METHODS FOR EVALUATION OF COSTS ASSOCIATED WITH PERMANENT AND TEMPORARY CONTROL METHODS FOR SALT MARSH MOSQUITO ABATEMENT[1]

JOSEPH K. SHISLER[2] AND TERRY L. SCHULZE[3]

ABSTRACT. Faced with reduced operating expenses, mosquito control agencies must be able to assess cost-effectiveness of various control techniques using practical and simple procedures. Previous economic literature on this subject is sparse, controversial, and not routinely applicable. This paper proposes and tests methodologies for comparing costs of temporary and permanent control strategies utilizing actual biological and cost data routinely generated by two New Jersey mosquito extermination commissions.

INTRODUCTION

In today's economy, government agencies and private industries are faced with a high degree of accountability regarding expenditures. Mosquito control agencies are no exception. Passage of regulations in California (Proposition 13), Massachusetts (Proposition 2½), and New Jersey (5% Cap on county budgets) requires many control commissions to justify individual components of the control programs and to more judiciously allocate shrinking operating funds.

The development of practical methods to evaluate the economics of mosquito control has not been adequately addressed in the literature. Complex theoretical manipulations of cost analysis data regarding mosquito control (DeBord et al. 1975, Carlson and DeBord 1976) are often impractical for local mosquito control agencies. Recent publications (Sarhan et al. 1979), Langham and Lanier 1981) in economic journals questioned the results of DeBord et al. (1975). Shisler et al. (1979) and Langham and Lanier (1981) suggested that DeBord et al. (1975) did not adequately consider the scientific data and limitations of the survey techniques employed in their study.

In essence, practical application of economic criteria varies substantially both between mosquito control commissions and within a commission because of the varying and sometimes unique nature of the control problem. Sarhan et al. (1979), based upon changes in light trap indices for *Aedes nigromaculis* (Ludlow) and *Culex tarsalis* (Coquillett), showed permanent control to be more economical than temporary measures for both short- and long-term evaluations. Hansen et al. (1976), Shisler et al. (1979), and Shisler and Schulze (1981) compared the costs of mosquito control utilizing permanent and temporary control measures in salt marshes against *Ae. sollicitans* (Walker) and showed permanent methods to be more cost-effective in the long run. Shisler and Harker (1981) evaluated costs of permanent and temporary control in upland areas and found that not all permanent control projects can be justified economically. The disparity of conclusions regarding the advisability of implementing temporary versus permanent control underscores the need to assess each control problem on an individual basis. Mosquito control agencies are in need of fundamental methods of evaluating control strategies which incorporate both economic and control principles.

Organized mosquito control has long espoused, contributed to, and practiced the Integrated Pest Management (IPM) approach for controlling mosquitoes. The use of source reduction techniques, biological means, surveillance and insecticides has led to the development of an effective "Organized Mosquito Control" program (Olson 1979). However, under recent budgetary constraints the major emphasis of IPM programs has shifted towards assessment of cost-effectiveness of the various methods utilized (King and Brooke 1977). In response, this paper will assess two methods of mosquito control over an extended period of time on New Jersey salt marshes, and will propose and test possible methods of cost evaluation that could be incorporated into various IPM programs.

METHODS. The data used in developing the cost analysis components presented below were extracted from actual records of mosquito control agencies.

COST ANALYSIS DEVELOPMENT AND DISCUSSION

Any evaluation of costs over an extended period of time must take into account a variety of factors. Year to year variations of *Ae. sollicitans* populations, because of changes in envi-

[1] New Jersey Agricultural Experiment Station Publication No. D-40502-2-83.

[2] Mosquito Research and Control, New Jersey Agricultural Experiment Station, Cook College, Rutgers—The State University of New Jersey, New Brunswick, NJ 08903.

[3] Environmental Connection, Inc., P.O. Box 69, Perrineville, NJ 08535.

ronmental conditions (e.g., tidal flooding, rainfall and wind), will affect the number of treatments on a given area of salt marsh (Downing 1978, Shisler et al. 1979). Actual yearly differences in *Ae. sollicitans* nightly light trap populations in one county under evaluation (County A) ranged from arithmetic means of 34.68 (1975) to 2.72 (1980), or with Williams' means (Downing 1976) from 4.23 to 0.69 respectively. Environmental conditions favorable to mosquito production may occasionally necessitate temporary control measures in areas previously treated for permanent control (Shisler et al. 1979).

A second factor affecting costs of mosquito control is the inflation rate. Since 1974, yearly inflation rates have ranged from a low of 5.8% (1976) to a high of 12.4% (1980) (Consumers Price Index). Inflation not only impacts upon chemical costs but also increases salaries and equipment costs, whether purchased or rented. The estimated 50% overhead costs to defray salaries of administration and clerical staffs, supplies and fringe benefits becomes similarly inflated (Shisler et al. 1979).

Another variable complicating long-term cost evaluation involves changes in control methods. To illustrate, Table 1 depicts a comparison of larviciding costs per hectare in two counties studied. In 1977, County A converted from use of granular material to flowable concentrate in its larviciding program. The savings per hectare (Table 2) went from 7.2% in 1977 to 21.8% in 1980 over the projected costs for utilizing granular material. County B also implemented similar substitution in larvicide but did not continue its use because control results were inadequate.

The above comparisons exemplify some factors that should be considered in assessing costs for temporary control, and underscore the need to evaluate individually specific programs between and within county control agencies.

Cost estimates are more easily determined for permanent control methods and the cost, including the 50% overhead (Shisler et al. 1979), is fixed at the time the project is completed. Perhaps the most comprehensive parameter to measure involves the comparison of breeding potential of an area. After an area is altered, the estimated breeding potential as well as the costs for control must be compared with a similar unaltered area. In New Jersey, the U.S. Army Corps of Engineers Permits authorizing Open Marsh Water Management (OMWM) projects require that 1% of the area to be managed remain unaltered and used for future evaluations. As with temporary control procedures, variations in inflation rates also affect evaluation of permanent control costs when viewed over an extended period of time. We recommend using the inflation rate of the year the project is instituted and projecting the same rate through the evaluation period for both temporary and permanent control methods.

Life of the permanent control project is an estimate. A number of water management projects in New Jersey are over 10 years old and have not required maintenance or larvicide treatments during that period (Hansen 1979, Shisler 1978). We estimate that many of these projects will continue to function without major maintenance for 25 years.

As with temporary control, cost analysis per hectare for permanent control is calculated by dividing total costs by the number of hectares on which permanent control was conducted. For illustration, actual larviciding costs over a 3- to 7-year period for three potential water management projects are presented in Table 3, and are compared with 1980 estimates of costs (calculated as suggested above) for implementation of permanent control projects. Two projects (A and C) had a larviciding cost in their respective 3- and 7-year histories that exceeded the estimated permanent control expenditures. As such, permanent control would have been cost-effective within these brief periods had water management been implemented in 1981. Permanent control for Project B would not be

Table 1. Cost ($/ha) comparison for larviciding salt marshes in two counties in New Jersey from 1974 thru 1980.

	County	
Year	A	B
1974	15.14	18.67
1975	15.91	22.13
1976	64.54	18.94
1977	18.50	17.96
1978	16.33	19.24
1979	21.46	20.65
1980	16.52	30.21

Table 2. Comparison of costs ($/ha) in County A associated with a change in larviciding chemicals from a granular (GR) to a flowable concentrate (FC) in 1977.

Year	Actual costs ($/ha)		Projected GR ($/ha)	% saved
1974	15.14	GR		
1975	15.91	GR		
1976	64.54	GR		
1977	18.50	FC	19.83	7.2
1978	16.33	FC	18.62	14.1
1979	21.46	FC	23.96	11.6
1980	16.52	FC	20.13	21.8

Table 3. Actual cost of temporary control larviciding measures compared with 1980 estimated permanent control (water management) costs on several projects in New Jersey salt marshes in County A.

	Year	Total ha[1]	$/ha[2]	Yearly $
Project A	1978	2648.7	$19.24	$ 50,960
(607.5 ha)	1979	1577.1	20.65	32,567
	1980	1349.5	30.21	40,767
Actual larviciding costs for 3 yrs				$124,295
ESTIMATED COST OF PERMANENT CONTROL				$100,000
Project B	1974	572.7	$15.14	$ 8,670
(405 ha)	1975	384.7	15.91	6,121
	1976	89.9	64.54	5,800
	1977	175.4	18.50	3,244
	1978	982.7	16.33	16,047
	1979	434.8	21.46	9,331
	1980	440.4	16.52	7,275
Actual larviciding costs for 7 yrs				$ 56,488
ESTIMATED COST OF PERMANENT CONTROL				$ 72,000
Project C	1974	440.2	$15.14	$ 6,665
(202.5 ha)	1975	496.5	15.91	7,900
	1976	89.6	64.54	5,782
	1978	587.9	16.33	9,600
	1979	478.6	21.46	10,271
	1980	407.2	16.52	6,727
Actual larviciding costs for 7 yrs				$ 56,541
ESTIMATED COST OF PERMANENT CONTROL				$ 12,000

[1] Total ha treated per year.
[2] From Table 1.

as cost-effective over this same brief period of time, being about 27% more costly than larviciding. Permanent control varies with the amount of larval habitat and type of work.

Often, such cost analysis is not that straightforward. Allowances must be made in case temporary control measures are required once water management has been completed. To illustrate, larviciding data of a 36.8 ha OMWM-treated site (Project D) indicated that even after permanent management, some additional chemical treatments were required to control mosquito populations (Table 4). To assess these costs, a ratio of hectares sprayed between OMWM areas needing treatment and a breeding, non-altered control area (NON) receiving spray was calculated using 1974 values. The resulting figure may be used as a guide in determining future yearly temporary control costs once OMWM is completed. For example, in 1974 the ratio of breeding areas treated for OMWM/NON was 2.8. In 1975, 40.7 ha (the actual accumulated area larvicided in the NON plot) times the 2.8 factor yielded an estimate of 114.1 ha that would have had to be sprayed in the OMWM treatment area if not controlled by OMWM. That year, 13.4 ha of OMWM areas actually required chemical treatment for control of mosquito populations. The estimated 1975 costs for temporary control, had OMWM not been implemented, is calculated by subtracting 13.4 ha from 114.1 ha. As such, an estimated 100.7 ha of breeding habitat were controlled by OMWM that would have been chemically treated if OMWM had not been performed. At a 1975 larviciding cost of $15.91/ha, a yearly cost of treating these 100.7 ha was estimated to be $1603. The same rationale was carried through the remaining years, so that by the end of 1980 temporary control was estimated to cost $9650. In contrast, 1975 permanent control costs were estimated to be $9000 in an area of similar size. Therefore, permanent control had hypothetically paid for itself in savings over a period of six seasons.

On occasion, multiple OMWM/NON ratio data may be available, and may be utilized by calculating the mean of these ratios. The inflation rate and multiple chemical treatments per year must also be considered in the cost evaluation. These factors were taken into account in our evaluation of the cost-effectiveness of OMWM in Project E. The 810 ha site had been studied regarding larviciding versus OMWM costs (Launay and Widjeskog 1978, Hansen 1979). Launay and Widjeskog (1978) estimated, without considering inflation, that the project would recoup the OMWM investment of $175,000 in 5 years by eliminating the necessity of larvicide treatments. The site had a mean larvicide record of 4 treatments/year (Hansen 1979). At a cost of $17.96/ha/treatment and utilizing a 10% inflation rate for 5 years (see Shisler and Harker 1981 for calculation), temporary control measures would require an expenditure of $354,961 over 5 years. As such, implementation of permanent control would, in 5 years, be 2.03 times more cost-effective than temporary control. Using similar procedures, cost-effectiveness ratios may be projected over longer periods. Table 5 presents such projections for Project D and Project E at 5-year intervals from 10 to 25 years. Without maintenance, the cost-effectiveness ranged at the end of 25 years was 12.78 times better with water management for Project D and 34.48 time better with water management for Project E.

SUMMARY AND CONCLUSION

The reality of increasing costs with reduced budgets necessitates that organized mosquito control agencies become more cognizant of the

Table 4. Determination of additional temporary spray costs for salt marsh mosquito control on a 36.8 ha OMWM-treated site, Project D in county A (see text). Ha receiving spray in 1974 are known, and the maximum amount of ha that would have needed spray from 1975 to 1980 is estimated based on actual spray use in an adjacent control plot (NON) during this period, with an adjustment downward for ha in the OMWM site actually sprayed during this same period.

Year	NON (Actual sprayed)	OMWM Est. spray need (NON × 2.8)*	OMWM Actual OMWM sprayed	Ha saved by OMWM from more spray	Spray costs $/ha	Total spray costs saved
1974	23.1		64.9			
1975	40.7	114.1	13.4	100.7	$15.91	$1,603
1976	9.4	26.2	0.4	25.8	64.54	1,667
1977	18.6	52.2	0.0	52.2	18.50	965
1978	22.9	64.2	25.1	39.1	16.33	639
1979	47.5	133.1	0.0	133.1	21.46	2,857
1980	45.4	127.1	10.9	116.2	16.52	1,919
					(1975–1980)	$9,650

* From ratio of actual sprayed Ha in 1974 for OMWM/NON (64.9/23.1 = 2.8).

Table 5. Ratios of temporary/permanent costs associated with the control of salt marsh mosquitoes on two projects in New Jersey.

Years	Project D	Project E
10	2.07	5.59
15	4.13	11.14
20	7.44	20.08
25	12.78	34.48
	(2 treatments/yr) 36.8 ha	(4 treatments/yr) 810.0 ha

economics involved in their operations. While most of these agencies remain current on control techniques and strategies, little information is available regarding control economics. The published literature on mosquito control costs leans heavily towards complex economic analysis, but pays only passing attention to the varied ecological and technological problems which daily confront control agencies.

In order to be productive, or in some cases even survive, mosquito control agencies must demonstrate cost-effectiveness in their programs. They must be able to understand and analyze many factors, such as environmental events or cycles affecting mosquito populations, inflation, overhead, components of IPM and material and applications costs, all of which impinge upon successful assessment of which control strategies to employ. Most importantly, mosquito control personnel must realize that virtually all control projects are essentially unique and should be evaluated independently.

The methodologies presented are intended to be a guide in determining cost-effective mosquito control. Each agency will undoubtedly encounter additional factors for consideration and/or will need to place varying emphasis on these factors.

ACKNOWLEDGMENTS

This research was performed as part of NJAES Project 40502 and was funded by the New Jersey Mosquito Control Commission. The authors with to thank T. Candeletti of the Ocean County Mosquito Extermination Commission and J. Hansen of the Cape May County Mosquito Extermination Commission, plus their respective commissions, for allowing this cost analysis of methodologies. A. Hajek and P. Horan are acknowledged for their invaluable assistance in preparing the manuscript.

References Cited

Carlson, G. A. and D. V. DeBord. 1976. Public mosquito abatement. J. Environ. Econ. Manag. 3:142–153.

DeBord, D. V., G. A. Carlson and R. C. Axtell. 1975. Demand for and cost of coastal salt marsh mosquito abatement. N.C. Agric. Exp. Stn. Tech. Bull. 232.

Downing, J. D. 1976. Statistical analysis and interpretation of mosquito light trap data. Proc. N. J. Mosq. Control Assoc. 63:127–133.

Downing, J. D. 1978. Population fluctuations in *Aedes sollicitans*. Proc. N.J. Mosq. Control Assoc. 65:187–189.

Hansen, J. 1979. Reduced use of pesticides through open marsh water management. Proc. Utah Mosq. Abatement Assoc. 32:33–34.

Hansen, J. A., F. H. Lesser, R. W. Lombardi, J. K. Shisler and P. Slavin. 1976. The economics of marsh water management—a New Jersey view. Proc. N. J. Mosq. Cont. Assoc. 63:77–81.

King, J. B. and J. P. Brooke. 1977. The concept of integrated control of vector-borne disease. Mosq. News 37:358–361.

Langham, M. R. and R. Lanier. 1981. Public mosquito abatement. J. Environ. Econ. Manag. 8:97–99.

Launay, E. J. and L. E. Widjeskog. 1978. Evaluation of the Tuckahoe open marsh water management project: First year progress. Proc. N. J. Mosq. Control Assoc. 65:225–228.

Olson, J. K. 1979. Application of the concept of integrated pest management (IPM) to mosquito control programs. Mosq. News 39:718–723.

Sarhan, M. E. S., R. E. Howitt and C. V. Moore, 1979. Pesticide resistance externalities and optimal mosquito management. J. Environ. Econ. Manag. 6:69–84.

Shisler, J. K. 1978. The efficiency of water management in coastal areas. Proc. N.J. Mosq. Control Assoc. 65:196–198.

Shisler, J. K., F. Lesser and T. Candeletti. 1979. An approach to the evaluation of temporary versus permanent measures in salt marsh mosquito control operations. Mosq. News 39:775–780.

Shisler, J. K. and W. Harker. 1981. Source reduction as an economical approach to mosquito management. Mosq. News 41:419–423.

Shisler, J. K. and T. L. Schulze. 1981. Comparison of costs for mosquito control on New Jersey disposal sites. Mosq. News 41:465–469.