CONCEPTUAL MODEL FOR THE USE OF AERIAL COLOR INFRARED PHOTOGRAPHY BY MOSQUITO CONTROL DISTRICTS AS A SURVEY TECHNIQUE FOR *PSOROPHORA COLUMBIAE* OVIPOSITION HABITATS IN TEXAS RICELANDS[1]

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ABSTRACT. Two photographic missions per year are recommended to provide information on land-use and mosquito oviposition habitats. A winter mission, following a rain, will provide a view of low areas within fields which may be obscured by summer vegetation. A summer mission will provide current land-use and crop distribution information and may show plant stress conditions due to excessive soil moisture. An aerial color infrared photographic survey with directed ground verification should result in a substantial savings in cost and increased efficiency in surveillance of mosquito producing habitats over ground survey techniques currently employed by mosquito control districts.

INTRODUCTION

Knowledge of the distribution and activity of mosquitoes is basic to developing and implementing effective management strategies that will reduce the importance of these insects as sources of annoyance and vectors of disease agents. Ground survey techniques employed by mosquito control agencies to locate breeding habitats of such floodwater mosquito species as *Psorophora columbiae* (Dyar and Knab) in southern riceland agroecosystems are time-consuming, expensive and possibly inaccurate due to the dynamics of the riceland agroecosystem. The dynamics of the system include the rotation of crops, alternation of topography through cultivation and seedbed preparation, and the flooding and draining of fields during irrigation. In this regard, mosquito control agencies need less expensive and more efficient methods of mosquito surveillance.

Remote sensing techniques are generally considered to be quicker, less expensive and more accurate than ground survey techniques for the detection and assessment of changes in the dynamics of target pest insect populations (Colwell 1963). Aerial photographic surveys of tree kill by the Douglas-fir beetle, *Dendroctonus pseudotsugae* (Hopkins), were equally accurate and less expensive than field surveys (Wear et al. 1964). A combined aerial photography-ground survey of mortality, deformation and stand deterioration of balsam fir, *Abis balsamea* (L.) Mill, by the balsam wooly aphid, *Chermes piceae* Ratz. was more economical than a ground survey alone (Heller et al. 1967). Photointerpretation of beetle infestations of forested areas on many photo samples greatly increased efficiency and lowered costs over conventional ground surveys (Heller and Wear 1967). Citrus blackfly, *Aleurocanthus woglumi* Ashby, was surveyed more efficiently and with less expense with aerial color infrared photography (Hart et al. 1973). Fleetwood et al. (1981) explained how *Ps. columbiae* could be monitored in rice and fallow fields in southwest Louisiana more economically with a combined aerial visual plus ground inspection than conventional ground surveillance.

Results of a recent study of the use of aerial color infrared photography as a survey technique for *Ps. columbiae* oviposition habitats (Welch[7]) suggest a possible financial savings to mosquito control districts and an increase in the efficiency and accuracy of their surveillance programs designed to detect potential egg-laying habitats in riceland agroecosystems. The purpose of this paper is to present a conceptual model for the integration of aerial color infrared photography with a traditional surveillance program, describing the logistics of implementing this technique by mosquito control practitioners, and a discussion of its economic advantages.

METHODS

Data gathered during the aerial color infrared photographic study (Welch et al. 1989) was used

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[7] Welch, J. B., 1983. The use of aerial color infrared photography as a survey technique for *Psorophora columbiae* (Dyar and Knab) (Diptera: Culicidae) oviposition habitats in a Texas riceland agroecosystem. Ph.D. dissertation, Texas A&M University, College Station, TX, 226 pp.

to develop the conceptual model described herein, which summarizes the most efficient and effective way for mosquito control practitioners to use aerial color infrared photography as a survey technique in their *Ps. columbiae* surveillance programs in southern riceland areas. The model was developed from the analysis of *Ps. columbiae* oviposition site ground truth data (Welch et al. 1986, Welch and Olson 1987) and the correlation of these data with photographic characters as supported by ground verification (Welch et al. 1989).

In conjunction with the gathering of the color infrared photographic data associated with the study described by Welch et al. (1989), a simple economic comparison was made between ground survey techniques currently employed by mosquito control practitioners and the estimated cost of aerial color infrared photographic survey techniques used in this study. Ground survey costs were obtained from M. M. Yates, at the time when he was Director, Chambers County Mosquito Control District, Anahuac, TX. Estimated expenses for an overflight and the resulting photographic coverage for the riceland agroecosystem within Chambers County, TX, were obtained from data supplied by A. R. Benton, Jr., Remote Sensing Center, Texas A&M University, College Station, TX.

RESULTS AND DISCUSSION

The conceptual model of the use of aerial color infrared photography by mosquito control practitioners as a survey technique for *Ps. columbiae* oviposition habitats within the riceland agroecosystem is presented in Fig. 1. A spring or summer overflight, either contracted out or flown by mosquito control personnel, would result in photographic coverage of the riceland agroecosystem while crops were present in the field. Information provided by photointerpretation would include current land-use and crop distribution patterns. Acreages of fields planted to rice, soybeans and permanent pastures could be easily calculated.

Photointerpretation of plant vigor and topography within fields during the spring or early summer would permit the location of potential *Ps. columbiae* oviposition habitats. Ground survey personnel would then be sent to specific areas for ground verification and assessment of mosquito habitats. Decisions concerning treatment or nontreatment would be made based on the field data acquired by ground survey personnel, and actions would be taken accordingly. The photographs and concurrent crop, topographic, and mosquito population information would then be added to the mosquito control district's data base providing an increased knowledge of the local environment and mosquito oviposition patterns. This information would serve as a permanent record of activities that season and would be available for future comparison and decision making.

A winter photographic mission would provide coverage of the riceland agroecosystem when crops are not in the fields and vegetation within

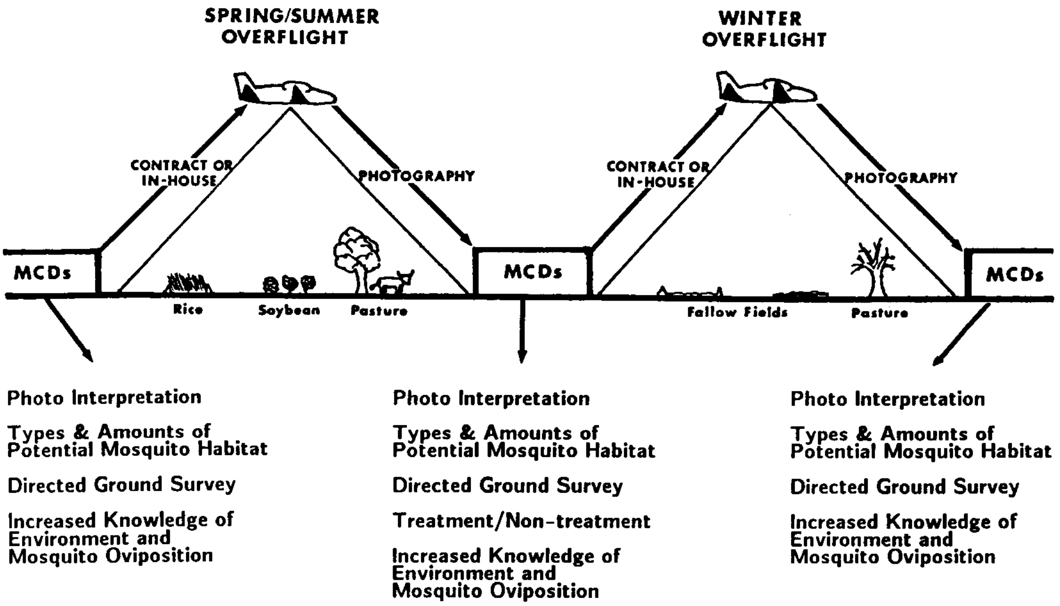

Fig. 1. Conceptual model of the use of aerial color infrared photography by mosquito control districts (MCDs) as a survey technique for *Psorophora columbiae* oviposition habitats within a riceland agroecosystem.

pastures is dormant. Topographic features within fields normally obscured by crop canopies or natural vegetation during the growing season would be visible for photointerpretation. Localized depressions potentially capable of holding water after rainfall would be located by the photographs and ground survey personnel would be sent to the field for verification. Information obtained from photointerpretation and ground verification would provide increased knowledge of the environment and potential mosquito oviposition sites. The aerial color photographs would again be a permanent record for future consultation.

Aldrich and Drooz (1967) reported that the season for accomplishing aerial photography was important in their estimation of insect infestation, summer being poor because of unfavorable weather conditions. This may also be true to some extent along the coastal regions of the southern rice-producing areas of the United States since southerly winds commonly bring in scattered clouds during the summer. According to Smith and Anson (1968), there are an average of 18–28 clear days with 10% cloud cover or less, suitable for aerial photography along the Texas Gulf Coast during June–September. Cloud cover conditions experienced in Chambers County, TX, during 1979–81 (J. B. Welch, unpublished data) suggest an average of 7 days were clear enough for aerial photography in this area during June–September. Cloud cover during the winter should not be a factor since there is a reported average of 20–32 clear days (Smith and Anson 1968) during December–March along the coast. Observations made during 1979–81 in Chambers County, TX, supported the estimated clear days occurring during the winter.

The literature suggests that smaller scale photography is more practical than larger scale because of the increased area of land per photograph with the smaller scale (Aldrich and Drooz 1967, Ciesla et al. 1971). Aldrich and Drooz (1967) reported the photographic scale of 1:7,920 was more practical than 1:3,960 in their study. The 1:15,000 scale photographs used in work with *Malacosoma disstria* Hbn. were more practical than 1:6,000 scale (Ciesla et al. 1971). Wagner et al. (1979) reported using high altitude color infrared photography of 1:120,000 scale to map forested wetlands, open wetlands, marshes, and residential areas. During the investigation of Welch et al. (1989), aerial color infrared photography of scales of 1:4,000 to 1:42,000 were used to locate and identify habitats potentially attractive to *Ps. columbiae* for oviposition. The use of magnification is recommended for interpretation of 1:42,000 scale photographs.

Photographic scales of 1:40,000 and 1:20,000 were requested in the bid for photographic coverage of the riceland agroecosystem within Chambers County, TX, as discussed further on in this section. The reason for requesting the coverage of 50,000 acres at the larger scale was for comparative purposes with the smaller scale. It is suggested that during the initial use of the aerial color infrared photography survey technique, a few areas known to be attractive for *Ps. columbiae* oviposition be flown at the larger scale as references for their appearance and the appearance of other previously undetected oviposition habitats on the smaller scale photographs.

As for the economics of using aerial color infrared photography for surveillance, the bid for aerial color infrared photographic coverage of the riceland agroecosystem (estimated 286,138 acres) within Chambers County, TX, at a scale of 1:40,000 plus coverage of an additional 50,000 acres at a scale of 1:20,000 was $3,570.00. This breaks down to approximately $0.012 per acre. In comparison, estimated costs of ground survey techniques encountered by Chambers-County Mosquito Control were approximated as follows:

Cost for mapping fields each year	
Vehicle cost	$4,356.00
Labor cost	$5,227.00
Cost for surveillance of fields	
Vehicle cost	$9,365.00
Labor cost	$14,984.00
Total	$33,932.00

Thus, if 286,138 acres were surveyed at a cost of $33,932.00, approximately $0.12 per acre was expended using conventional ground survey methods. This cost per acre was only a rough estimate since total acreage surveyed was unknown. Surveillance crews are unable to cover all the riceland in Chambers County during the peak mosquito period. Only 100–125 rice fields per week, or about 25–50% of the total acreage was actually surveyed. Fields planted to soybeans were surveyed to a lesser extent, and no reference was made concerning permanent pastures (M. M. Yates, unpublished data).

The preliminary investigation into the economic feasibility of using the aerial color infrared photographic technique to survey potential *Ps. columbiae* oviposition sites suggests a substantial savings in cost over the ground survey technique currently used by mosquito control practitioners in the riceland agroecosystem. The estimated reduction in surveillance costs using aerial color infrared photography and ground verification proposed by this study would be approximately 10 times that of using conventional ground survey techniques employed in 1982.

The fact that such a savings would be experienced is in agreement with the findings reported by Wear et al. (1964), Heller et al. (1967), Heller and Wear (1969), and Hart et al. (1973) for other insect pests. A combined aerial photography-ground survey of *A. balsamea* mortality, deformation and stand deterioration by *C. piceae* was 2.5 times less expensive than a ground survey alone (Heller et al. 1967). Fleetwood et al. (1981) reported that the combination of an aerial visual plus ground inspection survey technique to monitor *Ps. columbiae* in rice and fallow fields in southwest Louisiana reduced inspection costs almost 2.5 times what they were using conventional ground surveillance alone. In addition to greater savings experienced with the use of aerial color infrared photography, a permanent record could be provided for future reference.

The estimated reduction in cost of surveillance by a factor of 10 with the use of the aerial color infrared photography is only a rough estimate. Although labor costs for photointerpretation and ground verification were not computed and vehicle costs would still be encountered, probable savings would still be realized. Whereas ground surveillance crews can only cover ca. 25–50% of the acreage of fields planted to rice, and less of the acreage of soybean fields and permanent pastures during the peak mosquito period, photography would provide 100% coverage of all 3 field types. Using photographs as guides, ground surveys, as limited as they are, could be directed to only those areas which appear most attractive for oviposition. Thus, efficiency would be increased and would lend to savings in that respect. Actual cost reduction will be determined when the aerial color infrared photography surveillance technique is put into actual use by a mosquito control district.

SUMMARY

The use of aerial color infrared photography survey techniques for riceland mosquito surveys would not only provide for a more complete assessment of mosquito breeding conditions in a given rice producing area but would also define areas that should be targeted for mosquito control efforts. The better definition of such targets would allow for a more efficient use of mosquito control manpower and material by concentrating them on these targets and would reduce the overall impact that mosquito control efforts would be limited to only those areas actually requiring them.

Photointerpretation of aerial color infrared photographs obtained from the 8 photographic missions (Welch et al. 1989) suggests this remote sensing technique should be of value to mosquito control practitioners by increasing the accuracy and efficiency of surveillance of potential *Ps. columbiae* oviposition habitats. In addition to providing land-use patterns and crop distribution, surveys with aerial color infrared photography are capable of locating potential oviposition habitats previously unknown to mosquito personnel due to their invisibility from the ground.

Knowledge acquired during the study of Welch et al. (1989) suggests a need for 2 photographic missions per year, i.e., a spring or early summer overflight to provide land-use and crop distribution and a midwinter overflight to provide information on topographic features within fields.

Data collected during this study also suggest a reduction in costs using aerial color infrared photography with ground verification should be gained over conventional ground survey techniques. The use of the aerial color infrared photography survey technique should be easily incorporated into the integrated systems currently used by mosquito control districts.

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REFERENCES CITED

Aldrich, R. C. and A. T. Drooz. 1967. Estimated Fraser fir mortality and balsam wooly aphid infestation trend using aerial color photography. Forest Sci. 13:300–313.

Ciesla, W. M., L. E. Drake and D. H. Wilmore. 1971. Color photos, aerial sprays and the forest tent caterpillar. Photogram. Eng. 37:867–873.

Colwell, R. N. 1963. Aerial photo interpretation for the evaluation of vegetation and soil resources, pp. 314–331. *In:* Papers prepared for the United Nations conference on the application of science and technology for the benefit of the less developed areas. Vol. II, Natural Resources. UN Regional Photographic Conference for Africa, Nairobi, Kenya, July 1–13, 1963.

Fleetwood, S. C., M. D. Chambers and C. Terracina. 1981. An effective and economical mapping system for the monitoring of *Psorophora columbiae* in rice and fallow fields in southwestern Louisiana. Mosq. News 41:174–177.

Hart, W. G., S. J. Ingle, M. R. Davis and C. Mangum. 1973. Aerial photography with infrared color film as a method of surveying for citrus blackfly. J. Econ. Entomol. 66:190–194.

Heller, R. C., J. H. Lowe, Jr., R. C. Aldrich and F. P. Weber. 1967. A test with large scale aerial photographs to sample balsam wooly aphid damage in the northeast. J. Forestry 65:10–18.

Heller, R. C. and J. F. Wear. 1969. Sampling forest insect epidemics with color films, pp.1157–1167. *In:* Proc. 6th Symp. Rem. Sens. Environ., Inst. Sci. Tech., Univ. of Mich., Ann Arbor, MI.

Smith, J. T. and A. Anson, (eds.). 1968. Manual of color aerial photography. Am. Soc. Photogram. Falls Church, VA. 550 pp.

Wagner, V. E., R. Hill-Rowley, S. A. Narlock and H. D. Newson. 1979. Remote sensing: a rapid and accurate method of data acquisition for a newly formed mosquito control district. Mosq. News 39:283–287.

Wear, J. F., R. B. Pope and P. G. Lauterbach. 1964. Estimating beetle-killed Douglas-fir by aerial photo and field plots. J. Forestry 62:309–315.

Welch, J. B. and J. K. Olson. 1987. Oviposition habitats of *Psorophora columbiae* in soybean fields of a Texas riceland agroecosystem. J. Am. Mosq. Control Assoc. 3:251–258.

Welch, J. B., J. K. Olson, W. G. Hart, S. G. Ingle and M. R. Davis. 1989. Use of aerial color infrared photography as a survey technique for *Psorophora columbiae* oviposition habitats in Texas ricelands. J. Am. Mosq. Control Assoc. 5:147–160.

Welch, J. B., J. K. Olson and M. M. Yates. 1986. Occurrence of *Psorophora columbiae* eggs in different field types comprising a Texas riceland agroecosystem. J. Am. Mosq. Control Assoc. 2:52–56.