern was seen for the pupae except that total abundance peaked 1 or 2 wk after those of the larvae (1st week of May and 2nd week of July).

Larval density (larvae/m^3) per week is presented in Table 2 and was calculated by dividing the total number of larvae collected in a given week by the product of the total number of dips in the same week with 0.0375 (total no. larvae/(total no. dips × 0.0375)). Larval density values ranged between 0 larvae/m^3 and 1,458.28 larvae/m^3 and were higher later in the season after pools were replenished by rain.

DISCUSSION

All culicid species collected have been recorded previously from Quebec (Wood et al. 1979, Maire and Aubin 1980). Although few studies have been done on the Island of Montreal, all culicid species

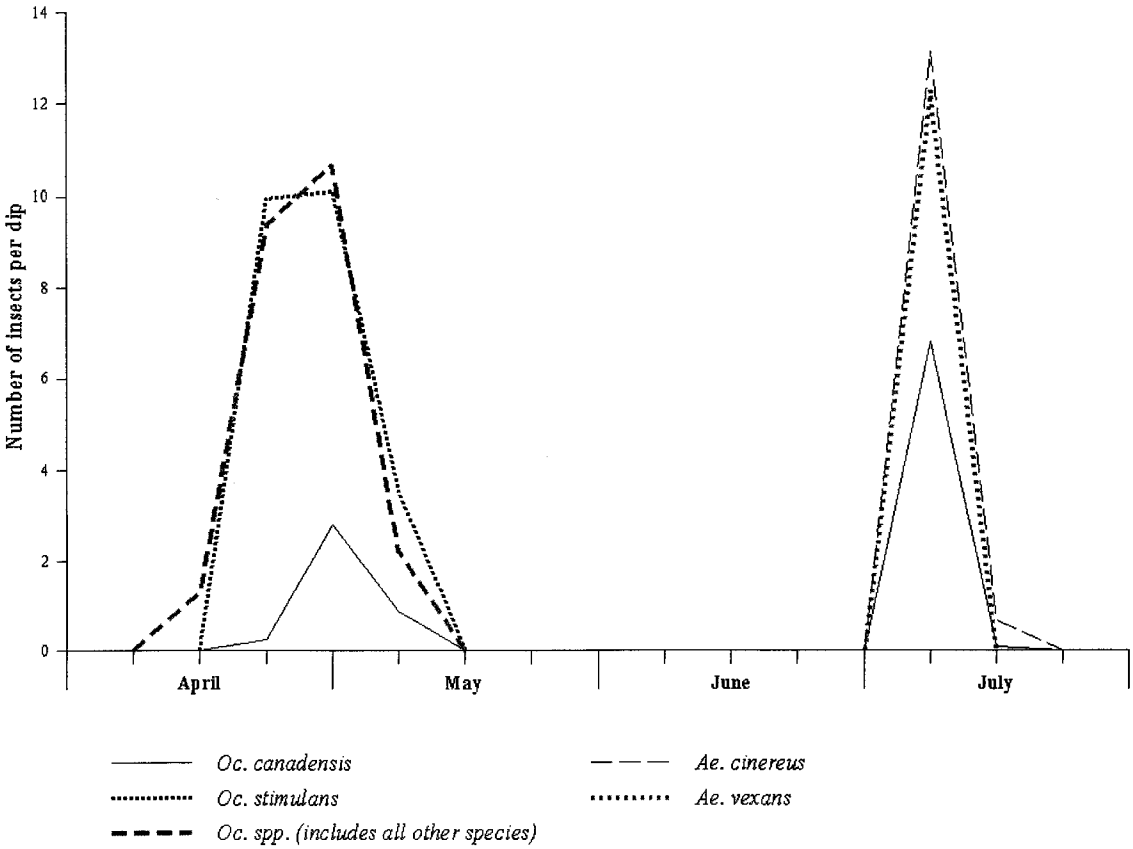

Fig. 1. Seasonal distribution and abundance of *Aedes* and *Ochlerotatus* species in vernal pools in suburban Montreal.

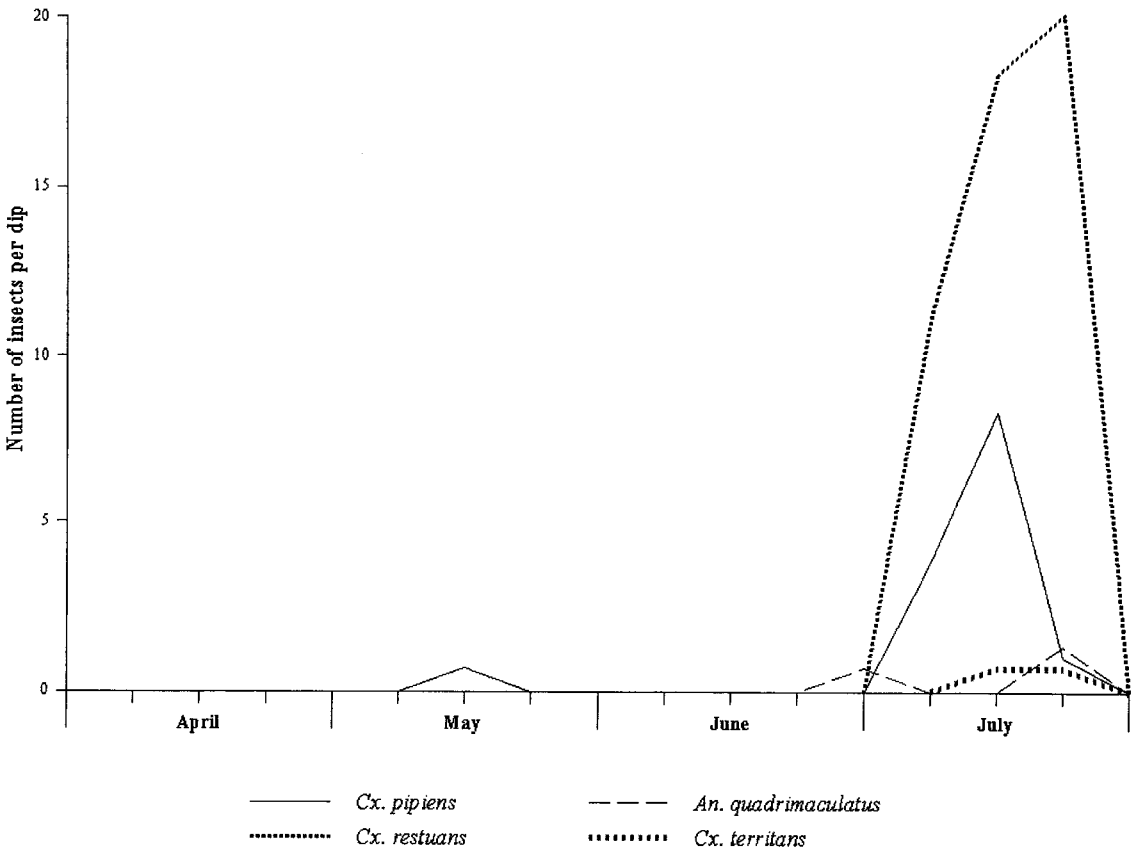

Fig. 2. Seasonal distribution and abundance of *Culex* and *Anopheles* species in vernal pools in suburban Montreal.

collected were indigenous to the southern portion of the province (Wood et al. 1979, Maire and Aubin 1980). It was not surprising to observe these insects in the study pools because vernal pools represent one of the most commonly used habitats by mosquitoes in the Nearctic region (Happold 1965, Bay 1974, Clements 1992, Batzer and Wissinger 1996). They can also be found in pools that have hydroperiods as short as 10 days (Karadatze 1979). Therefore, our study pools provided an excellent habitat for mosquito development, irrespective of their location in a suburban environment.

Examination of Figs. 1 and 2 reveals that the number of specimens collected per dip are quite low for most species. For example, at peak abundance, the number of *Oc. stimulans* collected per dip was approximately 10 insects/dip. This number is low considering that this species was the most abundantly collected (Table 1). When calculating number of insects per dip, data from all pools were combined together regardless of whether or not species were found in all pools. Therefore, the numbers calculated for each species are artificially low. Not all mosquito species were collected in all pools and in many cases were restricted to pools in the same locality. Spatial distribution of species is dependent upon habitat preferences such as shade cover and the nature of the vegetation (Maire et al. 1978, Maire and Aubin 1979, Wood et al. 1979, Laird 1988). If the number of insects per dip for *Oc. canadensis* at peak abundance is calculated for pools in which they occurred, approximately 18 insects/dip were collected. Therefore, the values for all other species are likely underrepresented in Figs. 1 and 2.

Although fewer larvae were collected after the pools were replenished by summer rains (Table 1), the number of insects per dip was generally higher than before dessication (Figs. 1 and 2). Pools earlier in the season were larger and more numerous, and therefore the number of dips was greater than later in the season (Table 2). Higher values later in the season also correspond to higher larval densities (Table 2) during the postdessication period. Although more larvae were collected early in the season, larval density in the pools was greater late in the season after the pools were replenished by rain. Larval density values in suburban pools on the Island of Montreal (Table 2) are similar to other pools found in remote regions such as in northern Quebec (Mailhot and Maire 1978, Maire and Aubin 1979) and in the Trois-Rivières region (Maire et al. 1978).

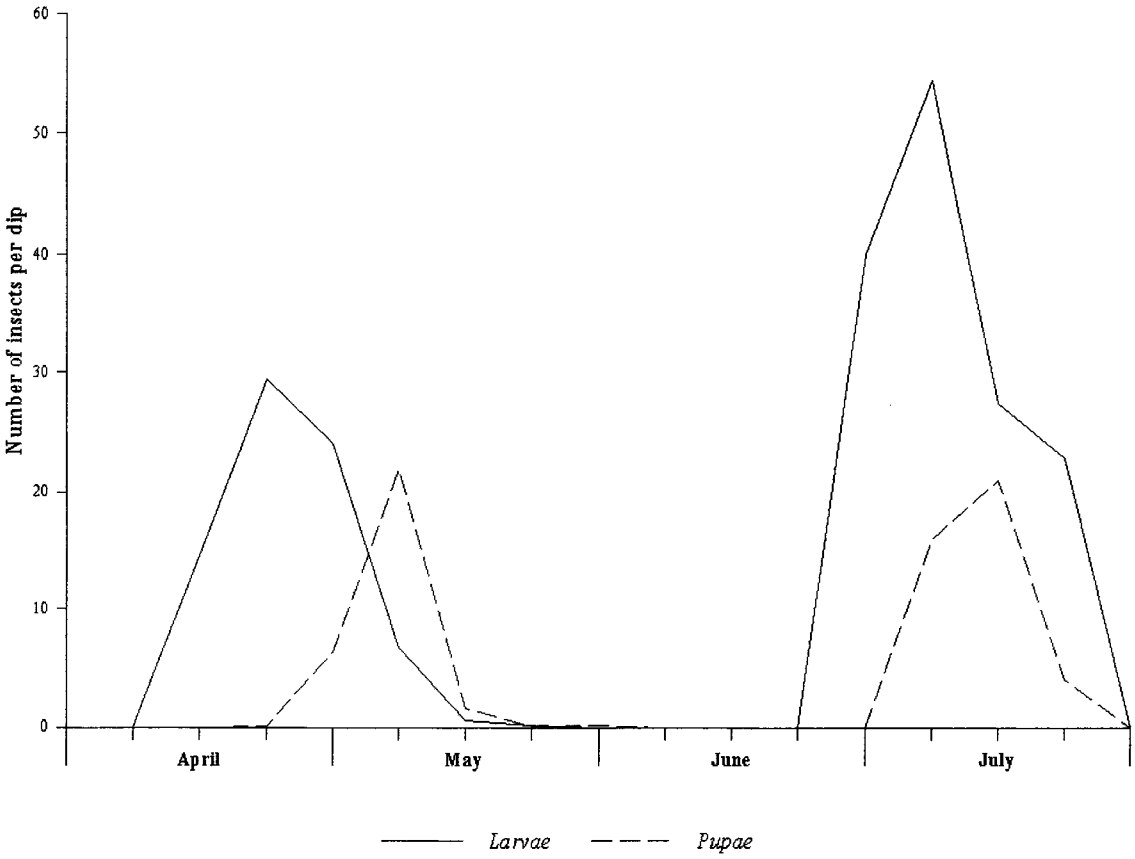

Fig. 3. Seasonal distribution and abundance of culicid larvae and pupae in vernal pools in suburban Montreal.

Ochlerotatus species were the 1st to appear in late April and May, followed respectively by *Culex, Anopheles,* and *Aedes* species. The seasonal distribution of these species corresponds to what has been recorded previously in pools in remote regions (Maire et al. 1978, Maire and Aubin 1979, Wood et al. 1979). Although the same is generally true for similar species found in suburban pools across Canada, many of these pools are not directly comparable because their mosquito communities were different from those of our study (Judd 1954, Dixon and Brust 1972, Selka et al. 1991). The seasonality of various species is dependent upon the timing of oviposition and hatching of individual species. The appearance of *Ochlerotatus* species early in the season is due to their overwintering as eggs, which hatch in the spring thaw. *Culex* and *Anopheles* species differ in that adults overwinter and lay eggs in pools in spring and summer (Wood et al. 1979), thus they appear later on in the season. *Aedes cinereus* and *Ae. vexans* do overwinter as eggs but in order to hatch they generally require warmer temperatures (10–15°C) found later in the season (Horsfall 1956, Brust and Costello 1969, Karadatze 1979). Most species were found only before or after pool dessication with the exception of *Oc. canadensis* and *Cx. pipiens*; these 2 species are multivoltine (Wood et al. 1979).

Although some pools were quite small and shallow (10 × 10 m; water depth less than 15 cm), their hydroperiods were long enough to allow complete larval development. This was observed particularly in pools that were replenished by summer rains in late June; several of these remained wet for only 1 wk, yet pupae could be found as early as 4–5 days after replenishment (Fig. 3). Pupal counts in pools replenished later in the season terminated at the same time as the larval counts because of the desiccation of the pools. If pools remained wet for an additional week, pupal counts would have extended beyond larval counts. In warm temperatures it is not unusual for immature mosquitoes to complete their development in this time frame (Wood et al. 1979) and in suburban environments where vernal pools are exposed more to sunlight, this is probably a common occurrence.

CONCLUSION

Except for a few studies conducted in Ontario, Quebec, and Manitoba, vernal pools in Canadian suburban environments have not been examined to

any great extent. Winnipeg is one of the few cities that regularly monitors for mosquitoes and has even set up an insect control hotline for the public. The paucity of research of vernal pool communities in Montreal is surprising because it is one of the largest urban centers in Canada. Our study has revealed that pools on the Island of Montreal contained a diverse mosquito community that was present after spring thaw and late in the season once pools were replenished by rains. Our study also revealed that these suburban pools supported an abundance of mosquitoes somewhat equal to pools found in remote regions. This study may have important implications for municipalities wishing to control mosquito populations because it demonstrates that vernal pools can harbor a great number of mosquitoes not only in the spring but also later in the summer.

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