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IMPACT OF NALED (DIBROM 14®) ON THE MOSQUITO VECTORS OF EASTERN EQUINE ENCEPHALITIS VIRUS

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ABSTRACT. In central New York, aerial mosquito adulticide applications have been used in response to eastern equine encephalitis (EEE) outbreaks and have targeted the swamp habitats of the primary enzootic vector of EEE virus, *Culiseta melanura* (Coquillett). The organophosphate insecticide naled (1, 2, dibromo-2, 2-dichloroethyl dimethyl phosphate) has been the insecticide of choice in this region. This study reports on analyses of 11 years (1984–94) of mosquito collection data from Cicero and Toad Harbor swamps in relation to applications of naled. Naled applications were successful in achieving short-term reductions in mosquito abundance. However, despite repetitive applications, populations of the primary vector of EEE virus, *Cs. melanura*, have increased 15-fold at Cicero Swamp. Preventive applications had no noticeable impact on the enzootic amplification of EEE virus, and isolations of virus following preventive applications have resulted in additional spraying. The possibility that applications of naled contributed to increased populations of *Cs. melanura* discredits the rationale that preventive applications of naled reduce the risk of EEE.

INTRODUCTION

Ultra-low volume (ULV) aerial applications of the mosquito adulticide Cythion® in response to outbreaks of arthropod-borne viruses gained acceptance during the 1960s when used during St. Louis encephalitis outbreaks in Texas (Kilpatrick and Adams 1967). In 1972 and 1974, aerial ULV applications were used in Massachusetts in response to epidemics of eastern equine encephalitis (EEE). Although evaluations of spraying efficacy produced equivocal results (Grady et al. 1978), in Massachusetts the application of malathion continues to be the recommended response during EEE epidemics (Edman et al. 1993). In central New York, aerial mosquito adulticide applications have also been used in response to EEE outbreaks and have targeted the swamp habitats of the primary enzootic vector of EEE virus, *Culiseta melanura* (Coquillett) (Morris 1988). The organophosphate insecticide naled (1, 2, dibromo-2, 2-dichloroethyl dimethyl phosphate) has been the insecticide of choice in this region. The formulation used is Dibrom 14® mixed with heavy aromatic naphtha, a fast-acting, short-residual adulticide developed for mosquito control (Haile et al. 1982), applied at a rate of 0.2 liter/ha (1 pint/acre). All applications have been performed by the same contractor using Piper Aztecs equipped with Micromist 900® spray systems (Warm 1986).

Morris (1988) stated that a single well-timed application of an adulticide could control *Cs. melanura*. This statement was based on evaluation of 1-day pre- and postefficacy data from the treated area and the resultant absence of equine EEE from upland areas following adulticide applications (Morris, unpublished data). Following the second human EEE fatality in central New York (Howard et al. 1988), a more liberal mosquito spraying policy was adopted by local municipalities. The 2 areas most frequently subject to control were Cicero Swamp in Onondaga County and Toad Harbor Swamp in Oswego County, the recognized enzootic foci of EEE virus in central New York (Morris et al. 1980, Howard et al. 1996). Aerial applications of naled have occurred as preventive measures in response to large numbers of mosquitoes, as a reaction to the detection of Highlands J (HJ; a mosquito-borne virus of birds that is not pathogenic to humans), the detection of EEE virus in mosquitoes, or the occurrence of EEE. With the exception of 1993, when 25% of Toad Harbor Swamp was experimentally treated with Altosid® (methoprene) pellets (Woodrow et al. 1995), larval control activities have not been undertaken in these swamps.

Yearly summaries of mosquito and virus surveillance data question Morris' conclusion regarding the effectiveness of aerial adulticiding. These summaries revealed a trend toward increasing numbers of *Cs. melanura* and EEE virus isolations during the late 1980s and early 1990s (Howard et al. 1994) and led to the current study. During the 1983 EEE outbreak in central New York, a majority (91%, $n = 21$) of EEE virus isolations were made from mosquitoes collected in Cicero Swamp (Howard et al. 1988). There were 11 isolations of EEE virus from 1,118 *Cs. melanura* and 7 isolations from 1,534 *Culiseta morsitans* (Theobald) collected and assayed between July 1 and mid-October 1983. In 1990, there were 86 EEE virus isolations from central New York, of which 27 were from 21,857 *Cs. melanura* and 1 from 816 *Cs. morsitans* collected and assayed from Cicero Swamp between June 7 and late October 1990. In 1992, although there were no EEE virus isolations from central New York (Howard et al. 1994), 55,749 *Cs. melanura* and 157 *Cs. morsitans* were collected and assayed from Cicero Swamp between June 1 and the late September 1992. This paper reports on the evaluation of short-term, seasonal, and long-term quantitative mosquito population data in response to aerial applications of naled to Cicero and Toad Harbor swamps over an 11-year period, 1984–94.

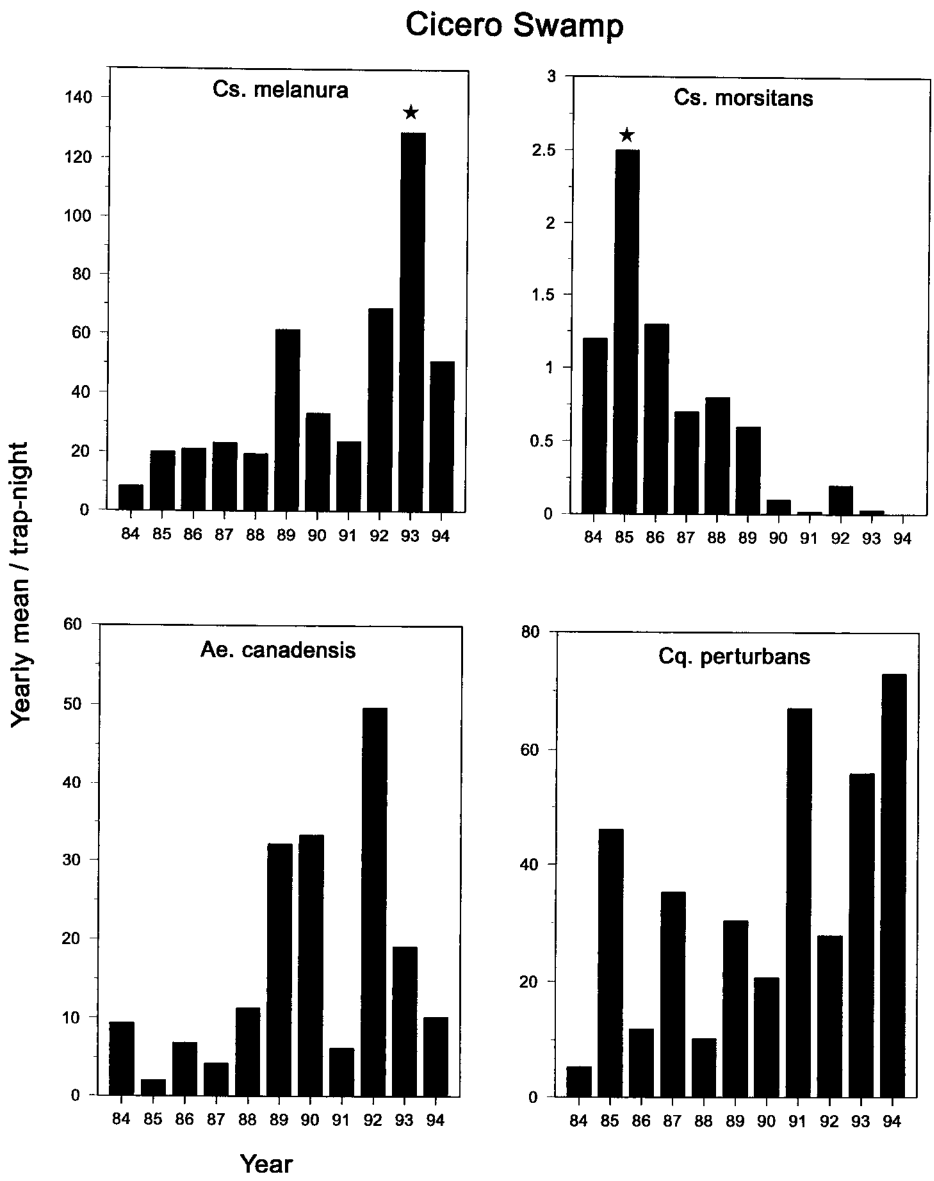


Fig. 1. Yearly trap-night means (Y) for *Cs. melanura, Cs. morsitans, Ae. canadensis,* and *Cq. perturbans* at Cicero Swamp, NY, 1984–94 (★ mean is significantly higher than all other means; GLM, Duncan's groupings, $P < 0.01$).

MATERIALS AND METHODS

Treatment areas: Cicero Swamp is a 1,600-ha state-owned game management area located in northeastern Onondaga County, 16 km from the city of Syracuse (Morris et al. 1980). Cicero Swamp was sprayed twice prior to 1984, in September 1974 and September 1983. Toad Harbor Swamp is 2,000 ha, of which approximately two-thirds is the Three Mile Bay Game Management Area. Toad Harbor Swamp was sprayed twice prior to 1984, in August 1976 and September 1983. We assume that mosquito populations in both swamps have recovered from any impact of the 1970s' sprays and that the sprays in September 1983 occurred too long after the peak of adult mosquito activity to have an impact on the current study. Spray dates and number of hectares treated during 1984–94 were obtained from documents filed with the New York State Department of Health (NYSDOH). Spray events were categorized as preventive or reactive. Preventive applications were based on numbers of mosquitoes only. Reactive applications were in response to isolations of HJ or EEE viruses or the occurrence of EEE.

Mosquito population data—treatment areas: Adult mosquito population data were derived from

Table 1. Memorial Day to Labor Day yearly trap-night means[1] (Y) for 4 vector species at Cicero Swamp, NY, 1984–94.

Year	*n*	*Cs. melanura*	*Cs. morsitans*	*Ae. canadensis*	*Cq. perturbans*
1984	103	9.8h	1.5bc	16.9c	10.0e
1985	99	33.3def	3.3a	2.9e	127.8ab
1986	100	14.5gh	1.9b	13.6cd	24.6de
1987	123	31.2def	1.0cd	5.4e	121.7ab
1988	121	20.1fg	1.0cd	17.7c	23.0de
1989	101	65.0bc	0.6d	44.6b	37.6cd
1990	110	39.6cde	0.2e	94.7a	135.7ab
1991	134	21.1efg	0.03e	6.1de	185.1ab
1992	147	103.5ab	0.2e	116.4a	79.7bc
1993	132	173.3a	0.08e	26.5bc	154.9ab
1994	118	58.5bcd	0.03e	14.0cd	219.0a

[1] Means with different letters are significantly different (general linear models, Duncan's groupings, $P < 0.01$).

collections made in carbon dioxide-baited CDC miniature light traps at 4 trap sites at Cicero Swamp, Onondaga County, and 2 trap sites at Toad Harbor Swamp, Oswego County, from 1984 to 1994. Generally, traps were operated 2 nights/wk throughout the active mosquito season (May–September), with more frequent trapping during the weeks surrounding spray events. Each collection was speciated and enumerated by personnel from the Onondaga and Oswego county health departments.

Mosquito population data—nontreatment data: There were no trap sites in either Cicero or Toad Harbor swamps that were not subject to treatment. Additionally, there were no swamps within central New York of similar physiography with significant populations of *Cs. melanura* or that have been under constant mosquito surveillance to use as control (nontreatment) collection data. Thus, to determine nontreatment population trends of the species of interest, we used the surveillance data from Toad Harbor Swamp collected during 3 years without adulticiding applications, 1984–1986. A comparable data set was not available for Cicero Swamp. Weekly population trends were constructed for the populations of all species collected and for the primary (enzootic) vectors of EEE virus, *Cs. melanura* and *Cs. morsitans,* and secondary (epizootic) vectors, *Aedes canadensis* (Meigen) and *Coquillettidia perturbans* (Coquillett) (Howard et al. 1994).

Data analysis: Raw data provided to the NYSDOH by both county health departments represented daily counts (n) of all species collected from the 6 trap sites. Analyses were performed for the population indices of all mosquitoes collected and each of the 4 vector species. Daily collections (n) were log transformed ($X = \log_{10}[n + 1]$; Williams 1937, Moore et al. 1993) and analyzed using version 6.08 of the statistical analysis system (SAS Institute, Inc. 1989) at Syracuse University. Yearly means for all collection dates and for only collection dates between Memorial Day and Labor Day (last week in May to 1st week in September), representative of the major mosquito activity period in central New York, were compared using general linear models (GLM) with Duncan's mean groupings at $P = 0.01$ for all species and for each of the vector species. Weekly means were the sums of all collections occurring during a 7-day period, Sunday–Saturday, divided by the number of trap-nights. Yearly and weekly trap-night means are reported as anti-log values ($Y = 10^x[-1]$). Impacts on all species and on each of the 4 species were defined as short term (reduced numbers of mosquitoes observed for a week postspray), seasonal (reduced numbers for the remainder of the year), and long term (reduced numbers of mosquitoes seasonally and during the following year[s]).

RESULTS

Cicero Swamp—long-term trends: There has been a trend for increased numbers of *Cs. melanura* collected per year over the past 11 years (Fig. 1). Yearly trap-night means (Y ± SE) for *Cs. melanura* ranged from 8.5 ± 0.17 in 1984 to 129 ± 0.13 in 1993. The 1993 yearly mean for *Cs. melanura* was significantly higher than all other years and the 1984 mean significantly lower than all other years (GLM, Duncan's groupings, $P = 0.01$). For *Cs. morsitans,* yearly means declined over the study period (Fig. 1). Means ranged from 2.5 ± 0.1 in 1985 to 0.03 ± 0.01 in 1994. The 1985 mean was significantly higher than all other years. Means for 1990–1994 were significantly lower than all previous years. Populations of *Ae. canadensis* and *Cq. perturbans* were more variable. There were no obvious trends, and no yearly mean was either significantly higher or significantly lower than other years (Fig. 1). Means for *Ae. canadensis* ranged from 49.7 ± 0.18 in 1992 to 2.0 ± 0.11 in 1985. For *Cq. perturbans,* means ranged from 72.9 ± 0.28 in 1994 to 5.2 ± 0.2 in 1984. Yearly means (GLM, Duncan's grouping, $P = 0.01$) for the period from Memorial Day to Labor Day did not result in any substantial changes in the observed trends for these 4 species (Table 1).

Toad Harbor Swamp—long-term trends: There were no distinguishing trends for *Cs. melanura* at Toad Harbor Swamp (Fig. 2). Yearly means for *Cs. melanura* ranged from 33.4 ± 0.15 in 1985 to 4.7 ± 0.17 in 1988, but no mean was either significantly higher or lower than any other year. Populations of *Cs. morsitans* followed a trend similar to that observed in Cicero Swamp (Fig. 2). The highest yearly mean was 4.0 ± 0.17 in 1985 and the lowest was 0.25 ± 0.05 in 1994, although neither mean was significant. For *Ae. canadensis* and *Cq. perturbans,* no mean was either significantly higher or lower than all other years (Fig. 2). Yearly means for *Ae. canadensis* ranged from 36.9 ± 0.42 in 1989 to 2.4 ± 0.19 in 1987. Yearly means for *Cq.*

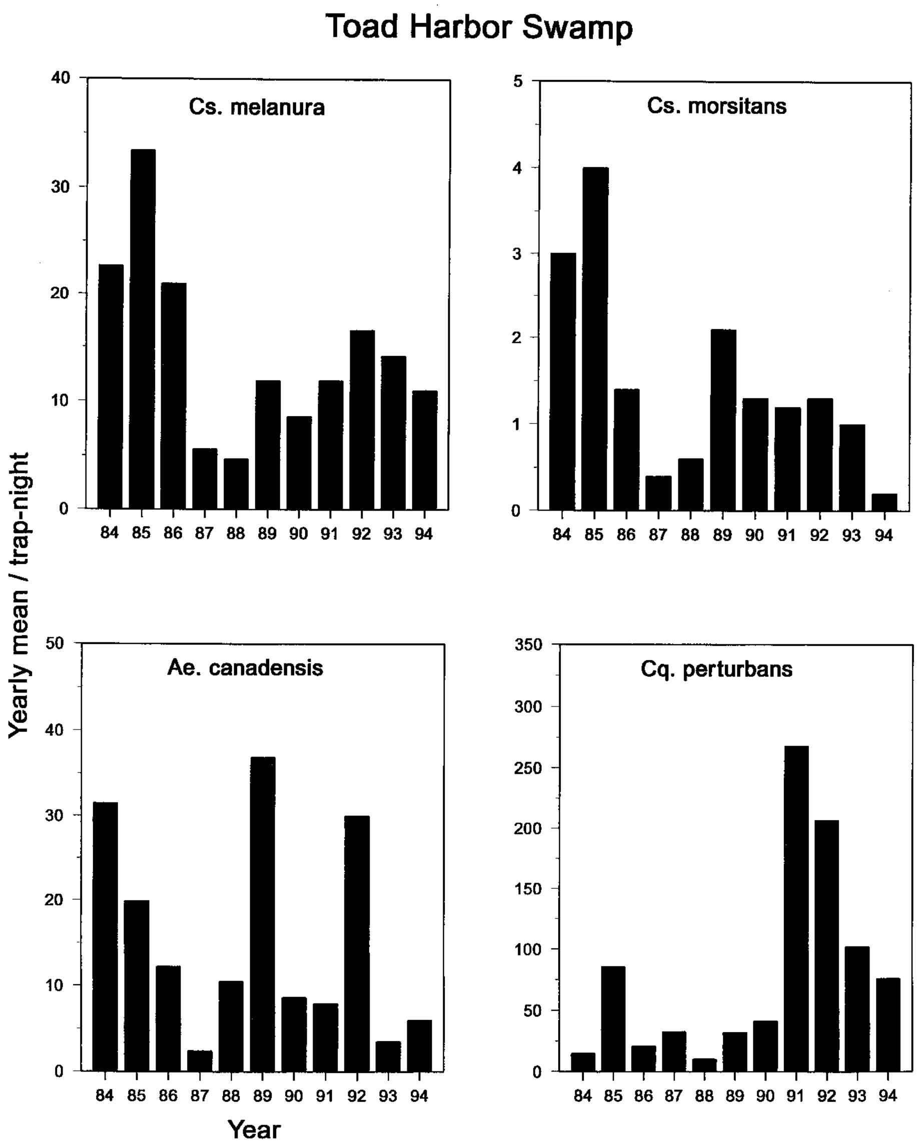


Fig. 2. Yearly trap-night means (Y) for *Cs. melanura, Cs. morsitans, Ae. canadensis,* and *Cq. perturbans* at Toad Harbor Swamp, NY, 1984–94.

perturbans ranged from 267.9 ± 0.46 in 1991 to 9.9 ± 0.24 in 1988. Yearly means during 1991–1993 were the 3 highest for *Cq. perturbans.* Analyses of data for the Memorial Day–Labor Day period did not result in any substantial changes in these results (Table 2).

Nontreatment seasonal trends: Seasonal population trends for all species and each of the 4 vector species are illustrated in Figs. 3 and 4, respectively. Mosquitoes were collected from mid-May to the end of September in baited light traps, with peak collections occurring in mid-July (Fig. 3). *Culiseta melanura* was the only species collected throughout the season. This species initially peaked in mid-July followed by 2 similar peaks at 3-wk intervals in mid-August and early September (Fig. 4). *Culiseta morsitans* was collected during most of the surveillance season, although at substantially lower numbers than *Cs. melanura* (Fig. 4). Peak collections of *Cs. morsitans* occurred during mid-June–mid-July, and this species gradually declined during the remainder of the season. Collections of *Ae. canadensis* peaked in early June and early July, and then collections declined rapidly (Fig. 4). Few *Ae. canadensis* were collected after mid-August. *Coquillettidia perturbans* was the most abundant of the 4 species. Collections of this species peaked in mid-July, with few individuals collected after mid-August (Fig. 4).

Treatment history: Between 1984 and 1994, Cic-

Table 2. Memorial Day to Labor Day yearly trap-night means[1] (Y) for 4 vector species at Toad Harbor Swamp, NY, 1984–94.

Year	n	*Cs. melanura*	*Cs. morsitans*	*Ae. canadensis*	*Cq. perturbans*
1984	52	25.8ab	4.0a	76.0a	36.5cd
1985	49	46.8a	6.1a	35.0ab	218.3ab
1986	52	21.5bc	1.8b	24.0b	55.8cd
1987	69	6.4e	0.6cd	3.0e	71.9bc
1988	61	5.7e	0.7cd	19.7bc	20.6d
1989	52	11.2cde	2.1b	82.3a	64.1bcd
1990	55	8.0de	1.7b	17.5bcd	91.9abc
1991	52	11.9cde	1.2bc	7.9cde	267.9a
1992	55	16.6bcd	1.3bc	30.0ab	206.8ab
1993	56	14.7bcd	1.1bc	3.5e	120.4abc
1994	53	11.0cde	0.3d	6.0de	75.8bc

[1] Means with different letters are significantly different (general linear models, Duncan's groupings, $P < 0.01$).

ero Swamp was sprayed with naled 15 times and with resmethrin (Scourge®) once (Table 3). Cicero Swamp was sprayed once in 1984 and at least once each year from 1987 through 1994. Two applications per year occurred in 1987, 1988, and 1992. Three applications per year occurred during EEE outbreaks in 1990 and 1991, including the application of Scourge on September 18, 1990. There were 8 preventive and 7 reactive applications of naled. The earliest and latest applications of naled to Cicero Swamp were June 4 and September 8, and there were 2 sprays in June, 7 in July, 3 in August, and 3 in September.

Toad Harbor Swamp has been sprayed 7 times with naled, once as a preventive and 6 times as reactive sprays (Table 3). Two naled applications per year occurred in 1987, 1988, and 1990, and there was one application in 1991. The earliest and latest applications at Toad Harbor Swamp were July 22 and September 4, and there were 3 sprays in July and 2 each in August and September.

Impacts of naled—Cicero Swamp: Short-term reductions in all mosquito populations occurred following 13 of the 15 applications of naled. Reductions in collections of all species during postspray weeks ranged from 81% after the preventive application in 1992 to 99% in 1984 (Table 3). Reductions in collections of all species following the 9 initial applications (8 preventive and one reactive) averaged 89%. The average short-term impact is illustrated in Fig. 3 for the preventive application of July 20, 1988. The 2 applications where no short-term impact occurred, and in fact populations increased, were both reactive sprays. Populations increased 200% following the reactive application on September 8, 1988 (Fig. 4) and increased 87% following the application on August 13, 1991. With the exception of the June 1984 spray, no seasonal or long-term impact on collections of all species was achieved by the applications of naled.

The 4 vector species (*Cs. melanura, Cs. morsitans, Ae. canadensis, Cq. perturbans*) represented 73.7% of all collections at Cicero Swamp during the study period, with yearly percentages ranging from 54.7% in 1984 to 82.5% in 1993. Short-term impacts of naled applications for each of the 4 vector species were as described for all species. The 1988 applications are used to illustrate impacts on the 4 vector species (Fig. 5). Additionally, there were seasonal and long-term impacts evident for some of these vector species. Within 2 wk postspraying, populations of *Cs. melanura* generally rebounded to prespray levels. In 1988 (Fig. 5) and 1992, collections of *Cs. melanura* peaked after preventive applications of naled. Naled did not produce any long-term impact on *Cs. melanura* populations (Fig. 1). All applications during July and early August resulted in seasonal impacts on *Cs. morsitans.* This species was virtually absent from collections following the 7 applications during July and August. These applications also produced long-term impacts on *Cs. morsitans* populations at Cicero Swamp (Fig. 1).

Seasonal reductions in *Ae. canadensis* and *Cq. perturbans* were achieved by sprays in June or mid-July. The preventive application in June 1984 also achieved a long-term impact on *Ae. canadensis* through 1985 and possibly through 1987 (Fig. 1). The spray in June 1991 produced a seasonal impact on *Ae. canadensis,* but there was no long-term impact (Fig. 1). Sprays in late July and August occurred too late to produce seasonal or long-term impacts on *Ae. canadensis* and *Cq. perturbans.*

Impacts of naled—Toad Harbor Swamp: Short-term reductions in all species collected following the 7 applications of naled to Toad Harbor Swamp ranged from 32% in 1990 to 98% in 1991; the least effective spraying was the 2nd application in August 1990 (Table 3). With the exception of this application, sprayings to Toad Harbor Swamp achieved 81–98% reductions in all species as illustrated for the earliest spraying of Toad Harbor on July 22, 1988 (Fig. 2). Because all applications to Toad Harbor occurred 2 or more weeks following peak collections of all species, no seasonal or long-term impact was evident.

The 4 vector species accounted for 77% of all mosquitoes collected at Toad Harbor Swamp during the 11-year study period and ranged from 62% of collections in 1984 to 88% in 1985. Seasonal impacts on individual species were similar to Cicero Swamp. *Culiseta melanura* rebounded to prespray levels within 2 wk postspray and, in 1988, reached peak numbers following the naled application on July 22. There was no evidence that naled had a long-term impact on *Cs. melanura* populations (Fig. 2). Applications generally achieved seasonal impacts on *Cs. morsitans, Ae. canadensis,* and *Cq. perturbans* but occurred too late each season to produce long-term impacts (Figs. 2 and 4).

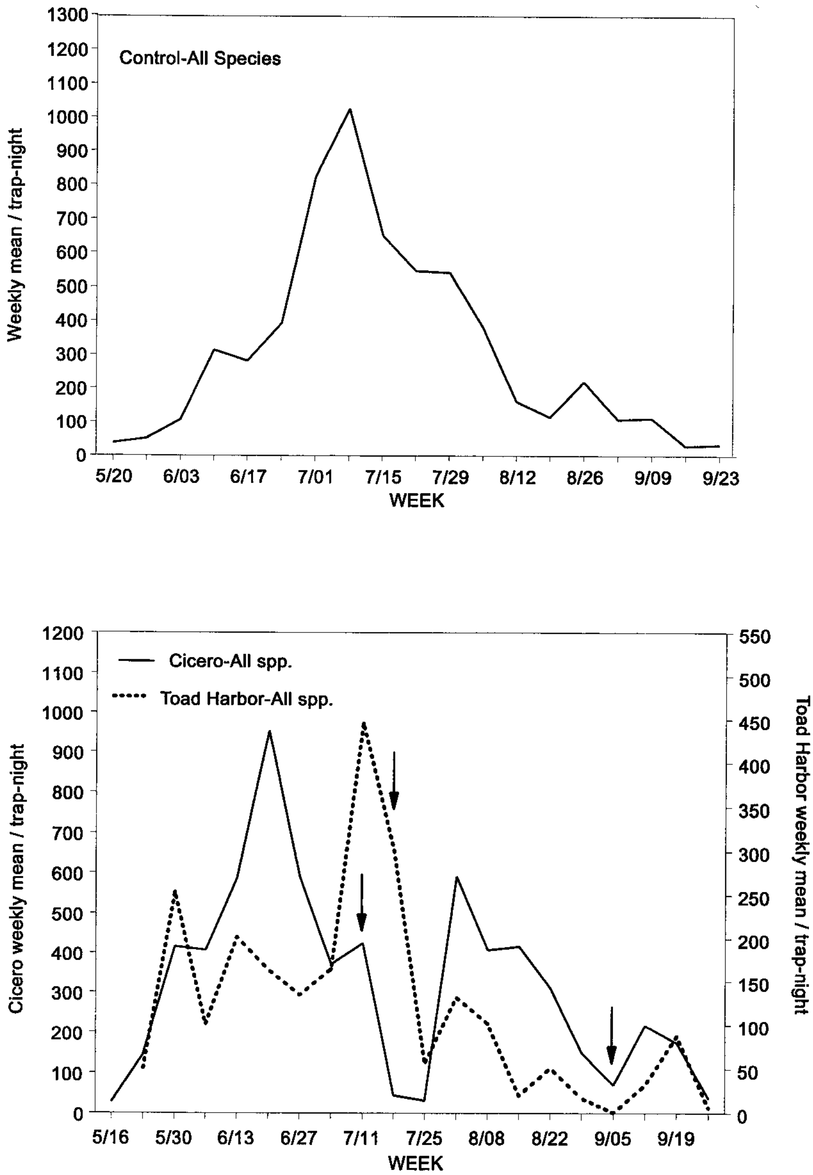
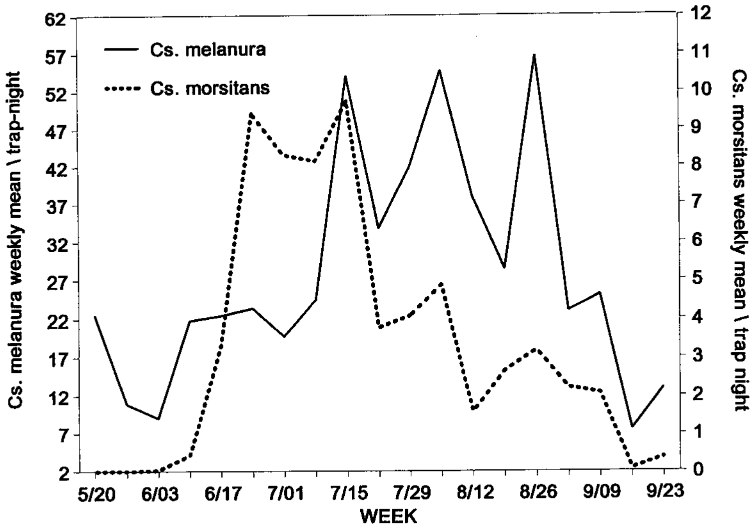


Fig. 3. Weekly trap-night means (Y) for control (nontreatment) collections of all species at Toad Harbor Swamp, 1984–86 and for 1988 collections of all species at Cicero and Toad Harbor swamps, NY, (↓ indicates naled applications).

DISCUSSION

Application of naled was successful in achieving short-term reductions in mosquito populations, including populations of the 4 vector species. Seasonal reductions in numbers of the 3 univoltine species were also achieved. However, with the exception of a single application in 1984, the use of naled did not produce a long-term impact on vector species, and, despite repetitive applications, populations of the primary enzootic vector of EEE virus, *Cs. melanura,* have increased at Cicero Swamp from 1984 to 1994. Over the 11-year study period, populations of *Cs. melanura* have increased 15-fold despite the 2-fold increase in the area treated. Concurrent with this increase, there has been an 83-fold decrease in populations of *Cs. morsitans.* The decrease in *Cs. morsitans* populations at Cicero Swamp during the study period is attributed to multiple long-term impacts of naled (Fig. 1).

Possible explanations for increases in *Cs. melanura* populations at Cicero Swamp are that Cicero Swamp naturally produces larger populations of this species, that the data for Cicero Swamp are somehow biased, that *Cs. melanura* in Cicero Swamp are resistant to naled, or that pest resurgence has contributed to increased populations of



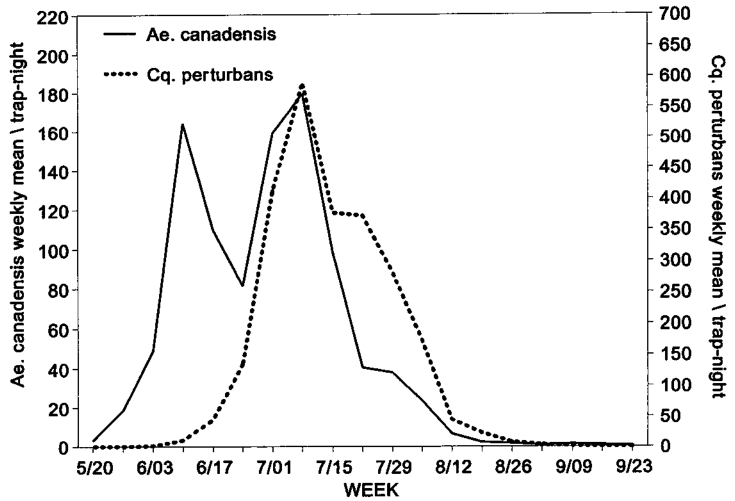


Fig. 4. Weekly trap-night means (Y) for control (nontreatment) populations of *Cs. melanura, Cs. morsitans, Ae. canadensis,* and *Cq. perturbans* based on collections at Toad Harbor Swamp, NY, 1984–86.

Cs. melanura coincident with declines in *Cs. morsitans* populations.

Larger populations: In terms of the physiographic features that could influence mosquito abundance (habitat, size, and precipitation), the 2 swamps are remarkably similar. They are 10 km apart, both are approximately 3,000 ha of similarly vegetated wetlands with muck-peat soil substrates, and each is subjected to lake-effect precipitation created by proximity to Lake Ontario (Morris et al. 1980). It has been suggested that Cicero Swamp is wetter than Toad Harbor Swamp because of the presence of beaver (*Castor canadensis*). Above average populations of *Cs. melanura* in 1 year have been associated with above average summer precipitation that followed excess precipitation the preceding fall (Hayes and Hess 1964). Presumably, high water tables in the fall increase the survival of overwintering larvae. If the increases in *Cs. melanura* were related to higher water levels in Cicero Swamp, one would expect that the same factor would influence population levels of *Cq. perturbans,* which also overwinters as larvae (Wood et al. 1979). This expectation for *Cq. perturbans* was not observed during the study period (Fig. 1). A similar comparison can be made between *Cs. morsitans* and *Ae. canadensis.* Both species overwinter in the egg stage, albeit *Cs. morsitans* as egg rafts and *Ae. canadensis* as individual eggs, deposited on vegetation above the waterline (Wood et al. 1979). Spring rainfall influences seasonal populations of these species. If the decline in *Cs. morsitans* pop-

Table 3. Applications of naled to Cicero and Toad Harbor swamps, NY, 1984–94.

Year	Date	Hectares	Rationale[1]	Efficacy[2] (%)
		Cicero Swamp		
1984	June 22	2,833	Preventive	−99
1987	July 15	2,833	Preventive	−85
	Sept. 4	3,116	Reactive (EEE virus)	−87
1988	July 20	3,116	Preventive	−89
	Sept. 8	3,116	Reactive (EEE virus)	+200
1989	July 15	3,116	Preventive	−92
1990	Aug. 3	3,116	Preventive	−87
	Aug. 23	4,856	Reactive (EEE virus)	−88
	Sept. 18[3]	4,856	Reactive (EEE)	−85
1991	June 4	3,116	Preventive	−82
	July 6	4,856	Reactive (EEE virus)	−91
	Aug. 13	4,856	Reactive (EEE)	+87
1992	July 21	3,116	Preventive	−81
	Sept. 4	3,541	Reactive (HJ virus)	−95
1993	July 8	4,856	Reactive (HJ virus)	−93
1994	July 26	4,856	Preventive	−93
		Toad Harbor Swamp		
1987	July 27	2,752	Preventive	−86
	Sept. 4	2,752	Reactive (EEE virus)	−84
1988	July 22	2,962	Reactive (EEE virus)	−81
	Sept. 1	2,962	Reactive (EEE virus)	−95
1990	Aug. 9	3,237	Reactive (EEE virus)	−94
	Aug. 23	2,978	Reactive (EEE)	−32
1991	July 30	3,237	Reactive (EEE virus)	−98

[1] EEE = eastern equine encephalitis; HJ = Highlands J.
[2] Percent change in all mosquito species collected 1 wk postspray.
[3] Application of resmethrin (Scourge®).

ulations at Cicero Swamp, and to a lesser extent at Toad Harbor Swamp, were the result of a series of drier than normal springs, then it would be reasonable to expect that *Ae. canadensis* populations would also decline. This expectation was not observed during the study period. As to the influence of beaver, we have conducted walking surveys around the perimeters of both swamps and observed an equal number of active beaver impoundments (J.J.H., unpublished data).

Biased data: The data sets analyzed were compiled from routine mosquito and virus surveillance activities conducted by county health departments. The extent and nature of surveillance activities are directly related to the level of interest of the participating municipalities and availability of personnel. There are a number of ways in which unintentional biases could have been introduced into the data, such as misidentification of specimens, increased surveillance activities either by number or location of traps set, length of trapping seasons, and different trapping methodologies. Although we had no control over these influences, it is unlikely that they contributed significantly to the results presented herein. Both counties rely on seasonal employees to conduct the surveillance, speciate collections, and tabulate data, but the same supervisors trained surveillance personnel throughout the duration of this study. Certainly minor errors in identification may have occurred, but it would be unreasonable to expect that a majority of the collections were misidentified. Although Onondaga County does operate more traps for longer periods of time in Cicero Swamp, data were analyzed as log transformed values per trap-night for both the season and for a comparable period, Memorial Day–Labor Day. Reported trends appeared in both data sets. Finally, both counties used the same surveillance equipment and generally operated traps the same nights, Monday and Wednesday, each week (Howard et al. 1994).

Resistance: Resistance of mosquitoes has been reported for organophosphates but has not been noted for naled (Boike and Rathburn 1975, Linley and Jordan 1992). A resistant species would not be affected by the chemical. *Culiseta melanura* was affected for 1–2 wk following an application of naled but then rebounded and sometimes exceeded prespray levels. Although repopulation probably results from the staggered larval development of the summer brood of *Cs. melanura* (Joseph and Bickley 1969, Oliver et al. 1996), this does not account for the observed resurgence of this species.

Pest resurgence: Resurgences of pest populations are associated with the elimination of natural predators or parasites (Metcalf 1986) or with species replacement through the elimination of a sympatric species (Service 1993). *Culiseta morsitans* "biologically and epidemiologically parallels *Cs. melanura*" (Morris 1984). Both species occur in

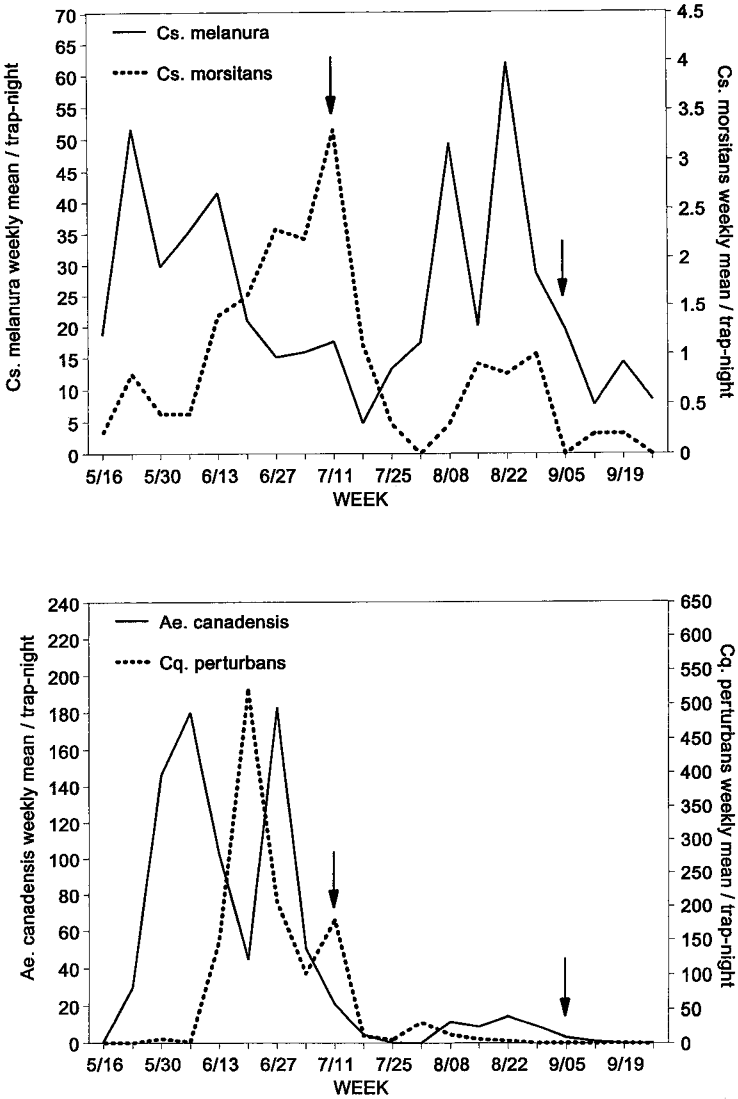


Fig. 5. Weekly trap-night means (Y) for treatment populations of *Cs. melanura, Cs. morsitans, Ae. canadensis,* and *Cq. perturbans* at Cicero Swamp, NY, during 1988 (↓ indicates naled applications).

the same swamp habitats, both prefer to feed on birds, and associated species of both include *Ae. canadensis* (Means 1987). Reasons that aerial spraying would affect *Cs. morsitans* but not *Cs. melanura* are related to differences in the biologies of the 2 species. Unlike *Cs. melanura, Cs. morsitans* is univoltine and overwinters in the egg stage (Wood et al. 1979). Eggs hatch in the spring, and although adult *Cs. morsitans* are present for much of the season, this species has an extended gonotrophic cycle, and few individuals complete more than one ovarian cycle (Morris 1984). Peak adult abundance of *Cs. morsitans* occurs between late June and early July, intermediate between the spring and summer broods of adult *Cs. melanura* (Morris 1984). Nine aerial applications have occurred in Cicero Swamp between mid-June and the end of July and have severely affected reproductive populations of *Cs. morsitans.* These data strongly support the observation that the exponential increase in *Cs. melanura* populations in Cicero Swamp has occurred concurrently with significant reductions of a sympatric species, *Cs. morsitans.* Reduction in the *Cs. morsitans* population has allowed *Cs. melanura* to occupy the niche utilized by *Cs. morsitans,* resulting in the resurgence (increased populations) of *Cs. melanura.* The decline in *Cs. morsitans* may be an indicator of broad-scale ecological impacts on nontarget insects within these swamp communities. Ecological balance between the 2 species may be restored by reducing naled applications to these swamps.

Whether or not any of these factors has contributed to the observed population trends, there is the overriding issue related to the rationale for conducting preventive aerial applications to *Cs. melanura* breeding habitats. Naled is used to control the populations of vector mosquitoes to reduce the risk of EEE. Eastern equine encephalitis results from nonswamp contact with EEE virus (McLean et al. 1985, Howard et al. 1996), and the proposed mechanisms for the movement of virus from swamp to upland foci include dispersion of infected primary (Howard et al. 1996) or secondary vectors or of infected avian hosts (McLean et al. 1985). Although the applications of naled have generally been effective in reducing the numbers of secondary vectors, EEE has occurred despite preventive and reactive applications (Howard et al. 1994, 1996). But, the objective of spraying the swamp habitats of *Cs. melanura* was to prevent the enzootic amplification of EEE virus. Preventive applications have had no noticeable impact on the enzootic amplification of EEE virus, and isolations of virus following preventive applications have resulted in reactive sprayings that were also ineffective in achieving seasonal or long-term impact on virus transmission (Howard et al. 1996). The possibility that frequent applications of naled contributed to increased populations of *Cs. melanura* further discredits the rationale that preventive applications of naled reduce the risk of EEE.

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