Aquatic insect populations in transplanted and natural populations of the purple pitcher plant, *Sarracenia purpurea*, on Prince Edward Island, Canada

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Abstract: In early July 1991, 234 pitcher plants (*Sarracenia purpurea*) were transplanted from a Prince Edward Island bog being mined for peat into three bogs that varied with respect to previous pitcher plant abundance. One bog had a thriving natural pitcher plant population prior to transplant, while the other two had fewer than three pitcher plants. Between mid-June and late August 1993, abundances of the pitcher plant inquilines *Wyeomyia smithii* (Diptera: Culicidae), *Metriocnemus knabi* (Diptera: Chironomidae) and an unidentified sarcophagid fly (Diptera: Sarcophagidae) from transplant bogs were compared with remaining populations in the source bog and with other natural populations. Of the three inquilines, *W. smithii* was the most severely affected by transplant; it was extremely rare or absent in transplanted pitchers, although it was found in all other bogs investigated on Prince Edward Island. *Metriocnemus knabi* larvae were common in all bogs investigated, except for those transplant bogs where pitcher plants were rare prior to transplant. Sarcophagid larvae were found in all of the bogs sampled, and were apparently unaffected by transplant. Desiccation during the transplant process, as well as the time of the transplant, may play a role in the success of recolonization of the pitcher plants after transplanting.

Résumé : Au début de juillet 1991, 234 sarracénies (*Sarracenia purpurea*) ont été transplantées d'une tourbière exploitée de l'Île-du-Prince-Édouard à trois autres tourbières variables par l'abondance des sarracénies. L'une de ces tourbières avait une population naturelle florissante de sarracénies avant la transplantation et les deux autres possédaient moins de trois sarracénies. Entre la mi-juin et la fin d'août 1993, l'abondance des espèces inquilines dans les sarracénies, *Wyeomyia smithii* (Diptera : Culicidae), *Metriocnemus knabi* (Diptera : Chironomidae) et un sarcophagide non identifié (Diptera : Sarcophagidae) dans les tourbières recolonisées a été comparée à l'abondance des populations restantes dans la tourbière d'origine ainsi qu'à l'abondance d'autres populations naturelles. *Wyeomyia smithii* s'est avérée l'espèce inquiline la plus affectée des trois par la transplantation; ces insectes étaient extrêmement rares ou absents dans les sarracénies transplantées, bien qu'ils aient été trouvés dans toutes les autres tourbières étudiées de l'île. Les larves de *M. knabi* étaient abondantes dans toutes les tourbières visitées, sauf dans les tourbières recolonisées où les sarracénies étaient rares avant la recolonisation. Les larves du sarcophagide ont été trouvées dans toutes les tourbières échantillonnées et ne semblent pas avoir été affectées par la transplantation. Le dessèchement des plants pendant le processus de transplantation de même que le moment de la transplantation peuvent affecter le succès de la recolonisation des sarracénies après la transplantation.
[Traduit par la Rédaction]

Introduction

The fluid contained in leaves of the purple pitcher plant (*Sarracenia purpurea* L.) provides a home for a number of organisms, including microorganisms, small crustaceans, and insects (Juniper et al. 1989). Larvae of three species of Diptera (Insecta) are obligate symbionts of the pitcher plant: the mosquito *Wyeomyia smithii* (Coq.) (Culicidae), the midge *Metriocnemus knabi* Coq. (Chironomidae), and a suite of sarcophagid flies, mainly *Blaesoxipha (Fletcherimyia) fletcheri* (Aldrich) (Sarcophagidae). Unlike many carnivorous plants, *S. purpurea* apparently does not possess digestive glands, and relies on autolytic enzymes within the prey and bacterial decomposition in the pitcher to break down insect prey (Bradshaw and Creelman 1984; Givnish 1989). *Blaesoxipha fletcheri* and *M. knabi* both feed directly on insect carcasses; *B. fletcheri* feeds at the water surface and *M. knabi* is found in the debris that accumulates at the bottom of the pitcher (Bradshaw and Creelman 1984). Feeding by these species accelerates the breakdown of prey by disrupting the integrity of the cuticle, resulting in increased growth of microorganisms like bacteria and Protozoa. The microorganisms are subsequently filtered from the water by *W. smithii* during feeding (Bradshaw and Creelman 1984). Both *M. knabi* and *W. smithii* can be present in considerable numbers in pitchers (Nastase et al. 1995), but *B. fletcheri* shows intraspecific aggressive behaviour, so rarely exceeds one larva per pitcher (Forsyth and Robertson 1975).

Pitcher plant communities provide an example of a pro-

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cessing chain commensalism, where consumers specialize on food at different stages of processing (Heard 1994*a*). Midges feed at the top of this chain, feeding directly on prey that fall into pitcher fluid. Mosquitoes rely on the processed food, therefore their abundance is directly affected by the activities of the midges, although they have little direct effect themselves on the midges (Heard 1994*a*). Sarcophagids feed at the same level of the processing chain as the midges, but partition the pitcher spatially (Bradshaw and Creelman 1984). The activities of these inquilines result in rapid release of nutrients such as nitrogen and carbon to the plant, completing the chain.

The symbiotic relationships mentioned above depend upon the availability of suitable habitat for pitcher plants, which are found in bogs over much of temperate North America (Schnell 1976). Bogs may be degraded by draining for agriculture, horticulture, silviculture, or peat harvest (Moore and Bellamy 1974). On Prince Edward Island (PEI), all large bogs either are being mined or are slated to be mined for peat (C. Lacroix, University of Prince Edward Island, personal communication), resulting in recent public calls for mitigation procedures, particularly with respect to bog plants. Consequently, when Miscouche bog (a large bog in western PEI) was scheduled to be mined for peat in 1992, a local conservation group (The Island Nature Trust) initiated a transplant of "rare and/or interesting plants," including 234 pitcher plants, from that bog to three other bogs (Warren and Waddell 1991).[3] Because of the apparent success of this transplant procedure, further transplants are proposed for other bog developments (C. Lacroix, personal communication). However, although efforts were made to assess the post-transplant success of the plants as part of the mitigation procedure (Warren and Waddell 1991),[3] no attention was paid to other organisms that might be associated with the transplants, such as pitcher plant inquilines.

The inquilinous relationship is not obligatory for the pitcher plant, which can grow and reproduce in the absence of the inquilines, but there is growing evidence that the relationship is mutualistic (Givnish 1989). However, it is still not clear how much benefit the plant receives (Givnish 1989). The feeding and metabolic processes of the inquilines release ammonia and CO_2 into the leaves of the pitcher plant, which rapidly take up the ammonia and CO_2 and infuse O_2 into the water (Bradshaw and Creelman 1984). Although the plants can complete their development in the absence of macroinvertebrate processors (Bradshaw and Creelman 1984), the rapid uptake of nutrients in their presence suggests that disrupting the processing chain by transplanting could also disrupt the plants, lowering their potential long-term survivorship.

Pitcher plant inquilines have not previously been studied on PEI, so no base-line data on pre-transplant abundance were available for comparison with post-transplant conditions. Therefore, the objective of our study was to investigate population density of insect inquilines in both natural and transplanted purple pitcher plant (*S. purpurea*) populations in bogs throughout PEI to determine (*i*) if broad-scale abundance patterns existed that could be compared with those of transplanted pitchers, and (*ii*) if transplanting pitchers had a detrimental effect on insect inquilines.

[3] K. Warren and J. Waddell. 1991. Miscouche bog transplant final report. Unpublished report, Island Nature Trust, Charlottetown, P.E.I. [Available from Island Nature Trust, P.O. Box 265, Charlottetown, PE C1A 7K4, Canada.]

Materials and methods

Transplanting pitcher plants

Pitcher plants were removed from Miscouche bog (Fig. 1) in early July 1991 by digging into the sphagnum around the plants and placing the sphagnum and associated plants into burlap bags in plastic tubs. The plants were then transported in open trucks and transplanted within 24 h to MacKinnon's bog (161 plants; Fig. 1), Glenfinnan bog (50 plants; Fig. 1), and Wood Island bog (23 plants; Fig. 1). Transplanted plants were marked with stakes in each bog so that success of the transplant could be evaluated; therefore, transplanted pitchers were easily located in the years following the transplant.

Prior to the Miscouche bog transplant, MacKinnon's bog had only a single pitcher plant, which had been transplanted the previous year, as a test of the transplant procedure (D. Griffin, Island Nature Trust, Charlottetown, P.E.I., personal communication). Glenfinnan bog had a small population of three pitcher plants that had been transplanted 17 years previously, and Wood Island bog had a large natural population of pitcher plants prior to the transplant. Miscouche bog has been drained and peat is being harvested, but there are regions along the edges of the bog where pitcher plants persist.

Sampling

Twelve bogs (Fig. 1), including the 4 transplant bogs, were sampled between June 23 and August 26, 1993 (Table 1), to determine the natural diversity and distribution of pitcher plant inquilines on PEI. Abundance of the various inquilines was expected to vary seasonally, so one bog, Clarkin, was sampled at 3-week intervals through the summer to provide seasonal information for comparison with the other bogs. Clarkin bog was chosen for regular sampling because it had a large population of pitcher plants and was located nearby and easy to access for sampling.

Samples were collected only from intact, open pitchers on healthy plants by suctioning the fluid and (or) dissecting the leaves. New leaves first open in early July on PEI, so early in the season, sampled leaves were those that had overwintered and represented growth during 1992; subsequently, sampled pitchers were those produced during the 1993 season. Relative age of the 1993 leaves was determined by noting the position of the leaves on the apex of the plant and numbering them consecutively from 1 to 5 to indicate the youngest (closest to the apex) to the oldest (farthest from the apex) (Fish and Hall 1978). Equal numbers of leaves from each age-class were selected randomly for sampling, but abundance and distribution of inquilines showed no patterns with age of leaf (analysis of variance (ANOVA), $p > 0.05$), so data from all healthy leaves were combined. Unopened pitchers were not included, and the oldest leaves were not sampled, as they often showed signs of rot, resulting in loss of pitcher fluid. In the "transplant bogs" (those receiving transplanted pitcher plants), care was taken to sample only transplanted plants that were marked by stakes.

The most reliable sampling method for pitcher plant inquilines is to remove whole leaves to be dissected in the laboratory (Nastase et al. 1991). However, this method was considered too destructive for plants that were transplanted for conservation purposes, so a less destructive suction method was used to sample transplanted plants (modified from Fish and Hall 1978 and Nastase et al. 1991). The suction method is not as effective as the dissection method (Nastase et al. 1991), so the two methods were compared for pitchers collected from Clarkin bog early in the summer of 1993. Twenty-five pitchers were collected and siphoned, then dissected to determine the total number of inquilines present. The suction method collected,

Fig. 1. Prince Edward Island, showing locations of the sampling sites (bogs). BA, Baltic; CK, Clarkin; FR, Foxley River; GF, Glenfinnan; HB, High Bank; LI, Lennox Island; MI, Miscouche; MK, MacKinnon's; NC, North Cape; SP, St. Peter's; WI, Wood Island; WP, West Point.

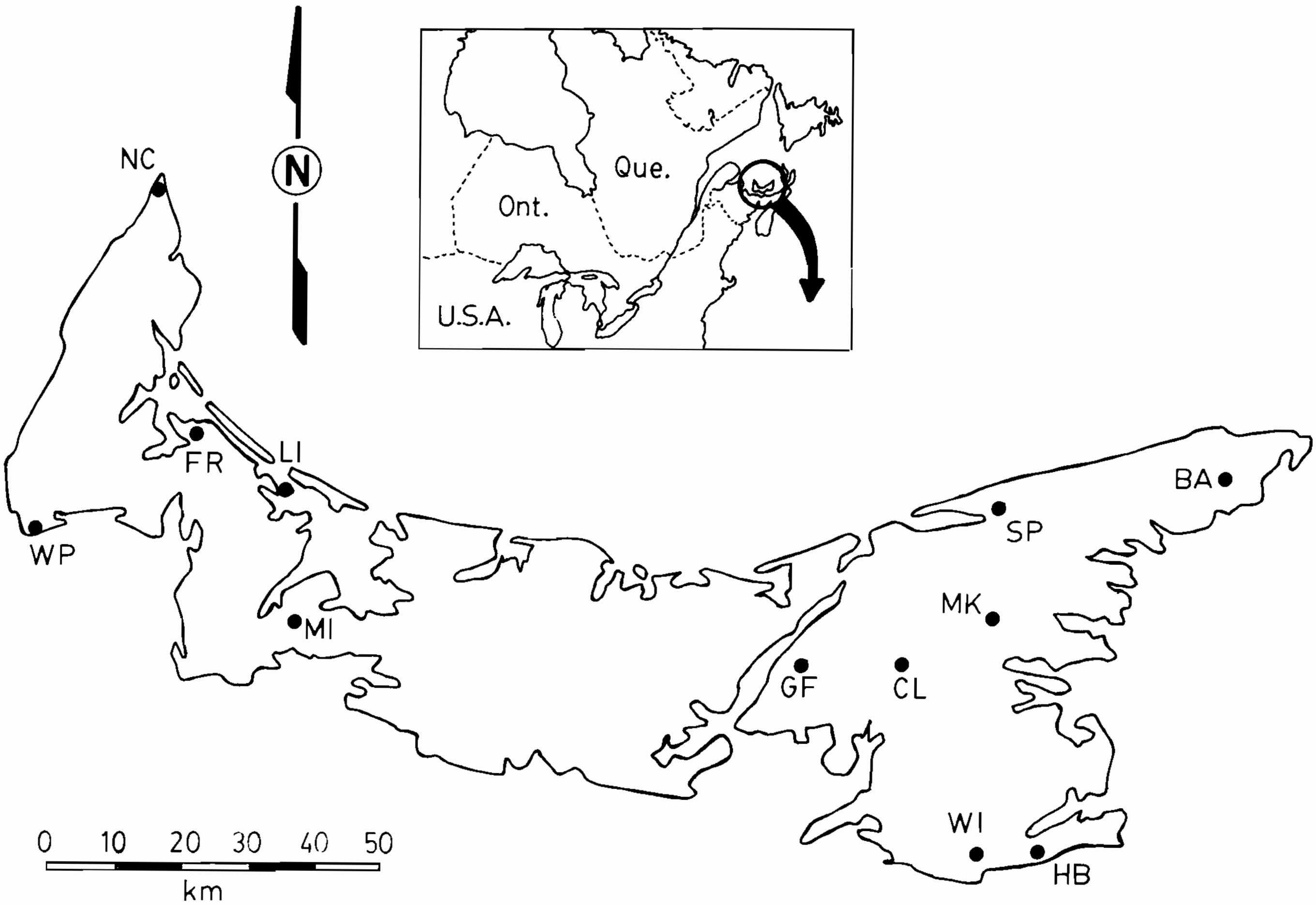


Table 1. Summary of sampling methods and collection dates used at each bog sampled on PEI.

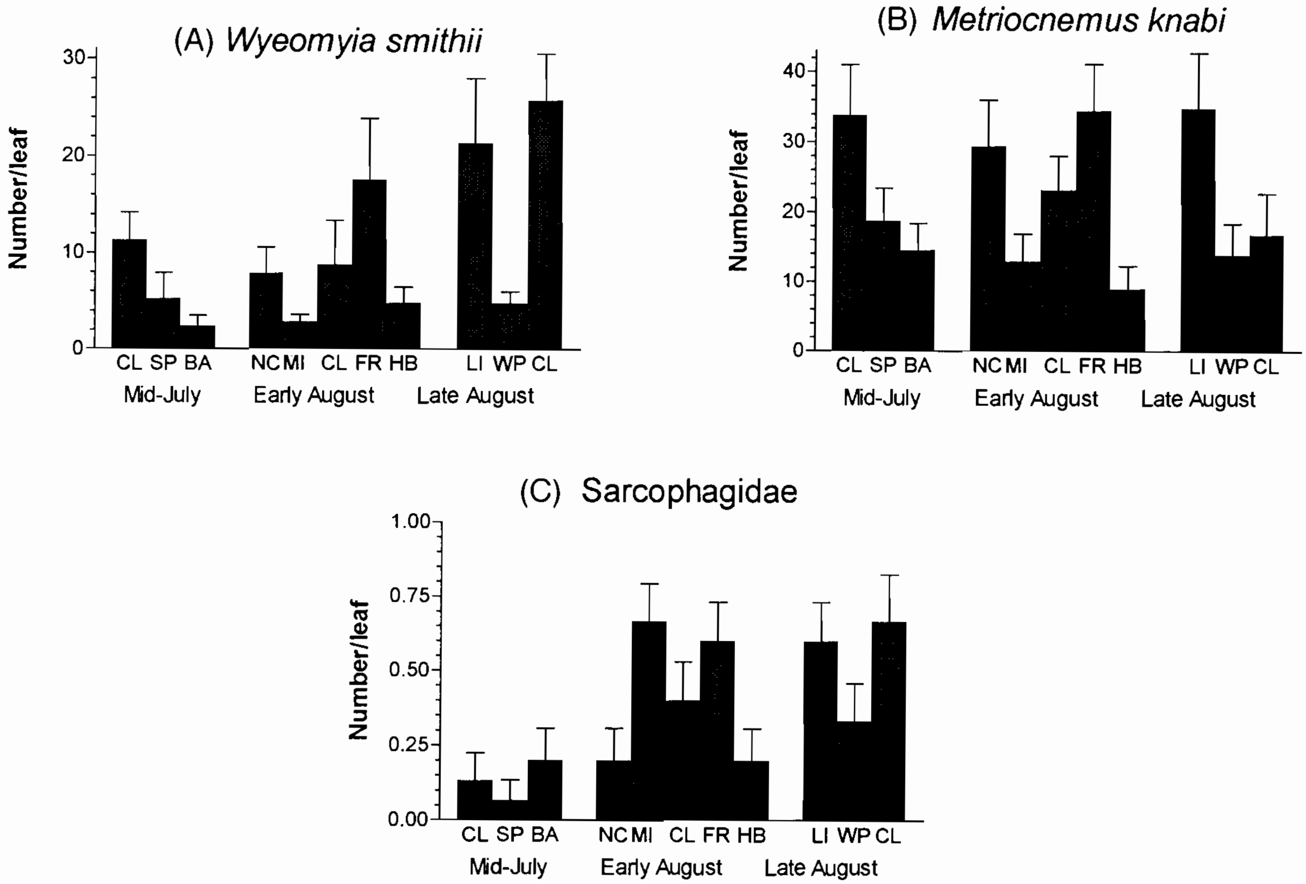
	Date of sampling	No. of pitchers	Method of collection
Clarkin bog	June 23	25	Suction, dissection
	July 14	15	Dissection
	August 3	15	Dissection
	August 26	15	Dissection
Glenfinnan bog*	June 24	25	Suction
	August 27	15	Suction
MacKinnon's bog*	July 4	15	Suction
	August 26	15	Suction
Wood Island bog*	July 14	15	Suction
Miscouche bog*	July 27	15	Dissection
St. Peter's bog	July 20	15	Dissection
Baltic bog	July 20	15	Dissection
North Cape bog	July 27	15	Dissection
Foxley River bog	August 10	15	Dissection
High Bank bog	August 12	15	Suction
Lennox Island bog	August 19	15	Dissection
West Point bog	August 19	15	Dissection

*Site involved in transplant.

on average, 90% of the mosquitoes (*W. smithii*) and 41% of the midges (*M. knabi*), so these conversion factors were used to correct the values collected by the suction method. The dissection method was used for the nontransplant bogs that had large, established pitcher plant populations, and for the bog that was actively being mined, and the suction method was used on transplanted pitchers. Sample size was determined by sampling a large number of pitchers in Glenfinnan and Clarkin bogs and calculating a travelling mean of the abundance from successive pitchers (i.e., the mean from five samples was calculated, then the mean from the next five samples, and so on until the mean ceased to fluctuate (Elliott 1977)). This procedure resulted in a sample size of 15 leaves (pitchers), which was followed for subsequent sample dates and locations.

For each pitcher, the total fluid capacity was measured as an indicator of pitcher size ("potential volume"; Nastase et al. 1991), and counts were analysed as both number per leaf and number per 10 mL potential volume. Total pitcher capacities were very similar for all pitchers sampled, so the patterns were the same for both methods. However, since only one sarcophagid larva generally occupies a pitcher (leaf) (Forsyth and Roberston 1975), only number per leaf is considered here, for consistency among groups. The contents of each pitcher were sieved in a 200-μm sieve and preserved in 70% ethanol, then identified and enumerated. Counts for abundance include both larvae and pupae for *W. smithii* and *M. knabi*. The data were tested for normality by plotting *N* scores against residuals. Data for all bogs were grouped by date and compared using analysis of covariance (ANCOVA) to determine

Fig. 2. Variation in densities of *Wyeomyia smithii* (A), *Metriocnemus knabi* (B), and sarcophagid larvae (C) in naturally occurring pitcher plants in bogs sampled across PEI ($\bar{x} \pm$ SEM; n = 15 pitchers for all bogs). Sites are grouped according to time of sampling: mid-July, early August, and the end of August. For an explanation of abbreviations see Fig. 1.



the broad-scale patterns of abundance for PEI bogs and whether abundance in remaining pitchers in the source bog differed from values for other bogs. Abundance of inquilines in transplant bogs was compared with that in the source bog using a one-way ANOVA.

Inquilines were held in natural pitchers in a greenhouse at ambient light conditions to be reared to confirm identifications. *Wyeomyia smithii* and *M. knabi* were the only mosquitoes and midges obtained from the pitchers. Attempts to rear the sarcophagid were unsuccessful, so it is not known which species were present (or even if there were more than one species); however, *B. fletcheri* is generally the most common pitcher plant sarcophagid in this region (Fairchild et al. 1987).

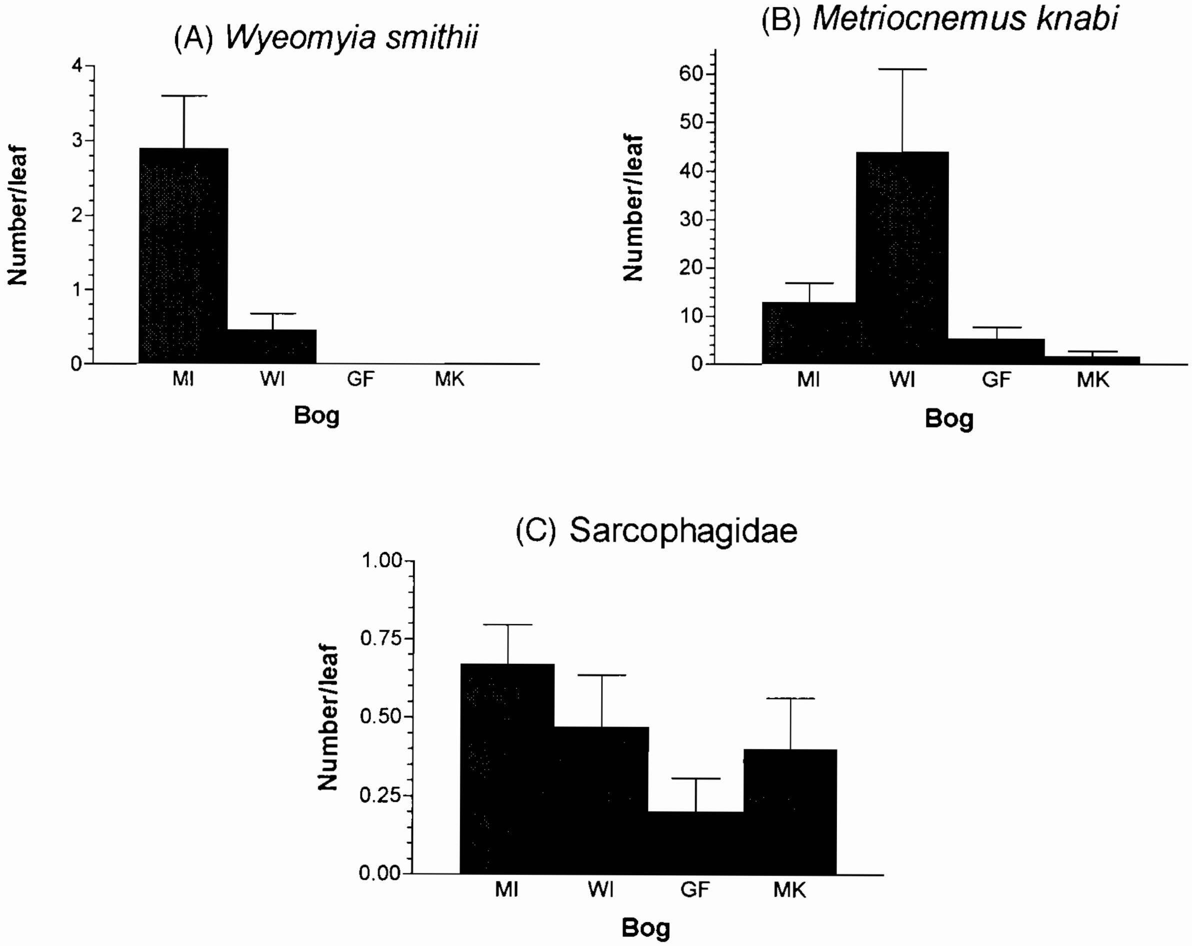
Results

Natural abundance of inquilines across PEI

The sample bogs all contained natural populations of pitcher plants consisting of at least 100 plants. *Wyeomyia smithii* was found in all of the bogs sampled that contained natural pitcher plant populations, at densities ranging from an average of 2.4 to 25.7 larvae per leaf in the different bogs (Figs. 2A and 3A). *Metriocnemus knabi* was found in all bogs sampled and was the most abundant of the inquilines in the PEI bogs, at densities ranging from 9 to 44 larvae per leaf (Figs. 2B and 3B). Sarcophagid larvae were also found in all bogs sampled, but in numbers much lower than the other inquilines. No more than one sarcophagid was found in any pitcher, and densities ranged from 0.07 to 0.67 larvae per leaf (Figs. 2C and 3C), corresponding to a frequency of 1/15 to 10/15 pitchers occupied by sarcophagids.

There were significant differences among bogs (ANOVA, $p < 0.05$) in the densities of each of the inquilines sampled across PEI, but these patterns appeared to be related to sampling date for *W. smithii* and the sarcophagids and to bog location for *M. knabi*. Both *W. smithii* and the sarcophagids increased in numbers at Clarkin bog over the sampling period (ANOVA, *W. smithii*, $p < 0.001$, Fig. 4A; sarcophagids, $p < 0.001$, Fig. 4C). The data were subsequently grouped by date, corresponding to the periods during which Clarkin bog was sampled, and an ANCOVA was performed on the data. When grouped by sampling date, there were no significant differences among bogs (ANCOVA, *W. smithii*, $p = 0.15$; sarcophagid, $p = 0.67$). In contrast, abundance of *M. knabi* did not vary significantly with sampling date (ANOVA, $p = 0.36$, Fig. 4B), but there was a pattern of much higher densities of plants in bogs located in the far northwestern corner of PEI (North Cape, Foxley River, and Lennox Island). These bogs are coastal bogs, and are located in very open areas, in contrast to the other bogs, which are sheltered by forest. When midge densities were grouped by location (coastal bogs versus remaining bogs), there were no significant differences in numbers among the bogs (ANCOVA, $p = 0.86$).

Fig. 3. Comparison of inquiline densities in transplanted pitcher plants with those in the source bog, Miscouche (MI). Glenfinnan bog (GF) previously had three pitcher plants, MacKinnon's bog (MK) had a single pitcher plant, and Wood Island bog (WI) had a natural population of pitcher plants prior to the transplant. ($\bar{x} \pm$ SEM; $n = 25$ for Glenfinnan bog in early August; $n = 15$ for all others).



Seasonal patterns in Clarkin bog

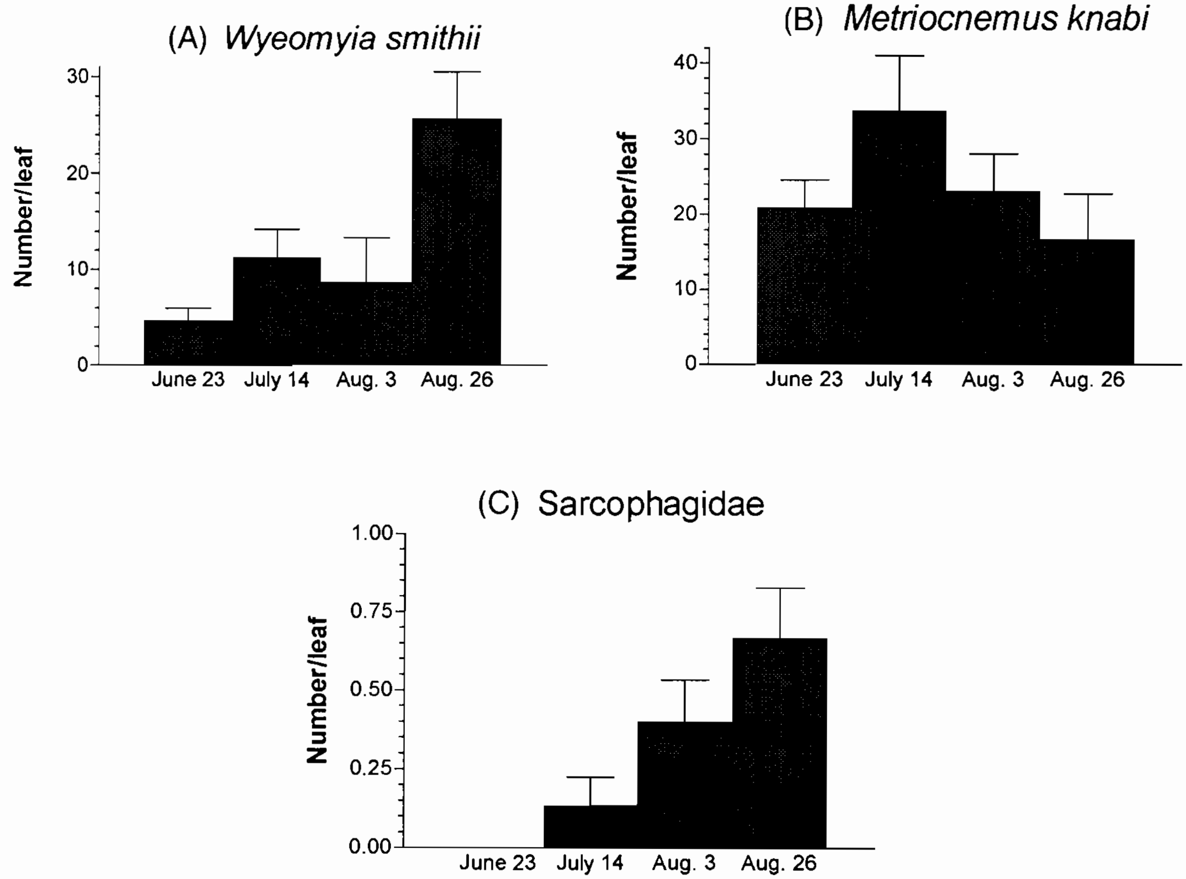
In Clarkin bog, *W. smithii* was found on all sampling dates but reached peak abundance late in the season (Fig. 4A). Mosquito abundance increased fivefold over the summer, ranging from 4.7 to 25.7 per leaf between 23 June and 26 August. Although most of the mosquitoes were either in their final larval instar or pupal stage on 23 June, they were present as early instars throughout the rest of the summer. *Metriocnemus knabi* was also found on each sampling date, and both larvae and pupae were abundant throughout the sampling period (Fig. 4B), with densities ranging from 17 to 34 larvae per leaf. Abundance peaked in mid-July, but differences in abundance were not significant over the sampling period (ANOVA, $p > 0.05$). Sarcophagid larvae were not found at Clarkin bog on 23 June, but increased in abundance over the sampling period, ranging from 0.13 to 0.67 per leaf (Fig. 4C).

Effects of transplanting on inquiline populations

Numbers of each of the inquilines were highly variable both within and among bogs, but *W. smithii*, *M. knabi*, and sarcophagid larvae were found in pitchers in all surveyed bogs with natural populations of pitcher plants. Overall densities, at least for *W. smithii* and *M. knabi*, were generally lower in the transplant-source bog (Miscouche) than in other bogs, although these differences were not statistically significant (ANCOVA, $p > 0.05$; Figs. 2A and 2B). However, in all cases the numbers of these inquilines in transplanted pitcher plants (Fig. 3) were lower than in nontransplanted plants in either the source bog (Fig. 3) or other island bogs (Fig. 2). *Wyeomyia smithii* was found in transplanted plants only in Wood Island bog (Fig. 3A), which supported a large natural population of pitcher plants prior to transplant; however, even in this bog, the numbers were far lower than in the source bog (Fig. 3A). *Wyeomyia smithii* was not found in transplanted plants at MacKinnon's bog or Glenfinnan bog. There was a significant effect of bog on mosquito abundance (ANOVA, $p < 0.001$), and abundance in the source bog was significantly different from that in the transplanted bogs (Tukey's comparison).

Metriocnemus knabi was found in all of the transplant bogs. At Wood Island bog (where there were many pitcher plants prior to transplant), midges were more abundant in transplanted pitchers than in the source bog (Fig. 3B). In contrast, abundance of *M. knabi* in the two bogs without previous natural populations of pitcher plants was much

Fig. 4. Seasonal patterns in densities of pitcher plant inquilines between June 23 and August 26, 1993, at Clarkin bog, PEI ($\bar{x} \pm$ SEM; n = 25 pitchers for the June 23 samples and n = 15 for all other samples).



lower than in the source bog (Fig. 3B). There was a significant effect of bog on midge abundance, both when transplant bogs were compared with all natural bogs and when they were compared with the source bog (ANOVA, $P < 0.001$).

Sarcophagid larvae were found in all of the bogs involved in the transplant (Fig. 3C) at densities that were comparable to those of natural populations at equivalent sampling times (Fig. 2C). When sampling date was considered, there were no significant differences in sarcophagid abundance between the source bog and the transplant bogs (ANOVA, $p = 0.67$).

Discussion

It is not possible to determine from our study exactly what effect the Miscouche bog transplant had on pitcher plant inquilines in this study because nothing is known about larval densities in the transplant plants prior to transplant. However, effects may be inferred by comparison with the source bog and with other bogs in the region. A major assumption in this study is that the population prior to transplant was similar to that found in the remaining plants in Miscouche bog, which was the source bog for the plants, during the study; in fact, densities of inquilines in Miscouche bog were consistent with those in most other bogs sampled on PEI.

Wyeomyia smithii

Wyeomyia smithii was rare or absent from plants in the transplant bogs, but was found in all of the bogs with natural pitcher plant populations at densities comparable to those found by Istock et al. (1975) for populations in Kennedy bog in Mendon, New York. Addicott (1974) reported that numbers of *W. smithii* were low in bogs containing few pitcher plants, even when these bogs were located close to others with high populations of both pitcher plants and mosquitoes. *Wyeomyia smithii* was absent from Glenfinnan and MacKinnon's bogs despite the large numbers of plants concerned in the transplant (50 and 161, respectively), suggesting that too few larvae may have survived the transplant procedure to maintain the population. Subsequently, the small population of *S. purpurea* in each bog prior to transplant (three plants in Glenfinnan and one plant in MacKinnon's) would not have provided colonizing mosquitoes from non-transplant plants. Surprisingly, populations were also low in transplanted pitchers in the bog that previously had a high natural population of pitcher plants (Wood Island bog). Therefore, colonization of new pitchers may be slow even when there is a source of colonists. *Wyeomyia smithii* preferentially oviposits in newly opened leaves (Farkas and Brust 1986*a*), therefore the timing of the transplant should have resulted in two periods (following the transplant but prior to sampling) when adults were on the wing and able to oviposit in transplanted plants (July 1992 and July 1993, prior to sampling). *Wyeomyia smithii* is reported to be a poor flier (Istock et al. 1983; Heard 1994*b*) and is also autogenous (non-blood-feeding), at least in the northern parts of its range (Istock et al. 1983), so adults have no need to fly in search of blood. Further, Wallis and Frempong-Boadu (1967) found that the adults were highly susceptible to desiccation and tended to remain very close to their home plants.

Seasonal information from Clarkin bog throughout the sampling period indicates that the 1991 transplant occurred when *W. smithii* should have been present as adults, eggs, or immatures. This seasonal pattern is similar to that reported by Mogi and Mokry (1980), who found that *W. smithii* oviposits from early to late July in Newfoundland. Wind and desiccation damage, and accidental spillage of the pitcher fluid, was noted during the transplant process (Warren and Waddell 1991, see footnote 2), suggesting that mortality of the larval inhabitants was likely. *Wyeomyia smithii* larvae live in the water column in the pitcher, and must rise to the surface to respire. Newly hatched mosquito larvae would have been particularly vulnerable to dessication, and by the time pitchers filled with fluid again in 1991, adults had likely completed oviposition, reducing the chances of recolonization in the first year following transplant.

Metriocnemus knabi

The densities of *M. knabi* in bogs not involved in the transplant were comparable to those found by Paterson and Cameron (1982) in New Brunswick. The relatively constant densities through the sample period, and the seasonal occurrence of the pupal stage, are consistent with the life cycle determined by Paterson and Cameron (1982). They found at least two cohorts present during all sampling periods, and concluded that the life cycle consisted of three generations within 2 years. Oviposition occurs in May, July, and August.

Metriocnemus knabi was found in all of the bogs sampled, including those receiving the transplants. They reached their highest abundance in transplanted plants in Wood Island bog, which had a large natural population of pitcher plants prior to the transplant. Three coastal bogs located in the northwest of PEI also showed a higher than average (based on other island bogs) abundance of pitcher plant midges, and this may have been related to the openness of the habitat.

Adults should have been present at the time of the transplant as well as later in the summer (Paterson and Cameron 1982), so they could have oviposited in transplanted pitchers throughout much of the summer of 1992, even if the larval stages were disrupted in the transplanted plants. In the transplant bogs without previous large pitcher plant populations (i.e., Glenfinnan and MacKinnon's bogs), *M. knabi* was present, but at a much lower abundance than that found in either the source bog (Miscouche) or any other bog on PEI. Midge larvae inhabit the layer of detritus located at the bottom of the pitchers, and do not respire at the water surface (Bradshaw and Creelman 1984). Therefore, as long as some dampness remained in the bottom of the pitchers, they may have been less likely to desiccate than the mosquito larvae. However, in pitchers that had lost most of their fluid, at increased density (per unit volume), midges could use up the available O_2, resulting in increased mortality (Cameron et al. 1977) and subsequent low densities in Glenfinnan and MacKinnon's bogs, where sources of colonists would be few. In contrast, a large natural population of pitcher plants in Wood Island bog may have provided a source of colonists for the transplanted plants.

Sarcophagid larvae

Sarcophagid larvae (probably *B. fletcheri*) were found in all of the bogs sampled, the differences in abundance being attributable to time of sampling. Forsyth and Robertson (1975) found that the *B. fletcheri* began larvipositing in early June in Kingston, Ontario, and reached peak larval density by late July. The phenology of the sarcophagid in PEI was such that life-cycle stages occurred later; no larvae were encountered earlier than 14 July, and larval density was highest at the end of August, on the last sampling date. Sarcophagid density was never more than one per leaf, which is consistent with previous findings (Forsyth and Robertson 1975; Fish and Hall 1978; Farkas and Brust 1986*b*). No transplant effect was noted on sarcophagid populations, though like mosquitoes, sarcophagid larvae are associated mainly with the water surface, where they feed on dead insects (Bradshaw and Creelman 1984). Although sarcophagid larvae were not found in pitchers on PEI until mid-July in this study, they should have been present as early-instar larvae or adults during the transplant period, and may have encountered the same difficulties in recolonization as *W. smithii* in the year of transplant. However, by the summer of 1993, their abundance in all transplant bogs was similar to that in other bogs in the region, suggesting that transport mortality was low or that sarcophagids may be better at colonizing new habitats than are mosquitoes.

Summary

We are not aware of any other studies addressing the transplant of entire microcosms for conservation purposes. Pitcher plant inquilines are believed to benefit the plant by increasing the rate of breakdown of the prey (Bradshaw and Creelman 1984) and by depositing excretory products in the fluid that provide nutrients to the plant (Paterson and Cameron 1982). Reduction in the number and diversity of pitcher plant inquilines caused by transplanting may have detrimental effects on the plant, and even result in lowered transplant success. Unfortunately, no rigorous follow-up studies have been conducted to determine the long-term success of transplanting these bog plants. However, future conservation efforts that include a transplant of pitcher plants, such as those proposed for other PEI bogs, should be timed to have the least effect on the inquilines involved, and care should be taken to avoid spillage of pitcher fluid during transport.

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