SPECIES COMPOSITION AND FEEDING SUCCESS OF MOSQUITOES ATTRACTED TO CAGED DOGS IN INDIANA[1]

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ABSTRACT. A field study using caged dogs in mosquito bait traps was conducted in eastcentral Indiana to determine the species composition of mosquitoes coming to feed. Fourteen species of mosquitoes from 5 genera were collected; *Aedes trivittatus* predominated. Feeding success rates were measured as the percentage of mosquitoes collected that had a fresh blood meal. The species having the highest rates were: *Culex erraticus, Aedes stimulans* and *Ae. trivittatus. Aedes vexans* and *Cx. pipiens/restuans* had markedly lower feeding success rates. A New Jersey light trap operated at the same site each year yielded a different species composition. Because of its propensity for feeding on dogs, *Ae. trivittatus* may be considered as a major potential vector of heartworm disease in dogs, even where it is one of several possible vector species present in abundance.

INTRODUCTION

Laboratory and field research on the mosquito vectors of *Dirofilaria immitis* (Leidy) has indicated that nearly 70 species of mosquitoes can support development of some microfilaria to the infective stage (Bemrick and Sandholm 1966, Ludlam et al. 1970). More recent reports have verified earlier research (Jankowski and Bickley 1976, Todaro et al. 1977, Christensen and Andrews 1976, Arnott and Edman 1978, Magnarelli 1978, Buxton and Mullen 1980, Lewandowski et al. 1980, Pinger 1982). Several of these mosquito species are abundant where heartworm disease transmission occurs and are considered important potential vectors. A knowledge of local vector-host associations adds useful information for incriminating the mosquito species most likely to be the primary vector(s) at a given location.

Animal-baited traps have frequently been employed to study associations between mosquitoes and other hematophagous Diptera and their vertebrate hosts. However, until now their use in the study of potential vectors of dog heartworm disease had not been reported. The purpose of the research described below was to examine mosquito-dog relationships in the field using caged dogs. Specifically, the objectives were to: (1) determine the percent composition of mosquito species attracted to caged dogs, (2) establish the feeding success rate for each species captured, and (3) formulate a hypothesis regarding the species most likely to be important in the transmission of *D. immitis* at this particular study site.

MATERIALS AND METHODS

DESCRIPTION OF STUDY AREA. This study was carried out at the Ball State University Wildlife Preserve, a 6.6 ha (16.42, acre) area located 4.4 km west of the center of Muncie, Indiana. The preserve is a remnant of White River bottomland which was isolated by the channeling of the river and subsequent construction of a levee. The old channel within the Preserve is a shallow oxbow pond. The area is dominated by sycamore (*Platanus occidentalis* L.), cottonwood (*Populus deltoides* Bartr.), hackberry (*Celtus occidentalis* L.) and silver maple (*Acer saccharinum* L.). The substrate is a coarse textured loam of moderate drainage. American elm (*Ulmus americana* L.) was a codominant until about 1950 when Dutch elm disease decimated the mature elms. The succession gap is evidenced by clumps of wild raspberry (*Rubus strigosus* Michx.), riverbank grape (*Vitus riparia* Michx.) and giant ragweed (*Ambrosia trifida* L.). Also abundant are poison ivy (*Rhus toxicodendron* L.) and Virginia-creeper (*Pathenocissus quinquefolia* (L.) Planch). There are numerous ground depressions in addition to the oxbow pond and these support substantial populations of *Aedes vexans* (Meigen) and *Ae. trivittatus* (Coquillett).

DESIGN OF KENNEL TRAPS. Dogs were placed in kennel traps modified from the design of Klowden and Lea (1979). The traps consisted of an inner restraining cage made of 2.54 × 2.54 cm (1 × 1") mesh 14 ga welded wire fencing. These cages were 69 cm long × 41 cm wide × 53 cm high, large enough to hold a small dog comfortably. The metal cages opened at the top and were closed with ties made of insulated copper wire. The holding cages were placed inside larger wood framed cages with a plywood floor and 0.14 cm mesh cloth screened sides. These outer cages were 91 cm long × 61 cm wide × 61 cm high. The roof of the outer cage was made of 2 sheets of 0.32 mm Plexiglas® 97 cm × 61 cm taped together along the long axis. These rested on removable wooden supports. The ends of the cages were sleeves made from large commercial plastic trash bags with holes in each end for access to inner cage. Mosquitoes could enter either through a 2 cm slit under each eave of the Plexiglas roof or through a 2

[1] This study was supported by grants from the Ball State University Foundation and the Indiana Academy of Science.

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cm slit on each side of the cage 24.5 cm above the ground. Net flanges built above each slit increased the probability that mosquitoes would enter.

TESTING PROCEDURE. In 1980 and 1981 field studies on insect repellents were conducted using 9 random bred dogs. Pre-application trials were run on all 9 dogs each year. During the repellent studies, 3 dogs remained untreated as controls. Treatment and control groups were randomly determined. The data reported here included the pretrial collections on all 9 dogs and the collections from the 3 control dogs throughout the study each year. The periods of the experiment were from June 27 through August 11 in 1980 and from June 6 through August 3 in 1981. The experiment was carried out on a total of 38 trap nights, 22 in 1980 and 16 in 1981.

Dogs were placed in the field in traps at the margin of the woods at 1800 hr each test day and were allowed to remain in the cages until 2100 hr when mosquito collecting commenced. Because there were 9 traps, it usually took 30–40 min to remove the mosquitoes from all traps with a mechanical aspirator. Collecting was aided by a flashlight which attracted most mosquitoes to the aspirator, but bloodfed mosquitoes were also collected on the walls and floor of the cages. Mosquitoes were placed in 0.48 liter cylindrical paper cups and transported to the Ball State University Public Health Entomology Laboratory for identification and determination of feeding condition.

A New Jersey (NJ) light trap was deployed at the study site in a moderately wooded location as it had been during the 3 previous years. The light trap was operated daily 1800 to 0600 hr. For the purposes of comparison of catches, only counts on the experimental evenings are considered here.

RESULTS

Over the 2 years of the study, 14 species representing 5 genera were collected in dog baited traps. These were: *Aedes canadensis* (Meigen), *Ae. sticticus* (Meigen), *Ae. stimulans* (Walker), *Ae. triseriatus* (Say), *Ae. trivittatus, Ae. vexans, Anopheles punctipennis* (Say), *Coquillettidia perturbans* (Walker), *Culex erraticus* (Dyar and Knab), *Culex pipiens/restuans* group, *Psorophora columbiae* (Dyar and Knab), *Ps. ferox* (Von Humboldt) and *Ps. horrida* (Dyar and Knab) (Table 1). In 1980, *Ae. trivittatus* predominated in both the dog cages (73.6% of the catch) and the NJ light trap collections (57.3% of the catch). In 1981, *Ae. trivittatus* again predominated in the dog cages (80.5% of the mosquitoes collected) even though *Ae. vexans* predominated in the NJ light trap collections making up 51.4% of the catch (Fig. 1).

Feeding success rates, measured as the percentage of the total catch for each species that was bloodfed, are summarized for both years in Table 1. Approximately 59% of all mosquitoes collected in the dog-baited traps during the two years were bloodfed. The species (N>20) having the highest rates were *Cx. erraticus* (72%), *Ae. stimulans* (68%) and *Ae. trivittatus* (66%). *Aedex vexans* (26%) and *Cx. pipiens/restuans* group (5%) demonstrated markedly lower feeding success rates.

Attack rates were calculated for each species as the number of mosquitoes trapped per hour, per caged dog. These were, however, much

Table 1. Species composition and feeding success rates of mosquitoes collected in dog-baited traps in 1980 and 1981, Ball State University Wildlife Preserve, Muncie, IN.

	1980			1981			Total		
Species	No. captured	No. fed	% fed	No. captured	No. fed	% fed	No. captured	No. fed	% fed
Ae. canadensis	8	3	(38)	2	1	(50)	10	4	(40)
Ae. sticticus	3	2	(67)	6	5	(83)	9	7	(78)
Ae. stimulans	14	11	(79)	8	4	(50)	22	15	(68)
Ae. triseriatus	5	4	(80)	2	2	(100)	7	6	(86)
Ae. trivittatus	501	297	(59)	597	423	(71)	1098	720	(66)
Ae. vexans	43	10	(23)	46	13	(28)	89	23	(26)
An. punctipennis	1	1	(100)	1	1	(100)	2	2	(100)
Cq. perturbans	3	1	(30)	1	1	(100)	4	2	(50)
Cx. erraticus	2	1	(50)	56	41	(71)	58	42	(72)
Cx. pipiens/restuans	94	5	(5)	18	1	(6)	112	6	(5)
Cx. territans	1	0	(0)	2	0	(0)	3	0	(0)
Ps. columbiae	1	0	(0)	0	0	(0)	1	0	(0)
Ps. ferox	2	2	(100)	1	1	(100)	3	3	(100)
Ps. horrida	3	3	(100)	1	1	(100)	4	4	(100)
Totals	681	340	(50)	741	494	(67)	1422	834	(59)

lower than expected based on the level of biting experienced by collectors while conducting these experiments. The highest attack rate on caged dogs for the entire study was 10 *Ae. trivittatus* per hour. Mosquitoes were observed trying unsuccessfully to enter the cages and occasionally mosquitoes were observed escaping after having entered.

DISCUSSION

Aedes trivittatus was clearly the predominant mosquito species attracted to and engorged on dogs in this locality between 1800–2100 hr in midsummer even though *Ae. vexans* was abundant in the study area and well represented, especially in 1981, in NJ light trap collections made in the same study area (Fig. 1). A direct comparison between New Jersey light trap collections and dog-baited trap collections made on the same nights is inappropriate because light traps were operated throughout the night while dog-baited trap collections were made from 1800 to 2100 hr only. Serial light trap studies in Wisconsin (Thompson and Dicke 1965), in Illinois (Horsfall et al. 1973) and in Ohio (Mitchell 1982) indicate that the activity of *Ae. vexans* was reflected in light trap collections peaks after 2100 hr in midsummer. Therefore, one would expect to see *Ae. vexans* in greater proportions in the light trap collections.

This does not entirely explain why so few *Ae. vexans* were collected from dog-baited traps, however, nor does it explain the relatively low feeding success rate for this species. Concurrent light trap and landing/biting collections of *Ae. vexans* in Wisconsin (Thompson and Dicke 1964) and of *Ae. vexans* and *Ae. trivittatus* in Iowa (Wright and Knight 1966) demonstrate that the peak biting period for *Ae. vexans* precedes the peak for light trap catches. In Wisconsin, the greatest numbers were achieved in hand collections from 30 to 40 min after sunset and, in Iowa, the highest biting rates on forearms were reported to be during the first 60 min of darkness. Wright and Knight (1966) further state that the maximum increase in biting activity of *Ae. vexans* occurred only 15 min after that of *Ae. trivittatus* which occurred at sunset. The experiments described here were carried out until 2100 hr which fell between 87 and 188 min after sunset depending upon day length. Therefore, the heaviest biting period of *Ae. vexans* reported above was included in the study.

These data suggest that *Ae. vexans* are not as attracted to dogs as *Ae. trivittatus*. This hypothesis is supported by the findings of Nasci (1984) who investigated feeding patterns of these 2 species in northern Indiana. He collected bloodfed mosquitoes at 3 types of sites, i.e., urban, suburban and rural, and identified the source of their blood meals by serological tests. He established that in urban woodlots where dogs were plentiful, they were preferred as a blood meal source by *Ae. trivittatus* but not by *Ae. vexans*. Forty-three percent of the identifiable blood meals of *Ae. trivittatus* were of canine origin while only 9% of those were *Ae. vexans*. In the present study the feeding success rate of the *Ae. vexans* (26%) was much lower than for *Ae. trivittatus* (66%), indicating that *Ae. vexans* does not feed readily on dogs even when in close proximity to them.

A statistical comparison of the 1980 and 1981 feeding success rates indicated a significant difference in the proportion of engorged mos-

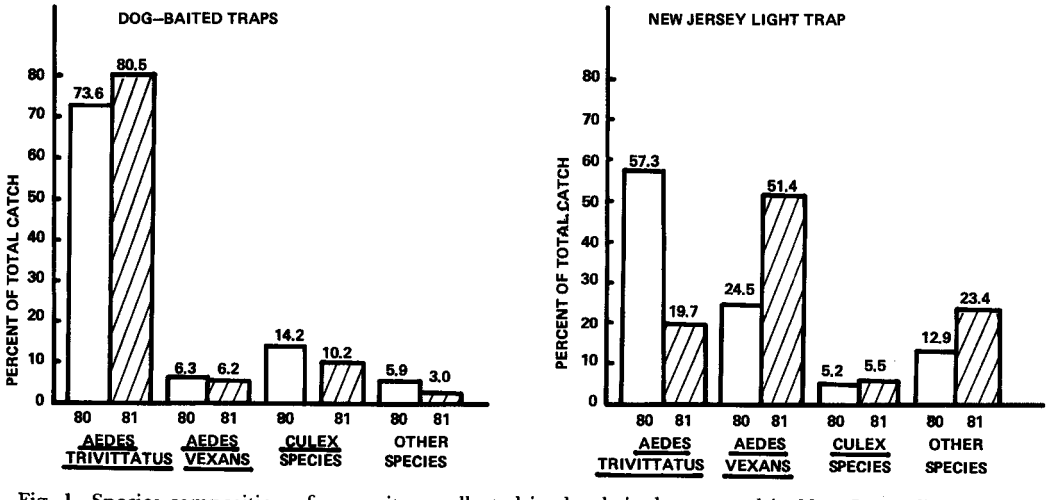

Fig. 1. Species composition of mosquitoes collected in dog baited traps and in New Jersey light traps in 1980 and 1981.

quitoes between the two years. In 1980, 50% of all the mosquitoes collected were bloodfed while in 1981 approximately 67% were engorged. The 70.9% (423/597) engorgement rate for *Ae. trivittatus* in 1981 was significantly higher than the 59.3% (297/501) rate of 1980 ($P<.001$). Similarly, when the engorgement rates of all other species combined were compared for 1980 and 1981, the 49.3% (71/144) in 1981 was significantly higher than the 23.9% (43/180) in 1980.

One explanation for the increase in feeding success of *Ae. trivittatus* might be more attractive hosts in 1981. Another possibility is that our choice of testing dates may have coincided with a feeding cycle of a particularly large brood of *Ae. trivittatus* in 1981. No significant increase in feeding success was evident in the *Ae. vexans* population over the 2 years.

It is evident from the data in Table 1, that the increase in feeding success rates for the remainder of the mosquito species can be explained by the change in species composition. In 1981, there was substantial increase in the number of *Cx. erraticus* and a decrease in the number of *Cx. pipien/restuans*. The shift in the numbers of these 2 species alone accounted for most of the difference between the 2 years.

The occurrence of 56 *Cx. erraticus* in dog-baited traps in 1981, and their high feeding success rate (72%) deserves further comment. According to King et. al. (1942) this species does bite man outdoors in southern states but is said to feed more readily on fowl. Edman (1979) reported *Cx. erraticus* feeding predominantly on birds (79%) but also on mammals (19%) in Florida. However, he did not report any canine blood meals. *Culex erraticus* is reported to have peak feeding activity periods at dawn and dusk and has been collected previously in Delaware County, Indiana in animal traps baited with a frog and a turtle (Siverly 1972). Its potential as a vector of heartworm disease in dogs is unknown.

The number of mosquitoes collected per hour in the kennel traps was much lower than expected based upon the level of human biting activity experienced by researchers. Perhaps dogs are not nearly as attractive to most species of mosquitoes as are humans. However, in some cases, mosquitoes were observed hovering around the cages for several minutes apparently having difficulty entering the traps. In other cases, mosquitoes were observed leaving the traps by way of entrance openings. Therefore, further improvements in trap design are recommended to maximize the efficiency of these kennel traps in any further research.

Aedes trivittatus has been incriminated as a vector of *D. immitis* in Iowa (Christensen and Andrews 1976, Christensen 1977) and infective stages of filarial worms indistinguishable from *D. immitis* have been found in field collected *Ae. trivittatus* from eastcentral Indiana (Pinger 1982). The strong association between *Ae. trivittatus* and dogs reported here indicates that *Ae. trivittatus* is particularly well suited as a potential vector of heartworm disease in dogs in this study area in midsummer, and perhaps at other localities in its range.

ACKNOWLEDGMENTS

Appreciation is expressed to Sharon Dettmer, Sandra Kivett and Stephen Madigosky for their assistance in carrying out this project. I am grateful to the Department of Biology for the use of their study area and particularly to Dr. William B. Crankshaw who helped with the identification of the flora in the study area. I also thank Dr. Roger Nasci who reveiwed this manuscript and made helpful suggestions.

References Cited

Arnott, J. J. and J. D. Edman. 1978. Mosquito vectors of dog heartworm, *Dirofilaria immitis*, in western Massachusetts. Mosq. News 38:222–230.

Bemrick, W. J. and H. A. Sandholm. 1966. *Aedes vexans* and other potential mosquito vectors of *Dirofilaria immitis* in Minnesota. J. Parasitol. 52:762–767.

Buxton, B. A. and G. R. Mullen. 1980. Field isolations of *Dirofilaria* from mosquitoes in Alabama. J. Parasitol. 66:140–144.

Christensen, B. M. 1977. Laboratory studies on the development and transmission of *Dirofilaria immitis* by *Aedes trivittatus*. Mosq. News 37:367–372.

Christensen, B. M. and W. N. Andrews. 1976. Natural infections of *Aedes trivittatus* (Coq.) with *Dirofilaria immitis* in central Iowa. J. Parasitol. 62:276–280.

Edman, J. D. 1979. Host-feeding patterns of Florida mosquitoes (Diptera: Culicidae). VI. *Culex (Melanoconion)*. J. Med. Entomol. 15:521–525.

Horsfall, W. R., H. W. Fowler, L. J. Moretti and J. R. Larson. 1973. Bionomics and embryology of the inland floodwater mosquito *Aedes vexans*. Univ. Ill. Press, Urbana. 211 p.

Jankowski, T. J. and W. E. Bickley. 1976. The mosquitoes *Aedes canadensis* and *A. vexans* as potential vectors of *Dirofilaria immitis* in Maryland. Ann. Entomol. Soc. Am. 69:781–783.

King, W. V., G. H. Bradley and T. E. McNeel. 1942. The mosquitoes of the Southeastern States U.S.D.A. Misc. Publ. No. 336. 96 p.

Klowden, M. J. and A. O. Lea. 1979. Effect of defensive host behavior on the blood meal size and feeding success of natural populations of mosquitoes (Diptera: Culicidae). J. Med. Entomol. 15:514–517.

Lewandowski, Jr., H. B., G. R. Hooper and H. D. Newson. 1980. Determination of some important

natural potential vectors of dog heartworm in central Michigan. Mosq. News 40:73–79.
Ludlam, K. W., L. A. Jachowski, Jr. and G. F. Otto. 1970. Potential vectors of *Dirofilaria immitis*. J. Am. Vet. Med. Assoc. 157:1354–1359.
Magnarelli, L. A. 1978. Presumed *Dirofilaria immitis* infections in natural mosquito populations of Connecticut. J. Med. Entomol. 15:84–85.
Mitchell, L. 1982. Time-segregated mosquito collections with a CDC miniature light trap. Mosq. News 42:12–18.
Nasci, R. S. 1984. Variations in the blood-feeding patterns of *Aedes vexans* and *Aedes trivittatus* (Diptera: Culicidae). J. Med. Entomol. 21:95–99.
Pinger, R. R. 1982. Presumed *Dirofilaria immitis* infections in mosquitoes (Diptera: Culicidae) in Indiana, USA. J. Med. Entomol. 19:553–555.
Siverly, R. E. 1972. Mosquitoes of Indiana. Indiana State Board of Health. Indianapolis, IN. 126 p.
Thompson, P. H. and R. J. Dicke. 1965. Sampling studies with *Aedes vexans* and some Wisconsin *Aedes* (Diptera: Culicidae). Ann. Entomol. Soc. Am. 58:927–930.
Todaro, W. S., C. D. Morris and N. A. Heacock. 1977. *Dirofilaria immitis* and its potential vectors in central New York State. Am. J. Vet. Res. 38:1197–1200.
Wright, R. E. and K. L. Knight. 1966. Effect of environmental factors on biting activity of *Aedes vexans* (Meigen) and *Aedes trivittatus* (Coquillett). Mosq. News 26:565–578.