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EFFECT OF PERMETHRIN TREATMENT OF CATTLE ON *PSOROPHORA COLUMBIAE* POPULATIONS: PRELIMINARY FIELD TEST OF A HOST MANAGEMENT CONCEPT[1]

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ABSTRACT. The results of a field test conducted in cooperation with the Jefferson Davis Parish Mosquito Abatement District (JDPMAD) during 1988 in southwestern Louisiana suggested that the biweekly treatment of cattle with permethrin reduced the number of adult *Psorophora columbiae* in nearby areas. Routine mosquito control operations by JDPMAD were similar from 1987 to 1988 in the cattle-treated area but increased an average of 41% in control areas. In spite of this, during the year of cattle treatment, captures in New Jersey light traps averaged 86 and 26% of the previous 4-year average in control and treated areas, respectively. Similarly, the proportion of trap nights in 1988 when *Ps. columbiae* captures exceeded 500 averaged 73 and 30% of the previous 4-year average in control and treated areas, respectively. Simulation model projections that took into account differences in JDPMAD operations, weather, cattle density, agricultural practices and the presence of treated cattle were accurate within an average of 9% of observed values for the treated and control areas. The simulation studies indicated that the treatment of cattle with permethrin reduced *Ps. columbiae* populations by 83%. These results suggest that host management may be a viable method for suppressing populations of *Ps. columbiae* and that some form of host management be considered for inclusion in integrated control programs in this environment. Further evaluation of this concept is warranted.

INTRODUCTION

Psorophora columbiae (Dyar and Knab) is one of the most abundant mosquitoes in the rice-cattle agroecosystem of the Gulf-south region of the United States. In these areas, it is a severe pest of man and animals. Cattle are the primary blood sources for *Ps. columbiae* (Kuntz et al. 1982). Because female *Ps. columbiae* fecundity and survival are strongly dependent on the availability of a blood meal soon after emergence, cattle density is a major population regulating factor (McLaughlin and Vidrine 1987, Focks et al. 1988a, 1988b; McLaughlin and Focks 1990).

This biological dependency of *Ps. columbiae* upon cattle led Kuntz et al.(1982) to propose host management (i.e., insecticide applications to cattle) as a potential control method for *Ps. columbiae*. Computer simulations have indicated that host management techniques, if effective, could exert continual pressure on female survival and fecundity, and result in significant, long-term population suppression (Focks and McLaughlin 1988). Other studies have shown that "noncatastrophic" suppression methods can significantly depress insect populations (Adetunji 1988, Thorne 1989). By noncatastrophic, we mean small changes in one or more life history parameters such as lowered fecundity or survival rates and prolonged development times. For example, Throne (1989) demonstrated with field and simulation studies that minor changes in these parameters had a significant impact on populations of the flat grain beetle, *Cryptolestes pusillus* (Schönherr).

A method for treating cattle with a persistent insecticide was tested by McLaughlin et al. (1989). The synthetic pyrethroid, permethrin, applied either as a water emulsion or as an oil-based pour-on formulation, caused significant mortality among female mosquitoes exposed to the cattle. This paper reports the results of a test designed to evaluate the host management concept of *Ps. columbiae* population suppression using the water-based permethrin formulation.

MATERIALS AND METHODS

Test sites, light traps and cattle densities: The test was conducted at 3 sites in Jefferson Davis Parish in southwestern Louisiana during 1988.

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Trends in mosquito abundance were measured using New Jersey light traps fitted with 25-W light bulbs and operated semi-weekly by the Jefferson Davis Parish Mosquito Abatement District (JDPMAD).

For purposes of determining cattle densities, the test sites were considered to encompass the land within a 1.6-km radius of the light trap. The location that received animal treatments had 2 traps which were 2.3 km apart. These traps were referred to as S. Jennings and S.E. Jennings. Approximately 100 head (range during the season was 75–125) were located in a single ca. 100-ha pasture immediately adjacent to the S.E. Jennings trap; there were several herds of 6–25 cattle each located on small pastures (<10 ha) in the vicinity of the S. Jennings trap. The S.E. Jennings trap had significantly more cattle in the immediate vicinity than the S. Jennings trap, although densities were calculated to be 0.14 cows/ha for both traps. The 2 control sites, which received only normal abatement actions by JDPMAD, were centered around individual traps known as N. Welsh and Fenton; associated densities of cattle here were 0.32 and 0.06/ha, respectively. Welsh is 16 km west of Jennings, and Fenton is 21 km northwest of Welsh.

Routine control activities of the abatement district: Normal mosquito control and surveillance were conducted in all 3 areas by JDPMAD during the study. Their control practices, virtually unchanged since 1984, included ground and aerially applied adulticide sprays (malathion and chlorpyrifos) and application of the larvicide *Bacillus thuringiensis* var. *israelensis* (De Barjac) into rice fields during reflooding for production of a second crop of rice. During 1988, JDPMAD applied control measures in all 3 test sites in response to telephone reports from the community, light trap data and weather.

Cattle treatment: Virtually all cattle at the Jennings site received 15 biweekly applications of an emulsified formulation of the synthetic pyrethroid permethrin (Atroban®, Pitman-Moore (formerly Cooper Animal Health), Mundelein, IL 60060) beginning April 11, 1988, and continuing through October. The cattle were confined in pens and circulated clockwise and then counter-clockwise as they were being sprayed to facilitate complete body coverage; special attention was given to spray the undersides and lower extremities thoroughly. The formulation was applied as a coarse spray until runoff occurred at the label rate (ca. 1–2 liters per animal of a 0.55 g AI/liter finished spray formulation).

Data analysis: Assessment of test results relied upon: 1) comparisons of 1988 and 1987 adulticide operations by the JDPMAD, 2) comparison of population trends as indicated by New Jersey light traps, and 3) computer simulation studies that had been validated with actual densities of *Ps. columbiae* populations at the 3 study sites.

Control operations by JDPMAD: This method utilized comparisons of the frequency of spray applications and the cumulative area (in ha) sprayed during the season by JDPMAD within a 3.2-km radius of each of the 3 test sites in 1987 and 1988. Spray activity is an indicator of relative mosquito abundance between areas as control action decisions are based upon a variety of factors that include adult population surveillance data, telephone requests from the community, and even the recent history of adulticidal actions in any one area. Control operations are also based on the total mosquito population and not just *Ps. columbiae.*

Light trap captures: The abundance of *Ps. columbiae* populations is extremely variable from week to week and year to year. Densities vary between locations because populations are episodic, being triggered by local rainfall and irrigation, and influenced by local host density, land use patterns and mosquito abatement operations. The situation is made more complex because these factors interact with conditions early in the season to influence subsequent mosquito populations (Focks et al. 1988b). For these reasons, traditional methods of analysis such as analysis of variance (ANOVA) were not seen as appropriate—there are too many factors that interact in complex ways over time. We did for the sake of completeness, however, analyze the light trap capture data using ANOVA (SAS Institute 1988). The hypothesis was: Average captures in 1988 were not significantly different than in previous years (1984–87) at any of the trap locations. The analysis was conducted on the reciprocal of the square root of the capture data plus one (Steel and Torrie 1980). The light trap data were also analyzed for the proportion of trap nights when captures exceeded 500/night. To detect differences between 1988, the year of cattle treatment, and previous years for each of the sites, these proportions were analyzed with logistic regression (SAS Institute 1988), allowing for extrabinomial variation (Williams 1982). The hypothesis was: The frequency of captures exceeding 500/night in 1988 was not significantly different than the frequency in previous years (1984–87) at any of the trap locations. In both analyses, *site* was the only independent variable included.

Computer simulation: PcSim is a simulation model of the population dynamics of *Ps. columbiae* in the rice-cattle agroecosystem (Focks et al. 1988a). It predicts populations (light trap captures and absolute estimates of adult, larval and egg densities) by integrating information on weather, agricultural practices, mosquito control activities, the influence of the residual cattle treatments, and a host of abiotic and biotic factors. This model has been validated (Focks et al. 1988b) and has previously been used to evaluate and optimize integrated strategies for *Ps. columbiae* control (Focks and McLaughlin 1988). We have used PcSim here because, in contrast to ANOVA, it allows the relative contributions and interactions of the various factors over time to be quantified for each area. With PcSim, it is possible to estimate the impact of residual cattle treatments against the backdrop of other interacting factors. The test of significance for the simulation results lies in the ability of PcSim to predict the annual light trap captures in the 3 study sites given detailed daily information on local conditions at each site over the course of the year.

The following data sources were used for the simulation studies: Daily weather information (date and amount of rainfall, maximum and minimum temperatures, and pan evaporation rates) from the Jennings NOAA weather station was used in the simulation studies; rainfall at each test site was modified as necessary by the semi-weekly accumulations of rain in gauges located at the light traps. Agricultural data including host density, first and second crop rice acreage, and the distributions of field preparation, planting and harvesting dates were obtained by JDPMAD personnel for each test site. To simulate the impact of JDPMAD activities, daily adult survival was reduced as a linear function of the proportion of land treated within a 3.2-km radius of the light trap assuming that spray mortality was 90% on the day of application. Larval survival in ricefields was reduced to reflect the timing and extent of *B.t.i.* applications by JDPMAD personnel within 3.2 km of the light trap at each site (see Focks and McLaughlin 1988 for details). For the Jennings site, an additional factor, mosquito mortality due to permethrin, was included in the model. Efficacy of each insecticide application was considered to decline slowly over time from a maximum mortality of 87% on the day after treatment to 22% at 14 days post-treatment (McLaughlin et al. 1989, Table 1, averages for the EC formulation of permethrin). Efficacy was set to zero after any rains in excess of 0.5 inches (12 mm) following the observations of Nasci et al. (1990) that insecticidal activity (as indicated by parity and sex ratio of mosquito vacuum samples in the vicinity of treated herds) was eliminated after significant rainfall.

Simulations were conducted for each of the 3 locations using parameter values that reflected the unique conditions at each location. A second simulation for the Jennings area was conducted with the efficacy of residual treatments set to zero to simulate expected populations had there been no treated cattle. Comparison of the 2 simulations for Jennings gave an estimate of the efficacy of the topical cattle treatment.

RESULTS AND DISCUSSION

Adulticidal applications: A summary of the ultra low volume (ULV) adulticide applications by the abatement district for each of the 3 test locations in 1987 and 1988 is presented in Table 1. Briefly, ULV treatments were more frequent and cumulative areas treated were greater in the 2 control sites in 1988 than in the preceding year. There were no corresponding increases in the treatment area in 1988. Specifically, in 1988 the number of spray nights in N. Welsh and Fenton was an average of 40% higher than in 1987; percentage change in Jennings was zero. Cumulative area sprayed was also up by a similar amount (42%) in the control sites whereas again, Jennings was essentially unchanged.

In assessing these results, recall that the frequency and extent of ULV treatments is primarily a function of mosquito abundance. A reduction in mosquito populations due to an effective residual cattle treatment would be expected to reduce the requirement for JDPMAD control operations, and perhaps, free up resources for other areas. These results do not demonstrate but are suggestive of a suppressive influence by the cattle treatment.

New Jersey light trap captures: The average captures presented in Table 2 demonstrate a high degree of year-to-year and site-to-site var-

Table 1. Summary of mosquito adulticidal operations through September of 1987 and 1988 in the area of influence of the light traps at Fenton, N. Welsh, and S. Jennings, Jefferson Davis Parish, LA.

	Area	1987	1988	1988 as a % of 1987
No. of spray nights	N. Welsh	42	59	141
	Fenton	26	36	138
	S. Jennings	44	44	100
Ha sprayed	N. Welsh	13,721	15,824	115
	Fenton	2,788	4,711	169
	S. Jennings	11,082	11,218	101

Table 2. Average annual nightly captures of *Psorophora columbiae* females in 4 New Jersey light traps in Jefferson Davis Parish, LA.[a]

Year	Trap location			
	Control areas		Treatment area	
	N. Welsh	Fenton	S. Jennings	S.E. Jennings[b]
1984	966	651	2,073	—
1985	562	493	476	—
1986	595	109	198	1,119
1987	2,201	280	220	647
1988	1,457	139	98	338
1988 as a % of mean of 1984–87	135	36	13	38

[a] Analysis of variance indicated no significant differences.
[b] S.E. Jennings trap not established until 1986.

Table 3. Proportions of nightly mean captures >500 of *Psorophora columbiae* in New Jersey light traps at 4 locations in Jefferson Davis Parish, LA.[a]

Year	N. Welsh	Fenton	S. Jennings	S.E. Jennings[b]
1984	0.47	0.33	0.31	—
1985	0.38	0.30	0.23	—
1986	0.27	0.10	0.13	0.32
1987	0.18	0.27	0.12	0.26
1988	0.37	0.08	0.00	0.17
1988 as a % of mean of 1984–87	114	32	0	59

[a] Analysis of variance indicated no significant differences.
[b] S.E. Jennings trap not established until 1986.

iation; these data reflect the influence of several independent variables that were not accounted for in the ANOVA. There is a correlation between host density and captures during the 1984–87 period: Welsh with the highest captures, averaging ca. 1,100/night, also had the highest host density (0.32/ha); values for Fenton and S. Jennings were, respectively, ca. 380/night and 0.06/ha (lowest captures and host density) and ca. 740/night and 0.14/ha (both intermediate). There was also a wide range in average annual captures recorded at any particular site during the 1984–87 period: There was about a 4-fold range at Welsh, about a 6-fold range at Fenton, and about a 10-fold range at S. Jennings. In addition, another major source of variation not accounted for in the ANOVA was the fact that JDPMAD mosquito control activities, proportional to mosquito abundance, work toward reducing any differences due to cattle treatments. It was therefore not surprising that the ANOVA did not demonstrate a significant difference at any of the sites between 1987 and 1988. We can only say that average captures at the 2 Jennings' traps during 1988, the year of animal treatment, were the lowest recorded for these sites since the inception of the abatement district in 1981 (J. Billodeaux, personal communication). We can also say that during 1988, captures in New Jersey light traps averaged 86 and 26% of the previous 4-year average in control and treated areas, respectively. Note also that this reduction in the Jennings area traps occurred during the year of cattle treatments without the increase in JDPMAD activities that occurred in the other 2 areas (see Table 1).

A similar set of statements can be made for the results presented in Table 3. There is a relationship between host density and frequency of nights throughout the year when captures exceeded 500 and there is also wide variation between years at each site. And, as in the case of average annual captures, the statistical comparison between frequency in 1988 and frequency in 1984–87 at each site was not significant. We can only comment that although the frequencies in 1988 were intermediate at Welsh and Fenton, the frequencies seen at the Jennings traps in 1988 were the lowest counts observed; there was not a single night in S. Jennings where a nightly capture exceeded 500—something that had not occurred during the 7 years of operation at this site. Also, the proportion of trap nights in 1988 when *Ps. columbiae* captures exceeded 500 averaged 73 and 30% of the previous 4-year average in control and treated areas, respec-

Table 4. Average annual light trap captures of *Psorophora columbiae* females observed in 1988 and predicted by the population simulation model PcSim.

Trap	Cattle		Mean annual light trap captures per night		
	Density (ha^{-1})	Treated	Predicted	Observed	Observed/Predicted (%)
Fenton	0.06	No	145	139	96
N. Welsh	0.32	No	1,564	1,457	93
S. Jennings	0.14	Yes	299	252	84
S. Jennings	0.14	No	1,466[a]	252	17

[a] Projected captures without residual cattle treatment.

tively. Again, unlike the control sites, these reductions in the Jennings site occurred without an increase in ULV applications.

Given the many sources of variability that cannot be accounted for in a traditional ANOVA and the ameliorative effect of JDPMAD activities, it was not expected that this analysis would yield significant differences. We do see, however, that the light trap data are suggestive of a suppressive influence by the cattle treatment.

PcSim model predictions: Simulation results for Fenton, N. Welsh and Jennings (with and without the effects of cattle treatment) are presented in Table 4. Integrating the interaction of local weather, agricultural practices and JDPMAD activities, the model predicted that light trap captures would average 145 per night in Fenton during 1988—the observed average was 139, or 96%, of predicted. PcSim did almost as well in N. Welsh, predicting captures to average 1,564 in 1988 when in fact they were 1,457—a value that is 93% of observed. The prediction for the 2 Jennings traps was also very close—the observed was 84% of predicted. This ability of the model to account for dynamics of *Ps. columbiae* in the face of differing host densities, frequency of ULV, etc., gives us confidence therefore to ask what would the expected captures have been had the residual treatments not been made. When their influence was removed from the model, PcSim predicted an annual average capture rate for the Jennings site of 1,466—this represents an almost 6-fold reduction corresponding to a treatment-related suppression of 83% during the test.

CONCLUSIONS AND SUGGESTIONS FOR FURTHER WORK

To determine the effect of the cattle treatments on mosquito blood feeding, Nasci et al. (1990) collected mosquitoes resting on the vegetation of the pastures in the Jennings and N. Welsh sites during this test with a vacuum sampler. Although they could not measure mortality, they did find that the proportion of resting mosquitoes that were blood-engorged in the treated pasture was lower than in the untreated pasture and attributed this to the permethrin treatment. The results presented here suggest that these treatments also resulted in suppression of the *Ps. columbiae* populations in the vicinity of the treated herds. Reduction of *Ps. columbiae* populations to nondetectable levels was not expected because alternate hosts were present to some degree and adult *Ps. columbiae* could move in from adjacent areas.

We believe that host abundance plays a more important role in mosquito abundance and distribution than is commonly appreciated. We appreciate that the results presented here are tentative—further evaluations are necessary of the host management concept. Permethrin is probably not the method of choice—there is the problem of resistance and cost. However, in this system, host animals provide a potential means of inserting some type of suppressive influence into the mosquito population. Potential methods could include zoning changes to alter the proximity of human and animal populations, assignment of the costs of mosquito control on the basis of the number and nearness of cattle to populated areas, the use of a systemic such as ivermectin, or a residual treatment such as used here.

Future tests would be improved if resources were available to: 1) increase the frequency of sampling and the number of types of sampling (in addition to New Jersey traps, perhaps CO_2-baited CDC traps without light bulbs and vacuum samples of resting mosquitoes taken in the vicinity of cattle herds examined for mosquito abundance, parity, blood feeding and sex ratio), 2) monitor the effectiveness of any animal treatments with caged insects, etc., and 3) enlarge the test areas to minimize the influence of migration. In light of the demonstrated relationship between cattle abundance and 7 of 10 species of mosquitoes in this environment (McLaughlin and Focks 1990), future studies should also include the evaluation of other species.

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