Paper No. 3

ECONOMIC THRESHOLDS IN MOSQUITO IPM PROGRAMS

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ABSTRACT. The components in developing an IPM program for mosquitoes attacking cattle are discussed. Included are sampling methods, determination of economic injury levels and data on the economics of mosquito control on cattle.

The use of the flow chart (Figure 1) shows the components that have been utilized to establish specific programs to control mosquitoes that attack cattle. The initial action must be to determine the pest intensity. In developing an IPM program for mosquitoes attacking cattle we used sampling methods that have been utilized by mosquito abatement districts over some 50 years and adapted or modified them to fit our needs. We utilized several light traps (Bidlingmayer 1968), animal baited traps (Roberts 1965), landing rate counts (Steelman et al. 1976), mosquito resting site areas, such as the World Health Organization technique of using grids painted on the wall of human dwellings, and other devices and methods developed for sampling mosquitoes that attack humans. Data have been collected using these various sampling techniques, and through statistical analyses we determined the effectiveness of the different methods in determining the rate of mosquito attack on cattle in any given area (Steelman et al. 1976). The World Health Organization technique of using grids painted on the walls of human dwellings was used to establish the population density of mosquitoes attacking cattle, therefore, determining the effects of mosquito attack on the average daily gain of cattle. Using two different light traps (CDC and New Jersey traps), WHO grid counts, and taking landing rate counts the correlation between mosquito

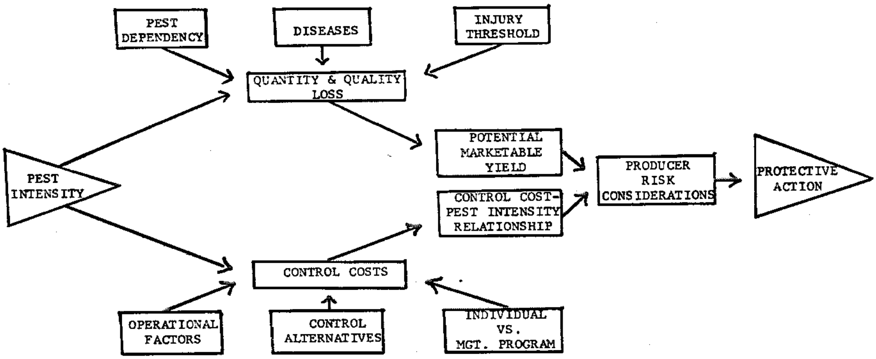

Fig. 1. Components used to constitute the data-base for establishing organized programs to control mosquitoes that attack cattle.

population density and the reduction in average daily gain of cattle caused by mosquito attack using any of the four methods was determined (Steelman et al. 1976).

Sophisticated photography systems are available that can be used to determine the potential production of mosquitoes from certain geographical areas. The National Aeronautics and Space Administration (NASA) has available both high altitude and satellite photography of the entire United States. Infrared photography can be used to identify mosquito breeding areas immediately adjacent to cattle production areas and determine the size of these breeding areas. This type of photography is most useful where mosquito species can be identified with specific types of vegetation, since various species of vegetation can be identified from the high altitude photography. Thus, areas correlated with breeding and/or resting areas and specific plant species can be mapped, measured and later inspected to determine the extent of mosquito breeding in areas adjacent to cattle production areas. Certain species of vegetation have been correlated with the breeding habitat of mosquitoes in Louisiana marshland (Fleetwood et al. 1978) and these breeding areas can be identified by infrared photography.

In order to establish area wide control programs for cattle, the pest dependency of the mosquito populations in the area to cattle hosts was determined. Using cattle baited traps (Roberts. 1965), collecting directly from cattle (Steelman et al. 1968a) and by using truck-traps (Steelman et al. 1968b) blood engorged mosquitoes were collected and the blood identified by precipitin tests to determine the host animal from which the mosquitoes had obtained the blood meal (Schaefer and Steelman 1969). The results of these tests indicated that about 76% of the some 16 species of mosquitoes collected had obtained a blood meal from cattle hosts. Animal baited traps are most useful in determining the range of species and population levels that feed on an animal host during a specific time period. For rice field mosquitoes, the time intervals during the rice growing season that certain species of mosquitoes were feeding on cattle was determined. The floodwater species, *Psorophora columbiae* (Dyar and Knab), occurred during the early part of the season when the rice fields were being flooded and later permanent water species (*Anopheles* and *Culex*) became important after the fields had received the permanent flood of water.

Disease transmission is another important component that must be considered, especially where certain diseases are of economic importance to the various forms of livestock. In cattle, anaplasmosis is an important disease, and mosquitoes play a part in the transmission cycle, serving as mechanical vectors of the *Anaplasma* organism. In Louisiana, purebred Holstein cows purchased in Pennsylvania were transported to Louisiana and compared with native dairy cows to determine their response to natural populations of anaplasmosis vectors. During the 2-year study 10–20% of the native dairy cattle were infected with the *Anaplasma* organism while the Pennsylvania cattle had as high as 44% positive reactors during the study (Steelman et al. 1968a). Diseases caused by the transmission of pathogenic organisms by vector species must be identified and considered in establishing the quantity and quality loss components making up the flow chart.

The most important component making up quantity and quality loss is the establishment of the injury threshold. Without these data it is almost impossible to promote the IPM program to livestock producers. In Louisiana, the injury threshold was established for purebred Hereford cattle, purebred Brahman cattle and for crossbred (Hereford X Brahman) cattle (Steelman et al. 1972, 1973, 1976, 1977). The population density during mosquito attack that caused statistically significant reductions in average daily gain was determined. Data obtained over a 6 year period showed that a reduction of 0.05 kg/head/day reduction in average daily gain was statistically significant and caused economic loss. These data for the different breeds of cattle were then correlated with the population densities of the mosquitoes, and the injury thresholds were established.

The control cost components consist of operational factors, control alternatives and comparison of individual producer control programs and Organized Pest Management Programs. Operational factors consist primarily of husbandry techniques. When the cattle are rotated from one pasture to another the adult floodwater mosquitoes follow and initiate egg deposition in the new hoofprints made by the cattle. Usually after one flooding caused by rainfall or pasture irrigation the eggs deposited in the old pasture hatch, and few eggs are deposited there as the mosquitoes disperse to pastures containing cattle and deposit their eggs in the new hoofprints. This change in egg deposition sites has not been taken advantage of in the past, thus, the chance has been missed to control these mosquito populations in the immature stage by the use of specific insecticides or more importantly, by removing the water soon after the eggs hatch and destroying the population by source reduction.

Control alternatives include activities such as source reduction, wherein breeding areas can be reduced by draining, impounding, and flushing. Mosquitoes can be controlled in certain situations with such agents as mermithid nematodes and the use of predator fish in rice fields. Mass rearing of both the fish and nematodes has been accomplished and the agents released into the mosquito breeding habitats with varying levels of control effected. These biocontrol agents can be included into IPM programs and used effectively.

The data accumulated in the rate of gain studies indicate the importance of cattle breed in the operational program. The Brahman cattle had significantly less response to mosquito attack than did the English breed cattle (Steelman et al. 1973). Therefore the selection of cattle breed as well as crossbreeding programs (Steelman et al. 1976) would reduce the amount of control necessary to keep the mosquito population density below the injury threshold.

Supplemental feeding with high energy intake (concentrate) rations during periods of high mosquito population density reduces or offsets the effects of the pest attack (Steelman et al. 1972). This was accomplished in Louisiana where high energy intake rations were fed during the period when rice fields were being flooded and were producing massive populations of *Ps. columbiae.* No significant ($P > 0.05$) difference existed between animals fed high energy rations and exposed to mosquito attack and check animals protected from mosquito attack.

The use of new insecticides such as the synthetic pyrethroid compounds and other chemicals that effectively kill the mosquitoes as a result of pest-animal contact could be an effective control technique. Thus, the cattle would be used as a "trap crop," attracting the mosquitoes into the specific area containing the host animal and egg deposition site after having been treated with insecticides, thus killing the mosquitoes before egg deposition. Over time this could reduce mosquito production in an area.

Insecticides have been used successfully to control mosquito larvae, thus preventing or reducing the number of adults that would attack cattle or other livestock. There are, however, important problems associated with the use of these chemicals such as the development of resistance, and the effects of these chemicals on non-target organisms in the aquatic breeding habitat. The economics of using these chemicals is also of importance in the IPM program, in that larvicide use is expensive when applied to large acreage (application costs, manpower, application equipment and insecticide).

Adulticiding is more widely used as it is safer to the environment (fewer non-target organisms affected), and resistance is less likely to develop since movement of the mosquitoes into the treated areas from untreated areas allows dilution of resistance characters. Adulticides for mosquito control are also less expensive than larvicides; ground application costs about $0.35/ha and aerial application costs about $0.67/ha acre in Louisiana. Adult control procedures must be carefully managed as timing of application is of the utmost importance in order to control the host-seeking mosquitoes before they can obtain a blood meal. Aerial application allows large areas to be treated in a given time period and areas not accessible to ground application equipment can be reached. It is used for these purposes even though it costs approximately twice as much as ground application. Aerial and ground application of chemicals for adult mosquito control is particularly effective when the management program personnel determines the exact time when mosquito populations disperse from the breeding areas. At this time entire broods of mosquitoes can be controlled by one application of insecticide.

The single most important component of control cost considerations in the IPM program is the individual's cost of having a control program vs. the organized management program costs. Research data from Louisiana indicated that on 405 ha of pasture containing 400 head of cattle the individual producer's cost of satisfactorily controlling mosquitoes with insecticides using ground equipment would be $24.53/ha or $24.83/head of cattle. Using aerial equipment it would cost $29.95/ha and $30.33/head of cattle. An organized mosquito control program financed by a property tax assessment to support the IPM program would cost this producer about $0.125/ha or $0.13/head/year, using source reduction, biological control, and ground and aerial application of chemicals (Table 1).

All of the various components that comprise quantity and quality loss (Figure 1) must be considered in determining po-

Table 1. Economics of controlling mosquitoes that attack cattle by individual producers vs. organized management programs.

CONTROL PROGRAM 405 HECTARES AND 400 HEAD OF CATTLE			
INDIVIDUAL PRODUCER		VS	PEST MANAGEMENT PROGRAM
Ground ULV Equipment			
Truck	$4000		405 hectares @ $25.00/hectare
ULV Unit	$3000		Property Tax Assessment & 5 Mill Program Tax = $50.00/year or $0.125/hectare or $0.13/head/year
Insecticide (208 liter @ $6.00/liter)—14 applications	$1375		
Labor @ $0.25/hectare ($4.00/hr) 14 applications	$ 142		
Truck & Unit Oper. @ $0.25/hectare—14 applications	$1418		
405 hectares = $24.53/ha or $24.83/head			
Aerial Equipment			
Aircraft @ $0.675/ha—14 applications	$3827		
Insecticide @ 7.5 fl oz/ha—14 applications	$8305		
405 hectares = $29.95/ha or $30.33/head			

tential marketable yield. This is indicated by the economic return the livestock producer realizes as a result of the control program. In Louisiana, research data indicate that control of mosquitoes on English breed cattle would return profits that ranged from $4.20 to $13.12/head, Brahman animals $2.71 to $9.01/head and Crossbred (English X Brahman) $0.42 to $2.20/head, depending on the year-to-year variation in mosquito population density and cattle prices (Steelman et al. 1972, 1973, 1976).

The control cost-pest intensity relationship (Figure 1) indicates the cost of the control that must be applied to keep the pest population below the injury threshold. In Louisiana, research conducted on varying land area sizes that contained varying numbers of cattle indicated the number of times the area required treatment, the cost of these applications and the success of the control operations (Steelman et al. 1977). The data indicated that the individual producer control program cost too much to be economically feasible when the organized IPM program was certainly economically feasible and biologically sound. Pasture areas ranging in size from 29 to 133 ha and having cattle numbers of 38 to 106 (regardless of cattle breed) required 3 applications by ground equipment/week to keep the mosquito population below the injury threshold and would cost the producer from $9.94 to $16.30/head which was more than the return he could expect from the control of the pests in increased marketable yield. However, an organized IPM program would cost the same produceers from $0.09 to $0.15/head.

In pastures having 133 ha and crossbred compared to purebred cattle, the number of applications was reduced to 2/week as compared to 3/week for the purebred animals, and for individual producers with crossbred cattle the per head cost was reduced to $9.22 as compared to the purebred producers cost of $16.30. The IPM program costs on this size operation was $0.13 for crossbred compared to $0.15 for purebred cattle. The crossbred producer costs on 266 ha pastures having 216 head of cattle was $5.33/head and required only one application per week while the purebred producer had to make 2 applications per week and cost $12.72 per head. The IPM program would cost both the purebred and crossbred producers $0.15/head.

An individual producer using aerial application of the chemicals would have to have a pasture size of ca. 956 ha and ca. 441 crossbred cows to be economically feasible ($7.98/head) and he would average 0.5 application/week. On smaller pasture sizes that range from 133 to 266 ha the producer would have to have 2 and 1 applications/week, respectively, and the cost per head would be $20.21 and $11.08, respectively. The organized IPM program would cost $0.27 on the larger land area while the cost on the smaller land area would be $0.14 to $0.15/head.

Producer risk considerations (Figure 1) combines the components of potential marketable yield with control costs—pest intensity relationships. The data obtained in Louisiana show that reducing mosquito attack below the injury threshold over the 6 years of study increased the economic value of purebred English breed cattle an average of $6.11/head, and from that the producer would have to subtract only the same $0.15 to $0.27/head for IPM costs. With purebred Brahman animals, the producer would get an economic increase of an average of $5.86/head while subtracting the same $0.15 to $0.27/head for IPM costs. The crossbred producer would return on the average $1.31/head and have the same cost for the IPM program.

These various components on the flow chart indicate the kind of data necessary to establish IPM or organized mosquito control programs for cattle. Utilizing this flow chart as a guideline, data gaps and areas where we have adequate data can be identified. The injury threshold and economic threshold data can be used effectively to initiate organized mosquito control programs, and once initiated, the IPM program can be utilized to further identify areas that require additional research effort in order to increase the effectiveness of pest management.

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Paper No. 4

FUNDING FOR INTEGRATED PEST MANAGEMENT IN MOSQUITO CONTROL

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ABSTRACT. Funds for mosquito IPM research, pilot programs or implementation are very scarce and lagging far behind support for IPM in crop production. The relevance of IPM to mosquito control is being accepted and conceptual endorsement of funding by several agencies is occurring. It appears that funding of mosquito IPM will have to come largely from traditional sources including operational support.

The question of funding for mosquito control integrated pest management (IPM) has 2 aspects. One is allocation of existing resources; the second is identification of new money specifically designated for IPM.

To allocate existing resources, mosquito control decision makers have long considered the principles now embodied in the overall concept called IPM. The 3 basic control technologies, namely physical, biological, and chemical, all historically have been used in combination, with funding priorities being assigned de-