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Sampling, Distribution, Dispersal

Establishment of *Culex* (*Melanoconion*) *erraticus* (Diptera: Culicidae) in Southern Ontario, Canada

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ABSTRACT *Culex* (*Melanoconion*) *erraticus* (Dyar and Knab) is now established in southern Ontario, Canada. This species was first discovered in 2002 during a province-wide adult mosquito surveillance program for West Nile virus. Using CO_2-baited CDC miniature light traps, a few *Cx. erraticus* were collected from 2002 to 2011, but the total number increased during the 2012 and 2013 seasons. The number of Ontario Public Health Units with records for *Cx. erraticus* has also increased since 2002, demonstrating that the geographic distribution of this species is expanding northward. *Cx. erraticus* is a potential arboviral bridge vector for a number of pathogens and its establishment in Ontario should be considered a potential public health concern.

KEY WORDS *Culex erraticus*, distribution, first record, Ontario

Culex (*Melanoconion*) *erraticus* (Dyar and Knab) is a mosquito species native to the southeastern United States and much of South America (Pecor et al. 1992, Cupp et al. 2003, Darsie and Ward 2005). In recent years, it has been identified beyond its native range in California (Lothrop et al. 1995), Connecticut (Anderson et al. 1999), New Jersey (Farajollahi and Crans 2012), New York (Kulasekera et al. 2001), and now Ontario, Canada. The establishment of this species in Ontario appears to be part of a North American range expansion.

Cx. erraticus is of both medical and veterinary importance because it is known to vector eastern equine encephalitis virus (Chamberlain et al. 1954, Cupp et al. 2003), dog heartworm *Dirofilaria immitis* (Bemrick and Sandholm 1966, Afolabi et al. 1989), St. Louis encephalitis virus (Mitchell et al. 1980), various causative agents of reptilian malaria (Klein et al. 1987), and West Nile virus (WNv; Hribar et al. 2004, Cupp et al. 2007), while vector competence for Rift Valley fever virus has been demonstrated in laboratory conditions (Turell et al. 2008). *Cx. erraticus* was first described in 1906 as larvae (Dyar and Knab 1906) collected from Baton Rouge, LA. *Cx. erraticus* females are opportunistic blood-feeders known to feed on amphibians, birds, mammals, and reptiles (Hassan et al. 2003, Robertson et al. 1993, Burkett-Cadena at al. 2008). Adult females are also known to be aggressive and persistent biters with painful bites (King et al. 1960). Larvae are commonly found in swamps as well as along the grassy edges of ponds, lakes, slow flowing creeks, and rivers. They can also be found hiding from predators in duckweed (*Lemna* spp.), tree roots, and other sheltered areas (King et al. 1960, Robertson et al. 1993). Larvae are typically found with *Anopheles quadrimaculatus* (Say) and *Psorophora* mosquitoes (King et al. 1960, Breeland et al. 1961). *Cx. erraticus* females overwinter inseminated and initiate blood feeding in late April and early May (Robertson et al. 1993, Burkett-Cadena et al. 2012). We have partnered with Entomogen Inc. to examine the mosquito data they have generated as part of province-wide mosquito surveillance for WNv. Here, we show the data collected over the past decade that show *Cx. erraticus* has become established in the province of Ontario.

Materials and Methods

Adult mosquitoes were collected using CO_2-baited CDC miniature light traps (hereafter, light traps) by staff from various Health Units (HU) and First Nations Communities from 2001 to 2013, as part of a province-wide adult mosquito surveillance program. Samples were sent on ice to Entomogen Inc., where they were freeze-killed for subsequent species identification. During the 2013 season, the authors set additional light traps in the Niagara Region. For each identified specimen of *Cx. erraticus*, we obtained the collection date and global positioning system (GPS) coordinates of the light trap. Adult *Cx. erraticus* mosquitoes were identified using the keys described by Darsie and Ward (2005) and Thielman and Hunter (2007). ERSI ARC-Map 10.2 was used to map GPS coordinates of light traps that collected *Cx. erraticus*. It is possible that individuals from the same breeding population could

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be collected at different sampling sites if the distance between sites from the same year were located within the estimated flight range of an adult female *Cx. erraticus* (0.97–3.21 km per gonotrophic cycle; Estep et al. 2010). To separate individuals from the same breeding populations and individuals from unique breeding populations a geographic information system (GIS) proximity analysis was conducted among collection sites of the same year. We defined any two collections within a distance of 9.63 km (three times the maximum estimated flight range per gonotrophic cyle) as a single collection event.

Results

Our collections included a total of 413 specimens (Table 1) collected from 19 HUs (Fig. 1). Data points from First Nations Communities are included in the HU, within which the First Nations are located. The first record of *Cx. erraticus* in Ontario was a single adult female collected in Durham Region on 28 August 2002. Two more specimens were identified in the same year on 9 September in Windsor-Essex County and on 18 September in Durham Region. In 2003, 23 specimens were collected from a single trap in Windsor-Essex County. No specimens were collected during 2004–2007. The 2008 season yielded three specimens trapped in Middlesex-London and two specimens in Lambton County. During the 2009 season, a single specimen was collected in Brant County. No specimens were collected during the 2010 season. In 2011, two specimens were collected in Halton Region. During the 2012 season, the number of collected specimens increased drastically to 339 distributed among 17 HUs. More than half of the specimens (202 of the 339) were trapped in Brant County and Lambton County. In 2013, 40 specimens were collected within six HUs. More than half of the specimens (22 of the 40) were collected in Middlesex-London and 2 specimens were collected in the Niagara Region.

Overall, the majority of specimens (398 of the 413) were collected in August and September (EPI weeks 31–40). More than half of the specimens (274 of the 413) were collected during EPI weeks 35 through 37; this corresponds to late August and early September. No specimens were collected prior to EPI week 28 or after EPI week 40.

Using GIS proximity analyses, we determined that several traps within the same sampling year could be single collection events based on the given parameters. The analysis identified 7 of the 42 sites in 2012 and 2 of the 14 sites in 2013 to be within 9.63 km of each other.

Table 1. Number of specimens of *Cx. erraticus* collected during adult mosquito surveillance from 2002 to 2013 from within Ontario's Health Unit boundaries

Health Unit	Year								
	2002	2003	2008	2009	2010	2011	2012	2013	Total
BRN	0	0	0	1	0	0	97	1	99
CHK	0	0	0	0	0	0	8	6	14
DUR	2	0	0	0	0	0	1	0	3
GBO	0	0	0	0	0	0	3	0	3
HAL	0	0	0	0	0	2	16	3	21
HKP	0	0	0	0	0	0	1	0	1
HUR	0	0	0	0	0	0	1	0	1
LAM	0	0	2	0	0	0	105	6	113
MSL	0	0	3	0	0	0	15	22	40
NIA	0	0	0	0	0	0	33	2	35
NPS	0	0	0	0	0	0	3	0	3
NWR	0	0	0	0	0	0	1	0	1
OXF	0	0	0	0	0	0	41	0	41
PTC	0	0	0	0	0	0	3	0	3
SMD	0	0	0	0	0	0	2	0	2
WDG	0	0	0	0	0	0	8	0	8
WEC	1	23	0	0	0	0	0	0	24
YRK	0	0	0	0	0	0	1	0	1
Total	3	23	5	1	0	2	339	40	413

Some collections were from First Nations Communities within the HU boundaries.

Abbreviations: BRN, Brant County; CHK, Chatham-Kent; DUR, Durham Region; GBO, Grey Bruce; HAL, Halton Region; HKP, Haliburton-Kawartha-Pine Ridge District; HUR, Huron County; LAM, Lambton County; MSL, Middlesex-London; NIA, Niagara Region; NPS, North Bay Parry Sound District; NWR, Northwestern; OXF, Oxford County; PTC, Peterborough County-City; SMD, Simcoe Muskoka District; WDG, Wellington-Dufferin-Guelph; WEC, Windsor-Essex County; YRK, York Region. All identifications were verified by the authors.

Discussion

These data strongly suggest that *Cx. erraticus* has become established in southern Ontario and is expanding its range further north (Fig. 2). The introduction of this species to Ontario is believed to be a range expansion. Hongoh et al. (2012) has hypothesized a similar scenario for *Culex pipiens* L. in North America using climate projections with increasing yearly temperatures. Our records indicate low numbers of adult females collected from 2002 through 2011. However, the 2012 season yielded the largest collections to date, spanning the greatest number of HUs. In 2013, we observed a decrease in both the number of specimens collected and the number of HUs that collected them.

Unfortunately, we have yet to collect larvae of this species, despite repeated attempts to do so. We conducted a proximity analysis among light trap locations. This resulted in 16 of the 65 traps being identified to be within the maximum suggested flight range of *Cx. erraticus*. Arguably, therefore, we have specimens from at least 49 independent source sites for *Cx. erraticus* in Ontario.

Population size for *Cx. erraticus* is known to be inversely proportional to the amount of precipitation (Robertson et al. 1993, Cupp et al. 2004). According to Environment Canada, the summer of 2012 had periods with drought-like conditions. During periods of drought, water levels in potential oviposition sites are decreased by evaporation; this exposes areas of high vegetation, *Cx. erraticus*' preferred oviposition sites. This may explain why we observed our largest collections to date during the 2012 season. Our seasonal distribution data—with peak collections in August and September—correspond to those reported by Robertson et al. (1993) for North Carolina.

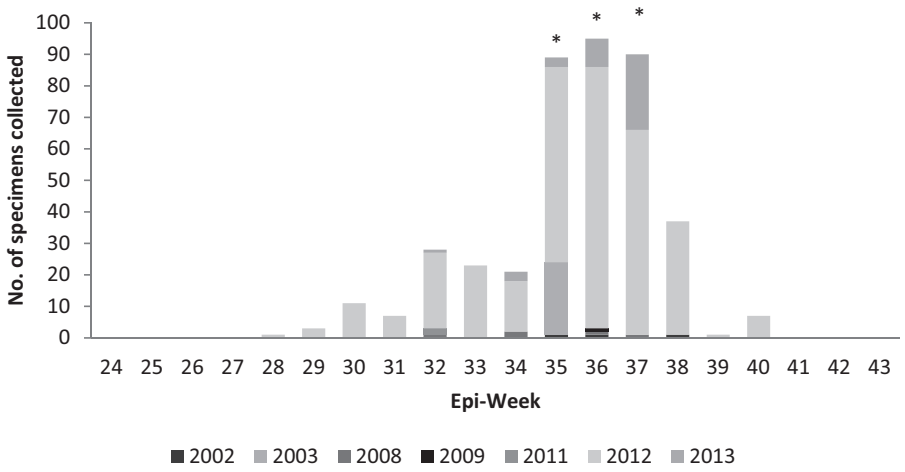

Fig. 1. Seasonal distribution of collected *Cx. erraticus* in southern Ontario from 2002 to 2013. * Indicates significant peak collections (defined as being at least two standard deviations above the mean).

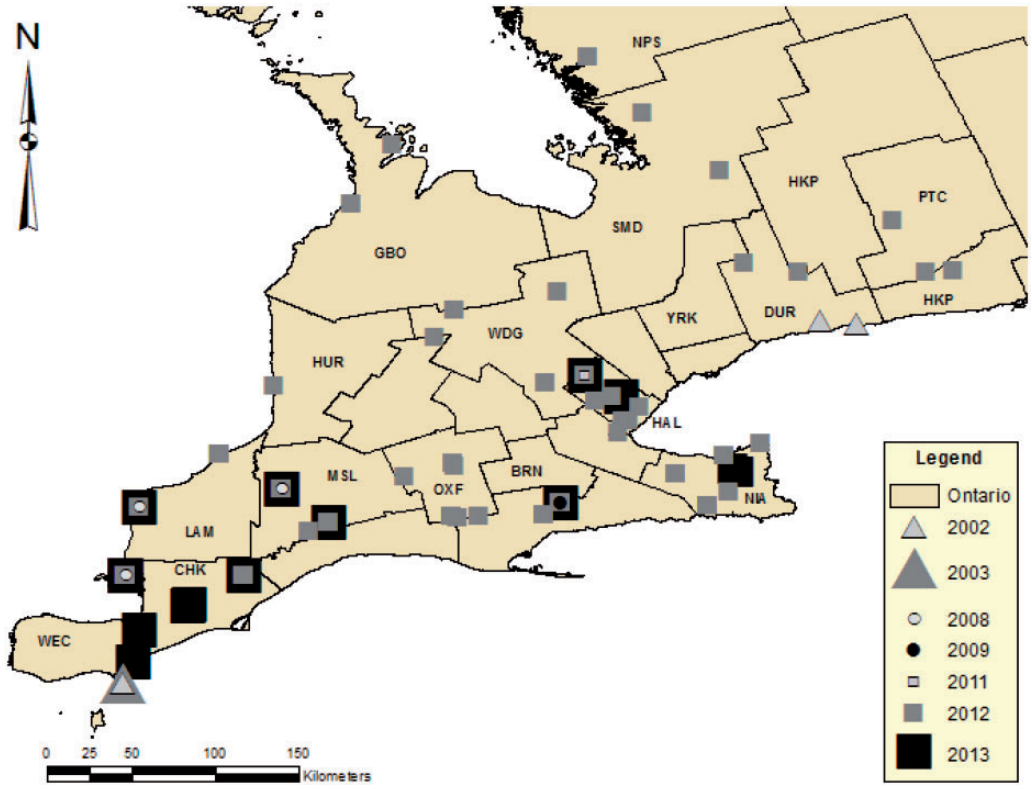

Fig. 2. Collection sites that yielded *Cx. erraticus* in southern Ontario from 2002 to 2013. Health unit abbreviations are as in Table 1.

Cx. erraticus is a known vector of several pathogens, including WNv, and should be included in the list of mosquito species endemic to Ontario. Further research is required on this species' blood-feeding behaviors, larval habitat, and vector competence for WNv before we can fully understand its involvement in future epidemic years.

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