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# FACTORS AFFECTING CAPTURE RATES OF INSECT TAXA BY RETAIL ELECTROCUTORS AND ELIMINATORS IN NORTHERN LOWER MICHIGAN

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## ABSTRACT

We compare the abundance and types of insects captured at several locations, with and without a chemical attractant and in varying weather conditions using two different devices advertised to kill biting insects. Using both an insect electrocutor that uses ultraviolet light as an attractant, with and without octenol as an added attractant, and an insect eliminator that uses carbon dioxide, heat and octenol as attractants, more non-biting than biting insects were captured. Numerous harmless and beneficial insects were killed with electrocutors. Although eliminators were more target-specific, they captured fewer insects overall compared to electrocutors. The numbers and types of insects captured also varied by location and temperature conditions. More insects were killed by electrocutors located next to a lake compared to those located in an inland forested area and more were killed at lower compared to higher heights above the ground. More insects were also killed by electrocutors on warmer than on cooler nights. More non-biting insects were killed with electrocutors baited with octenol than without octenol.

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Several different devices designed to attract insects with ultraviolet lights and electrocute them have been on the market for the past several decades. For the purpose of this study, we shall refer to these products as insect electrocutors. Manufacturers commonly advertise them as an environmentally safe way to rid backyards of dipteran insect pests such as mosquitoes (Culicidae), blackflies (Simuliidae) and biting midges (Ceratopogonidae), given that they do not rely on the use of pesticides. However, there has been considerable debate concerning their effectiveness. Woods (1997) reported a study in Florida in which over 10,000 insects were killed in one night by an electrocutor but only 8 of those were mosquitoes. Tallamy and Frick (1996) found that biting insects comprised only 0.25% (31 of over 13,000) of the insects killed by an electrocutor in a summer-long study in a suburban area. Similar results were reported by Surgeoner and Helson (1977), Nasci et al. (1983) and Jensen et al. (2000) in various regions.

Many insects are attracted to ultraviolet light, which is a widely accepted method of broadcast capture for scientific purposes. Biting insects are attracted by several other stimuli. For instance, mosquitoes use cues that range from changes in temperature and humidity to movement, contrast and chemicals given off by host species; several species are repelled by lighting greater than approximately 0.5 watts (Gadsby 1997). Carbon dioxide traps are frequently used to collect them. Other chemical cues include lactic acid and many fatty acid components emitted from mammalian skin oils and sweat. The human foot bacterium *Brevibacterium epidermis* is thought to attract mosquitoes to varying

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degrees (Mboera et al. 2000). Blackflies (Simuliidae) are known to be attracted by combinations of carbon dioxide, various components of mammalian sweat, movement, and certain dark colors (Crosskey 1990). By the 1990s, it was rather widely accepted that electrocutors did not work well for capturing biting insects. Several manufacturers responded by including packets of octenol – a known mosquito attractant (Mboera et al. 2000, Murphy et al. 2001) – to be used in combination with electrocutors.

Other manufacturers responded to the known drawbacks of electrocutors by designing devices that rely on attracting mosquitoes and biting flies using a combination of carbon dioxide, heat and octenol. These devices do not use lights or electrocution. They are also more expensive than electrocutors but show more initial promise given that they use at least some of the known stimuli that attract biting insects (Kline and Lemire 1995). We refer to these devices as insect eliminators. They work by burning propane fuel to create heat and carbon dioxide. Octenol is vaporized by the heat and is released slowly from a separate cartridge. Insects are trapped by either suction or a sticky adhesive surface located around the core of the device. The device we tested used the latter method of killing.

Here we assess the numbers and types of insects killed by eliminators and electrocutors in and around residential cabins in Northern Lower Michigan. First, we compare the numbers and families of insects killed at a residence on a lake with those killed at a residence located in an inland forested area (location effect). This was done with both electrocutors and eliminators, thus the numbers and types of insects killed by these devices can be directly compared (device effect). We compare the numbers and families of insects killed with electrocutors hung two ft above ground with those hung nine feet above ground (height effect) and with electrocutors using octenol as bait versus those that don't (octenol effect). Lastly, we compare the numbers and types of insects killed with electrocutors as a function of temperature and wind speed (weather effects).

## MATERIALS AND METHODS

This study was conducted during late May and early June, 1999 and 2002 at the University of Michigan Biological Station (UMBS), Pellston, MI, a biosphere reserve of over 10,000 acres located in Emmet and Cheboygan Counties in northern lower Michigan (Heinen and Vande Kopple 2003). In 1999, four insect electrocutors were purchased from a local retail outlet and placed at two different residential locations to mimic household use. They were the Director's Cabin (Lakeside) and Hilltop Housing (Hilltop), a wooded location several hundred meters away. Lakeside is situated at 218 m above MSL on the shores of Douglas Lake, and Hilltop is situated at 237 m above MSL (T37N, R3W, S34; Anonymous 1982). At each location, two electrocutors were set up 6 ft above ground. The octenol attractant provided by the manufacturer was placed on one electrocutor at each site, and the devices separated by 50 ft and on opposite sides of the residences to avoid cross-attraction. The packets of octenol contained 6.5% octen-3-ol, and were advertised to attract mosquitoes for up to 30 days. During that year, lights were turned on for five-hr periods (7:00 PM to midnight) on six different nights (22, 26, 27, 28, 29 and 30 May). Temperatures and wind speeds were recorded every hour during collection times and averaged over each period.

In 2002, six devices were used. Two electrocutors and one eliminator were placed at Lakeside and Hilltop, respectively. The eliminators were purchased in that year from a local retailer and the electrocutors were those used in 1999. Because the results from 1999 had shown that few insects were captured before 8:00 PM or after 11:00 PM, the protocol was modified in 2002 such that the devices were only kept running for 3 hr periods (8:00 PM to 11:00 PM). Also, because temperature proved very important for numbers of insects captured in 1999, we only placed devices out on nights with starting temperatures (at 8:00 PM) above 18°C in 2002.

One electrocutor was set at 2 ft above ground and the other was set at 9 ft above ground at each site. The sole eliminator at each site was set at 2 ft above ground. The devices were 50 ft apart and electrocutors were placed on different sides of the building to avoid cross-attraction. Sampling in 2002 was done on five different days (30 May, 4 - 7 June).

Buckets were attached to the bottoms of all electrocutors to assure that insects that were killed were also collected. All specimens were brought back to a laboratory on the UMBS campus, and all individuals were identified to family. For eliminators, insects were picked (in the laboratory) from the adhesive surfaces after each trial. During both years, some insects caught by electrocutors were not actually killed (e.g., large beetles and moths). We therefore assumed that those that were disoriented and found in buckets up to several hours after capture were injured such that recovery was unlikely, and we counted them among dead specimens. Chi-square tests of independence and homogeneity (Fienberg 1980, Sokal and Rohlf 1981) were used to compare the distribution of insects captured as a function of location, device, height, octenol, and weather, respectively. A significance level of 0.05 was used for all statistical tests.

## RESULTS

In 1999, of a total of 8,309 insects captured by electrocutors, 31 (0.37%) were biting insects of four different families: Ceratopogonidae, Culicidae, Simuliidae and Tabanidae (Table 1). Large numbers of midges (Chironomidae) were electrocuted as were smaller numbers of moths, beetles, ants, wasps, caddisflies and others. The results were similar in 2002. Of 11,076 insects killed in that year, only 98 were biting insects and most of the insects killed were midges (Table 1). Those results confirm, for this area, studies done in other areas that have shown the general ineffectiveness of electrocutors in killing biting insects (e.g., Surgeoner and Helson 1977).

During both years, more insects were killed at Lakeside than at Hilltop ($P < 0.01$; Tables 2, 3, 4) and, in 2002, many more insects were killed by electrocutors than eliminators ($P < 0.0001$), although proportionally more biting insects were killed by eliminators ($P < 0.001$; Tables 2, 4). Only 69 insects in total were killed by eliminators, of which 19 (27.5%) were biting insects of three families: Ceratopogonidae, Culicidae and Simuliidae. Also in 2002, more insects were killed with electrocutors located at 2 ft above ground than at 9 ft above ground ($P < 0.05$; Tables 2, 4). Thus the position, device and height effects were all significant.

The numbers of biting insects killed at both Lakeside and Hilltop were not significantly different with or without octenol. However, the numbers of *non*-biting insects killed were significantly greater with the attractant at both sites ($P < 0.001$). The major difference was that more midges and moths were killed by electrocutors baited with octenol. In 1999, the numbers of insects killed each day varied as a function of temperature ($P < 0.001$; Table 2). However, wind speed had no significant effect on the numbers of insects killed by electrocutors.

## DISCUSSION

Our results, collectively, show that insect electrocutors in all treatments, and across both years, killed vastly more non-biting than biting insects in this study area as has been shown for other study areas (e.g., Nasci et al. 1983, Surgeoner and Helson 1977, Tallamy and Frick 1996). Furthermore, we showed that there was no significant effect of using octenol as an attractant on the numbers of biting insects killed by electrocutors, although the numbers of non-biting insects (especially midges and moths) that were killed increased greatly with the bait. The proportions of biting insects killed by eliminators were significantly greater than those killed by electrocutors. However, for both types of devices, more non-biting insects were killed than biting insects. No independent measures of biting versus non-biting insect

Table 1. Total numbers of insects killed by insect electrocutors and eliminators during 1999 and 2002. Asterisks denote biting insect families.

| Order | Family | Totals (1999) | Totals (2002) |
|---|---|---|---|
| Coleoptera | | 105 | 314 |
| | Carabidae | 13 | 78 |
| | Cantharidae | 34 | |
| | Coccinellidae | 1 | |
| | Dytiscidae | 2 | 2 |
| | Elateridae | 6 | 11 |
| | Hydrophilidae | 0 | 2 |
| | Lampyridae | 1 | |
| | Leiodidae | 6 | |
| | Scarabaeidae | 41 | 200 |
| | Scolytidae | | 1 |
| | Silphidae | 1 | 3 |
| | Staphylinidae | 4 | |
| | Tenebrionidae | 3 | 17 |
| Diptera | | 7757 | 10689 |
| | Anthomyiidae | 14 | |
| | Asilidae | 3 | |
| | Bombyliidae | | 1 |
| | Ceratopogonidae* | 1 | 1 |
| | Chironomidae | 7661 | 10583 |
| | Culicidae* | 27 | 84 |
| | Muscidae | 8 | 2 |
| | Mycetophilidae | 2 | |
| | Sciomyzidae | | 5 |
| | Simuliidae* | 2 | 13 |
| | Tabanidae* | 1 | |
| | Tipulidae | 27 | |
| | Unknown | 10 | |
| Homoptera | | | 2 |
| | Cercopidae | | 1 |
| | Cicadellidae | | 1 |
| Hymenoptera | | 41 | 33 |
| | Braconidae | 1 | |
| | Formicidae | 1 | 2 |
| | Ichneumonidae | 39 | 31 |
| Lepidoptera | | 405 | 33 |
| | Geometridae | 3 | |
| | Noctuidae | 62 | 12 |
| | Pterophoridae | 1 | |
| | Pyralidae | 302 | 21 |
| | Saturniidae | 30 | |
| | Unknown | 1 | |
| Neuroptera | | | 5 |
| | Coryadalidae | | 1 |
| | Sialidae | | 4 |
| Trichoptera | Unknown | 1 | |
| | Grand Totals: | 8309 | 11076 |
| | Biting Insects: | 31 | 98 |

Table 2. General statistical summary results showing the location, device, height, octenol and weather effects on the numbers of insects killed in 1999 and 2002 by insect electrocutors and eliminators. In all cases, chi-square tests were used.

| **Effect** | **Description** | ***P*-value** | **Result** |
|---|---|---|---|
| 1. Location | lakeside vs. hilltop | < 0.01 | More insects were killed at lakeside, electrocutor and eliminator combined. |
| 2. Device | electrocutor vs. eliminator | < 0.0001 | Electrocutors killed significantly more insects overall than did eliminators. |
| | biting versus non-biting | < 0.01 | Eliminators killed proportionally more biting insects than did electrocutors. |
| 3. Height | 2 ft. vs. 9 ft. | < 0.05 | Electrocutors hung at 2 ft killed significantly more insects than those hung at 9 ft. |
| 4. Octenol | biting insects | 0.1 > p > 0.05 | Octenol did not effect the numbers of biting insects killed by electrocutors. |
| | | < 0.001 | Electrocutors baited with octenol killed more non-biting insects than electrocutors not baited with octenol. |
| 5. Weather | temperature | < 0.001 | Electrocutors killed more insects on warmer nights. |
| | wind speed | 0.5 > p > 0.1 | Wind speed did not effect the numbers of insects killed by electrocutors |

Table 3. Numbers of insects collected with electrocutors both with (1) and without (2) octenol, in 1999. More insects overall were caught at Lakeside than at Hilltop, and more non-biting insects were caught with octenol.

| | | Hilltop | | Lakeside | | |
|---|---|---|---|---|---|---|
| **Order** | **Family** | **1** | **2** | **1** | **2** | **Totals** |
| Coleoptera | Carabidae | 2 | 1 | 8 | 2 | 13 |
| | Cantharidae | 3 | 12 | 11 | 8 | 34 |
| | Coccinellidae | 0 | 0 | 0 | 1 | 1 |
| | Dytiscidae | 0 | 1 | 1 | 0 | 2 |
| | Elateridae | 0 | 2 | 4 | 0 | 6 |
| | Lampyridae | 0 | 1 | 0 | 0 | 1 |
| | Leiodidae | 0 | 0 | 6 | 0 | 6 |
| | Scarabaeidae | 8 | 3 | 10 | 20 | 41 |
| | Silphidae | 0 | 0 | 1 | 0 | 1 |
| | Staphylinidae | 0 | 0 | 0 | 4 | 4 |
| | Tenebrionidae | 2 | 1 | 0 | 0 | 3 |
| Diptera | Anthomyiidae | 4 | 0 | 0 | 10 | 14 |
| | Asilidae | 1 | 1 | 1 | 0 | 3 |
| | Ceratopogonidae | 0 | 0 | 0 | 1 | 1 |
| | Chironomidae | 1347 | 894 | 3271 | 2149 | 7661 |
| | Culicidae | 10 | 5 | 3 | 9 | 27 |
| | Muscidae | 0 | 3 | 2 | 3 | 8 |
| | Mycetophilidae | 2 | 0 | 0 | 0 | 2 |
| | Simuliidae | 0 | 1 | 1 | 0 | 2 |
| | Tabanidae | 0 | 0 | 0 | 1 | 1 |
| | Tipulidae | 3 | 13 | 9 | 2 | 27 |
| | Unknown | 2 | 7 | 0 | 1 | 10 |
| Hymenoptera | Braconidae | 0 | 0 | 0 | 1 | 1 |
| | Formicidae | 0 | 1 | 0 | 1 | 1 |
| | Icheumonidae | 4 | 9 | 17 | 9 | 39 |
| Lepidoptera | Geometridae | 0 | 0 | 1 | 2 | 3 |
| | Noctuidae | 7 | 5 | 46 | 4 | 62 |
| | Pterophoridae | 0 | 1 | 0 | 0 | 1 |
| | Pyralidae | 19 | 35 | 183 | 65 | 302 |
| | Saturniidae | 22 | 5 | 1 | 2 | 30 |
| Trichoptera | Unknown | 0 | 0 | 0 | 1 | 1 |
| | Totals: | 1436 | 1001 | 3577 | 2295 | 8309 |

| | | | | | Totals |
|---|---|---|---|---|---|
| Summary: | Hilltop: | 2437 | Lakeside: | 5872 | 8309 |
| | No Octenol: | 3296 | Octenol: | 5013 | 8309 |

Table 4. Numbers of insects killed with electrocutors set at two heights and eliminators in 2002. More insects overall were caught at Lakeside than at Hilltop, and at lower than higher heights above ground. Electrocutors were set at 2 ft (1) and 9 ft (2) above ground; eliminators (3) were set at 2 ft above ground.

| | | **Hilltop** | | | **Lakeside** | | | |
|---|---|---|---|---|---|---|---|---|
| **Order** | **Family** | **1** | **2** | **3** | **1** | **2** | **3** | **Totals** |
| Coleoptera | Carabidae | 8 | 12 | 1 | 15 | 42 | 0 | 78 |
| | Dytiscidae | 0 | 1 | 0 | 0 | 1 | 0 | 2 |
| | Elateridae | 8 | 3 | 0 | 0 | 0 | 0 | 11 |
| | Hydrophilidae | 0 | 0 | 0 | 1 | 0 | 1 | 2 |
| | Scarabaeidae | 63 | 21 | 0 | 55 | 60 | 1 | 200 |
| | Scolytidae | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| | Silphidae | 0 | 2 | 1 | 0 | 0 | 0 | 3 |
| | Tenebrionidae | 1 | 2 | 0 | 9 | 5 | 0 | 17 |
| Diptera | Bombyliidae | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| | Ceratopogonidae | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| | Chironomidae | 2182 | 2664 | 11 | 4159 | 1549 | 18 | 10583 |
| | Culicidae | 23 | 13 | 4 | 30 | 7 | 7 | 84 |
| | Muscidae | 0 | 0 | 0 | 0 | 0 | 2 | 2 |
| | Sciomyzidae | 3 | 0 | 0 | 1 | 1 | 0 | 5 |
| | Simuliidae | 1 | 0 | 8 | 0 | 0 | 4 | 13 |
| Homoptera | Cercopidae | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| | Cicadellidae | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| Hymenoptera | Formicidae | 0 | 0 | 0 | 0 | 2 | 0 | 2 |
| | Icheumonidae | 22 | 3 | 0 | 4 | 2 | 0 | 31 |
| Lepidoptera | Noctuidae | 9 | 1 | 0 | 1 | 1 | 0 | 12 |
| | Pyralidae | 9 | 3 | 1 | 4 | 4 | 0 | 21 |
| Neuroptera | Coryadalidae | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| | Sialidae | 0 | 0 | 0 | 0 | 0 | 4 | 4 |
| | Totals: | 2329 | 2726 | 29 | 4280 | 1674 | 38 | 11076 |

| | | | | | Totals |
|---|---|---|---|---|---|
| Summary: | Hilltop: | 5083 | Lakeside: | 5993 | 11076 |
| | Electrocutors, 2 ft. | 6609 | Electrocutors, 9 ft. | 4400 | 11009 |
| | Electrocutors, 2 ft. | 6609 | Eliminators, 2 ft. | 67 | 6676 |

populations in the area were made. Thus, there may have been few biting insects present, which may have led to our (and other) results of low capture rates. On the evenings sampled, the human collectors were regularly bitten by both mosquitoes and blackflies, suggesting their presence. Even if biting insects had been rare when these studies were performed, the fact that both types of devices killed many non-biting insects is of concern for conservation.

More insects were killed overall with electrocutors at Lakeside than at Hilltop both with and without octenol as an attractant. Most of the insects captured, by number, were species with aquatic larval stages but devices set at Lakeside also captured more moths than those at Hilltop. This is perhaps due to the fact that the ultraviolet lights at Lakeside were visible for greater distances across water than those located at Hilltop. More insects were killed overall with electrocutors set at 2 ft above ground than those set at 9 ft above ground. The beetles captured at 2 ft above ground tended to be heavy-bodied and terrestrial. The moths captured at 2 ft above ground were generally pollinators, and most insect-pollinated plant species in the region are herbs or small shrubs. Thus moths may tend to fly low. Similarly, many species of Ichneumonid wasps in the region parasitize insects that can be found at or near the ground. More insects were captured on warm nights, which was expected over the 13°C temperature difference recorded here (11° to 24°C). No effect of wind speed was found on the number of insects captured. The lowest wind speed recorded was 1.79 mph, while the highest was 5.08 mph. It is therefore likely that the variation in wind speed recorded in 1999 was not enough to show an effect.

Several differences recorded here may be artifacts of differing conditions across years. For example, more insects were killed by electrocutors in 2002 than in 1999, despite fewer sampling days and shorter sampling periods in 2002. This is probably because we chose consistently warm days one week later in the growing season for sampling in 2002. In spite of greater numbers of individuals, fewer families were identified in 2002 than in 1999. Since different people were helping collect and identify insects during different years, there could have been some observer bias. However, such bias is not critical for this study as it would not affect the main statistical results comparing the total numbers of insects killed, and the general categories of biting versus non-biting insects killed, as a function of various treatments. Since many families identified here were either very rare in the area or not attracted to traps (i.e., represented by one or a few individuals in the sample; Tables 1, 3, 4), it is possible that this is random variation typical of many community-level samples (e.g., Pielou 1966, Magurran 1988).

Overall, more insects were killed by electrocutors than by eliminators and they were more effective on warmer nights, at lakeside locations and placed low to the ground. These factors should be considered for the selection and placement of devices for insect control. Nevertheless, many more non-biting than biting insects were killed, and many were beneficial species (e.g., important pollinators, prey species of songbirds and game fish, etc.). Thus, the use of both types of devices has negative consequences for non-target species, and may have some adverse ecological implications at local scales.

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