SIGNIFICANT ASSOCIATIONS BETWEEN MOSQUITO CONTROL SERVICE REQUESTS AND MOSQUITO POPULATIONS[1]

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ABSTRACT. Correlation and multiple regression analyses were used to examine the relationships between mosquito population densities and the numbers of telephone requests for mosquito control services made by people in Polk County, Florida. In 32 of 42 census tracts, there were significant ($P < 0.05$) correlations between mosquitoes and requests and that, for 16 tracts, a significant linear relationship could be demonstrated between service requests and only one mosquito taxon. The significant associations were dependent on the types of mosquitoes rather than the relative abundance among mosquito groups. Service requests were most often related to *Aedes*, followed in importance by *Culex salinarius* and *Anopheles*; least often to *Cx. nigripalpus*. Evidence to support a cause and effect relationship is also presented.

INTRODUCTION

For over 30 years mosquito control programs in Florida and elsewhere have used telephone requests for mosquito control service to help guide daily pest mosquito control operations decisions. This use of service requests is logical in that one of the main objectives of many programs is to reduce the man-mosquito interactions to the point where the public does not perceive mosquitoes as a problem. The real indication of success in meeting this objective is the reduction in numbers of service requests, not necessarily the reduction of mosquito populations, although obviously the latter is the primary means of achieving the former.

The use of service request data has provided Florida mosquito control programs with an inexpensive and direct measure of the nuisance problem caused by mosquitoes. In recent years the reliance on service request data by Florida control programs has been strongly criticized by state and private environmental organizations. This scrutiny led to changes in 1987 in the State rules with regard to mosquito control. Prior to 1987, Florida mosquito control programs could conduct their business almost anywhere at anytime without documentation of the need for the control measures taken. The 1987 rule changes required programs to document the need for mosquito control and that the documentation take the form of monitoring adult mosquito populations.

Establishing and maintaining an adult mosquito monitoring system was a new venture for most Florida mosquito control programs and consequently added new costs to the programs. In addition, there are no scientifically established mosquito nuisance threshold levels for any of the currently used mosquito collection methods to which programs could compare their data to help in their treat/no treat decision process.

If a quantifiable relationship between mosquito population levels and service request numbers for a well defined geographic area could be established, mosquito control programs would have reason to continue using their service request data to help guide daily control operations. This would also allow for a much reduced adult mosquito surveillance system and substantial monetary savings to the program.

In 1986 a series of studies were begun to evaluate the potential of using service request data as a reliable quantifiable measure of mosquito populations in all areas of a mosquito control program's jurisdiction. It is the purpose of this paper to report results of those studies that evaluated the relationships between service requests and mosquito populations in well-defined geographic areas.

Service request data are, of course, not without bias. People who call to request service are representative of the people in the neighborhood with the exceptions that callers are more allergic to mosquito bites, are at home more during the day and tend to do more outdoor activities than non-callers (Morris and Clanton 1988a). Also, the number of calls received per 1,000 people in an area is primarily related to the racial makeup and socioeconomic status of the neighborhood (Morris and Clanton 1988a). It is possible, however, to adjust service request data for these biases so that comparisons can be made across geographic areas (Morris and Clanton 1988a). Results of these studies have been completed and will be presented elsewhere.

Also, the degree of usage of the telephone by residents to request service is, in all likelihood, also influenced by a number of other factors such as, the degree of citizen awareness of the mosquito control services available, their cur-

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rent perception as to what constitutes a mosquito problem, season of the year, day of the week, meteorological and astronomical events and relationship to significant cultural events and holidays. These relationships between service requests and these parameters are yet to be quantified.

MATERIALS AND METHODS

The data for this study were gathered in Polk County, Florida between July 28, 1986 and July 30, 1987. During that time the mosquito control program of Polk County received 1,521 telephone service requests. The calls came from 1,084 addresses in 27 cities and communities. Service requests were grouped, by week, by the U. S. census tracts used in the 1980 census.

Adult mosquito populations were monitored in 42 census tracts using a network of CO_2-baited CDC miniature light traps which were operated for 3–4 hours, centered on official sunset. This network was an established system set up independent of service requests. Trap collections were not made at the homes of requesters. All trap data within a census tract were combined to estimate mosquito densities on a weekly basis.

Analyses of data for each of the 42 census tracts initially consisted of calculating correlation coefficients between the weekly numbers of each of 9 mosquito groups and the weekly number of service requests received. Both raw and log-transformed mosquito and service request data were used. Based on the results of the initial analyses, additional correlations were calculated for service requests and various combinations of the mosquito groups. In addition, multiple regression analyses were used to determine which mosquito species in each tract had the highest association with, and could possibly be used to predict, service request numbers.

Analyses of data across census tracts consisted of calculating the correlation coefficient between the mean rank of abundance of 8 mosquito groups and the number of census tracts which showed significant direct correlations between service requests and that mosquito group. All calculations were made on an IBM XT computer using statistical procedures of SPSSPC+ (Norusis 1988).

RESULTS AND DISCUSSION

During the study period, traps were operated at each of 62 sites once weekly from July 28 to November 20, 1986 and at 105 sites once weekly from April 7 to July 30, 1987. This resulted in 3,149 collections.

A total of 730,169 female mosquitoes representing 9 genera and 24 species were collected (Table 1). For analysis with service request data, mosquitoes were placed into the following 9 groups: 1) *Culex salinarius* Coquillett, 2) *Culex nigripalpus* (Theobald), 3) *Psorophora columbiae* Dyar and Knab, 4) *Psorophora ciliata* (Fab c.), 5) Total *Aedes* (41.3% *Ae. atlanticus-tormentor*; 38.8% *Ae. infirmatus* (Dyar and Knab); 12.4% *Ae. vexans* (Meigen)), 6) Total *Anopheles* (93.1% *An. crucians* Wiedemann), 7) *Coquillettidia perturbans* (*Walker*), 8) Total *Mansonia* (66.4% *Ma. titillans* (Walker); 33.6% *Ma. dyari* Belkin, Heinemann and Page) and 9) Total female mosquitoes.

Thirty-two (76.2%) of the 42 census tracts for which there were sufficient data showed significant correlations ($P < 0.05$) between the number of service requests and the abundance of one or more of the 9 mosquito groups. Nineteen tracts had only positive correlations, 6 tracts had only negative correlations and 7 tracts had both.

There were 69 significant ($P < 0.05$) correlations (50 direct, 19 inverse) between the number of service requests (raw or log-transformed) and one of the 9 mosquito groups (raw or log-transformed) (Table 2). The number of correlations

Table 1. Mosquitoes collected in 3,149 CDC + CO_2 trap collections in Polk County, Florida, between July 28, 1986 and July 30, 1987.

Mosquitoes	Number collected	Percent of total
Culex salinarius	170,783	23.4
Culex nigripalpus	143,489	19.7
Culex erraticus-pilosus group	25,228	3.5
Culex quinquefasciatus	546	0.1
Culex species	13,311	1.8
Psorophora columbiae	110,793	15.2
Psorophora ciliata	6,064	0.8
Psorophora species	224	<0.1
Anopheles crucians	92,461	12.7
Anopheles quadrimaculatus	6,320	0.9
Anopheles species	511	0.1
Coquillettidia perturbans	44,328	6.1
Aedes atlanticus-tormentor group	31,853	4.4
Aedes infirmatus	29,918	4.1
Aedes vexans	9,576	1.3
Aedes aegypti	1,281	0.2
Aedes triseriatus	791	0.1
Aedes species	3,709	0.5
Mansonia titillans	25,028	3.4
Mansonia dyari	12,689	1.7
Mansonia species	406	0.1
Culiseta species	280	<0.1
Uranotaenia species	278	<0.1
Wyeomyia species	7	<0.1
Total	730,169	

depended on whether or not the data for one or both variables were log-transformed (Table 3). Since the objective of the analysis was to attempt to determine which mosquitoes had the closest relationships with and presumably influenced service requests, all significant relationships using raw or log-transformed data were used in subsequent evaluations.

Individual mosquito groups were directly correlated with service requests in from 3 to 11 tracts (7.1 to 26.8%) (Table 2). Service requests were correlated most often with *Aedes, Cx. salinarius* or *Anopheles*. Service requests were least often correlated with *Ps. columbiae* or *Cx. nigripalpus*. Mosquitoes were inversely correlated with service requests in from 1 to 5 tracts (0 to 11.9%). In general, inverse correlations were more common with mosquito groups that had fewer direct correlations. We were more interested in direct rather than inverse relationships between service requests and mosquitoes since we were, in essence, inferring cause and effect.

Using the above results as a guide, additional correlation analyses were done using 9 combinations of the original 9 mosquito groups to see if greater numbers of significant correlations could be obtained; the idea being that service requests are a response to biting mosquitoes in general, not just one species or genus. With the exception of the *Aedes/Cx. salinarius* combination, combining mosquito groups did not increase the percentages of direct correlations above the best percentage obtained for only one component of each combination.

Multiple linear regression analyses were made for each census tract using the number of service requests as the dependent variable and the numbers of *Aedes, Anopheles, Mansonia, Cq. perturbans, Cx. salinarius, Cx. nigripalpus* and *Psorophora* (*Ps. ciliata* + *Ps. columbiae*) as independent variables. Prior to running the regression analyses, correlation matrices were used to detect significant interactions among the mosquito groups within each census tract. Only those mosquito groups which were independent of each other were used in the regression analysis.

Results of these analyses indicated that: 1) in 16 tracts only one mosquito group was needed to obtain a significant (ANOVA $P < 0.05$) linear regression with service requests, 2) 12 of the 16 tracts had at least one mosquito group with a direct association with service requests, 3) two mosquito groups were required in 4 tracts and 4) a significant regression could not be calculated for 22 tracts.

Results of multiple regression, like the results of the correlation analyses, indicate that *Aedes, Cx. salinarius* and *Anopheles* are directly associated with service requests most frequently and that *Cx. nigripalpus* is least often directly, and most often inversely, associated with requests (Table 4). The major difference between the correlation (Table 2) and regression (Table 4) results is that the *Mansonia* were an important group in 5 tracts using the correlation analysis but were never important using the regression analysis.

Table 2. Number (percent) of significant ($P < 0.05$) correlation coefficients between service requests and each of 9 mosquito taxa.

Mosquitoes	Number of census tracts	Type of association with service requests		
		Direct	Inverse	Total
Aedes	41	11 (26.8)	2 (4.9)	13
Cx. salinarius	34	8 (23.5)	3 (8.8)	11
Anopheles	41	7 (17.1)	1 (2.4)	8
Mansonia	37	5 (13.5)	2 (5.4)	7
Cq. perturbans	27	4 (14.8)	0 (0.0)	4
Ps. ciliata	24	3 (12.5)	1 (4.2)	4
Total females	42	5 (11.9)	2 (4.8)	7
Ps. columbiae	41	3 (7.3)	3 (7.3)	6
Cx. nigripalpus	42	3 (7.1)	5 (11.9)	8
Totals	42	50	19	69

Table 3. Number of significant ($P < 0.05$) correlation coefficients between the weekly number of service requests and the abundance of each of 9 mosquito groups in 42 census tracts.

Type of data used		Type of association		
Mosquito	Service request	Direct	Inverse	Total
Raw or log	Raw or log	50	19	69
Raw or log	Raw	48	3	51
Raw or log	Log	47	8	55
Raw	Raw or log	42	4	46
Raw	Raw	40	0	40
Raw	Log	38	4	42
Log	Raw or log	36	6	42
Log	Log	35	6	41
Log	Raw	35	3	38

Table 4. Frequency of 7 mosquito taxa being required for a probability of F of <0.05 in multiple regression analysis.

Mosquitoes	Type of association with service requests		
	Direct	Inverse	Total
Aedes	8	1	9
Cs. salinarius	4	2	6
Anopheles	2	0	2
Psorophora	2	0	2
Cq. perturbans	1	0	1
Cx. nigripalpus	0	3	3
Mansonia	0	0	0
Totals	17	6	23

In order to get an overall evaluation of the relative importance of each mosquito group, we counted the one mosquito group, or in 4 cases 2 groups, that had the highest associations with service requests in the census tract. The highest association was defined as either providing a major contribution to the coefficient of determination (r^2) in multiple regression and/or had the largest positive or negative correlation coefficient (r).

The results (Table 5) clearly suggest that *Aedes* is the single most important contributing factor to promoting service requests, with *Cx. salinarius* a distant second. The third most important mosquito groups were *Anopheles, Mansonia, Mansonia + Cq. perturbans*, and *Psorophora.*

The relative importance of a mosquito group was independent of the relative abundance of that group in the census tract. The most abundant species in most census tracts was *Cx. nigripalpus* (Table 6), a species which was, apparently, consistently unimportant as an initiator of service requests. Conversely, the most important mosquito group with regards to service requests was *Aedes*, yet it was consistently the third to fifth most abundant group in the tracts. The correlation between mean rank of abundance of a mosquito group and the number of tracts which showed a significant direct correlation between that group and service requests was not significant ($r = -0.17$).

Table 5. Number of census tracts where each mosquito group had the highest degree of association[a] with the numbers of service requests.

Mosquitoes	Type of association with service requests	
	Positive	Inverse
Aedes	10	1
Cx. salinarius	5	2
Anopheles	3	0
Mansonia	3	0
Mansonia + Cq. perturbans	2	0
Ps. ciliata + Ps. columbiae	2	0
Cq. perturbans	1	1
Cx. nigripalpus	1	3
Aedes + Ps. ciliata + Ps. columbiae	1	0
Aedes + Cx. salinarius	1	0
Ps. ciliata	0	1
Subtotal	29	8
None = 9		
Total = 46[b]		

[a] The mosquito group either provided a major contribution to r^2 in multiple regression and/or had the largest positive or negative correlation coefficient.

[b] The total is >42 because in 4 census tracts multiple regression analysis indicated that 2 species were required to calculate a significant regression.

Table 6. Frequency distribution of ranks of mosquito abundance.

Mosquitoes	n	Rank among taxa present								Overall	
		1	2	3	4	5	6	7	8	Mean	Rank
Cx. nigripalpus	42	*27*	7	3	2	2	1	0	0	1.76	1
Ps. columbiae	42	4	*17*	4	8	3	6	0	0	3.17	2
Anopheles	42	3	7	*11*	9	6	4	2	0	3.67	3
Cx. salinarius	42	7	5	*9*	4	7	7	3	0	3.76	4
Aedes	42	1	5	10	*11*	10	2	2	1	4.02	5
Mansonia	42	0	0	3	7	8	*11*	6	7	5.74	6
Cq. perturbans	38	0	1	2	1	6	6	*19*	3	6.18	7
Ps. ciliata	35	0	0	0	0	2	3	7	*23*	7.46	8

The geographic distribution of the census tracts with significant correlations between service requests and each of 8 of 9 original mosquito groups (*Ps. ciliata* and *Ps. columbiae* were combined) are presented in Fig. 1. Since the correlations for each census tract were independent, a close geographic proximity of tracts associated with a particular mosquito group increases confidence in the cause and effect assumption (that the particular mosquito group was a major reason people called).

Aedes, only the fifth most abundant mosquito group, was the single most important stimulator of service requests in Polk County on a county-wide basis. Eleven tracts, scattered throughout the county but with a concentration in the north, had significant correlations between service requests and this group. *Aedes* populations in these 11 tracts (mean = 30.7 per trap night) were nearly 3 times greater than in the other tracts (mean = 10.1). This difference was significant (ANOVA $P = 0.003$).

The influence of *Anopheles* on service requests was apparently widespread and substantial. In the 7 tracts associated with *Anopheles*, those populations were 2.6 times greater than in the other tracts (34.0 to 13.1, ANOVA $P = 0.14$). *Anopheles* were only the fourth most abundant mosquito group in the county and do not have a long flight range. However, they breed in marshes and at the edges of the numerous lakes in Polk County (Callahan and Morris 1987). Lake shore residential lots have the highest land value and are usually developed first. Consequently, many people live adjacent to *Anopheles* breeding areas and were, apparently, bothered by them.

The distributions of tracts where service requests were associated with *Cx. salinarius* or *Cx. nigripalpus* were complementary. Six of the 8

Cx. salinarius related tracts were in or near the Green Swamp region of northern Polk County. The *Cx. salinarius* populations in these 8 tracts were more than 2.6 times higher, and significantly greater, than in the other 34 tracts (81.1 to 30.6, ANOVA $P = 0.04$). The 3 *Cx. nigripalpus* related tracts were more scattered, and the *Cx. nigripalpus* populations in those 3 tracts were actually lower than in the other tracts (24.2 to 45.5, ANOVA $P = 0.5$). Although *Cx. salinarius* and *Cx. nigripalpus* are similar in appearance and biology, *Cx. salinarius* is more of a nuisance to man than *Cx. nigripalpus*.

Tracts with service requests correlated with *Ps. columbiae* and *Ps. ciliata* were primarily suburban and arranged in a north-south line in the center of the county. The 3 tracts with correlations between service requests and *Ps. ciliata* had significantly higher *Ps. ciliata* populations (4.1 to 1.1, ANOVA $P = 0.03$) than the other tracts. The 3 tracts in which *Ps. columbiae* were related to requests had populations of *Ps. columbiae* nearly twice as large as the other tracts (43.6 to 24.3, ANOVA $P = 0.27$).

The tracts with service requests associated with *Cq. perturbans* were grouped primarily in the northern part of the county where *Cq. perturbans* populations are very high. The 4 tracts with correlations with *Cq. perturbans* had significantly greater *Cq. perturbans* populations than the other tracts (15.8 to 6.4, ANOVA $P = 0.03$)).

Tracts with service requests associated with *Mansonia* generally complemented the distribution of the closely related *Cq. perturbans*. Tracts with significant correlations had *Mansonia* numbers similar to the other tracts (5.0 to 7.8, ANOVA $P = 0.97$). The numbers of *Mansonia* were significantly higher in the sparsely populated southwest region of the county, but this genus was associated with service requests in only one tract in that region. In contrast, *Mansonia* were least abundant in the urban areas, where most tracts with service requests associated with *Mansonia* were located.

The breeding habitats of *Ma. titillans* and especially *Ma. dyari* are highly restricted, being essentially limited to water bodies containing water-hyacinth (*Eichhornia crassipes*) and water-lettuce (*Pistia stratiotes*) respectively. Also, because these 2 species do not disperse far from their breeding areas,[2] the influence of *Mansonia* appeared to be greatest in highly populated areas immediately adjacent to their preferred larval habitats. Populations of water-lettuce and water-hyacinth are few and scattered in Polk County. Thus, one is not as likely to accurately predict *Mansonia* problems using census tract mosquito data. One should monitor the genus on a smaller geographic scale.

Service requests were correlated with total mosquitoes in 6 tracts. In 5 of these tracts, however, requests were also significantly correlated with one or more other mosquito groups. In 4 of the 5 tracts, requests were also associated with the dominant species, *Cx. salinarius* or *Cx. nigripalpus*. An association between service requests and total mosquitoes apparently just reflects the association observed with the dominant species. Although it is possible to demonstrate associations between service requests and total mosquitoes without specifying the species, this method is less sensitive and more misleading than the comparison of service requests to specific mosquito taxa and is, therefore, not recommended.

The number of service requests can be related to mosquito densities, more accurately so in smaller geographic areas. County wide, the number of service requests received in Polk County were primarily influenced by *Aedes*, *Cx. salinarius* and *Anopheles* populations. The census tracts with service requests related to *Aedes*, or *Cx. salinarius* were concentrated primarily in the northern portion of the county. Tracts associated with *Anopheles* were, on the other hand, discontinuous, apparently due to the highly focal nature of *Anopheles* breeding in the county.

The influence of the 2 *Psorophora* species and *Cq. perturbans*, while less important overall, were regional in nature and therefore detectable by tract-wide mosquito densities. In contrast, the influence of *Mansonia*, similar to the *Anopheles*, was more localized. These latter 2 genera should be monitored on a smaller than census tract geographic scale.

Culex, while very abundant was, apparently, a minor cause of service requests in Polk County. While *Cx. salinarius* appears to have had some influence, depending on its density in the more heavily populated tracts, the influence of *Cx. nigripalpus* was virtually inconsequential.

The results of this and other studies (Morris and Clanton 1988a, 1988b) initiated a change in the Florida state rules regarding surveillance for mosquito control. The rules were amended to allow the use of service request data as an acceptable measure of mosquito problems, except in environmentally sensitive areas or in areas where there are members of the public who object to pesticide applications. In those cases,

[2] Lounibos, L. P., V. L. Shively and C. D. Morris. 1987. Dispersal and survival of *Mansonia* and *Coquillettidia* mosquitoes. A final report to the Florida Dept. of Health and Rehabilitative Services, Office of Entomology, Jacksonville.

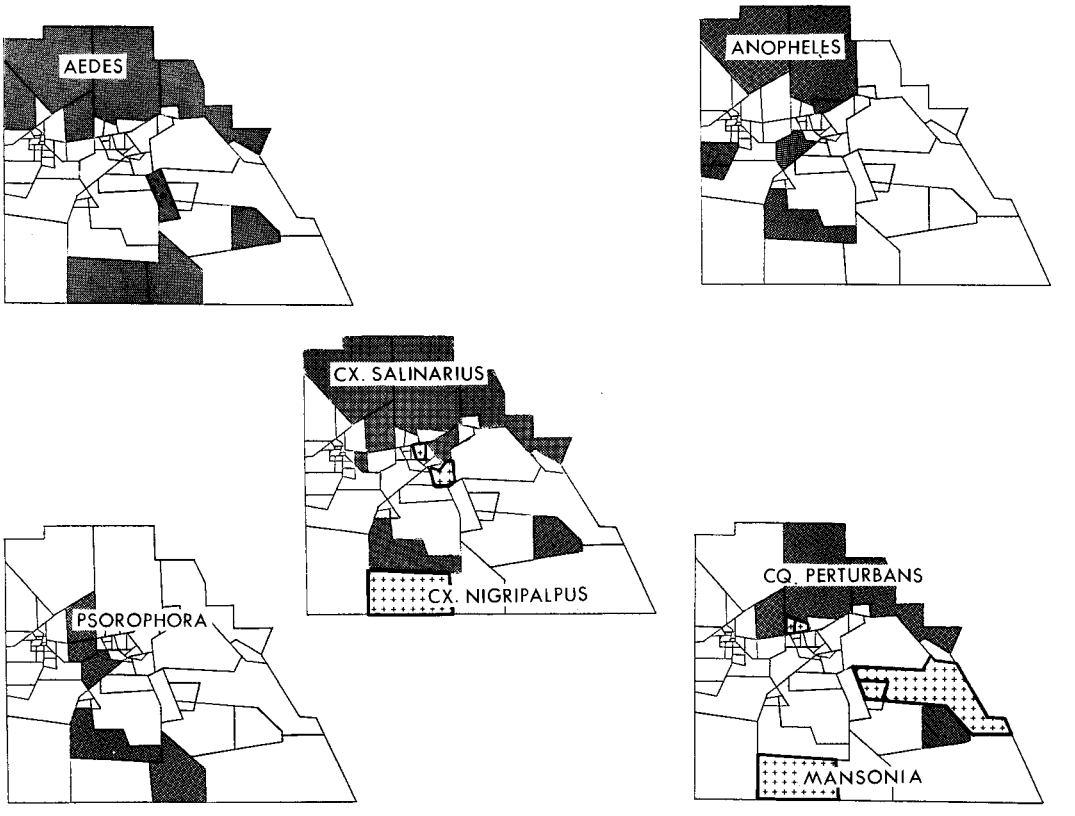

Fig. 1. Distribution of census tracts with significant correlations between numbers of service requests and numbers of 8 mosquito groups.

before control spraying is initiated, the control program must still document, by trapping, the presence of mosquito populations which meet one of the 4 criteria set forth in the rules.

REFERENCES CITED

Callahan, J. L. and C. D. Morris. 1987. Survey of 13 Polk County Florida lakes for mosquitoes (Diptera: Culicidae) and midge (Diptera: Chironomidae) production. Fla. Entomol. 70:471–478.

Morris, C. D. and K. B. Clanton. 1988a. The potential use of service requests (complaint calls) as an indication of mosquito abundance. A final report to the Florida Dept. of Health and Rehabilitative Services, Office of Entomology, Jacksonville.

Morris, C. D. and K. B. Clanton. 1988b. Quantification of a nuisance mosquito problem in Florida. J. Am. Mosq. Control Assoc. 4:377–379.

Norusis, M. J. 1988. SPSS/PC+ V2.0 Base manual for the IBM PC/XT/AT and PS/2. SPSS Inc., Chicago, 606 pp.