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Species Diversity and Emergence Patterns of Nematocerous Flies (Insecta: Diptera) from Three Coastal Salt Marshes in Prince Edward Island, Canada

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ABSTRACT: Emerging insects were monitored every 10 days between early May and late August 1993, from tidal pools in three coastal salt marshes on Prince Edward Island, Canada. The salt marsh pools ranged from about 1 m^2 to > 1,000 m^2 in surface area, and had salinities ranging from 11–27‰. Water temperatures through the study period ranged from 4–46°C. Most of the emerging insects were flies (Diptera; 85%), and two-thirds of these were in the sub-Order Nematocera, mainly Chironomidae, Ceratopogonidae, and Culicidae. Forty-three species of Nematocera were identified, although most of these were rare occurrences, and twelve of the species are undescribed. No consistent relationships were found between abundance or diversity and pool size or marsh for Nematocera species overall, although some species showed a statistical preference for a particular marsh or pool size. Emergence patterns were consistent between marshes for species found in different marshes, but overall patterns were highly variable, depending upon species.

Introduction

Coastal salt marshes are areas where marine and terrestrial habitats meet (Glooschenko et al. 1988; Adam 1990). They are generally restricted to temperate coastal zones (Vernberg 1993), and those that occur along the Atlantic coast have been widely studied with respect to their development, vegetation patterns, primary productivity, energy flow, and nutrient cycling (Reimold 1977; Long and Mason 1983; Roberts and Robertson 1986; Adam 1990; Vernberg 1993). Aquatic habitats associated with salt marshes, including tidal creeks, intertidal pools, and flooded marsh, may be highly variable with respect to temperature, salinity, and other parameters (Adam 1990). Salinity in salt marsh pools may vary from 0‰ to > 50‰ depending on tidal inundation and precipitation (Glooschenko et al. 1988). Although many macroinvertebrate groups have been studied in coastal salt marshes, relatively little data is available on the aquatic insects inhabiting saline pools within the marsh.

The aquatic insect component of saline pools has been generally undervalued in studies of salt marshes. The high intertidal and terrestrial portions of the marsh are dominated by a highly diverse community of terrestrial insects, often including the adults of insects that inhabit saline pools as larvae (Daiber 1977). The terrestrial insect community has been intensively studied in several locations, including North Carolina (Davis and Gray 1966), California (Cameron 1972), Maryland (Bickley and Seek 1975), and Florida (Rey and McCoy 1986). Studies of the aquatic invertebrates of the saline habitats have generally focussed on the marine invertebrates (e.g., the annelids, crustaceans, molluscs) and have under-reported the diversity of aquatic insects. These studies usually report low diversity, but high abundance and productivity (e.g., Cammen 1976; Bromley and Bleakney 1979; Kneib 1984; Rader 1984; Wenner and Beatty 1988; Sardá et al. 1995). Although they usually report marine invertebrates to species, the insects are identified to the order or family level only, with rare attempts at genus or genus-group identification. Many have also relied on sampling methods that are biased against aquatic Diptera, the dominant insect group in the marsh (LaSalle and Bishop 1987), since they incorporate large sieve sizes (≥ 500 μm) that allow most individuals to escape collection. Most of these studies are carried out during periods when many of the insects may be absent from the aquatic habitat and present as terrestrial adults. Even studies that have focussed on the aquatic insects in salt marshes have mainly limited identification to genus-level, because of the problems with identifying larvae (e.g.,

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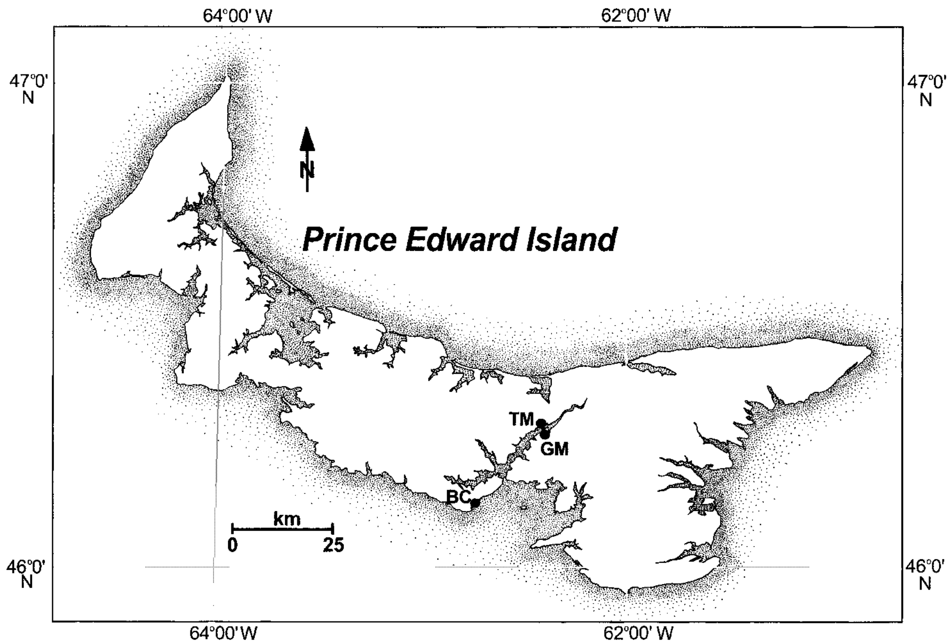

Fig. 1. Prince Edward Island, Canada, showing study sites. TM = Tenmile Marsh (46°19′N, 62°58.5′W); GF = Glenfinnan Marsh (46°18′N, 62°59′W); BC = Bacon Cove (46°09′N, 62°13.5′W).

Wall 1973; Ward and FitzGerald 1983; LaSalle and Bishop 1987; LaSalle et al. 1991). Aquatic insects are not only important as part of the aquatic food chain in the marsh, but may be critical as a source of energy transfer between the marsh and surrounding terrestrial habitat as they emerge (LaSalle and Bishop 1987).

Prince Edward Island (PEI) is located off the coast of eastern Canada. Nearly 1,000 salt marshes can be found along its coast, comprising an area of 2,767 ha (Wells and Hirvonen 1988). Many birds nest in and around the marshes and rely to varying degrees on insects produced in the marsh for food (Giberson and Burgess 1995). Because many PEI marshes are also breeding grounds for two species of salt marsh mosquito, they may be treated with *Bacillus thuringiensis* var. *israelensis* (*Bti*) (which targets nematocerous Diptera) to control the levels of nuisance mosquitoes (Giberson unpublished data). The objective of this study was to collect emerging adult insects from salt marsh pools in three coastal marshes in PEI to determine the diversity and emergence patterns of the salt marsh Nematocera community in marshes that have no history of *Bti* application, to provide baseline information for comparisons to treated marshes on PEI. We wished to determine whether species composition and diversity could be related to individual marshes or pool types.

Materials and Methods

Study Sites

The study marshes were all located on the south shore of Prince Edward Island, off the east coast of Atlantic Canada (Fig. 1). Sites were selected to be as similar as possible to each other with respect to vegetation patterns, overall marsh size, and number and size of saline pools, but with no history of mosquito control with *Bti.* Tenmile and Glenfinnan marshes are estuarine marshes and Bacon Cove is located on an open bay on the Northumberland strait between PEI and the mainland. The marshes were dominated by *Spartina alterniflora* in the lower marsh with *Spartina patens* also occurring especially in the middle and high marshes. All sampling was carried out in the salt marsh pools located in the middle to upper marshes. The pools were variable in size, ranging from small pothole-like pools with diameters of $\leq$ 1 m to large irregularly shaped pools with surface area of $\geq$ 1,000 m^2. At least one large (> 200 m^2), one medium (40–100 m^2), and two small (< 10 m^2) pools were monitored in each marsh.

Physical Habitat Data

Water temperature was monitored with maximum-minimum thermometers placed on the sediment surface in each marsh, one in a large pool and one in a small pool, and temperatures were recorded during each visit to the marsh (at least every 10 d, but more frequently during concurrent bird surveys; Giberson and Burgess 1995). The salinity of each pool was measured using a YSI salinity meter on each sampling date, but these salinity data were discarded after the discovery that the meter was not functioning properly. Reported salinity data are based on several years data collected subsequent to the study on several pools in each marsh, determined with a salinity refractometer. Pool size was determined by measuring directly for small pools, and with a polar planimeter from aerial photos for the large pools.

Aquatic Insects

Aquatic insects were monitored using cone-shaped emergence traps suspended over the marsh pools. Emergence trapping was chosen over benthic sampling to obtain adults which could be identified to species and to provide information on seasonal timing of emergence to the terrestrial habitat. These traps enclosed an area of 0.07 m^2 and consisted of a circular ring at the bottom attached to a fabric mesh (30 × 150 μm mesh size) that narrowed towards the top, to form a cone. The top of the cone was attached to a PVC tube inserted into a collecting jar filled with 70% ethanol. The entire trap was suspended from the top of a tripod, and the bottom of the trap was tied to the tripod legs below water level at low tide, slightly above the sediment level. As water levels fluctuated (either due to precipitation or tidal inundation) the traps remained stable and did not move up and down. Emerging insects would fly up the cone and become trapped in the ethanol in the collecting jar. Traps were set up so that they were over permanent water bodies, but were located close to shore so that traps could be emptied without disturbing marsh sediments. In most cases, that meant that traps were approximately 0.75 m from the pool edge, but in the case of some very small pools the traps were centered in the pool and trap-edges may only have been a few cm from shore. These traps may have missed species that emerged from the centre of large pools or those that migrate to shore to emerge in shoreline vegetation.

Ten traps were set up in each marsh, with 6 traps located in large pools, 2 in medium pools, and 2 in small pools (see Study Site section for definitions of pool sizes). The traps were placed in the marshes on May 8 and emptied at approximately 10-d intervals from May 18 to August 24, 1993 (giving 9 sampling periods throughout the summer); this sampling frequency was determined in preliminary sampling to provide suitable data for investigating emergence patterns. Traps were sampled by unscrewing the bottle from the suspension rope, and tipping the trap to empty the collecting bottle into a sample jar. The bottle was then refilled with 70% ethanol and resuspended.

TABLE 1. Surface area, salinity, and temperature of study pools in the three study marshes on PEI. Numbers in parentheses refer to number of traps located on each numbered pool.

	Bacon Cove	Glenfinnan Marsh	Tenmile Marsh
Surface area (m^2) pool			
1	2.3 (1)	10 (1)	2 (1)
2	4.8 (1)	10 (1)	2.5 (1)
3	42 (2)	82 (2)	65 (2)
4	4,844 (6)	243 (3)	533 (3)
5	—	255 (3)	714 (3)
Salinity range (‰) in pools			
Small	15–27	11–25	11-25
Large	15–23	11–19	11–19
Temperature range (°C) in pools			
Small	4–45	6–45	4–46
Large	6–42	8–36	na

Aquatic insects were initially sorted to Family, then the Nematocera (Diptera) were identified to lowest taxonomic level for analysis of emergence and habitat preference patterns (Specific references and characters used to identify each taxon group are available from the corresponding author). Emergence timing for individual taxa did not differ among marshes, so data from all marshes were combined to plot the emergence phenology for the dominant taxa in the three marshes. Abundance patterns among marshes and pool sizes were tested for dominant taxa using ANOVA (following normalization of data). Species similarity was evaluated for the entire Nematocera community using Cluster analysis (Pearson Clustering, complete linkage; Systat, version 8.01). Diversity patterns were evaluated by calculating Shannon diversity ($H' = -\Sigma p_i \log p_i$, where p_i = importance proportion in column i; PC-ORD version 4), species richness (S = total number of species), and evenness ($H'/\ln S$; PC-ORD version 4). Voucher specimens for this study have been retained by Bohdan Bilyj, in his permanent collection.

Results and Discussion

Physical Data

Surface area, salinity, and temperature for each marsh pool sampled are summarized in Table 1. The large pools appear to dominate the marshes because of their large open water areas, but small and medium pools were also very abundant in the salt marshes. Small pools showed higher fluctuations and greater extremes in both temperature and salinity than did large pools.

Specific salinity patterns in the study pools during the sampling period are not available due to a meter malfunction, but regular measurements were collected in the pools between 1994–1997. Sa-

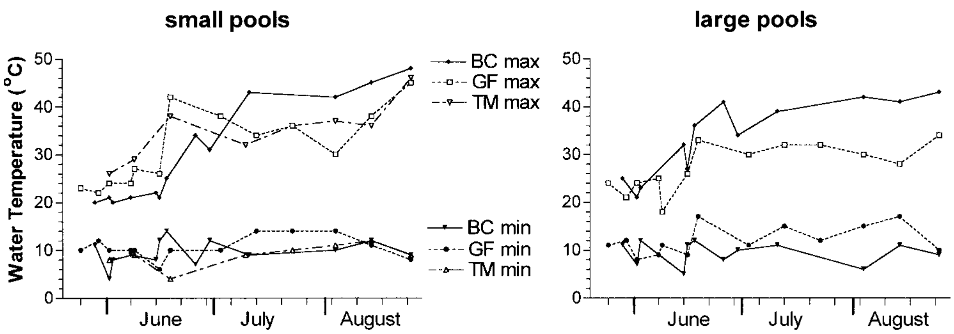

Fig. 2. Temperature patterns in salt marsh pools in three PEI salt marshes, summer 1993, as recorded from maximum-minimum thermometers placed into pools in each marsh. Min refers to the minimum temperature encountered during the study interval and max is the maximum temperature. TM = Tenmile marsh; GF = Glenfinnan marsh; BC = Bacon Cove. Data for large pools in Tenmile Marsh are missing due to loss of those thermometers early in the season.

linity patterns within a marsh zone were generally consistent between similarly sized pools on a given date but tended to fluctuate widely between dates (Giberson unpublished data). Salinity measurements in the PEI marshes ranged between 11‰ and 27‰, with greater fluctuations noted in small pools than in large ones. These values are similar to those reported in Quebec by Ward and FitzGerald (1983) but are somewhat lower than reported in the salt marsh pools along the southern Atlantic coast; Wall (1973), Campbell and Denno (1978), and Robert and Matta (1984) reported salinities to 32‰, 39‰, and 50‰, respectively. Unlike southern coastal marshes, where tides and evaporation are major factors influencing salinity in the upper marsh, northern Atlantic coastal marshes are dominated by the freshwater table, and salinity may decrease at low tide even without precipitation inputs (Wells and Hirvonen 1988).

The spring of 1993 was unusually cool in Atlantic Canada and was characterized by generally low air temperatures persisting well into June. Water temperatures followed a similar pattern, but also varied with pool size. Small pools were warmer than large ones and fluctuated more widely (Table 1 and Fig. 2). All pools showed extremely high temperatures later in the summer, with some small pools reaching 48°C. These temperature values may not reflect the temperatures that the insects in the sediment were actually experiencing since Ward and FitzGerald (1983) showed that sediment temperatures may be much less extreme and fluctuate less than temperatures in the overlying surface water in salt marsh pools in Quebec.

TABLE 2. Community structure patterns in pools in three Prince Edward Island salt marshes, summer 1993.

Marsh and Pool Size Class	Species Richness (no. of Nematocera species)	Species Evenness	Shannon Diversity
Bacon Cove: Total	23	0.659	2.067
Small	11	0.436	1.046
Medium	17	0.694	1.966
Large	13	0.615	1.578
Glenfinnan Marsh: Total	21	0.638	1.941
Small	12	0.705	1.751
Medium	12	0.705	1.751
Large	10	0.597	1.374
Tenmile Marsh: Total	28	0.728	2.425
Small	21	0.723	2.2
Medium	16	0.654	1.812
Large	8	0.833	1.732

Community Patterns

Tenmile marsh had the highest Nematocera species diversity, followed by Bacon Cove, and Glenfinnan marsh (all diversity indicators; Table 2). The diversity indicators were also evaluated for each pool size, to test the hypothesis that species diversity and abundance of the macrobenthos in salt marshes would be affected by pool size, as a function of species/area or stability relationships. Ward and Fitzgerald (1983) found no relationship between richness and pool size among small, medium, and large-sized pools in a Quebec, Canada salt marsh. Because we frequently observed fish in medium and large pools, but not in small ones, we expected differences in abundance and diversity. We found no consistent relationship between pool size and abundance or any of the diversity measures within a marsh (Table 2 and Fig. 3a). Some other community patterns, though, could be attributed to pool size. Although most species were quite evenly distributed among all pool sizes, a few species showed a statistical preference for a particular pool size. Species composition was the variable that showed the strongest relationship with pool size when it was compared among marshes and pool sizes using Cluster analysis (Fig. 3b). For two of the marshes (Tenmile marsh and Bacon Cove), the small and medium sized pools clustered together indicating relatively high species similarity.

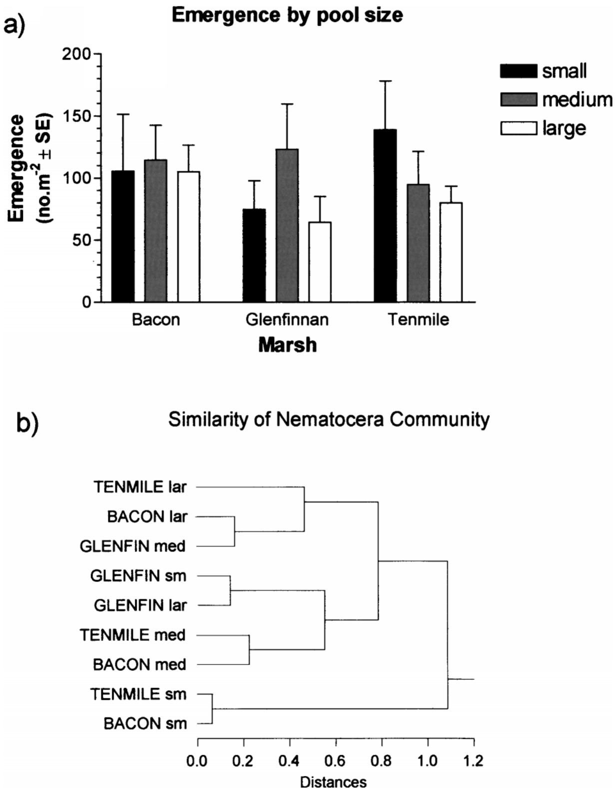

Fig. 3. Abundance and species patterns among different pool sizes in the three marshes: a) emergence density by pool size in each marsh (no. m^{-2}, calculated as mean for the entire sampling season) and b) cluster analysis showing similarity of the species composition in each pool in each marsh.

Large pools from Tenmile and Bacon Cove also clustered together, but this cluster also included the medium-sized pools from Glenfinnan. Small and large pools clustered together at Glenfinnan. These data suggest that Tenmile and Bacon Cove marshes were more similar to each other than to the Glenfinnan marsh. Tenmile and Glenfinnan are estuarine marshes, located just across from each other on the same tidal river and were expected to be more similar to each other than to Bacon Cove, the marsh on the open coastal bay (Fig. 1).

Species Patterns

Eighty-six percent of the emerging insects in the salt marshes were flies (Diptera) and two-thirds of these were Nematocera. At least 43 species of nematocerous Diptera were identified in 7 families and 23 genera in the three study marshes (Table 3), confirming our premise that family-level or genus-level identification drastically under-represents species diversity for this group. Several of the taxa could not be reliably identified to species due to presence of females only (for which keys are not usually available) or because the genus is in need of revision, but all could be separated with respect to species grouping. At least 12 species (9 chironomids, including 5 in the genus *Pseudosmittia,* 1 in the genus *Smittia,* and 3 in the genus *Tanytarsus*; and 3 ceratopogonids in the genus *Dasyhelea*) have not been described previously. Most of the Nematocera taxa represented rare occurrences with 31 of the taxa each making up less than 1% of the total, and 10 species making up > 90% of the total abundance of emerging Nematocera. Individual patterns for common Nematocera taxa are treated below, and additional taxonomic and ecological notes are available from the corresponding author.

Chironomidae, Orthocladiinae

Cricotopus sylvestris is widespread in fresh and salt water habitats throughout the northern hemisphere, occurring in North America, Europe, and Asia (Ashe and Cranston 1991). This species made up about 2% of the emerging Nematocera in the PEI salt marshes (Table 3). Although it did not show any significant differences in abundance among marshes (Fig. 4), it was most common in medium sized pools (Fig. 5). It generally emerged throughout the spring and summer in PEI, declining by early August (Fig. 6). Menzie (1981) reported this species to be the dominant chironomid in a study of a brackish cove (salinity 0–6‰) along the Hudson River, New York, where it emerged between May and October with a peak in July. Colbo (1996) also found *C. sylvestris* to be important in Newfoundland coastal rock pools with a salinity range of 0–6‰.

Halocladius variabilis has been reported from North America, Greenland, and Europe (Ashe and Cranston 1991). It is a halophilous species that commonly inhabits coastal waters (Cranston et al. 1989) and has been reported from intertidal rock pools (Colbo 1996). Hirvenoja (1973) reported a univoltine emergence period (May–June) on the southern coast of Finland and a bivoltine pattern on the west coast of Norway (emergence April–May and then June–July). This species made up less than 1% of the emerging nematocera in the PEI salt marshes, but was found in each marsh (Table 3), with no differences among pool sizes. Half of the 7 specimens collected were found between May 18 and June 18 and the other half were found between July 9 and August 3, suggesting that a bivoltine cycle may also be operating in PEI.

Limnophyes asquamatus has been reported from North America, Greenland, Europe, and the far East (Wang and Sæther 1993). This is the first record for the maritime provinces of Canada. The adults have been collected from or near freshwater habitats, especially lakes (Brundin 1947; Sæther 1969, 1975; Tuiskunen and Lindeberg 1986 [as *L.*

TABLE 3. Total numbers of Nematocera emerging from the three study marshes in Prince Edward Island, May 8 to August 28, 1993 (10 traps per marsh, trap size 0.07 m²).

Species	Bacon Cove	Glenfinnan Marsh	Tenmile Marsh	Totals
CHIRONOMIDAE, Orthocladiinae,				
Bryophaenocladius sp.	1	0	0	1
Corynoneura sp. 1	0	1	0	17
Corynoneura sp. 2	0	0	1	1
Cricotopus (*Isocladius*) *sylvestris*	15	18	5	38
Halocladius (*Halocladius*) *variabilis*	1	3	3	7
Limnophyes asquamatus	97	117	155	369
Pseudosmittia sp. 1	0	3	0	3
Pseudosmittia sp. 2	1	0	0	1
Pseudosmittia sp. 3	2	0	1	3
Pseudosmittia sp. 4	0	1	0	1
Pseudosmittia sp. 5	2	0	0	2
Smittia sp. 1	1	0	0	1
CHIRONOMIDAE, Chironominae, Chironomini	92	46	84	222
Apedilum elachistus				
Chironomus (*Chironomus*) *plumosus*	2	91	18	111
Chironomus (*Chironomus*) *riparius*	0	2	4	6
Dictrotendipes modestus	89	14	93	196
Glyptotendipes (*Glyptotendipes*) sp.	0	0	1	1
Lauterborniella agrayloides	0	1	0	1
Polypediulum (*Tripodura*) sp.	0	0	1	1
CHIRONOMIDAE, Chironominae, Tanytarsini				
Paratanytarsus laccophilus	0	0	10	10
Paratanytarsus sp.	0	1	2	3
Tanytarsus sp. 1	1	0	15	16
Tanytarsus sp. 2	4	0	3	7
Tanytarsus sp. 3	50	0	6	56
CERATOPOGONIDAE, Forcipoyiinae				
Atrichopogon jamnbacki	16	12	2	30
Atrichopogon sp.	0	2	1	3
Forcipomyia (*Forcipomyia*) sp.	0	1	13	14
CERATOPOGONIDAE, Dasyheleinae				
Dasyhelea grisea	140	149	77	289
Dasyhelea mutabilis group	9	12	17	98
Dasyhelea pseudocincta	2	17	14	36
Dasyhelea sp. 1	0	0	9	14
Dasyhelea sp. 2	1	2	0	3
Dasyhelea sp. 3	1	0	0	1
CERATOPOGONIDAE, Ceratopogoninae				
Bezzia cockerelli	1	0	0	1
Brachypogon (*Isohelea*) sp.	2	0	0	2
Culicoides hollensis	32	1	5	38
CULICIDAE,				
Aedes cantator	135	3	67	205
Aedes sollicitans	0	0	1	1
TIPULIDAE,				
Limonia (*Dicranomyia*) *brevivena*	2	0	1	3
Pseudolimnophila noveboracensis	0	0	1	1
CECIDOMYIIDAE	6	2	4	12
PSYCHODIDAE	1	0	0	1
SCIARIDAE	14	2	2	18
Total	720	501	611	1,832

smolandicus]; Cranston and Oliver 1988 [as *L. hamiltoni*]). This is the first record of *L. asquamatus* from coastal salt pools, although an unidentified species of *Limnophyes* was collected from oligohaline tidal marshes in Mississippi (LaSalle and Bishop 1987). Larvae in that study preferred pools with a salinity of 0–6‰ and achieved their greatest density in March. *L. asquamatus* was the most common species of nematocera in the PEI salt marshes (Table 2), and showed no significant preference for marsh (Fig. 3) or pool size (Fig. 4). The species was an early summer species with most of the emergence occurring between May 18 and June 8 in all marshes (Fig. 5).

Chironomidae, Chironominae, Chironomini

Apedilum elachistus is widely distributed in the United States, occurring from California to Florida

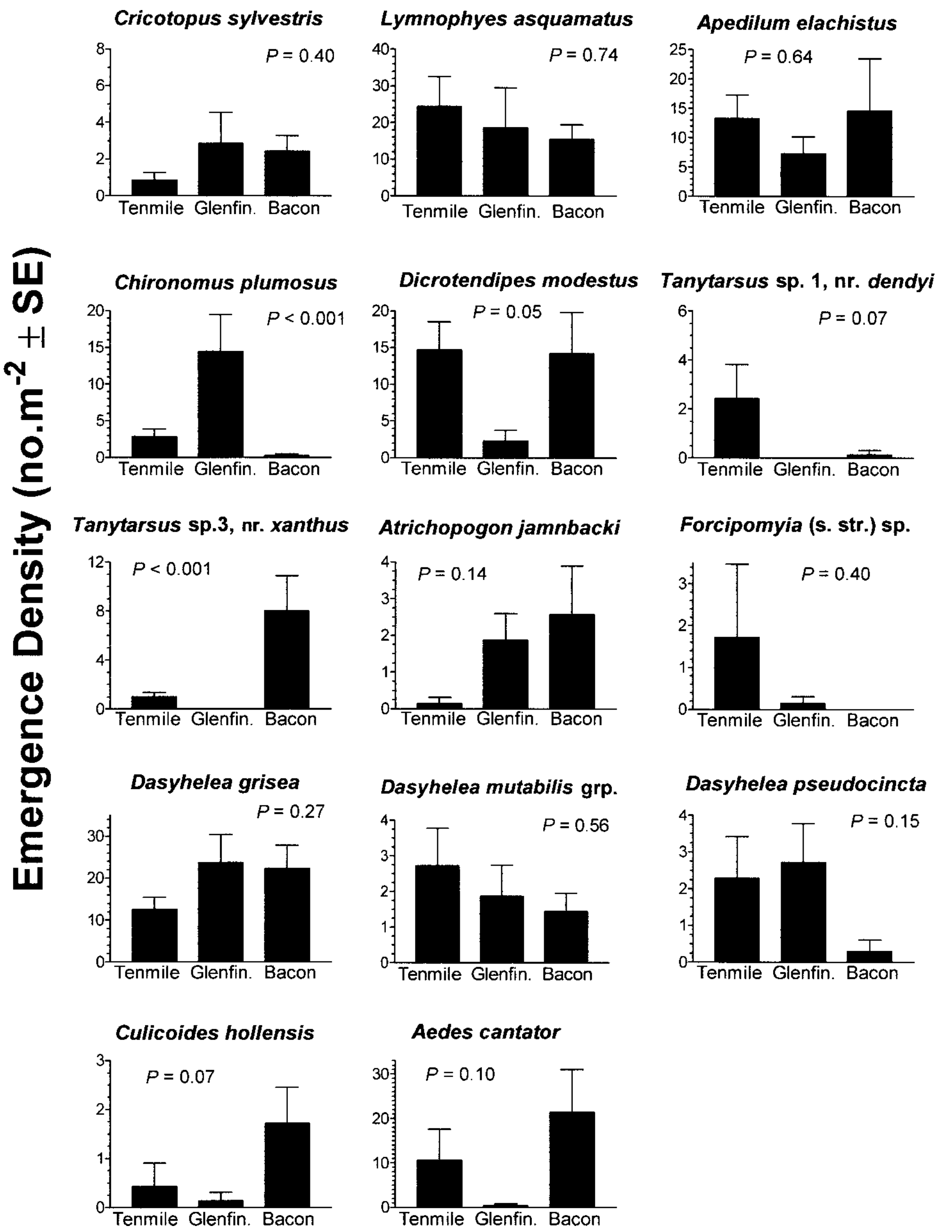

Fig. 4. Emergence densities (no. m^{-2}, calculated as mean for the entire sampling season) of dominant Nematocera in three Prince Edward Island salt marshes, summer 1993 (p values derived from ANOVA).

and north to Massachusetts (Oliver et al. 1990). It has also been identified from Mexico (Bilyj unpublished data) and Brazil (Nolte 1995), but this is the first published record for Canada. It was one of the most common species of Nematocera found in the three study marshes (Table 3), and there were no differences in abundance among marshes (Fig. 4). Epler (1988) has recorded the larvae of this species from both fresh and brackish water. Nolte (1995) found it to be a common opportunistic species in ephemeral freshwater rock pools, where it was able to complete its development in < 7 d. In the PEI saltmarsh pools, it showed an apparent (but not statistically significant) preference for the larger and more stable pools (Fig. 5). Gerry (1954) recorded it as a pestiferous species from a brackish pond in Massachusetts with nearly continuous emergence from May to mid October and three main emergence peaks (May, July, and late August). *A. elachistus* emerged throughout the summer in PEI with the main peak in early August (Fig. 6).

Chironomus plumosus has a global distribution and has been reported from Europe, Russia, Asia,

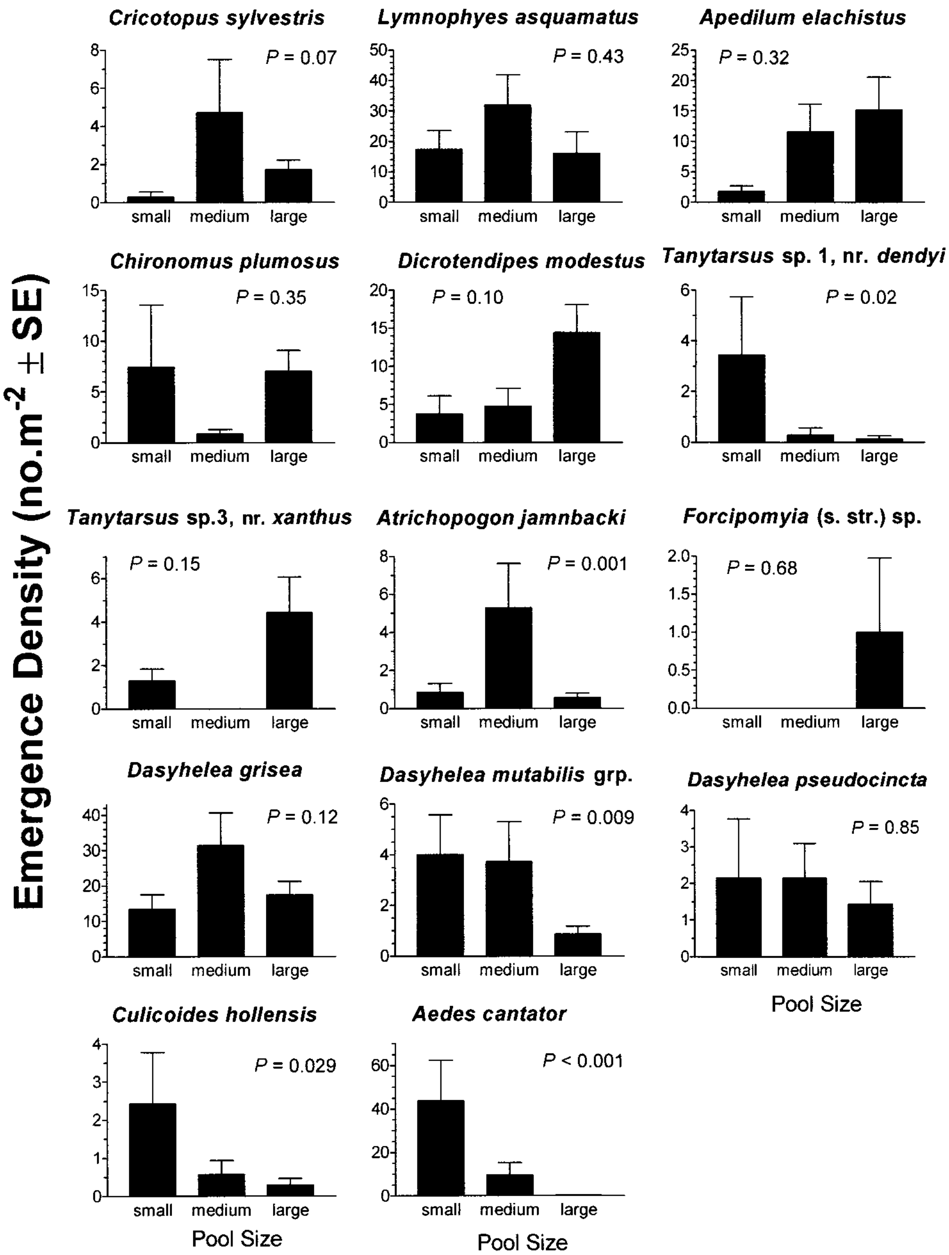

Fig. 5. Emergence densities (no. m^{-2}, calculated as mean for the entire sampling season) of dominant Nematocera in different sized pools in PEI salt marshes, summer 1993 (p values derived from ANOVA).

Africa, Canada, and the U.S. (Oliver et al. 1990 [Neotropical region]; Ashe and Cranston 1991). It is generally considered to be a freshwater species but has been reported from brackish waters near the Baltic Sea (Thienemann 1954) and in North America (Cannings and Scudder 1978; salinity range 0.4–3‰). Larvae are generally reported from lake sediments, where the 2nd to 4th instar larvae construct U-shaped burrows in soft mud, and in Wisconsin, 2 generations occur each year with peak emergences in May and July–August (Hilsenhoff 1966). *C. plumosus* was found in all the study marshes (Table 3), but was significantly more common in Glenfinnan Marsh than the other locations (Fig. 4), and showed no statistical preference for pool size (Fig. 5). Emergence occurred throughout the summer with peaks in mid June and late August (Fig. 6).

Chironomus riparius is a widely distributed Holarctic species that has been reported from Canada, the U.S., and Greenland (Oliver et al. 1990), and Europe and Asia (Ashe and Cranston 1991). Spies

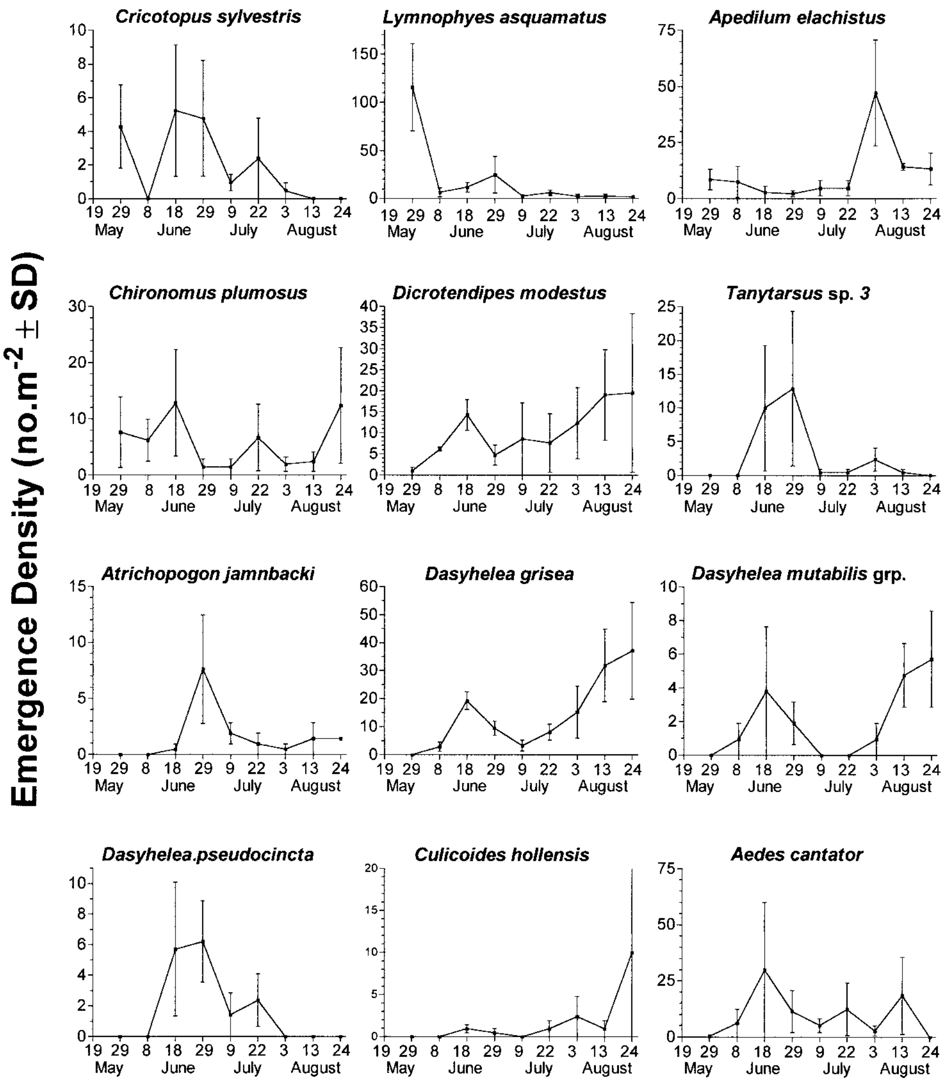

Fig. 6. Emergence phenologies (no. m^{-2} ± SD, on each sampling date) of dominant Nematocera in three Prince Edward Island salt marshes, summer 1993.

and Reiss (1996) also tentatively list the species from Argentina and the Virgin Islands. This species is considered to be one of the important indicator species of polluted waters and is used in laboratory cultures to assess biological tolerance to various harmful contaminants, so it may also be tolerant of relatively high salinity conditions. Colbo (1996) collected it from Newfoundland coastal rock pools with a salinity range of 0–5‰, and other researchers have reported unidentified *Chironomus* species in salt marshes in Quebec (Ward and Fitzgerald 1983) and Massachusetts (Wall 1973). *Chironomus* (s. str.) *riparius* is common in mud-bottomed streams, ponds, and the shallow margins of eutrophic lakes and is univoltine in Alberta with a spring emergence (Rasmussen 1984). In PEI, it was found in the two estuarine study marshes (Table 3), over a wide range of pool sizes, with scattered emergence occurring over the entire summer.

Dicrotendipes modestus is a widely distributed Holarctic species whose distribution includes Canada, the U.S., and Greenland (Oliver et al. 1990), and Europe and Asia (Ashe and Cranston 1991). Epler (1987) reported that larvae are most common in freshwater lentic habitats or slow moving portions of large rivers, but also collected larvae in silken cases attached to *Typha* in brackish water. Menzie (1980) found it in the sediments of an estuarine cove in New York, where salinities ranged from 0–6‰. The species was found in all three study marshes in PEI (Table 3), but showed significantly lower abundance in Glenfinnan Marsh than the other two sites (Fig. 4) and no significant pattern with pool size (Fig. 5). Menzie (1980) reported continuous emergence with peaks in June, July, and September in New York with emergence numbers declining as the season progressed. The opposite pattern was seen in PEI with emergence numbers increasing over the season, and two peaks could be identified: one in June and the other in August (Fig. 6).

Chironomidae, Chironominae, Tanytarsini

Paratanytarsus laccophilus is widely distributed in Europe (Ashe and Cranston 1991) and has been reported from North Korea (Reiss 1980) and North America (Oliver et al. 1990). This appears to be the first record for the maritime provinces of Canada. The larvae are found in shallow waters such as ponds, ditches, and the littoral zones of lakes (Reiss and Säwedal 1981), and have not been reported from brackish or saline waters, but larvae of an unknown *Paratanytarsus* were collected from brackish rock pools off the coast of Newfoundland (Colbo 1996) and from saline lakes in Saskatchewan (TDS from 3.2–14.0 g l^{-1}; Timms et al. 1986). The species was restricted to Tenmile Marsh in this study (Table 3), where it showed no significant pattern of abundance with pool size.

Three previously undescribed *Tanytarsus* species belonging to the *mendax* group were found in the study marshes, and all were restricted to Bacon Cove and Tenmile Marshes (Table 3). *Tanytarsus* sp. 1 was most common in Tenmile marsh (Fig. 4) where it preferred small pools (Fig. 5), and *Tanytarsus* sp. 3 was most common in Bacon Cove (Fig. 4) showing no significant pattern with pool size (Fig. 5). *Tanytarsus* sp. 2 was not as common and was found in approximately equal numbers in both marshes (Table 3). Both *Tanytarsus* sp. 1 and *Tanytarsus* sp. 2 emerged between early July and early August, compared to *Tanytarsus* sp. 3 (Fig. 6), which emerged in late June. Reiss and Fittkau (1971) report that the larvae of species within the *mendax* group inhabit shallow eutrophic lentic waters of various sizes.

Ceratopogonidae, Forcipomyiinae

Larvae of this sub-family are usually terrestrial or semi-aquatic and are often found among moist mosses or under bark (Downes and Wirth 1981). *Atrichopogon jamnbacki* has been reported from Nova Scotia south to North Carolina and is restricted to salt marshes (Wirth 1994). *A. jamnbacki* was most common in Glenfinnan and Bacon Cove marshes in PEI (Table 3), but abundance differences among marshes were not significant (Fig. 4), and the species showed a definite preference for medium sized pools (Fig. 5). The species was found throughout the summer, but showed a peak in emergence during the latter part of June (Fig. 6). Other species of *Atrichopogon* may also be found in salt marshes as well (e.g., Massachusetts; Wall 1973), and females of another *Atrichopogon* were found in Glenfinnan and Tenmile Marshes (Table 3), but could not be identified to species. All three specimens were found in traps over small pools, but those in Glenfinnan emerged in early June, and the one from Tenmile Marsh emerged in late August.

Forcipomyia females cannot be confidently identified except in a few species. The species found in PEI marshes was most common in Tenmile marsh, was absent in Bacon Cove (Table 3) and was only found in large pools (Fig. 4). All specimens from the study marshes were collected in late August. *Forcipomyia* may visit flowers, but females require a blood meal to mature their eggs, so will bite vertebrates, mainly mammals and birds (Downes and Wirth 1981).

Ceratopogonidae, Dasyheleinae

Larvae of the Dasyheleinae are often found in restricted habitats like rock pools and tree holes (Downes and Wirth 1981). Several species were found in the genus *Dasyhelea,* including three undescribed ones. This genus is poorly known, and the presence of undescribed species is not surprising (Borkent personal communication). Female *Dasyhelea* adults are common on flowers where they take nectar, but have non-biting mouthparts (Downes and Wirth 1981). *Dasyhelea pseudocincta* has previously been reared from salt marshes (Waugh and Wirth 1976), and an unidentified species of *Dasyhelea* was found in a Massachusetts salt marsh (Wall 1973). *Dasyhelea grisea* has been reported from California to Quebec and south to Texas and Florida (Waugh and Wirth 1976) where adults have been reared from blanket algae in ponds and from lake edges. *Dasyhelea mutabilis* is a species complex with a number of species and has been previously reared from swamps and sphagnum bogs (Waugh and Wirth 1976). *Dasyhelea* sp. 1 was restricted to Tenmile Marsh (Table 3), where it was found in small and medium sized pools between mid June and early August. *Dasyhelea* sp. 2 was rare, found in Bacon Cove and Glenfinnan marshes (Table 3) between mid June and mid July over a range of pool sizes. *Dasyhelea* sp. 3 was represented by a single individual from a large pool in Bacon Cove (Table 3) in mid June.

D. grisea was very common in all of the three PEI marshes (Table 3 and Fig. 4) and showed no significant preference for pool size (Fig. 5). They emerged throughout most of the summer, but there were two main emergence peaks, the first in mid June and the second in late August (Fig. 6). The individuals in the *D. mutabilis* group were present, but not common, in all three marshes (Table 3) and showed a significant preference for small and medium sized pools (Fig. 5). They also showed two emergence peaks in mid June and late August (Fig. 6). *D. pseudocincta* was most common in the two estuarine marshes (Glenfinnan and Tenmile; Table 3), though these abundance patterns were not significant (Fig. 4), and no pattern was seen with pool size (Fig. 5). *D. pseudocincta* had a single emergence peak in June and July (Fig. 6).

Ceratopogonidae, Ceratopogoninae

Culicoides hollensis has been reported from New Brunswick and Nova Scotia south to Mississippi and Florida (Blanton and Wirth 1979). It is restricted to salt marshes and will bite humans, often in huge numbers (Blanton and Wirth 1979). It was relatively common in Bacon Cove in this study, but rare in the estuarine marshes (Table 3 and Fig. 4), and it showed a significant preference for small pools (Fig. 5). Wall (1973) reported *C. hollensis* in a Massachusetts salt marsh, and Ward and Fitzgerald (1983) reported an unidentified *Culicoides* species in salt marsh pools in Quebec. In PEI, *C. hollensis* began emerging in early June, but emergence was low until a peak late in the summer. Campbell and Denno (1978) found a similar pattern in a New Jersey salt marsh, where larvae were abundant in early spring and then disappeared. In Mississippi, LaSalle and Bishop (1987) found a larval pattern for this species in two oligohaline tidal marshes suggestive of two emergence peaks: one in spring and one in fall. *Culicoides* may visit flowers, but females require a blood meal to mature their eggs, so will bite vertebrates, mainly mammals and birds (Downes and Wirth 1981).

Family Culicidae

Two species of mosquito were found in the PEI salt marshes, *Aedes cantator* and *Aedes sollicitans,* but *A. sollicitans* was extremely rare in the PEI marshes during this study (Table 3). Both species are important pests, and some salt marshes in PEI are regularly treated with *Bti* to control their numbers (Giberson unpublished data). *A. cantator* is found along the Atlantic coast of North America from Newfoundland south to Virginia, and also in saline pools in inland New York (Wood et al. 1979). *A. sollicitans* is found along the Atlantic coast of North America from New Brunswick to Texas and the West Indies, and in isolated inland stations through to the midwest states (Wood et al. 1979). *A. cantator* was most common in Bacon Cove and Tenmile marshes (Table 3 and Fig. 4), where it preferred the small pools (Fig. 5). Mosquito larvae differ from most of the other Nematocera larvae found in the marshes by feeding in the pelagic zone, so they are highly susceptible to predation. Small fish were frequently observed in the larger pools during this study, and these may have controlled the mosquito numbers. Two main emergence peaks were noted (Fig. 6): one in mid June and the other later in the summer, although emergence occurred throughout the summer.

Other Families

Two tipulid species were found, *Limonia* (*Dicranomyia*) *brevivena* in Bacon Cove and Tenmile marshes, and *Pseudolimnophila noveboracensis* in Tenmile marsh (Table 3), but both were too rare to form any conclusions about pattern. *Limonia* (*Dicranomyia*) is known from intertidal zones or brackish water on the Atlantic Coast (Alexander and Byers 1981). Three other families of Nematocera were represented in the salt marshes, but were present in low numbers, and could not be reliably identified with available taxonomic literature. These were the Cecidiomyiidae, Psychodidae, and Sciaridae (Table 3).

Summary

Pools in Atlantic salt marshes are generally believed to harbor a low diversity community with a few species of Annelid (oligochaetes and polychaetes) dominating the fauna. This study illustrates how the aquatic insect diversity in salt marshes may be underestimated if identifiable stages are not collected and if seasonal emergence patterns which affect benthic abundance patterns are not considered. Studies which report the Diptera only to the family level (or rarely to the genus or genus-group level) will drastically underestimate species diversity in these habitats. Nematocera diversity and abundance patterns were generally similar between study marshes on PEI and showed no consistent pattern with marsh or pool size, despite predictions that diversity and abundance would be higher in larger, more stable pools.

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