J. Acad. Entomol. Soc. 3: 7-27 (2007)

Mosquito species composition, phenology and distribution (Diptera: Culicidae) on Prince Edward Island

Donna J. Giberson, Kathryn Dau-Schmidt, and Michelle Dobrin

Abstract: Recent concerns about the spread of the mosquito-borne West Nile Virus (WNV) through North America have prompted a number of regional studies of mosquito species composition and distribution. In this study, we report on intensive surveys of mosquitoes on Prince Edward Island (PEI). Larvae were collected by sampling standing water habitats (ponds, ditches, puddles, containers) along roadsides throughout the province, using a 0.5L dipper. Adults were collected through a combination of larval rearing, light trapping, and conducting landing surveys. Results of the study nearly doubled the known species numbers for the province from 18 to 32, and yielded information on larval habitats and adult flight periods. The different collection methods yielded very different results, indicating the importance of combining sampling methods to conduct a full species survey. For example, three species collected as adults were not collected as larvae, and four were collected only as larvae. Eleven species dominated the Island-wide fauna, including the salt marsh mosquitoes (*Ochlerotatus cantator and Oc. sollicitans*) which made up about half of the mosquitoes collected and were among the most aggressive biters. Twenty-two of the 32 species were attracted to humans with five (*Oc. abseratus/punctor, Oc. cantator, Oc. sollicitans, Oc. stimulans, and Coquillettidia perturbans)* making up ~80% of those that landed and attempted to bite. The *Culex* species (*Cx. pipians* and *Cx. restuans)* that have been identified as important enzootic vectors of WNV are reported on PEI for the first time, but their abundance is relatively low suggesting a low risk of WNV on PEI.

Résumé : Les inquiétudes soulevées récemment par la dissémination par les moustiques du virus du Nil occidental (VNO) en Amérique du Nord sont à l'origine d'un certain nombre d'études régionales de la composition et de la répartition des espèces de moustiques. Le présent rapport fait état des relevés intensifs des moustiques effectués à l'Île-du-Prince-Édouard (Î.-P.É.) dans le cadre de notre étude. Nous avons utilisé une louche de 0,5 L pour prélever des échantillons dans des habitats d'eau stagnante (étangs, fossés, mares, contenants) en bordure des routes dans toute la province et récolter des larves. Les adultes ont été récoltés à l'aide de diverses méthodes combinées : élevage de larves, pièges lumineux et relevés terrestres. L'étude a presque fait doubler le nombre d'espèces connues dans la province, le faisant passer de 18 à 32, et a fourni des données sur les habitats larvaires et les périodes d'envol des adultes. Les diverses méthodes de collecte ont donné des résultats très différents, une constatation soulignant l'importance de combiner des méthodes d'échantillonnage pour effectuer un relevé exhaustif des espèces. Ainsi, trois espèces ont été récoltées au stade adulte mais non pas au stade larvaire, et quatre espèces n'ont été récoltées qu'au stade larvaire. Onze espèces dominaient la faune insulaire, y compris les moustiques des marais salés (*Ochlerotatus cantator* et *O. sollicitans*) qui représentaient près de la moitié des moustiques récoltés et faisaient partie des insectes piqueurs les plus voraces. Vingt-deux des 32 espèces étaient attirées par l'homme, cinq d'entre elles (*O. abseratus/punctor, O. cantator, O. sollicitans, O. stimulans* et *Coquillettidia perturbans)* constituant environ 80 % de celles qui ont été capturées sur terre et ont tenté de piquer. C'est la première fois que des espèces de *Culex* (*C. pipians* et *C. restuans)*, qui ont été identifiées comme d'importants vecteurs enzootiques du VNO, sont signalées à l'Î.-P.-É., mais leur abondance est relativement faible, laissant supposer que le risque de transmission du VNO est faible à l'Î.-P.-É

Received 22 March 2007. Accepted 31 May 2007. Published on the Acadian Entomological Society website at http://www.acadianes.org/journal on 7 August 2007.

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INTRODUCTION

Mosquitoes (Culicidae) are one of the best known groups of Diptera, due to their importance in disease transmission as well as their nuisance value. However, before the emergence of West Nile Virus (WNV) in North America, relatively little was known about the species composition, distribution and phenology of mosquitoes in eastern Canada, including the island province of Prince Edward Island (PEI). Prince Edward Island is a large (5660 km^2) island in the Gulf of St. Lawrence, located off the coasts of New Brunswick and Nova Scotia. Approximately 400 km^2 of wetlands, including bogs, fens, fresh marshes, and salt marshes, occur on PEI, making up ~7% of the provincial land mass, with a further 40% of the land mass under agricultural production and ~45% in forest (PEI Agriculture and Forestry 2000). Fifteen mosquito species were reported on PEI by Twinn (1953), and the last comprehensive guide to mosquitoes in Canada (Wood et al. 1979) listed only 17 species on PEI. An eighteenth species, the pitcher plant mosquito, *Wyeomyia smithii*, was reported on PEI by Hardwick and Giberson (1996).

In 1952, C. Twinn travelled to PEI from Ottawa to investigate reports of nuisance mosquitoes in and near Prince Edward Island National Park (hereafter referred to as the National Park), supplementing previous work he had done on PEI in 1940 (Twinn 1953). His report (Twinn 1953) provides a summary of the problem from the PEI innkeepers association in 1952: "Our beaches are outstanding and safe, the temperature of the water ideal, we have some nice playgrounds, but on certain days no one can enjoy any of those facilities on account of the mosquitoes.". Despite more than 50 years of control attempts on PEI, nuisance mosquitoes continue to be a problem, prompting frequent news reports about the negative impact of the mosquitoes on the tourism industry (e.g., Eco-Net 2003). Most recently, control methods have been carried out almost exclusively using *Baccillus thuringiensis israelenis* (*Bti*) (Vectobac®), to try to minimize environmental impacts of mosquito control. The control efforts have not been particularly successful, probably because they have focussed on salt marshes which were widely believed to be the main source of the nuisance mosquitoes. Prior to this study, few attempts were made to identify the pest mosquitoes or their larval habitats, so it was not known how much of the mosquito problem actually originated from the salt marshes. With the emergence of WNV as a potential mosquito-borne disease in eastern Canada, there was new interest in determining the species composition and habitat requirements for mosquitoes on PEI. Information was needed on potential vectors, to assess whether the disease could spread by migrating birds to other parts of eastern North America (Turrell et al. 2005). Therefore, a survey was carried out during the summer of 2000 to sample mosquitoes throughout the province to provide information on the presence of potential amplification or bridge vectors of WNV. A more intensive survey was then initiated in and around the National Park in 2003 and 2004, in response to continued concerns by local tourism operators about nuisance mosquitoes. This latter study component also allowed a comparison with the Island-wide survey and the 1952 survey by Twinn (1953). The goal of this study was to provide data on habitats and phenology of nuisance mosquitoes throughout PEI to evaluate WNV risk and as an aid to potential management strategies.

METHODS

Mosquitoes were collected using three methods: larval sampling, light trapping of adults, and collection of landing adults (those that were aspirated as they landed to bite). During the summer of 2000, sampling was carried out at 421 sites around PEI (Fig. 1a) between late April and early October, consisting of weekly sampling trips to look for larval habitat, carry out landing counts, and service adult light traps. In 2003, an adult landing survey was carried out in and around the National Park (Fig. 1b) on the PEI North Shore (total of 99 sites). In 2004, a more intensive larval and adult survey was carried out in the central area of the Park (300 sites).

Larval sampling consisted of water dips from puddles, road ruts, pond edges, containers, and any other potential habitats using a 0.5 L mosquito dipper. For each water body found (Fig. 1a), a minimum of 5 dips were collected, with greater sampling effort in areas of low mosquito density, and the location and habitat conditions were recorded. For the Island-wide survey (2000), sampling was carried out while travelling to the far eastern portion of the province one week and to the far western portion of the province the next week to service mosquito light traps (at the start and end of each week). Each week, a network of secondary roads and back lanes in each part of the province was driven en route to the light trap locations, all the while looking for water bodies to sample. No larval sampling was carried out in the National Park during 2003, but an intensive larval survey was carried out in the Brackley or central region of the Park in 2004. Water bodies in the Park were located and mapped using a combination of GIS data, air photos, and walking through the Park. These

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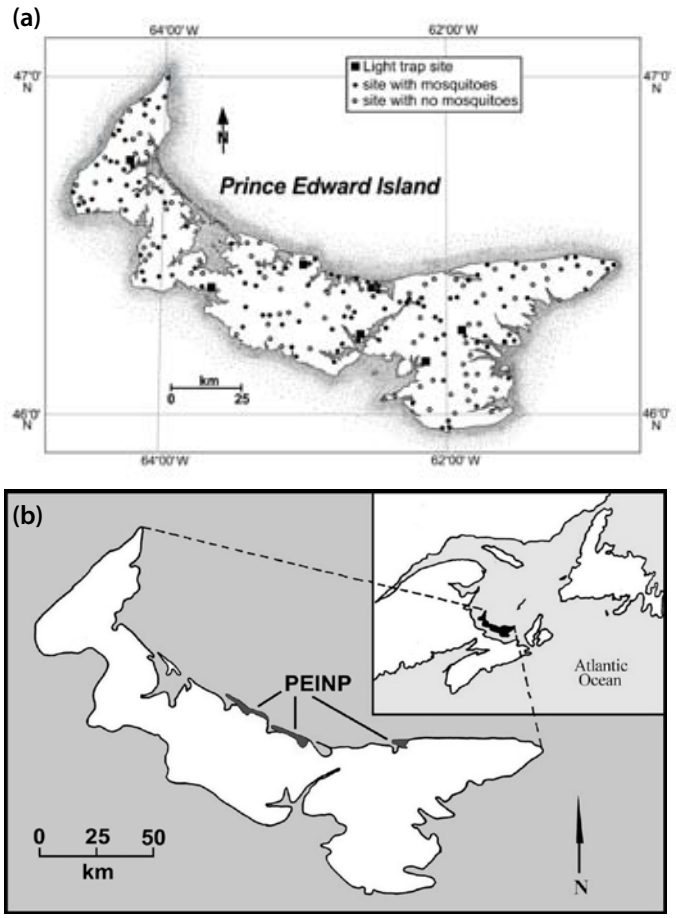
Fig. 1. Prince Edward Island, showing location of mosquito sampling sites and location of light traps (a), and the National Park (PEINP) (b). The light traps locations in the National Park were monitored in 2004, and the other traps were monitored in 2000.



water bodies were sampled weekly from June to September using the protocols described above. Mosquitoes were returned to the lab alive in plastic rearing cups, where a sample of the mature larvae was removed and preserved in 70% ethanol for later identification using the key of Wood et al. (1979). Immature larvae were allowed to grow to a size where they could be identified, and several larvae and any pupae from each sample were also reared to the adult stage to confirm larval identifications (Wood et al. 1979). A secondary purpose of the adult rearing was to provide pristine adults for comparison with those collected in light traps, which were often damaged and difficult to identify without reference to voucher material.

The 2000 PEI survey included two methods of adult sampling: general light trapping and collection of human biters (adults that landed on humans to bite). Five CDC (Centre for Disease Control) mosquito light traps were placed around PEI (Fig. 1a) in 2000 to collect adults that were attracted to light. Light trapping in 2000 was scheduled to begin in early May, but was delayed until June due to delays in receiving the light traps from the supplier who experienced a backlog created by the WNV outbreak. Each light trap was set up in or near wooded areas, away from artificial lights, and in localities where biting mosquitoes had been reported by local residents. Locations were picked to give 2 traps in western PEI (Profitt's Pond near O'Leary - N46°48', W64°10', and in a civic park in Summerside - N46°24', W63°48'w); two traps in eastern PEI (the McPhail Homestead at Orwell - N46°10, W62°50', and the fish hatchery at Cardigan - N46°15', W62°38'); and, one trap on the grounds of the Agricultural Station in Charlottetown - N46°15', W63°08'). Traps were set up to run for 4 nights between the Monday and Friday of the week for their particular region. In eastern and western PEI, traps were operated every other week (i.e., traps in the eastern part of PEI were monitored one week, and those in the west were monitored in the next week). The Charlottetown trap was operated every week. In 2003, a single light trap was used to monitor mosquitoes in the National Park; this was alternated between the Cavendish (western) and Brackley Beach (central) sections of the Park, and set up near the Visitor Centre at Cavendish (N46°30', W63°24'), and the Park Office in Brackley (N46°25', W63°05').

The traps were battery operated with a UV light source and a light sensor. Insects that were attracted to the light were pulled into a collecting chamber by a continuously operating fan and held there until traps were collected. The Charlottetown trap was run continually through the summer of 2000, and was supplemented with the use of dry ice as a CO_2 source; dry ice was not used in the other locations in 2000 due to difficulties in keeping the more isolated traps supplied. In 2003, the trap in the National Park was operated with a CO_2 cylinder.

Human biters were assessed for both species composition and relative abundance using surveys of landing counts. These counts were made by aspirating adults that landed on and attempted to bite a person wearing a bug shirt but no insect repellent, and standing still during a 3-5 minute period whenever adult mosquitoes were encountered. These surveys were mainly carried out during larval survey trips and trips to service the light traps during 2000. However, because this method could create a bias towards species that bite during the day, additional evening collections were made by recruiting student volunteers to carry out weekly landing counts (as described above) throughout

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Table 1. Mosquito species identified during the 2000 PEI Mosquito survey and the 2004 PEINP survey. Species names followed by a asterisk or a cross indicate those that were listed as present in PEI by (+) Wood et al. (1979) or by (*) Hardwick and Giberson (1996). [1]*Oc. abserratus* and *Oc. punctor* could not always be separated reliably; for those cases, numbers are combined.

	No. of larvae		No. of landing adults			No. in light traps (5traps) (1trap)		Island-wide survey 2000		NP survey 2003/2004	
	PEI 2000	NP 2004	PEI 2000	NP 2003	NP 2004	PEI 2000	NP 2004	Total	%	Total	%
Aedes cinereus +	98	21	18	8	8	4	16	120	6.4	53	1.5
Ae. vexans +	53	2	10	12	2	23	24	86	4.6	40	1.1
Anopheles earlei	2	0	0	0	0	0	2	2	0.1	2	0.1
An. punctipennis	11	0	0	0	0	0	0	11	0.6	0	0
Coquillettidia perturbans +	0	0	50	0	1	51	18	101	5.4	19	0.5
Culex pipiens	94	0	0	0	0	50	14	144	7.7	14	0.4
Cx. restuans	46	0	0	0	0	24	0	70	3.7	0	0
Cx. territans	56	0	0	0	0	1	0	57	3.0	0	0
Culiseta (Climacura) melanura	0	0	0	0	0	1	0	1	0.1	0	0
Cu. (Culicella) morsitans +	2	10	0	0	0	2	16	4	0.2	26	0.7
Ochlerotatus abserratus +	3	32	4	0	3	0	0	7	0.4	35	1
Oc. abserratus/punctor[1] +	1	0	85	7	10	14	9	100	5.3	26	0.7
Oc. canadensis +	175	34	3	6	0	0	26	178	9.5	66	1.8
Oc. cantator +	170	1912	176	68	231	15	56	361	19.2	2267	62.1
Oc. communis +	10	0	26	0	170	5	9	41	2.2	179	4.9
Oc. decticus	2	4	0	0	0	0	0	2	0.1	4	0.1
Oc. diantaeus +	1	12	0	0	2	0	0	1	0.1	14	0.4
Oc. excrucians +	21	18	28	29	15	3	58	52	2.8	120	3.3
Oc. fitchii +	23	33	27	15	14	0	21	50	2.7	83	2.3
Oc. hexodontus (?)	0	0	1	0	0	0	0	1	0.1	0	0
Oc. implicatus +	24	4	0	0	9	0	0	24	1.3	13	0.4
Oc. intrudens +	1	0	1	0	9	1	0	3	0.2	9	0.3
Oc. mercurator	2	0	2	0	0	0	0	4	0.2	0	0
Oc. pionips	0	1	27	0	0	2	9	29	1.5	10	0.3
Oc. provocans	31	4	0	1	53	2	5	33	1.8	63	1.7
Oc. punctor +	15	13	3	0	7	0	0	18	1.0	20	0.6
Oc. rempeli	4	0	0	0	0	0	0	4	0.2	0	0
Oc. riparius	1	0	0	0	0	1	4	2	0.1	4	0.1
Oc. sollicitans +	1	67	74	5	27	6	0	81	4.3	99	2.7
Oc. sticticus	0	0	3	0	0	0	3	3	0.2	3	0.1
Oc. stimulans +	9	52	234	104	310	4	11	247	13.1	477	13.1
Oc. triseriatus	7	0	33	0	1	3	2	43	2.3	3	0.1
Wyeomyia smithii *	1	0	0	0	0	0	0	1	0.1	0	0
Totals	864	2219	805	255	871	212	303	1881	100	3649	100

the province. Actual biting mosquitoes were not assessed due to ethical concerns about the potential of exposing students to WNV during the study. Adults were monitored in this fashion throughout all parts of the National Park in 2003 and in the central part of the Park in 2004.

RESULTS AND DISCUSSION

Biodiversity patterns

The 32 mosquito species identified from the combined 2000 - 2004 sampling (Table 1) represent a near doubling of the previously recorded species list for PEI (Twinn 1953; Wood et al. 1979; Hardwick and Giberson 1996). Twenty-four of these species were found in the National Park survey, and included the 15 species reported in the Park in 1952 (Twinn 1953) as well as nine additional species that were relatively rare in 2003 and 2004, indicating that

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they may have been missed in 1952. About 80% of the mosquitoes collected in the PEI survey (2000) were in 13 species, which could be considered common (making up ≥3% of the total; Table 1). Three species made up nearly half the mosquitoes reported: *Oc. cantator* (Coq.) (19.2%), *Oc. stimulans* (Walker) (13.1%), and *Oc. canadensis* (Theobold) (9.5%). In contrast, only four species were common (>3%) in the National Park area: (*Oc. cantator* (61%), *Oc. stimulans* (13.1%), *Oc. communis* (DeGeer) (4.9%) and *Oc. excrucians* (Walker) (3.3%). Twinn (1953) also reported *Oc. cantator*, the brown salt marsh mosquito, to be the dominant nuisance mosquito in the National Park area. The apparent dominance of *Oc. cantator* in our study was skewed by our larval collections, as larval densities were extremely high in the salt marshes. Salt marsh mosquitoes only made up about a quarter of the adult captures in both the National Park (27.3%) and in the whole island survey (26.7%), and were not the major nuisance group in any location. In contrast, the major biter, *Oc. stimulans,* was rarely collected as a larva, but was very important as adults. These results suggest that control programs that focus mainly on the salt marshes would miss a number of nuisance species, even in areas such as near the National Park, where many large salt marshes occur.

No one method collected every species that was found and some proved much more efficient for particular species (Table 1). Larval collecting was the most effective single method for determining species composition on PEI, with 29 of the 32 species collected as larvae and four species identified only from larval collections. Two of the most common human biters were either not collected (*Cq. perturbans* (Walker)) or only rarely collected as larvae (*Oc. stimulans*) (Table 1). *Coquillettidia perturbans* spends its immature stages buried in the mud, breathing by piercing the roots of emergent plants (Wood et al. 1979), and is therefore not usually collected in larval surveys. *Ochlerotatus stimulans* completes its larval development in spring, but persists as a biting adult throughout the summer, long after larval development is complete (Wood et al. 1979). Each of the adult collection types (light trapping and landing counts) targeted slightly different species, and collected 22 species each (Table 1). A total of 28 species were collected as adults, with three species collected only in the adult stage.

Although the adult trapping was not as successful as larval sampling for determining biodiversity, it was important in assessing nuisance species and potential disease vectors. Light trapping was important for monitoring the potential WNV vectors in the genus *Culex*, since these were not attracted to humans during this study (Table 1). *Culex pipiens* (L.) and *Cx. restuans* Theobold are generally considered to be bird feeders, at least early in the season (Molaei et al. 2006; Wood et al. 1979), but many *Culex* also bite humans, at least opportunistically (Molaei et al. 2006; Turrell et al. 2005). The lack of any *Culex* in the landing surveys in this study may reflect their general low abundance on PEI, or may be because the individuals conducting the landing counts were not sampling when and where *Culex* were feeding. These species are crepuscular, and are usually found in areas where birds may be found (Turrell et al. 2005).

There were unexpectedly low trap captures in the light traps, especially in 2000 (Table 1). The low trapping success was probably weather related, as captures were low even when traps were supplemented by CO_2 (e.g., the Charlottetown and National Park traps). The spring and early summer of 2000 was cooler than normal (Fig. 2), and several evenings during that time period had temperatures below 10°C. All the light traps attracted large numbers of other small insects, including midges (Diptera, Chironomidae), confirming that the lights were effective. Light and CO_2 traps attracted some of the nuisance biting species, but not others. For example, the traps captured few *Oc. sollicitans* (Walker), even when supplemented by CO_2, despite large numbers that were biting workers while the traps were being serviced. This species is known to be poorly collected in CDC light traps, even when supplemented with CO_2 (Andreadis et al. 2005).

Many more mosquitoes were captured through the landing survey than were captured in the light traps, but this method alone was not a useful indicator of overall diversity, as it only targeted species that bite humans. None of the species landing to bite showed any apparent preference for a time of day, suggesting that they were as active during the day as in the evening, at least in the locations sampled. Daytime activity might be especially important in the early part of the season, when cool nights can persist well into June on PEI (Fig. 2). Only a few species were important human nuisance species on PEI (Table 1). The most important biter during the study was an early spring woodland species, *Oc. stimulans*. The two salt marsh mosquitoes comprised ~25% of landing captures, but may be more important in years with above-normal spring temperatures. A fourth species, *Cq. perturbans*, is also locally abundant, and can be the most important biter in locations near their breeding habitat of ponds with emergent vegetation. Only the salt marshes are treated regularly for nuisance mosquitoes.

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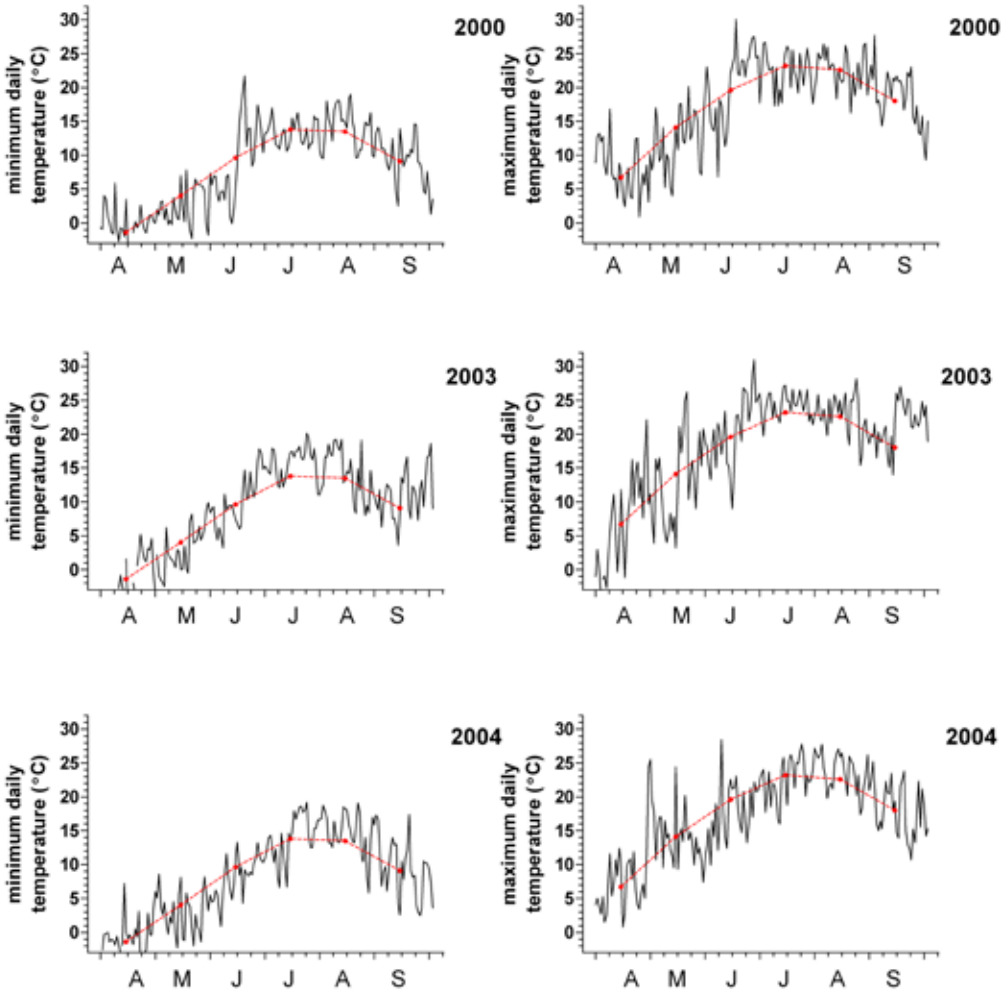
Fig. 2. Summer daily minimum and maximum temperatures at Charlottetown, 2000, 2003, and 2004, compared to the 30 year mean daily value for each month (1971 - 2000); Source: Environment Canada Climate Data on-line, accessed February 6, 2007: http://www.climate.weatheroffice.ec.gc.ca/climateData/canada_e.html



Habitat and phenological patterns

Over 800 sites were sampled during the 2000 larval survey and in and near the National Park in 2003 and 2004 (Fig. 1), resulting in >3000 larvae that could be identified or reared for identification (Table 2). About 1/4 of the sites (120) sampled in 2000 yielded mosquitoes (Fig. 1), and there was a strong seasonal component to mosquito larval abundance patterns. Nearly every potential habitat sampled in spring yielded mosquitoes, compared to much lower frequency as the summer progressed (Table 3). It also became difficult to find standing water during some periods in mid-summer. As half the species, mostly in the genus *Ochlerotatus*, had a univoltine life history pattern with larval development in spring or early summer (Fig. 3), these species would not have been present in sites sampled later in the summer. The multivoltine salt marsh and container breeding mosquitoes became more important as the season progressed. Some spring snow-melt species, like *Oc. stimulans*, continued to be important as adults throughout the summer, despite not being found as larvae (Fig. 3).

Mosquitoes were found in a wide variety of standing water habitats, including salt marsh pools, roadside ditches, pond edges, mud puddles, cattail marshes, bog pools, containers like tires or tubs, and road ruts (Table 2; Fig. 4). Larval and adult collections showed similar proportions

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Table 2. Mosquito larval habitats and periods, PEI, summers 2000 and 2004.

Species	Dates larvae found	Total found	PEI larval habitat notes
Aedes cinereus	May - Oct.	119	roadside pools and ditches, mud puddles,pasture pools, bog pools
Ae. vexans	June - Oct.	55	road ruts, mud puddles, roadside ditches, rocky puddles, pool in culvert
Anopheles earlei	Aug.	2	muddy roadside ditch
An. punctipennis	Sept.	11	clay road water-filled ruts & puddles
Coquillettidia perturbans	?	0	no larvae found (habitat not sampled)
Culex pipiens	July -Sept.	94	clay road water-filled ruts & puddles, roadside ditches, waterfilled tubs
Cx. restuans	Aug. - Sept.	46	clay road water-filled ruts & puddles, roadside ditches, waterfilled tubs
Cx. territans	June - Sept.	56	clay road water-filled ruts & puddles, bog pools, roadside ditches, mud puddles
Culiseta melanura	?	0	no larvae found
Cu. morsitans	May -June	12	roadside pond, bog pools, freshwater marsh
Ochlerotatus abserratus	May - June	35	sphagnum pool, freshwater marsh
Oc. canadensis	May - Oct.	209	ruts, mud puddles, pasture pools, bog pools, ditches, freshwater marsh
Oc. cantator	Apr. - Sept.	2082	mainly salt marsh pools, some fresh marshes (salinity range: 0 - 29 ‰)
Oc. communis	May and Aug.	10	rocky puddle, cattail swamp
Oc. decticus	May - June	6	sphagnum (bog) pools
Oc. diantaeus	May	13	ditch, pond edges, bog pools
Oc. excrucians	May - June	39	roadside ditches (with cattails or alders, may be muddy), pasture & bog pools
Oc. fitchii	May - Jun.	56	cattail marshes & pools, pasture & bog pools
Oc. hexodontus ?	?	0	no larvae found
Oc. implicatus	May	28	brackish & fresh pools near salt marshes, murky fresh marshes, cattail marsh, ditch
Oc. intrudens	June	1	ditch with alders
Oc. mercurator	May	2	marsh in cow pasture
Oc. pionips	June	1	freshwater marsh
Oc. provocans	May	35	roadside ditches (with cattails or alders), pond edges, freshwater marsh
Oc. punctor	May	28	cattail ditches and marshes, pond edges, mossy pools, bog pools
Oc. rempeli	May	4	mossy pool, roadside pond
Oc. riparius	May	1	pasture pools
Oc. sollicitans	June - Aug.	68	ditch, salt marshes (salinity range: 0 - 29 ‰)
Oc. sticticus	?	0	no larvae found
Oc. stimulans	May -June	61	cattail/shrub marshes, ditches with rushes & alders, puddles, pond edges
Oc. triseriatus	Aug.	7	in water in old tire (tree holes not sampled)
Wyeomyia smithii	June	1	in tire in pitcher plant bog (in pitcher plants throughout summer)
Total		**3082**	

of species associated with the different habitat types in the Island-wide survey in 2000. In contrast, larval captures around the National Park were dominated by the salt marsh species, reflecting the high densities of larvae in salt marsh pools as well as the accessibility of these sites, whereas the adult populations were dominated by woodland species. As the National Park comprises a small strip of land along the north shore of PEI and abuts both agricultural land and woodland, adults probably come in from adjacent areas. Species-specific habitat information can be found in the sections (below) on individual species patterns.

Potential for West Nile Virus transmission on PEI

Concern about the spread of the mosquito-borne WNV

Table 3 . Seasonal pattern in larval breeding sites and presence for the PEI Mosquito Survey, summer 2000 (note: some species could not be identified to species, so larval numbers in Table 3 may not correspond to Table 2).

Collecting period	No. of sites sampled	No. of sites with larvae	Percentage of sites with larvae	No. of larvae collected
April 20-25	2	2	100	39
April 26-30	0	--	--	--
May 1-5	5	5	100	53
May 6-10	15	11	73	86
May 11-15	12	12	100	68
May 16-20	12	11	92	109
May 21-25	13	9	69	42
May 26-31	0	--	--	--
June 1-5	0	--	--	--
June 6-10	16	10	63	55
June 11-15	10	6	60	43
June 16-20	28	6	21	42
June 21-25	7	0	0	0
June 26-31	17	2	12	5
July 1-5	4	0	0	0
July 6-10	25	1	4	5
July 11-15	7	2	29	26
July 16-20	24	5	21	39
July 21-25	15	1	7	9
July 26-31	21	1	5	18
August 1-5	17	2	12	24
August 6-10	12	0	0	0
August 11-15	13	4	31	35
August 16-20	12	3	25	31
August 21-25	13	7	54	78
August 26-31	23	2	9	15
September 1-5	23	6	26	75
September 6-10	0	--	--	--
September 11-15	0	--	--	--
September 16-20	15	1	7	16
September 21-25	9	5	6	22
September 26-31	9	1	11	1
October 1-5	26	3	12	3
October 6-10	16	2	13	6

to the Maritimes was a critical factor that prompted this study into mosquitoes of PEI. West Nile Virus was first detected in North America in New York City in the fall of 1999 and since then, the virus has been isolated from at least 60 species of mosquito in North America (Hayes et al. 2005; CDC 2006). Virus detection can occur in mosquitoes that have fed on an infected bird, and does not indicate vector competence, since not all mosquitoes can pass on the virus (Hayes et al. 2005; Turrell et al. 2005). The most important enzootic vectors belong to the genus *Culex*, many of which feed primarily on birds, especially early in the season (Molaei et al. 2006). *Culex* species are important in amplifying WNV within bird populations. Species that feed commonly on both mammals and birds ("bridge vectors"; Turrell et al. 2005) are necessary to pass the disease to humans. *Culex pipiens* may also bite humans (Molaei et al. 2006; Turrell et al. 2005), and has been implicated in the spread of various encephalitis diseases. We did not collect any *Culex* in landing surveys around PEI, even when working in areas where *Culex* were relatively common in the light traps, suggesting that *Culex* are not important bridge vectors on PEI.

Some of the species listed by Turrell et al. (2005) as potential bridge vectors occur on PEI (e.g., *Ae. vexans* (Meigen), *Cq. perturbans, Oc. canadensis, Oc. cantator,* and *Oc. sollicitans*, and *Oc. triseriatus* (Say)). These five species, present when *Culex* numbers are highest late in the summer, were much more important as biting adults later in the season than during spring and early summer (Fig. 2). *Culex* species persisted both as adults and larvae well into the fall. An Island-wide *Culex* survey in 2003 (McConnell 2004) showed two larval abundance peaks across the Island, with generally low adult numbers until late summer, confirming the pattern observed in 2000. Cool temperatures in spring and early summer on PEI (Fig. 2) probably maintain the *Culex* populations at low enough levels to keep the risk of WNV amplification very low on PEI.

Individual Species Patterns

Effective management of mosquito populations requires a good knowledge of the breeding habits and biology of the target species. Climate on PEI is affected strongly by the Gulf of St. Lawrence, which, because it freezes in winter, maintains cool temperatures into spring and early summer, but moderates temperatures through the summer and autumn. Therefore, phenological information given for other areas of similar latitude in Canada may not always be appropriate to PEI. Intensive surveys during 2000 and 2004 have provided data on larval and adult

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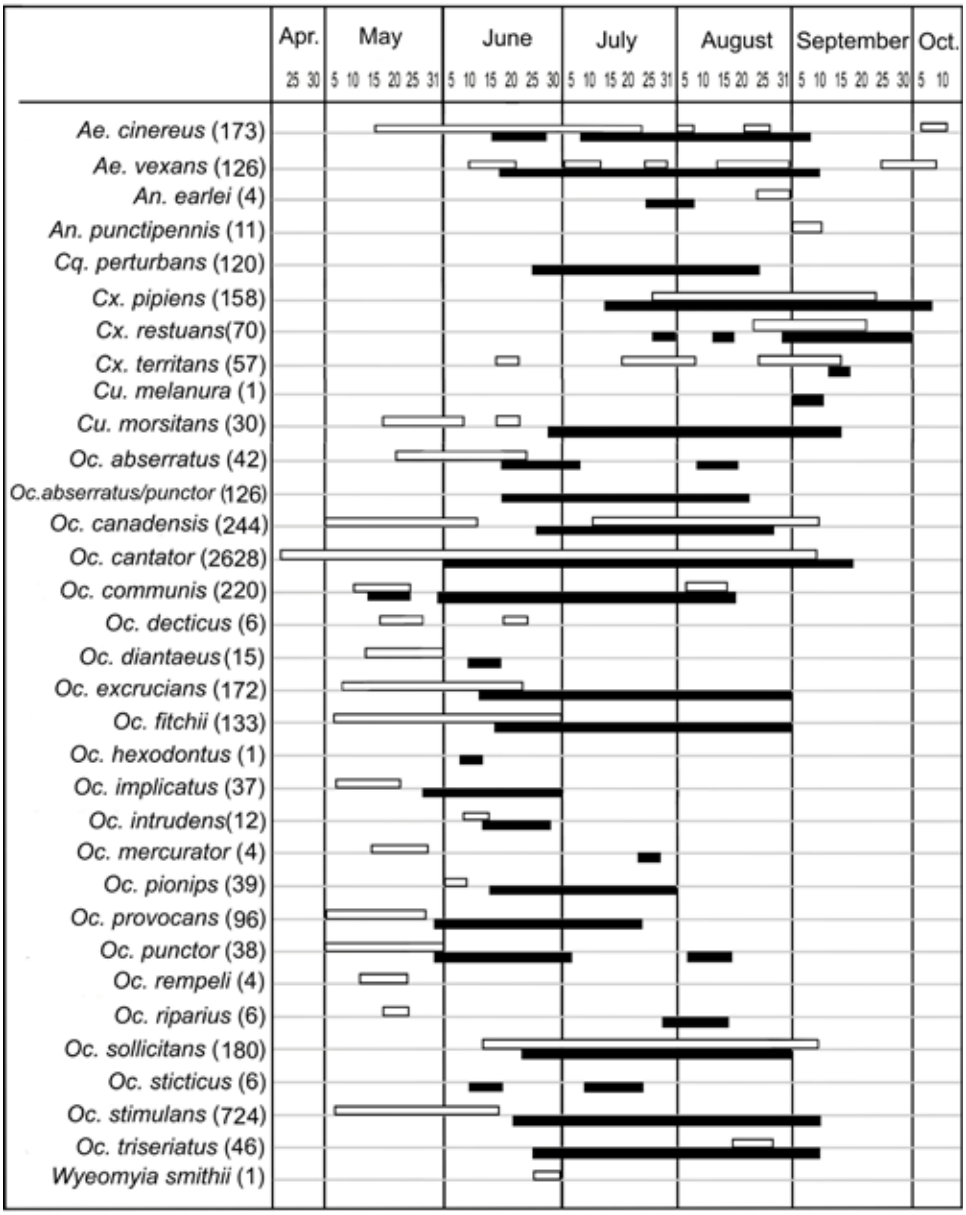
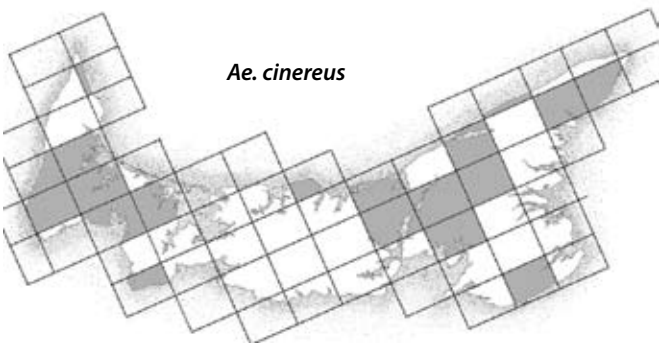
Fig. 3. Seasonal occurrence of mosquitoes collected during the PEI Mosquito survey, summers 2000 and 2004. Larvae (open bars); adults (closed bars); numbers in parentheses indicate total number collected.



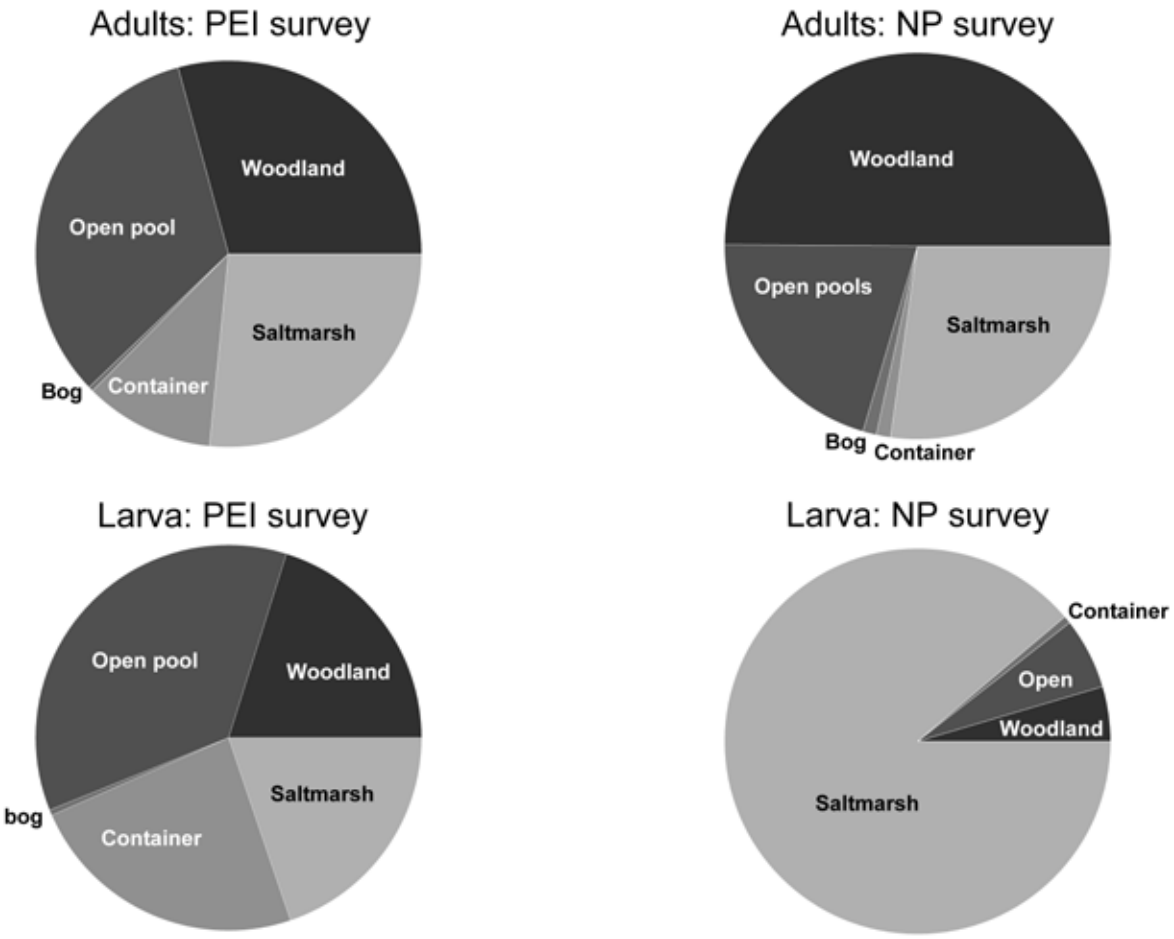
periodicity for at least the common species on PEI (Fig. 3) for comparison with literature information. The PEI distribution maps shown in this section include data from this study, and from information in Twinn (1953), Wood et al. (1979) and Hardwick and Giberson (1996).



Aedes cinereus Meigen

This species overwinters in the egg stage, but hatches later in spring than other *Aedes* species and can have more than one generation per year (Wood et al. 1979, Andreadis et al. 2005). On PEI, larvae were found throughout the summer from mid-May to October, and adults were

Fig. 4. Proportions of mosquitoes found in PEI surveys with primary breeding habitats (based on Wood et al. 1979) in open pools, marshes or ditches; woodland pools; saltmarshes; containers; or bogs.

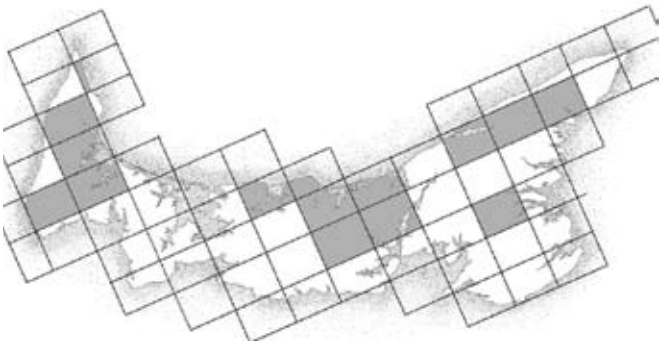


on the wing from mid-June to early September (Fig. 3).

This species is widespread across Canada (Wood et al. 1979), and was found in scattered localities across PEI. It is found in many habitat types but is most common at the edges of mixed cattail and sedge marshes, woodland pools, and in sphagnum bogs (Wood et al. 1979; Andreadis et al. 2005). On PEI, it was found in roadside pools and ditches, mud puddles, pasture pools and bog pools (Table 3).

Aedes cinereus made up ~6% of the mosquitoes collected during the 2000 Island-wide survey, but only 1.5% of those from the National Park Survey (2003/04). It was collected by all three collecting methods, but most commonly in the larval stage (Table 1). It was a relatively common human biter on PEI in 2000 (Table 1), reflecting its preference for mammalian hosts (Andreadis et al. 2005). It has tested positive for WNV (CDC 2006), but its vector competence is not known.

***Aedes vexans* (Meigen)**



Aedes vexans overwinters in the egg stage, and can produce more than one generation per year (Wood et al. 1970; Andreadis et al. 2005). They appear later than most *Aedes* species in spring, as eggs will not hatch until water temperatures rise above 8-10°C. In summer, the

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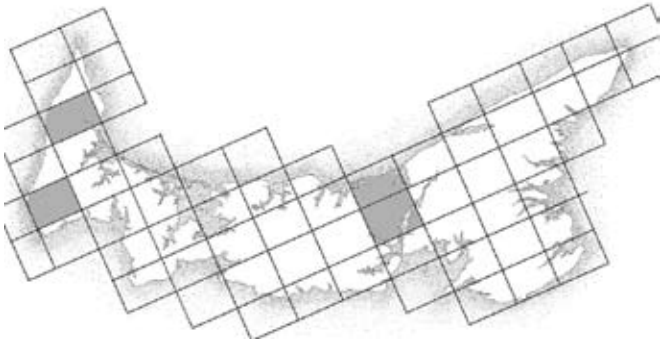
life cycle can be completed in just a few days (Wood et al. 1979). On PEI, larvae were not noticed until June, but were collected throughout the summer from June to October.

Adults were collected from June to September (Fig. 3). *Aedes vexans* is found across Canada (Wood et al. 1979). Adults were found in scattered locations throughout PEI, but larvae were only common in one location near Charlottetown. Their eggs are laid around depressions in the ground that will fill after snowmelt or heavy rains, and they prefer shallow grass-filled depressions in pastures or along roadsides and temporary woodland pools (Wood et al. 1979; Andreadis et al. 2005). On PEI, larvae were collected in road ruts and puddles, and in roadside ditches (Table 2).

This species is a major pest in most areas where it occurs (Wood et al. 1979), has a host preference for mammals (Andreadis et al. 2005), but it was not common in our landing or biting surveys (Table 1). It made up ~5% of the total mosquitoes collected in the PEI survey, but only ~1% in the National Park. It is most active after sunset (Wood et al. 1979), and was one of the more important taxa collected in the light traps during 2000 (Table 1). *Aedes vexans* is a natural vector of Western Equine Encephalitis virus (Wood et al. 1979), and has tested positive for WNV (CDC 2006). *Aedes vexans* is a moderately competent vector for WNV (Turrell et al. 2005), but its preference for feeding on mammals has led Andreadis et al. (2005) to rank it as a potential bridge vector for the virus in those locations where abundance is high.

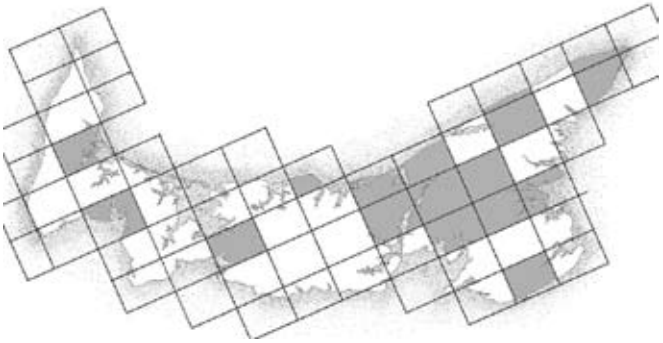
Anopheles earlei **Vargas and** ***Anopheles punctipennis*** **(Say)**



Anopheles earlei and *An. punctipennis* both overwinter as non-blood-fed adult females in buildings and mammal burrows. They will come out to bite on the first warm days of spring, and then lay their eggs in standing water (Wood et al. 1979). There may be a second or third generation if the season is warm and long enough (Wood et al. 1979). These species were not common on PEI, and made up < 1% of the total mosquitoes collected (Table 1). On PEI, they were too rare to adequately describe their phenology, but adults of *An. earlei* were collected first in July and larvae of both species were collected in late-August and early September (Fig. 2). No adult *An. punctipennis* were collected.

Anopheles earlei is found across Canada from coast to coast, and *An. punctipennis* has been reported from southern BC, southern Manitoba, and throughout most of eastern Canada. Both species breed in a variety of pools, especially in woodland areas, and *An. punctipennis* has occasionally been collected from tree holes and artificial containers (Wood et al. 1979; Andreadis et al. 2005). On PEI, the larvae were found in ditches, road ruts, and puddles (Table 2). *Anopheles earlei* larvae and adults were collected from the central part of the province, and *An. punctipennis* larvae were found in the eastern localities. Both species represent new provincial records. *Anopheles punctipennis* has tested positive for WNV (CDC 2006).

Coquillettidia perturbans **(Walker)**



Coquillettidia perturbans overwinters in the larval stage and produces a single generation per year (Wood et al. 1979; Andreadis et al. 2005). Adults have been reported in Ontario in mid-June (Wood et al. 1979), and in Connecticut in early June (Andreadis et al. 2005), but were not recorded on PEI until July in 2000, and late June in 2003 (Fig. 3). As larvae obtain oxygen by piercing plant stems and roots with their breathing siphon, and bury themselves in the bottom mud of marshes if disturbed, they are rarely collected (Wood et al. 1979). On PEI, only adults were collected, and they were still flying in late August.

Coquillettidia perturbans occurs across southern Canada from BC to Nova Scotia. On PEI, it was found in all three counties, but mainly in the east and in inland areas. This species is an important pest of humans and livestock (Wood et al. 1979), and feeds readily on both birds and mammals (Andreadis et al. 2005). Adults are active mainly in early mornings and in the evenings

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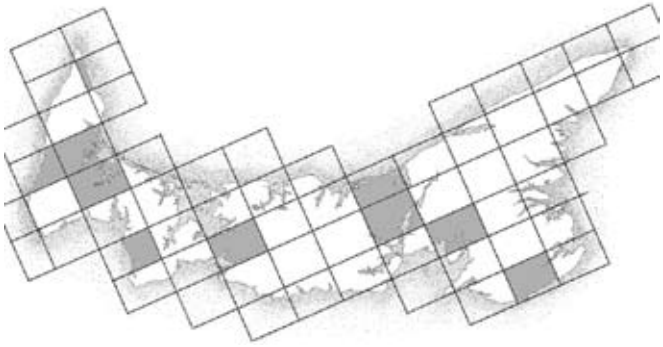
(Andreadis et al. 2005) and they were common both in biting surveys (6%) and in light traps (24%) in 2000 on PEI (Table 1). They were less common in the National Park surveys, rare in landing counts and about 6% of light trapped adults, due to the relatively few ponds with emergent vegetation in or near the Park. Wood et al. (1979) report that Eastern Equine Encephalitis virus was recovered from this species in Georgia, and it has also tested positive for WNV (CDC 2006). Turrell et al. (2005) indicate that it has only low competence for WNV transmission, so that even though it can be extremely abundant and feeds on both birds and mammals, it is ranked as having low potential as a WNV bridge vector.

Culex pipiens Linnaeus

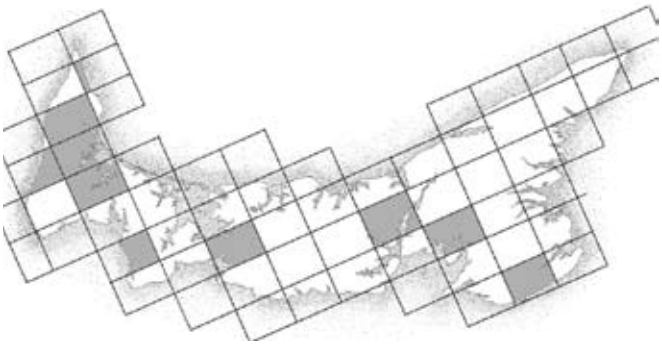


Culex pipiens overwinters as non-blood-fed females in basements, caves, burrows, and other similar habitats (Wood et al. 1979; Andreadis et al. 2005). Larvae usually begin to appear in May or June in southern Canada, and they can produce multiple generations in a year. Eggs are laid in rafts on the water surface, and during summer, larval development can be completed in a few days (Wood et al. 1979). On PEI, larvae and adults were collected from late July through August and September, and adults were collected as late as October (Fig. 3). A survey of larval breeding patterns and habitats in 2003 (McConnell 2004) showed peak abundance in early August for most locations.

This species is reported from south-western BC and from most of the eastern Canadian provinces (Wood et al. 1979). On PEI, it was found in scattered locations throughout the province, and was most abundant in western PEI. *Culex pipiens* had not been reported on PEI prior to this study. *Culex pipiens* is commonly called the rainbarrel or house mosquito, and will breed in all types of water containers, including ones that are polluted with organic wastes (Wood et al. 1979). As the populations build in late summer, they will also breed in roadside ditches, puddles and all sorts of artificial containers (Wood et al. 1979). On PEI, they were found in muddy ruts and puddles on clay roads, small puddles in roadside ditches, and in water-filled tubs and containers (Table 3).

Culex pipiens will transmit Western Equine Encephalitis and St. Louis Encephalitis (Wood et al., 1979) and is the principle vector reported for West Nile Encephalitis in eastern North America (Andreadis et al. 2005). They prefer to feed on birds over mammals, but will feed on humans when numbers are high and other hosts are unavailable (Wood et al. 1979, Molaei et al. 2006). Human-biting may be rare on PEI as no specimens of this species were collected in landing surveys in any of the study years, despite sampling at all times of day in areas where they were common in light traps. Relatively high numbers of larvae were found (10% of the total in 2000), mainly due to targeted collections in their known habitats. Despite being one of the common (24%) species attracted to the light traps in 2000 (Table 1), it was rare in the National Park, a possible explanation why it had not been reported on PEI prior to this survey. Twinn (1954) focussed his collections on the National Park area. Although this species is an important enzootic vector of WNV, the persistence of cool weather in spring and early summer on PEI means that adults are probably not too active during the spring bird migration period in this area, when birds carrying the virus may travel through PEI. The cool spring may also prevent this species from building population numbers to the point where amplification of the virus is likely. Therefore, there should be relatively low risk of WNV transmission from this species to mammal dead-end hosts on PEI.

Culex restuans Theobald



The life cycle of *Cx. restuans* is similar to *C. pipiens*, with overwintering females and multiple generations through the summer. *Culex restuans* population numbers usually reach their peak earlier in the season than *C. pipiens* in most areas where they are found (Wood et al. 1979; Andreadis et al. 2005). On PEI, however, both the larvae

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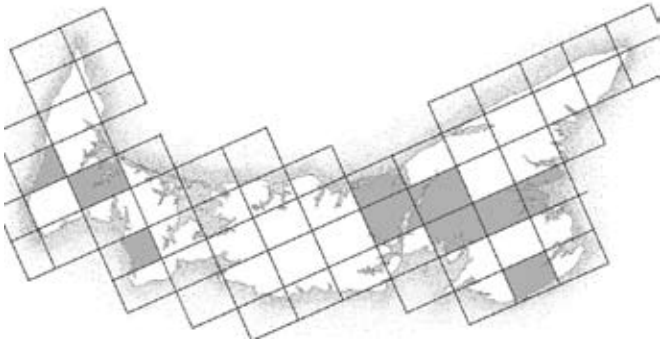
and adults of *Cx. restuans* were not seen until about three weeks later than the first *Cx. pipiens*, with larvae appearing in collections in mid-August, and adults seen from July through the end of September (Fig. 3). *Culex restuans* is found in Canada from central Alberta to the Maritimes (Wood et al. 1979). It is a new provincial record and was found in scattered locales around PEI. Although this species made up about 3% of the total captures in the island-wide survey in 2000, it was not found in the National Park area. Like *Cx. pipiens*, this species breeds in various artificial containers, rock pools, tree cavities, and ditches and temporary puddles (Wood et al. 1979). On PEI, they were found in ruts and puddles on clay roads, roadside ditches, and water-filled tubs (Table 1).

This species is not usually considered to be an important vector of encephalitis viruses, although viruses have been isolated from *Cx. restuans* in Manitoba and New Jersey (Wood et al. 1979). The species is not reported in the list of potential WNV vectors in Turrell et al. (2005). *Culex restuans*, like *C. pipiens* prefers to feed on birds, but will feed on mammals, snakes and turtles (Wood et al. 1979).

***Culex territans* Walker**



Like the other *Culex* species on PEI, *Cx. territans* overwinters as a non-blood-fed female, and emerges from hibernation in spring. There may be several generations per year and larvae may be seen as early as May or early June (Wood et al. 1979). On PEI, larvae were collected sporadically throughout the summer between mid-June and mid-September, and the single adult was recorded in a light trap in mid-September (Fig. 3). *Culex territans* has been reported across Canada from BC to Nova Scotia. It is a new provincial record for PEI and was mainly found in eastern localities. This species can be found in artificial containers like the other two PEI *Culex* speces, but is usually found in marshes with abundant emergent vegetation and will not be found if the water body is polluted (Wood et al. 1979). On PEI, larvae were found in water-filled ruts and puddles on clay roads, in bog pools and in roadside ditches (Table 3).

This species is believed to feed most commonly on amphibians and reptiles (Wood et al. 1979; Andreadis et al. 2005), though it has been observed to feed on birds, cattle and humans (Wood et al. 1979). It was common in larval collections in 2000, making up about 6.5% of all larvae collected, or 3% of the total. It was not collected in the National Park.

***Culiseta melanura* (Coquillett) and *Culiseta morsitans* (Theobald)**

Many *Culiseta* species overwinter as blood-fed females, but *Culiseta melanura* overwinters in the larval stage in Quebec whereas *Culiseta morsitans* overwinters in the egg stage in Canada (Wood et al. 1979). *Culiseta melanura* can produce more than one generation per year (Wood et al. 1979) and the single individual of this species found on PEI was collected from a light trap in early September (Fig. 2). *Culiseta morsitans* eggs hatch early in spring, probably with a single generation per year, and are often found in association with newly hatched spring *Ochlerotatus* spp. (Wood et al. 1979). On PEI, larvae were first seen early in the season in mid-May and persisted into June, but adults were found into September (Fig. 3).

Culiseta melanura is common in the southern US, and is widespread in Connecticut (Andreadis et al. 2005). Wood et al. (1979) reports it from Ontario and Quebec in Canada. The single adult was collected from the light trap in O'Leary in western PEI and is a new record for PEI. *Culiseta morsitans* has been reported across Canada from BC to Newfoundland (Wood et al. 1979), and was found in isolated locations around PEI. Wood et al. (1979) reported *Cu. melanura* in deep, water-filled depressions in bogs. No larval habitat information is available for PEI. *Culiseta morsitans* occurs in springs, cedar swamps, bogs, and small overflow pools (Wood et al. 1979), and on PEI, the larvae were found in bog pools and the edges of a roadside pond (Table 2).

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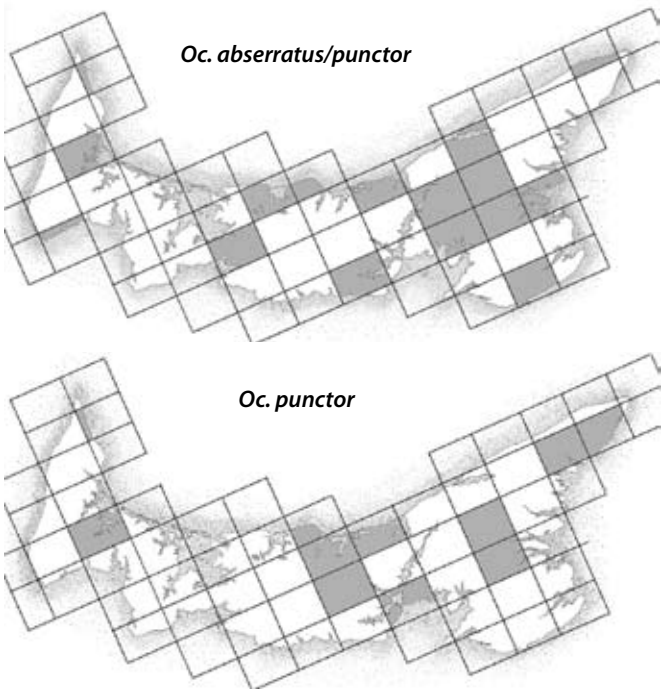
Females of both species prefer to feed on birds, but will also feed on small mammals and snakes (Wood et al. 1979). Eastern Equine Encephalitus has been isolated from *Cu. melanura*, but since the species is usually very rare, it is not thought to be an important vector (Wood et al. 1979). Neither species was common on PEI (Table 1).

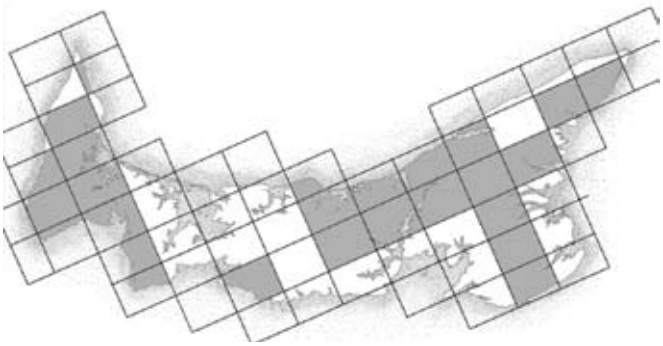
***Ochlerotatus abserratus* (Felt & Young)/*Oc. punctor* (Kirby)**



These two species cannot always be distinguished as adults, as identification depends on colour patterns that fade shortly after death. Most of the adult specimens collected on PEI during the summer 2000 study have therefore been recorded as "*Oc. abserratus/punctor*" and separate species only recorded when identifications were clear. The larvae can be distinguished easily, so larval timing and habitats could be determined. Wood et al. (1979) report both species to be common in early spring. They overwinter as eggs, and have one generation per year (Wood et al. 1979; Andreadis et al. 2005). On PEI, larvae were only seen in spring (May and early June), but adults were collected as late as August (Fig. 3). Andreadis et al. (2005) report both species to be persistent human biters, and they were one of the more common biters on PEI during the summer, together making up about 11% of the landing adults in 2000 (Table 1). *Ochlerotatus abserratus* inhabit a variety of larval habitats, including roadside ditches, cattail and sedge marshes, and muskeg pools. *Ochlerotatus punctor* can be found in bogs, grassy pools and grassy marshes (Wood et al. 1979). Together, the two species made up 6.7% of all mosquitoes collected during the 2000 survey and 2.5% of those collected in the National Park.

Ochlerotatus abserratus is an eastern species, whereas *Oc. punctor* can be found across Canada (Wood et al. 1979). On PEI, all the *Oc. abserratus* larvae collected were found in or near the central portion of the National Park, in a freshwater marsh and a sphagnum pool. The upper map shows the distribution for the combined *abserratus/punctor* adults, whereas the lower map shows the location of the *Oc. punctor* larvae and adults that could be identified. *Oc. punctor* larvae were collected from cattail ditches and marshes, pond edges, mossy pools and bog pools (Table 2).

***Ochlerotatus canadensis* (Theobald)**



Ochlerotatus canadensis overwinters in the egg stage, but can have more than one generation per year (Wood et al. 1979; Andreadis et al. 2005). On PEI, larvae were found throughout the summer, from early May to September, and adults were found through July and August (Fig. 3). *Ochlerotatus canadensis* occurs across Canada and the US (Wood et al. 1979) and was widespread across the Island. This species has been reported from diverse habitats including woodland pools, roadside ditches, cattail and sedge marshes, and bog pools (Wood et al. 1979). On PEI, larvae were common in mud puddles, ruts, ditches, and pasture and bog pools (Table 2). Relatively few adults of this species were collected by light trapping, even in areas where high numbers of larvae were found. Despite a reputation as a serious pest of humans (Andreadis et al. 2005), only a few were collected during biting surveys (Table 2). They made up 9.6% of all mosquitoes collected in the 2000 survey, and about 2% of those collected in the National Park.

***Ochlerotatus cantator* (Coquillett) and *Ochlerotatus sollicitans* (Walker)**

These are the two common salt marsh mosquitoes on PEI

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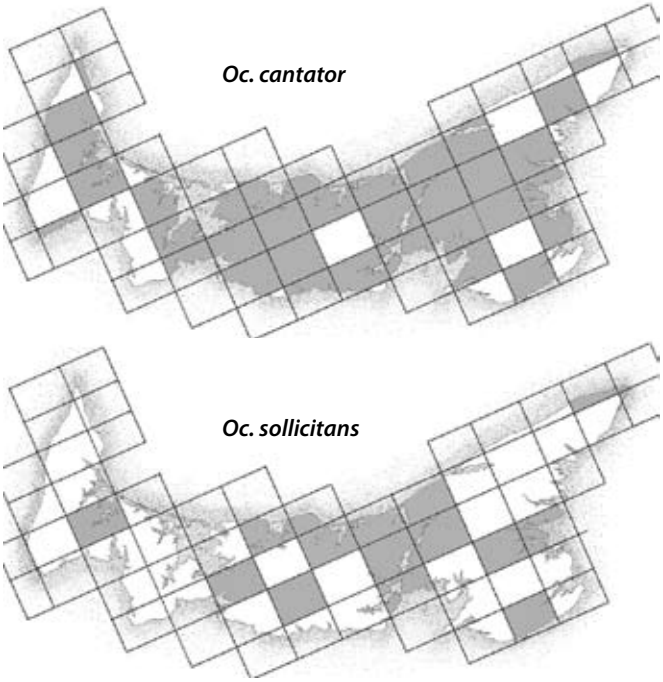
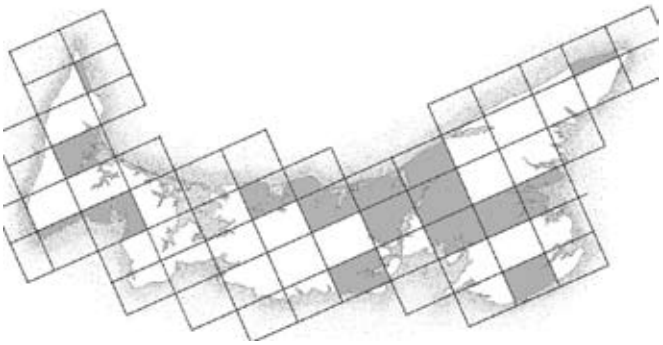
in summer, so will be considered together. *Ochlerotatus cantator* and *Oc. sollicitans* overwinter as eggs and can have several generations per year (Wood et al. 1979; Andreadis et al. 2005). Wood et al. (1979) reports that *Oc. cantator* is the more common of the two in early summer, with *Oc. sollicitans* becoming more dominant in midsummer, though in Connecticut, both species peak in early summer (Andreadis et al. 2005). On PEI, *Oc. cantator* is the most common of the salt marsh mosquitoes in most years until late summer, after which *Oc. sollicitans* becomes an important pest. Both species inhabit salt, fresh or brackish marshes, and can tolerate a wide range of salinities (Wood et al. 1979; Giberson et al. 2001). Both species are widespread in eastern North America near coastal areas, though they can also migrate inland (Wood et al. 1979). They were found throughout PEI during the summer of 2000. On PEI, *Oc. cantator* were mainly in coastal salt marshes but were also found in neighbouring fresh marshes. *Ochlerotatus sollicitans* larvae were only collected from salt marshes. Together, these two species made up nearly 1/4 of all mosquitoes collected during the summer of 2000 (24%); they dominated (>60%) the larval collections in the National Park, and were both important biters of humans (Table 1). *Ochlerotatus cantator* was also well represented in light traps, but *Oc. sollicitans* were rarely captured in the light traps, even when supplemented by CO_2, and even in areas where *sollicitans* activity was very high. We have also noted this pattern in ongoing surveys of a north shore PEI golf course. Andreadis et al. (2005) reported that this species is not readily collected in CO_2-baited CDC light traps.



***Ochlerotatus communis* (De Geer)**



Ochlerotatus communis overwinters in the egg stage, and usually hatches early in spring before the snow is gone (Wood et al. 1979). They are reported to have only a single generation per year (Wood et al. 1979; Andreadis et al. 2005), but on PEI, larvae were recorded in spring, and again in late summer (Fig. 3). Andreadis et al. (2005) report an adult flight period of May to June, but adults were collected from May through August on PEI (Fig. 2). This is one of the most abundant and widely distributed mosquito species in Canada and it is usually associated with woodland pools (Wood et al. 1979). Adults were found in scattered locations throughout the Island, but larvae were found only in a rocky puddle near Charlottetown and at the edge of a cattail marsh in western PEI (Table 2).

This species was collected by all three collecting methods, but was most common in the biting adult surveys, making up ~3% of landing adults in 2000, and >15% in the National Park area (Table 1). It made up ~4 % of all mosquitoes collected.

***Ochlerotatus decticus* Howard, Dyar & Knab, *Oc. diantaeus* Howard, Dyar & Knab**

These two species were too rare on PEI (<0.5%; Table 1) to

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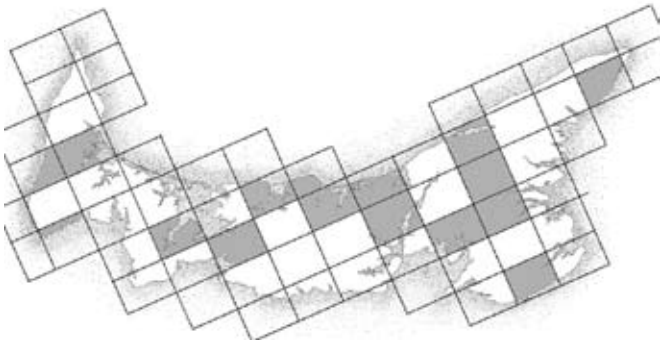
be sure of their phenology in the province. *Ochlerotatus decticus* was only collected as larvae on PEI, whereas *Oc. diantaeus* were collected as both larvae and adults (Fig. 3). Wood et al. (1979) give no information on seasonal timing, but Andreadis et al. (2005) indicate that the larvae of *Oc. diantaeus* are present in Connecticut in May and adults persist into June, confirming the pattern seen here (Fig.3).

Ochlerotatus diantaeus is widespread across Canada and was reported in the National Park area in 1952 by Twinn (1953). *Ochlerotatus decticus* has been reported from Alaska to Labrador in the north and from Michigan to Massachusetts, but not previously from the Maritimes (Wood et al. 1979). This report represents a new provincial record. In this survey, *Oc. decticus* was only found in the National Park and *Oc. diantaeus* was found in both the National Park and in the southeast. *Ochlerotatus decticus* is a bog species and *Oc. diantaeus* is associated with hardwood forest pools as well as boggy areas (Wood et al. 1979). On PEI, *Oc. diantaeus* larvae were collected from a ditch and several bog pools, whereas *Oc. decticus* larvae were only collected from bog pools (Table 2). This group was rare on PEI, making up <0.5% of the mosquitoes collected (Table 1).

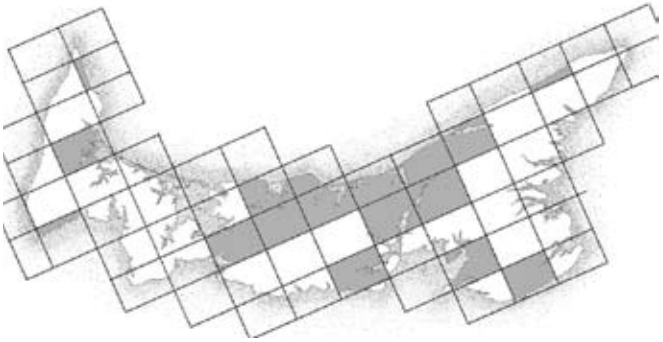
Ochlerotatus excrucians **(Walker)**



Ochlerotatus excrucians overwinters in the egg stage, and has only one generation per year (Wood et al. 1979; Andreadis et al. 2005). In Connecticut, larvae may be found in woodland pools from March through May, with adults flying from May to August. On PEI, larvae were found in May and June, and adults were recorded from the middle of June to the end of August (Fig. 3). *Ochlerotatus excrucians* was collected by all three collecting methods. It was a reasonably common human-biter, and was common in the light trap in the National Park (Table 1). It made up ~3% of the mosquitoes collected overall.

This species is widely distributed across Canada (Wood et al. 1979) and was collected in scattered locations all over PEI. This species can be found in virtually any kind of ground pool that supports mosquitoes, but is most common near edges of marshes and swamps (Wood et al. 1979). On PEI, it was found in roadside ditches with cattails or alders, muddy ditches, pasture pools and bog pools (Table 2).

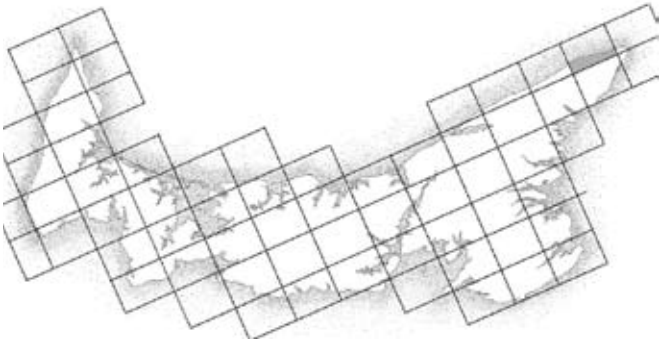
Ochlerotatus fitchii **(Felt & Young)**



This species overwinters as an egg, and has one generation per year (Wood et al. 1979; Andreadis et al. 2005). On PEI, larvae were collected in May and June, and adults were seen until late August (Fig. 3). The species is widely distributed across Canada (Wood et al. 1979), and was present in scattered localities all across PEI. Wood et al. (1979) report that *Oc. fitchii* is present "nearly everywhere", though they are not usually abundant. Larvae were found in cattail marshes and pools and pasture pools throughout PEI (Table 2).

Ochlerotatus fitchii are easily recognised in the larval stage, but adult females may be confused with other species, especially *Oc. stimulans*, with whom they overlap in timing on PEI. This species was collected by all three collection methods, but they were not particularly common, making up just under 3% of the total collected (Table 1).

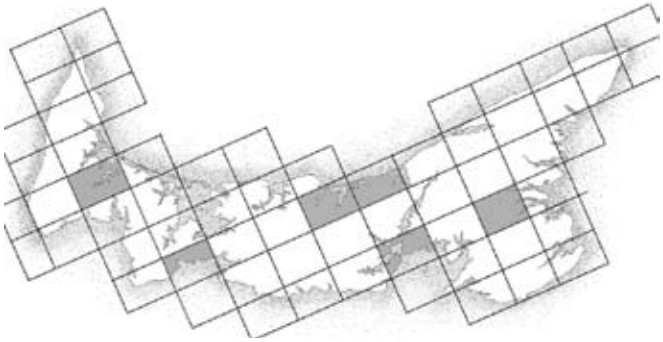
Ochlerotatus hexodontus **Dyar (?)**



Ochlerotatus hexodontus overwinter as eggs that can hatch when temperatures rise just above 0°C, and have a single generation per year (Wood et al. 1979). No larvae were found in the PEI survey, but the single adult was

collected in early July (Fig. 3). This species is abundant along the fringes of the boreal forest in northern Canada, and is a common northern species. The identification of this species is uncertain, and given that it is usually reported much further north than PEI, it is possible that this individual is actually *Ochlerotatus punctor,* a species with which it is often confused. The identification could not be confirmed by Dr. Roy Ellis following the study due to the condition of the specimen. If additional specimens of this species are found, they will represent a new provincial record. The single female was collected during a landing survey in the north-eastern part of PEI. This species has been reported from grass and sedge marshes, muskeg pools, and tundra pools (Wood et al. 1979). No larvae were found in this survey, so the larval habitat, if the species is confirmed, is unknown.

***Ochlerotatus implicatus* Vockeroth**



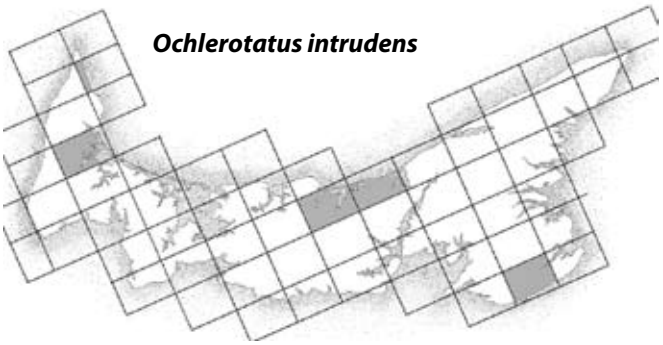
Ochlerotatus implicatus overwinters in the egg stage and has a single generation per year. It is one of the earliest species to appear as an adult in spring, and adults are relatively short-lived (Wood et al. 1979). On PEI, larvae were collected in early May (Fig. 3) and adults were collected sporadically through the early summer from late May into June. This species inhabits forest pools and brackish water along the coast (Wood et al. 1979). On PEI, it was collected from brackish (salinity to 4‰) and fresh pools in salt marshes, murky fresh marshes, cattail marshes, and a ditch (Table 2).

This species is distributed across Canada, but is not usually abundant (Wood et al. 1979). On PEI, it was found in scattered locales across the island. *Ochlerotatus implicatus* was collected primarily in the larval stage on PEI, but a few adults were captured during the landing adult surveys (Table 1). It was not very common, making up 1.3% of the total collected.

***Ochlerotatus intrudens* Dyar**

Ochlerotatus intrudens overwinters as an egg, and hatches early in spring, with one generation per year and short-lived adults (Wood et al. 1979; Andreadis et al. 2005).

Ochlerotatus intrudens



Wood et al. (1979) report this species from temporary woodland snowmelt pools, emerging before other species like *Oc. communis, punctor,* or *abserratus*. Only a single larva was collected on PEI, and it was found in early June (Fig. 1) in a ditch containing several alder bushes (Table 2). Adults were collected in June (Fig. 3). This species is distributed across Canada (Wood et al. 1979). On PEI, it was collected in three locales, but was rare, with a single larva and 11 adults collected. Females of this species can be confused with *Oc. communis* and *Oc. sticticus*, but larvae are easily distinguished. Although adults have been reported in Connecticut flying from May to August Andreadis et al. (2005), no larvae have been reported in that state. Wood et al. (1979) report this species to be a major biter in locations where it is common (Table 2).

***Ochlerotatus mercurator* Dyar**

Ochlerotatus mercurator overwinters in the egg stage, and has one generation per year, with larvae appearing early in spring (Wood et al. 1979). This species has been reported across Canada from Ontario to BC, though Wood et al. 1979 suggest that the North American distribution is largely unknown. On PEI, the species was rare, with only 4 individuals, 2 larvae and 2 biting females, captured (Table 1). This is a new record for PEI,

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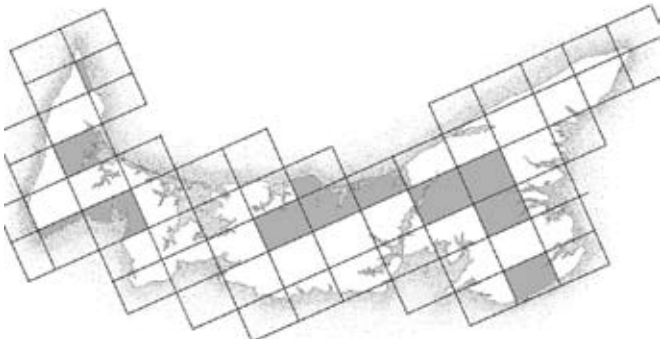
and represents a considerable range extension for the species. It is possible that adults may have been confused with *Oc. fitchii* in this survey, and larvae may have been confused with *Oc. pionips*, but identification was based on late stage larvae and a freshly reared female as well as the females captured from the landing survey, so we are quite confident of the identification. In addition, the larvae were found in appropriate habitat, and earlier in spring than would be expected for *Oc. pionips*. They were found in scattered localities in Queens and Kings Counties, with larvae appearing in mid-May (i.e., early spring on PEI). Adults were collected in July (Fig. 3). Wood et al. (1979) report this species from open marshes with abundant emergent vegetation, and on PEI, it was found in this type of habitat in cow pastures (Table 3).

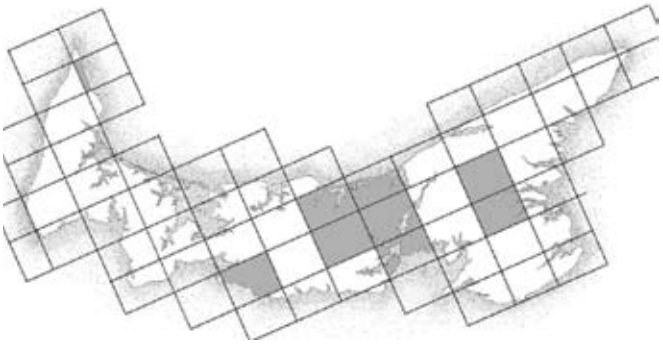
***Ochlerotatus pionips* Dyar**



Ochlerotatus pionips overwinters as an egg, and has a single generation each year, with larvae emerging somewhat later than other spring species of *Ochlerotatus* (Wood et al. 1979). A single larva of this species was collected in early June in the central part of the National Park but adults were collected through much of June and July (Fig. 3) in both the light traps and the landing surveys. Wood et al. (1979) reports this species to be common in the northern conifer forest and indicates that the larvae may be found in woodland pools, ditches, vehicle ruts, and other small pools. On PEI, it was found in a freshwater pool by some trees near the coast.

This is a transcontinental species, mainly restricted to the boreal forest zone. On PEI, adults were found in scattered localities all over the island, where it was locally abundant, occurring with *Oc. abserratus/punctor*, among the mosquitoes attracted to humans in the landing surveys (Table 1). It was also found in light traps, but was not particularly common overall, making up only 1.5% of the total mosquitoes collected in 2000. This is a new record for PEI.

***Ochlerotatus provocans* (Walker)**

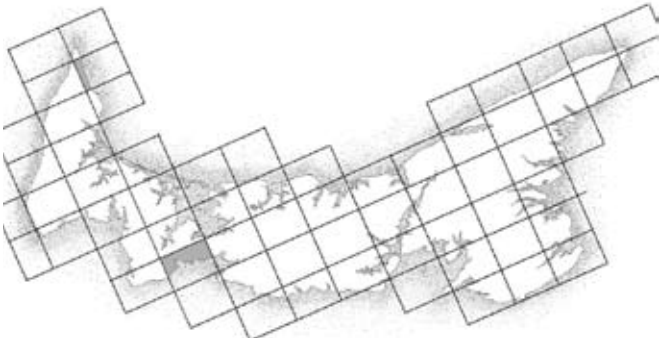


Ochlerotatus provocans overwinters in the egg stage, and has one generation per year (Wood et al. 1979; Andreadis et al. 2005). It is an early spring species, with short-lived adults. (Wood et al. 1979) and Andreadis et al. (2005) list adult female captures from May through July in Connecticut. On PEI, larvae were collected throughout the month of May, and adults were found in June and July (Fig. 3). Larvae are found along the edges of marshes and in woodland snowmelt pools and roadside ditches (Wood et al. 1979; Andreadis et al. 2005). On PEI, they were found in roadside ditches that had alder or cattail vegetation, as well as along pond edges (Table 2).

This species is mainly restricted to southern regions in Canada, but has been recorded across the country. On PEI, it was found in central portions of the province. *Ochlerotatus provocans* was well represented in both the larval surveys and the landing surveys, but was relatively rare in the light traps. Overall, it made up 1.7% of the mosquitoes collected (Table 1). This is another new provincial record for PEI.

***Ochlerotatus punctor:* (see section on *Ochlerotatus abserratus*)**

***Ochlerotatus rempeli* Vockeroth**



Ochlerotatus rempeli overwinters in the egg stage and has a single generation per year. On PEI, only larvae were found,

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and they occurred in early spring (Fig. 1). Wood et al (1979) report that this species is often found in rock-crevice pools but has also been recorded from larger pools. On PEI, larvae were collected from a mossy pool and roadside pond (Table 1). This species is thought to be widely but sparsely distributed in the boreal forest of northern Manitoba, Ontario, and Quebec, with one record as far south as Algonquin Park in Ontario (Wood et al. 1979). On PEI, it was found in one area only, in eastern Prince County. Adult females of this species can be confused with *Ochlerotatus pullatus* which has not been recorded on PEI, but larvae should be easily distinguished from other *Ochlerotatus*. This is a new record for PEI, and was quite rare, making up less than 0.5% of the total mosquitoes collected (Table 1).

Ochlerotatus riparius **Dyar & Knab**

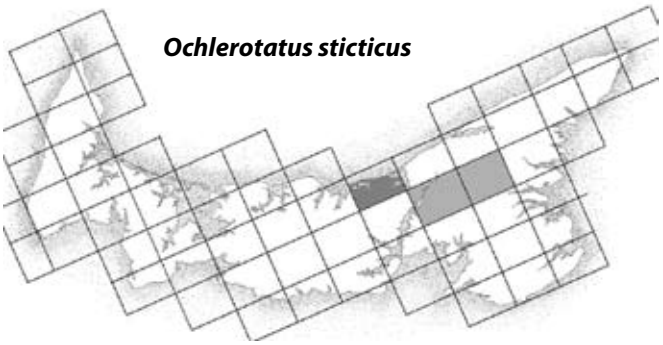
Ochlerotatus riparius overwinters in the egg stage, and has a single generation per year (Wood et al. 1979). In the PEI survey, the single larva was collected in mid-May (Fig. 3) in a pasture pool with specimens of *Oc. fitchii*. Adults were collected in the light traps in the National Park and near Summerside. Wood et al. (1979) also report that the larvae occur with *Oc. fitchii and excrucians* in Ontario.

Ochlerotatus riparius has been collected across Canada from just east of the Rocky Mountains to Nova Scotia, and is uncommon to rare over most of its range (Wood et al. 1979). The species, a new record for PEI, was rare here, found in scattered localities across the Island.

Ochlerotatus sollicitans **(see section on** ***Ochlerotatus cantator*****).**

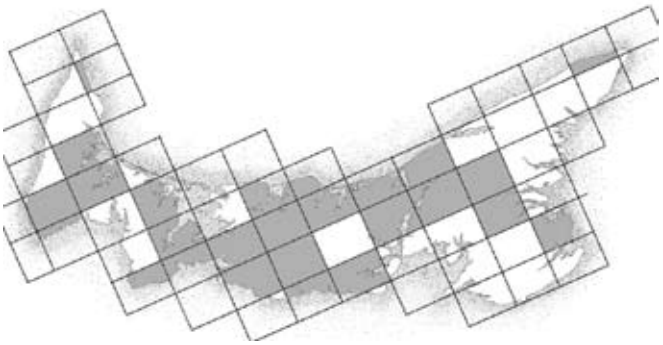
Ochlerotatus sticticus **(Meigen)**

Ochlerotatus sticticus is a floodwater mosquito that overwinters in the egg stage, and is usually univoltine (Andreadis et al. 2005), though a summer generation is possible if the breeding sites are flooded later in summer. Eggs can apparently remain viable for several years, and hatching occurs in spring in flooded areas following snowmelt or heavy rains (Wood et al. 1979). In the PEI survey, no larvae were found, but adults were present in June and July (Fig. 3). This species, another new provincial record for PEI, was rare, perhaps reflecting



the lack of suitable habitat on PEI. It has been reported across Canada from BC to New Brunswick. Landing adults were collected in the eastern part of PEI in one of the few large floodplain areas in the province, and three females were also captured in a light trap in the National Park. Both Wood et al. (1979) and Andreadis et al (2005) report this species to be a troublesome biter, particularly in the evenings. This is a new provincial record for PEI.

Ochlerotatus stimulans **(Walker)**



Ochlerotatus stimulans overwinters in the egg stage and has one generation per year, though adults are exceptionally long-lived and persist through the summer (Wood et al. 1979; Andreadis et al. 2005). This was one of the most common species and one of the most aggressive biters on PEI (Table 1). The larvae were collected from the earliest samples in the study (May through early June), and adults were recorded from mid-June to the beginning of September (Fig. 3). Wood et al. (1979) report that this species develops on wooded floodplains that flood during spring snowmelt, especially near lake and marsh edges associated with maple trees. On PEI, the larvae

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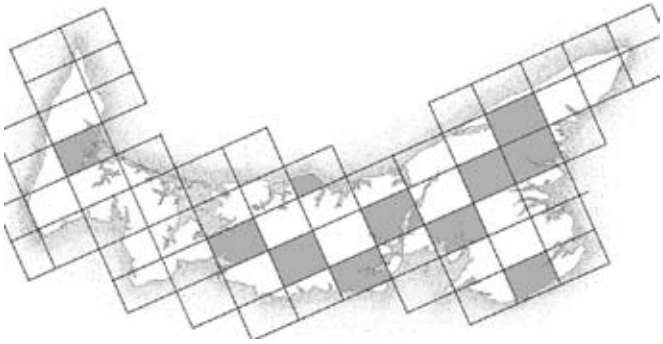
were found in and near woodlands in cattail marshes, ditches with rushes and alders, and in puddles (Table 3). Privately owned hardwood woodlots are common on PEI, and are rarely considered in the mosquito control programs which focus on the salt marshes and usually begin after *Oc. stimulans* larvae have emerged.

In Canada, *Ochlerotatus stimulans* has been reported in southeast Canada from southern Ontario through to the Maritimes, with a single locality in southern Manitoba (Wood et al. 1979). The species was found throughout PEI during the summer 2000 survey, and dominated the landing counts in both the Island-wide survey and the National Park survey. Despite its importance as a biter, it was poorly represented in the light traps. This species made up 13% of all mosquitoes collected (Table 1).

***Ochlerotatus triseriatus* (Say)**



Ochlerotatus triseriatus overwinters as an egg, and can produce more than one generation per year (Wood et al. 1979; Andreadis et al. 2005). This species breeds mainly in tree holes that fill with water and organic debris (Wood et al. 1979). It will also breed in artificial containers, such as barrels, tires, bottles, cisterns and gutters, provided they contain organic material and are shaded (Wood et al. 1979). On PEI, no tree holes were sampled, and the larvae that were collected were found late in the season in 2000 in water in a discarded tire in south-eastern PEI (Table 2), presumably when many of the tree holes were drying up. The adults were seen from July through to early September, but larvae were only collected in late August (Fig. 3).

This species is found in eastern North America, and has been reported in Ontario, Quebec, and New Brunswick. On PEI, adults were found in scattered locations around the province. This species was not overly common on PEI, making up ~2% of the total mosquitoes collected in 2000. It was very rare in the National Park area, probably reflecting a lack of habitat in a park dominated by sandy beach and wetland habitats. However, it was a relatively important human-biter on PEI, and is one of the species that has been implicated in the spread of WNV (Turrell et al. 2005). Wood et al. (1979) reports that females of *Oc. triseriatus* can also vector LaCrosse Encephalitis, as well as Eastern, Western and Venezuelan Equine Encephalitis, and transmission can occur trans-ovarially (i.e., from the female to the next generation by the egg). The difficulty in locating the larvae of this species would make it very difficult to control if PEI should experience an outbreak of WNV.

***Wyeomyia smithii* (Coquillett)**

Wyeomyia smithii is another container species, generally considered to be an obligate pitcher plant, *Sarracenia purpurea* L. (Sarraceniaceae), inhabitant (Wood et al. 1979). This species overwinters in the larval stage, and will produce more than one generation per year if conditions allow (Wood et al. 1979), but on PEI this species has a single generation (Hardwick and Giberson 1996). A single larva was collected at the end of June (Fig. 3) from a discarded tire in a bog near Charlottetown, but larvae have been found on PEI throughout the summer and winter (Hardwick and Giberson 1996). The distribution of this species in Canada is closely tied to that of the pitcher plant, and extends over most of Canada east of Alberta (Wood et al. 1979). The distribution shown on the map reflects data from Hardwick and Giberson (1996). *Wyeomyia smithii* does not take blood, at least for its first ovarian cycle, so in Canada, where it usually only produces a single generation per year, it does not blood-feed. It was rare during this survey (Table 1) due to lack of sampling of its specialized habitat, but can be locally abundant in the fluid of pitcher plants (Hardwick and Giberson 1996).

ACKNOWLEDGEMENTS

We thank the large group of UPEI biology students who willingly aspirated mosquitoes as they enjoyed various barbeques and recreational activities during the summer of 2000. Funding for the Island-wide study

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was provided by the Prince Edward Island department of Health, and the National Park survey was funded by Prince Edward Island National Park. Roy Ellis verified the voucher specimens, which are held in the UPEI museum.

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***Ochlerotatus cantator* probing to feed**

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