NEW RANGE RECORDS OF MOSQUITOES (DIPTERA: CULICIDAE) FROM NORTHERN ONTARIO

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Abstract *J. ent. Soc. Ont.* 144: 3–14

A survey for mosquitoes at 23 sites in the Ontario Shield and Hudson Bay Lowlands of northern Ontario, Canada, in 2011 and 2012 yielded 19 species, including 16 of *Aedes*, and one each of *Anopheles*, *Coquillettidia*, and *Culesita*. One species, *Aedes pullatus* (Coquillett) is newly recorded for Ontario. Eleven northern range extensions and one southern range extension are reported.

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Introduction

The distributions of many mosquito species (Diptera: Culicidae) in Canada are incomplete. Jenkins and Knight (1952) conducted a survey of larval mosquitoes in southern James Bay. Steward and McWade (1960) published range summaries of species in Ontario. Wood et al. (1979) compiled the most complete account of mosquito distribution in Canada The Canadian Endangered Species Conservation Council (CESCC 2011) assessed the status of many species, including mosquitoes. Yet, areas such as northern Ontario are still relatively little sampled.

Northern Ontario has become the focus of increased mineral exploration and development (FNSAP 2010). Additionally, the area is projected to undergo significant ecological transformation over the next several decades due to climate change (FNASP 2010). Together, these two driving forces create a need for better knowledge of species' distributions in northern Ontario before significant changes occur. A biological diversity survey of different taxa in northern Ontario was initiated in 2009 to address this issue (OMNR 2012). The species composition and diversity information obtained will help determine land use, and management and conservation planning, as well as provide baseline information to determine the impact of mining and climate change.

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Mosquito species lists for particular geographic areas include species that have not been collected there but are assumed to be present based on information from adjacent areas (e.g., Wood et al. 1979; Darsie and Ward 2005). Thus, it is reasonable to expect species to be found in northern Ontario if they have been found in similar habitats and at similar latitudes elsewhere, i.e., in spite of regional climatic differences, we expected to find species that have existing records from both adjacent western Quebec and northern Manitoba because of the large scale continuity of the ecosystems in the boreal and subarctic forests that span these three provinces. For mosquito species whose known distributional limits were either south or north of our study areas, we expected to extend known ranges north or south, respectively. Following this reasoning, and based on the range maps provided by Wood et al. (1979) and Darsie and Ward (2005), we predicted a maximum of 31 species in our surveys. In this paper we report new information on occurrences of known species (range extensions), new collection locations and records of species new to the province for Culicidae in Ontario from surveys of previously unexplored areas of the far north of Ontario. We use both rarefaction and a lognormal analysis to explore the maximum number of species predicted in these areas and to gauge their relative abundances.

Materials and Methods

Sampling took place within two different northern Ontario ecozones: the Ontario Shield and Hudson Bay Lowlands ecozones (Crins et al. 2009) in 2011 and 2012, hereafter referred to the western and eastern study areas, respectively, as part of a larger biological survey of animal and plant taxa undertaken by the OMNR (2012). The 2011 sampling occurred within 150 km of the First Nations communities near Big Trout Lake and Sandy Lake in the western study area. The 2012 sampling occurred within 150 km of the First Nations community of Fort Albany in the eastern study area. In each year 12 sample sites were randomly selected from the computer generated grid of National Forest Inventory (NFI) points (Gillis et al. 2005). Actual sample locations sometimes differed by as much as 15 km from the NFI coordinates depending on feasibility of landing a helicopter. Our plot locations are the sites at which field camps were established (OMNR 2012). Sample locations were within 1 km of the field camp, which was verified using a handheld GPS (Garmin Rino 530HCx, NAD83, ±3m accuracy). Sampling occurred from 29 May to 17 July in 2011 and 4 June to 5 July in 2012.

Habitats at these sites were dominated by coniferous and shrub wetlands comprised largely of black spruce (*Picea mariana* Britton, Sterns & Poggenb.) and tamarack (*Larix laricina* (Du Roi) K. Koch) as well as shrub and sedge fens, and sphagnum bog. The sites sampled in 2012 in the eastern study area generally had more standing water than those sampled in 2011 in the western study area.

In both years the mosquito component of the sample regimen included daily sampling both by individual collection (*ad hoc*, when mosquitoes were present, approximately 30 minutes total), and a dusk and dawn sweeping with an insect net for 6 minutes at each sampling location. Individual collection consisted of catching mosquitoes that landed on the face, arms, and legs of field crew members using snap cap vials (2.0 ml) before they had a chance to bite. These collections occurred throughout the day and late evening. Individual specimens in snap vials were preserved dry in the capture vials. Adult mosquitoes collected by sweeping were placed in labeled sample jars with a silica desiccant to prevent deterioration from moisture. A large proportion of them had scales on their thoraces abraded and so could not be identified to species. Therefore, more effort was placed on individual collection in 2012. All specimens were pinned and identified by JLR and DVB using the keys of Wood et al. (1979), and Thielman and Hunter (2007). Nomenclature was based on the WRBU Online Catalog (2013). Voucher specimens were assigned individual specimen numbers (Table 2) and are stored at the Trent University Biology Department in Peterborough, Ontario. Some vouchers are deposited in the Canadian National Collection of Insects, Ottawa.

Analysis

Rarefaction analysis for the 2011 and 2012 catch data was performed using software on the University of Alberta website (http://www.biology.ualberta.ca/jbrzusto/rarefact.php). This method relates sampling effort to number of species caught. The total number of species caught each year is used to calculate the expected number of species (with standard deviation) that would have been caught if fewer mosquitoes were sampled overall. Different species numbers for the same total catch sizes indicate community differences such as those due to site, e.g., habitat or phenological, or procedural differences.

We also fit the catch data (Table 1) to a lognormal distribution using the sum of squares method, i.e., Preston's method as described in Ludwig and Reynolds (1988). This allowed us to calculate the expected number of species by estimating the number of rare species not found in the samples. Essentially, it assumes that species of low abundance, e.g., about 1 per 1000 individuals, will only be found if at least 1000 individuals are collected. The lognormal distribution uses the abundance of different species and groups them into octaves or doubled catch classes, e.g., 0–1 individuals, 1–2 individuals, 2–4 individuals, 4–8 individuals and so on, and fits these frequencies to a lognormal curve by aligning the mode. Species that had only one individual caught could go into either the first or second class, so the number was divided between these classes, e.g., if one catches 5 species with only one individual each, then half of these (2.5) are assigned to the 0–1 class, and 2.5 to the 1–2 class (Ludwig and Reynolds, 1988). One of the assumptions of this method is that very rare species will not be sampled, but can be calculated from the area of the normal curve to the left of the 0–1 class or veil line. The biological interpretation is that this class (0–1) would become the 1–2 class if our total catch size was increased. This analysis requires an iterative method to find values for two parameters that provide the best fit: a (width), and So (height). We used the SOLVER optimization add-in function in Microsoft Excel 2007 version for this task.

Results

We caught 896 mosquitoes in 2011 and 826 in 2012. Mosquitoes caught directly from the face and arms and housed in vials could all be identified to species, whereas only 117 (13%) of individuals from 2011 and 192 (21%) from 2012 sweeping could be identified to species. Species collected and collection locations are summarized in Tables 1 and 2. Twelve species were collected in the western study area in 2011 and 16 species

TABLE 1. Culicidae species collected in 2011 within 150 km of Big Trout Lake and Sandy Lake, and in 2012 within 150 km of Fort Albany.

Species	Catch per year		Date(s) captured		Distribution change for Ontario
	2011	2012	2011	2012	
Aedes abserratus (Felt and Young)	1	29	June 17–July 7	June 8–July 7	gap infill
Aedes canadensis (Theobald)		2		June 25, 28	new northern record
Aedes cinereus Meigen		1		June 23	new northern record
Aedes communis (De Geer)	11	2	June 10, 11	June 15, 28	northwestern gap infill
Aedes dorsalis (Meigen)		4		June 10	new northern record
Aedes excrucians (Walker)	2	2	July 12	June 23, 25	new northern record
Aedes hexodontus Dyar	4	11	June 2–July 12	June 8–13	gap infill
Aedes impiger (Walker)	18		June 2		northwestern gap infill
Aedes implicatus Vockeroth	2	3	June 2–17	June 8, July 10	new northern record
Aedes intrudens Dyar		19		June 8–26	new northern record
Aedes nigripes (Zetterstedt)	1		July 7		new southern record
Aedes pionips Dyar	28	32	June 2–July 7	June 8–July 14	gap infill
Aedes provocans (Walker)		1		June 8	new northern and eastern record
Aedes pullatus (Coquillett)		1		June 10	first record for province
Aedes punctor (Kirby)	7	35	June 6–July 3	June 8–July 7	gap infill
Aedes rempeli Vockeroth		1		June 26	new northern record
Anopheles earlei Vargas	3	5	July 3	June 8, July 13	new northern record
Coquillettidia perturbans (Walker)	39	44	July 3–15	June 17 to July 13	new northern record
Culiseta impatiens (Walker)	1		June 6		new northern record

in the eastern study area in 2012 (Fig. 1, Table 1). The most abundant species identified in both years was *Coquillettidia perturbans* (Walker). Rare species, i.e., those represented by a single individual collected in either year were *Aedes cinereus* Meigen, *Ae. nigripes* (Zetterstedt), *Ae. provocans* (Walker), *Ae. pullatus* (Coquillett), *Ae. rempeli* Vockeroth and *Culiseta impatiens* (Walker).

Fitting to the lognormal distribution (Fig. 2), the expected number of species was 14.75 from the 2011 catches (fitted parameters a = 0.24, *So* = 2.0, Chi sq = 1.23, p = 0.94, d.f. = 5) and 23.4 species in the 2012 catches (fitted parameters a = 0.225, *So* = 2.97, Chi sq = 5.46, p = 0.36, d.f. = 5). By combining the two year's totals, our expected number of species for northern Ontario was 28.2 species (fitted parameters a = 0.21, *So* = 3.35, Chi sq = 2.94, p = 0.82, d.f. = 6).

Interpretations of new records and range extensions are based on comparison with range maps in Wood et al. (1979).

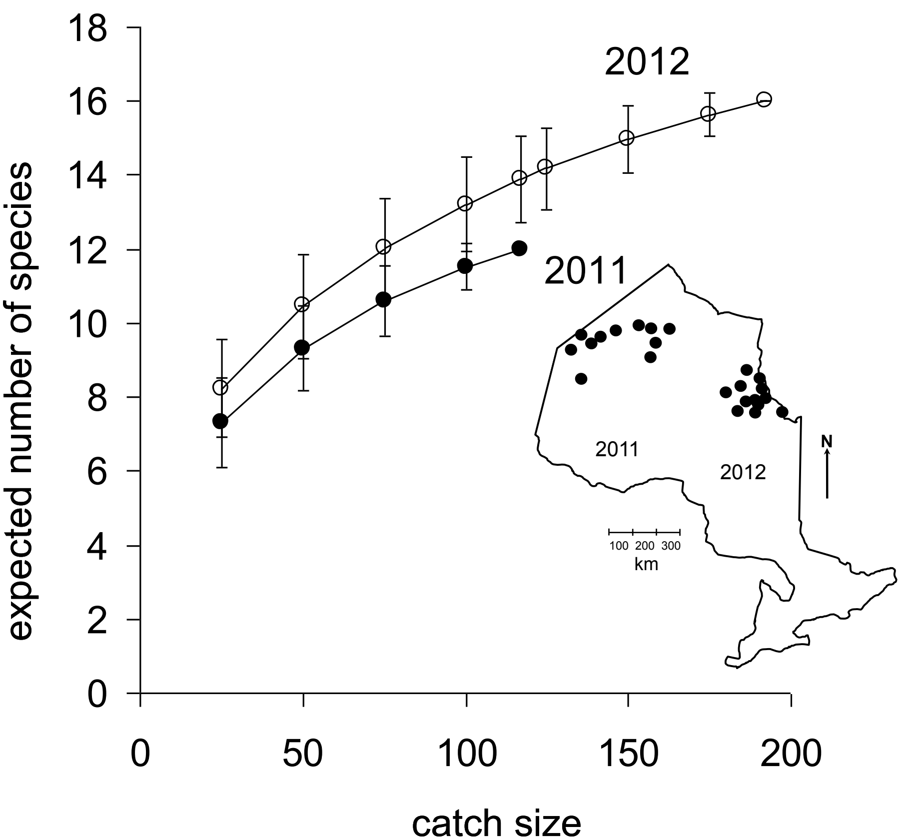

FIGURE 1. Rarefaction analysis of mosquito catches (means and SDs) within 150 km of Big Trout Lake and Sandy Lake in 2011 (closed circles) and within 150 km of Ft. Albany in 2012 (open circles). The inset map of Ontario shows the sampling locations in 2011 and 2012.

TABLE 2. Mosquito species found at each sampling site. Dates indicate when sampling was conducted. Only 11 sample sites listed in 2011 because collections from one of the July 12–21 sites were damaged by a bear. TUIC numbers are voucher specimens in the Trent University Insect Collection.

TUIC#	Year	2011										2012											
	Sampling dates	May 31 – June 7	May 31 – June 7	June 8 – 15	June 8 – 15	June 16 – June 23	June 16 – June 23	June 28 – July 5	June 28 – July 5	July 6 – July 13	July 6 – July 13	June 5 – June 11	June 5 – June 11	June 12 – June 18	June 12 – June 18	June 19 – June 25	June 19 – June 25	June 26 – July 2	June 26 – July 2	July 3 – July 9	July 3 – July 9	July 10 – June 16	July 10 – July 16
	Longitude (West)	89° 6' 28"	89° 40' 43"	88° 54' 51"	92° 1' 44"	90° 21' 38"	88° 33' 33"	93° 2' 33"	94° 13' 38"	91° 49' 9"	93° 32' 10"	81° 57' 48"	82° 39' 13"	80° 23' 11"	81° 50' 57"	81° 39' 23"	82° 41' 2"	83° 17' 24"	82° 49' 2"	82° 8' 2"	83° 2' 25"	83° 22' 44"	82° 3' 24"
	Latitude (North)	53° 12' 8"	54° 25' 50"	53° 45' 35"	54° 9' 30"	54° 27' 1"	54° 28' 19"	53° 27' 40"	52° 49' 28"	52° 27' 37"	53° 36' 9"	52° 46' 35"	51° 55' 53"	51° 26' 40"	51° 39' 8"	51° 58' 8"	52° 53' 25"	51° 29' 53"	52° 28' 27"	52° 23' 20"	51° 47' 50"	52° 18' 23"	51° 21' 22"
	Species																						
0001	*Aedes abserratus*								X			X	X	X	X	X	X	X		X			
0002	*Aedes canadensis*																	X					
0003	*Aedes cinereus*															X							
0004	*Aedes communis*				X										X			X					
0005	*Aedes dorsalis*											X											
0006	*Aedes excrcians*										X					X		X					

TABLE 2 continued...

TUIC#	Year	2011										2012											
	Sampling dates	May 31 – June 7	May 31 – June 7	June 8 – 15	June 8 – 15	June 16 – June 23	June 16 – June 23	June 28 – July 5	June 28 – July 5	July 6 – July 13	July 6 – July 13	June 5 – June 11	June 5 – June 11	June 12 – June 18	June 12 – June 18	June 19 – June 25	June 19 – June 25	June 26 – July 2	June 26 – July 2	July 3 – July 9	July 3 – July 9	July 10 – June 16	July 10 – July 16
0007	*Aedes hexodontus*				X						X	X	X			X					X		
0008	*Aedes impiger*		X																				
0009	*Aedes implicatus*	X										X											X
0010	*Aedes intrudens*												X		X	X	X	X					
0011	*Aedes nigripes*									X													
0012	*Aedes pionips*	X	X		X		X		X	X		X	X	X		X	X	X	X	X		X	
0013	*Aedes provocans*											X											
0014	*Aedes pullatus*												X										
0015	*Aedes punctor*				X	X			X				X			X	X	X	X	X	X		
0016	*Aedes rempeli*																	X					
0017	*Anopheles earlei*							X				X									X		
0018	*Coquillettidia perturbans*							X	X		X							X		X	X		X
0019	*Culiseta impatiens*	X																					

New Ontario record

Aedes pullatus has two distinct distributions, an eastern population in northern Quebec and Labrador and the western population in Alberta, British Columbia, and the Yukon (Wood et al. 1979). The single specimen we collected in the eastern study area is the first record in Ontario and extends the range of the eastern population westward.

Northward range extensions

Aedes canadensis (Theobald) is a widely distributed species found in forested regions of all Canadian provinces and the Yukon (Steward and McWade 1960). It is known to be found in Moosonee and Moose Factory in Ontario. Our collection was in the eastern study area.

Aedes cinereus is a common species in Ontario and has been found in Moosonee, Moose Factory and the town of Kenora (Steward and McWade 1960). Jenkins and Knight (1952) noted that *Ae. cinereus* was the most common larval species that they collected in the southern James Bay area but, oddly, they collected no adults. Our single specimen was collected in the eastern study area.

Aedes dorsalis (Meigen) is a rare northern species and in Ontario has only been collected in Moosonee and Moose Factory (Steward and McWade 1960). It was only collected in the eastern study area, which is not surprising because of its relative proximity to these communities.

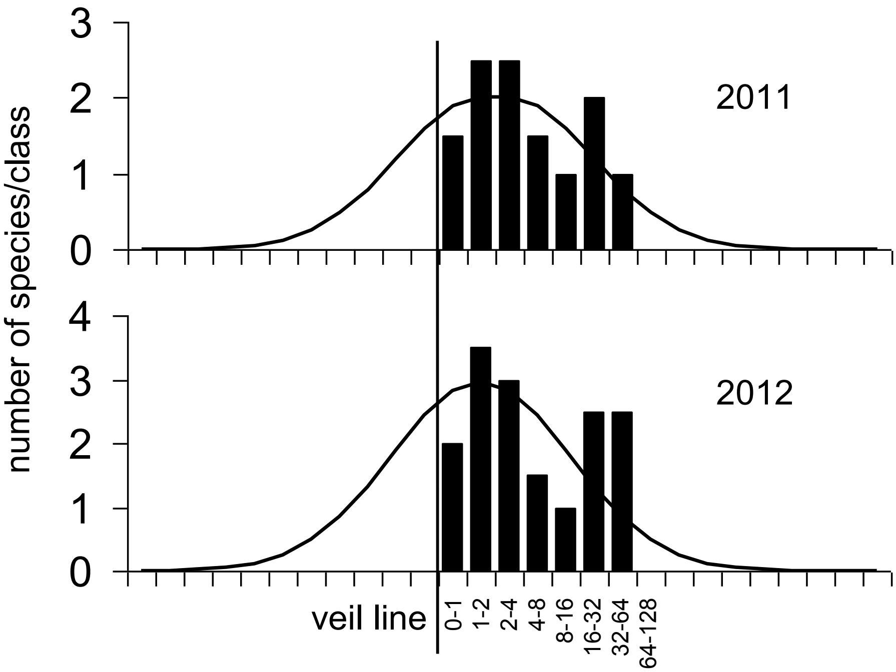

FIGURE 2. Fitted lognormal distributions of mosquito catches within 150 km of Big Trout Lake and Sandy Lake in 2011 and within 150 km of Ft. Albany in 2012. The area of the region left of the veil line represents species that were too rare to be sampled with our methodology.

Aedes implicatus (Vockeroth) is common in the northern and central parts of Ontario and has been collected in Moose Factory (Steward and McWade 1960). It was collected in both study areas.

Aedes excrucians (Walker) is found throughout North America (Wood et al. 1979). It was collected by Jenkins and Knight (1952) in Moose Factory and Moosonee and by Steward and McWade (1960). Our collection from the western study area provides a record for the gap between the eastern James Bay coast and Manitoba.

Aedes intrudens Dyar is found south of the tree line in late spring (Wood et al. 1979). It has been recorded from all provinces (Steward and McWade 1960). The species was common in the eastern study area, but was not found in the western study area.

Aedes provocans is a forest species and is a southern species in Ontario (Wood et al. 1979), except for a single record from Great Slave Lake, Northwest Territories. We collected a single specimen in the eastern study area.

Aedes rempeli is one of the rarest Canadian species (Vockeroth 1954). However, Wood et al. (1979) suggested that this species may be widely but sparsely distributed in northern Ontario. We caught a single specimen along the Albany River about 150 km upstream from the James Bay coast.

Anopheles earlei Vargas is the most common species of this genus in Ontario. Our collections of this species in both study areas extend the known range.

Coquillettidia perturbans is common in southern Ontario (Wood et al. 1979). Jenkins et al. (1952) found that this species was very abundant in a spruce forest west of Cochrane, Ontario. In both study areas it was our most abundant species.

Culiseta impatiens is a northern species usually found in forested regions and has been recorded from Moose Factory (Steward and McWade 1960). Our single specimen came from the western study area, providing a westward extension of the known range.

Southward range extensions

Aedes nigripes is an arctic species whose range, according to Wood et al. (1979), did not extend southward into Ontario. However, one recent record exists from Polar Bear Provincial Park (Beresford 2011). One specimens was collected in the western study area in 2011, even farther south than Polar Bear Provincial Park.

Range gap infills

Aedes absserratus (Felt and Young) is an uncommon species in Ontario (Wood et al, 1979). Steward and McWade (1960) reported the species from Moose Factory. Beresford (2011) collected it in Polar Bear Provincial Park. Our collection of this species in both study areas fills the gap. *Aedes communis* (De Geer) is one of the most widely distributed species in the northern hemisphere. Beckel (1954) stated that this species was rarely collected in the Churchill area of Manitoba because it is non-biting in that area. In Ontario, records show it to be generally present and often abundant throughout the province. This species was well represented (9.4%) in our collections from the western study area, but less so (1%) in the eastern study area.

Aedes hexodontus Dyar has been collected in Churchill, Manitoba both as larvae (Vockeroth 1954) and as adults (Beckel 1954), and also from western Quebec and western Ontario (Wood et al, 1979). Our collection fills the gap.

Aedes impiger (Walker) is generally found in Nunavut and the Northwest Territories (Steward and McWade 1960). It has been caught in Ontario at Moose Factory and along the Albany River (Steward and McWade 1960) and in Manitoba at Churchill (Downes 1965). Our collections from our western study area fill a gap between Churchill and the James Bay coast in Quebec. Surprisingly, we did not find any in our eastern collections, which are close to James Bay.

Aedes pionips Dyar is found in the forests of central and northern Canada, and has been collected from Moose Factory, Ontario (Steward and McWade 1960) and Churchill, Manitoba (Beckel 1954). Not unexpectedly, our collections fill the gap.

Aedes punctor (Kirby) is a common species in Ontario and throughout Canada (Steward and McWade 1960). Records are from Moosonee (Jenkins and Knight 1952) and Churchill, Manitoba (Beckel 1954). Our collections are within the expected range but fill distributional gaps in northwestern Ontario.

Discussion

As expected we produced new distributional records, including both northward and southward range extensions, and filled gaps in known ranges. All of the species we collected are considered by CESCC (2011) to be secure (relatively widespread or abundant), except for five with undetermined status: *Aedes impiger*, *Ae. implicatus*, *Ae. pionips*, *Ae. rempeli* and *An. earlei*.

The rarefaction analysis, which standardizes across different sample sizes, indicates that the eastern region (2012) had slightly more species than the western region (2011). For example, in collections of 100 individuals we would only have been able to catch about 13 species in the east compared to 11 in west (Fig. 1). The lognormal analysis shows the same pattern, with 23.4 species predicted to be in the eastern region compared to 14.75 in the western region (Fig. 2). These analyses reveal that this difference in species richness may be a function of the different regions (e.g., habitats) rather than catch effort. The 2012 eastern study area collections were from sites with lower elevations (1–88 m) than the western sites (148–379 m). However, because these two regions were sampled in different years, we cannot attribute this difference to region alone.

From our survey of the range maps we expected to find up to 31 species. Fitting the lognormal distribution to our overall catch numbers, our expected number of species was 28, a good estimate of species richness of this region.

In fact, we found only 19 species and four of the species we did catch were not expected from the range map analysis: *Aedes nigripes, Ae. provocans, Ae. pullatus, Ae. rempeli.* This means that 16 species from the range map analysis were expected but not found, either due to our sampling methods, phenology, or habitat preferences. Of these, *Wyeomyia smithii* (Coquillett) is fully autogenous and has not been reported bloodfeeding; *Ae. diantaeus* Howard, Dyar and Knab is not found in coniferous forests; *Ae. spencerii* (Theobald) is not found in forest regions; *Ae. sticticus* (Meigen) is generally restricted to floodwaters of rivers; *Culesita morsitans* (Theobald) and *Culex restuans* Theobald prefer to bloodfeed from birds; *Culex territans* Walker prefers reptiles and amphibians; *Culesita alaskaensis* (Ludlow) and *Ae. mercurator* Dyar are early spring species; *An. walkeri* (Theobald), *Ae. vexans* (Meigen) and *Ae. campestris* Dyar & Knab are primarily nocturnal biters. The remaining four of the expected species are rare, *Ae. riparius* Dyar & Knab, *Ae. flavescens* (Müller), *Ae. fitchii* (Felt & Young) and *Ae. decticus* (Howard, Dyar & Knab) (Wood et al. 1979).

All collection methods have inherent biases associated with them (Muirhead-Thomson 1991). Some important limitations to this survey are that collections occurred at randomly chosen sites (i.e., not selected for high probability of detecting mosquitoes) and using simple methods that were part of a larger diversity survey. The mosquito portion of that survey was limited by the logistics of available time and equipment at these remote sites. A collection effort that focused on targeting mosquitoes alone, within specific habitats, would likely have produced more of the expected species, and the use of CO_2 traps of CDC light traps would have produced far larger collections. Nevertheless, this study, despite its limitations, indicates that surveys undertaken in under-sampled regions can produce important baseline information that extends the previously known ranges.

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