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Color Photos and the Southern Pine Beetle

See Front Cover

Abstract: *Fifty-acre plots superimposed on color aerial photographs taken at a scale of 1:3960 were evaluated as a sampling unit for estimating the level of southern pine beetle infestations. Two color films were evaluated: Anscochrome D200, and Ektachrome Infrared Aero. Data from the photographs and subsequent field checks were analysed in accordance with procedures developed for analysing equivalent data taken from operation recorder surveys. This provided estimates of the number of infested areas and number of trees actively infested by the southern pine beetle with 90 per cent confidence limits. Ektachrome Infrared Aero film was superior to Anscochrome D200 because it was capable of discriminating between pines and hardwoods and had the ability to penetrate haze resulting in clearer imagery. Costs of photographic surveys conducted over three outbreak areas in 1966 ranged between $0.0055 and $0.0190 per acre depending upon the size of the area surveyed. These costs compared favorably with the cost of operation recorder surveys.*

Introduction

The southern pine beetle (*Dendroctonus frontalis* Zimm.) is one of the most destructive forest insect enemies of the southern yellow pines. This insect periodically reaches epidemic levels over extensive areas from Virginia to Texas, frequently causing millions of dollars worth of damage to the pine forests of this area. When an outbreak area is detected, survey entomologists estimate the level of infestation in terms of numbers of infestation centers (hereafter referred to as *spots*) and the number of actively infested trees. These data are obtained from a combination of aerial and ground surveys and serve to appraise the destructive potential of this insect and the need for control measures. In addition, these survey data help the forest land manager determine the size of the project required to do an effective control job.

The southern pine beetle has from three to six generations annually in the Southeast and appraisal surveys are made three times a year over outbreak areas to determine the status and trend of the insect population. These are generally made in late January, late June-early July and late August.

Two aerial survey methods are presently being used for estimating the level of southern pine beetle infestations, aerial sketchmapping (Heller, *et al.*, 1955) and operation recorder surveys (Ketcham, 1964). Aerial sketchmapping is an inaccurate procedure because aerial observers tend to overlook a large number of spots (Aldrich, *et al.*, 1958), therefore, infestation levels may be grossly underestimated.

Operation recorder surveys are more accurate because the observer's view is restricted to a five-chain wide strip at a flying height of 500 feet and the high omission error inherent in aerial sketchmapping is eliminated. Data from operation recorder surveys and subsequent ground surveys can be analysed according to statistical procedures which provide estimates of the number of spots and number of actively infested trees

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per 1,000 acres with 90 per cent confidence limits (Ketcham, 1964). The operation recorder survey can only be used in areas of level terrain, however, because differences in ground elevation vary the width of the sample strip viewed by the aerial observers. Plots of known acreage superimposed on color aerial photographs were evaluated in 1965 in order to provide survey entomologists with a sound technique for appraising southern pine beetle infestations in hilly and mountainous terrain as well as level terrain.

Physiography of the Study Area

The survey area encompassed approximately 60,000 acres in eastern Tennessee and included portions of Anderson, Knox, Loudon and Roane counties. The A.E.C. Oak Ridge Reservation (37,500 acres), the University of Tennessee Experimental Forest (2,200 acres) and adjoining private lands were included in the survey area. The topography of this area is typical of the ridge and valley province of eastern Tennessee, characterized by long narrow ridges which extend in a northeast-southwest direction. Elevations range from 800 feet above sea level in the valley bottoms to 1,200 feet at the crests of the highest ridges. The forest cover is composed of shortleaf and Virginia pines (*Pinus echinata* Mill., and *P. virginiana* Mill.) interspersed with upland hardwoods, primarily oaks (*Quercus* sp.) hickories (*Carya* sp.) and yellow poplar (*Liriodendron tulipifera* L.). Extensive plantations of loblolly pine (*P. taeda* L.) occur in the valleys.

A severe outbreak of the southern pine beetle was detected in this area early in 1965 and aerial sketchmap surveys indicated an unusually high level of 170.5 infested trees per 1,000 acres during July 1965.*

Methods

A 50-acre plot, measuring 22.37×22.37 chains was selected as the basic sampling unit. This plot size was selected because it could be conveniently placed on a 9×9-inch aerial photograph at a scale of 1:3960 (16 inch = 1 mile), a scale which has been shown to be highly effective for detecting trees killed by the southern pine beetle (Heller, *et al.*, 1959). The initial survey plan called for 100 photo plots with a total of 5,000 acres of sample area for an 8.3 per cent coverage. Plots were arranged in a systematic grid pattern on 20 north-south flight lines. Flight lines were were spaced at 0.75 mile intervals and plot centers were spaced at 1.2 mile intervals along each flight line.

Photography was flown in early August, 1965 by the Kentucky Air National Guard, Louisville, Kentucky. Photographs were taken at a scale of 1:3960 with a K17D aerial camera equipped with a 12-inch focal length lens. A stereo triplet with 60 per cent overlap was taken at each plot location.

Two color films were evaluated, Anscochrome D200 and Ektachrome Infrared Aero (Type 8443).† The latter film was used in combination with a Wratten #12 (minus blue) filter. Ektachrome Infrared Aero film has demonstrated a remarkable ability to differentiate between diseased foliage and healthy foliage in certain plants due to a decrease of infrared reflectivity in diseased leaf tissue which occurs before disease symptoms are visible to the naked eye, (Colwell, 1964) and was included in this evaluation to test its ability to differentiate between barkbeetle infested pines with green foliage and uninfested pines.

Plot centers were established at the principal point of the center photograph of each triplet. Each plot was scanned with an Old Delft scanning stereoscope on a fluorescent light table. The number of spots and the number of discolored crowns per spot were tallied for each plot. The acreage of susceptible host type was measured for each plot with a modified acreage grid (256 dots per square inch). Host type was defined as any stand where 25 per cent or more of the stems were pine.

All spots which appeared on sample plots were ground checked and the agent responsible for the mortality was determined. If the causal agent was the southern pine beetle, the number of redtopped and fading pines, the number of green infested trees and the total number of trees with active infestations was tallied.

Photo interpretation and ground checks were analysed by the procedure currently used for operation recorder surveys (Ketcham, 1964). Infestation levels were expressed in terms of numbers of spots and numbers of infested trees per 1,000 acres of host type.

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† Mention of commercial products in the text of this paper does not imply endorsement by the USDA.

Results and Discussion

Variation in air currents over the survey area resulted in a desirable quasi-random distribution of sample plots (Figure 1). A total of 84 sets of stereo triplets were obtained with Ektachrome Infrared Aero film resulting in a 7.0 per cent area coverage instead of the 8.3 per cent coverage originally planned. Unfortunately, camera malfunction resulted in a loss of one third of the photographs taken with Anscochrome D200 film. Therefore, survey results were based entirely on the photographs taken with Ektachrome Infrared Aero film. The series of photographs taken with Anscochrome D200 were used to compare ease and accuracy of photo interpretation on the two films.

Infested areas appeared vividly on both films and even small spots (groups of 1 to 5 trees) were detected with minimum difficulty by inexperienced photo interpreters. Photo interpreters had to field check several infested areas in order to relate colors on the Ektachrome Infrared Aero film to conditions on the ground. Pines, whose foliage had turned red, appeared vivid yellow. Fading pines were light yellow or beige and pines which had lost most of their needles were grey-green in color (See Front Cover, and Cover Note on page 857).

Twelve single tree and 26 multiple tree infestations were detected on the 84 plots photographed with Ektachrome Infrared Aero film. Ground surveys indicated that six of the 12 single trees, interpreted as pines, were actually lightning-struck hardwoods resulting in a 50 per cent commission error on single trees. All multiple tree infestations detected on the photo plots were the result of infestation by the southern pine beetle. Several groups of discolored hardwoods appeared in the photo plots but were readily distinguished from groups of discolored pines on the basis of crown form and appeared in rather uniform beige tones. All of the hardwood discoloration was due to early fall coloring of elm (*Ulmus* sp.), dogwood (*Cornus florida* L.) and sassafras (*Sassafras albidum* (Nutt.) Nees.).

Twenty-one of the 26 multiple tree spots detected on the photo plots contained trees with active southern pine beetle infestations. Eighteen of these multiple tree spots contained from one to 223 green infested trees (Table 1). Detailed examination of these spots on the photographs failed to reveal the presence of color differences between pines infested by the southern pine beetle but which still had green foliage and uninfested pines. Apparently the foliage of pines infested by the

Fig. 1. Location of sample plots photographed with Ektachrome Infrared Aero Film—Oak Ridge, Tennessee—August 1965.

southern pine beetle does not lose its infrared reflecting capacity to the degree necessary for detection by this film until long after the insects infesting these trees have completed their development and emerged. This is evidenced by the fact that red-topped pines photograph as a yellow color on Ektachrome Infrared Aero film. Red-colored objects which have the capacity to reflect infrared radiation, such as the foliage of healthy deciduous trees turned red in the autumn, are known to photograph yellow or orange on Ektachrome infrared film.* Red colored objects which do not have the capacity to reflect infrared radiation photograph green, as did the areas of old, inactive infestation where the pines had lost most of their needles.

Ektachrome Infrared Aero film was superior to Anscochrome D200 for the purpose of this survey in spite of the fact that we were unable to detect green pines infested by the southern pine beetle. Healthy deciduous trees have a much higher infrared reflectivity than healthy conifers. Consequently, deciduous trees photograph in brilliant tones of red, orange and magenta, and conifers photograph in darker purple tones (Front Cover). The uniform green tones on the Anscochrome D200 prevented differentiation of pine type from hardwood type without tedious stereoscopic examination of the photo plots. In addition, Ektachrome Infrared Aero film used in combination with the Wratten #12 filter has remarkable haze penetration which enables survey entomologists to make aerial photographic surveys under the hazy conditions typical of the Southern Appalachian Region.

Comparison of ground counts of red-topped and fading pines in individual spots with photo counts, indicated a high omission error (Table 2). This may be due to the inexperience of the photo interpreters, the fact that most of the spots occurred in dense, over-

* Eastman Kodak Company, Rochester, N.Y. Instructions for exposing and processing Kodak Infrared Aero film, Type 8443.

TABLE 1

COMPARISON OF PHOTO COUNTS OF DISCOLORED CROWNS ON EKTACHROME INFRARED AERO FILM WITH GROUND COUNTS OF RED-TOPPED AND FADING PINES, INFESTED TREES WITH GREEN CROWNS AND NUMBERS OF TREES WITH ACTIVE INFESTATIONS ON 22 SPOTS INFESTED BY THE SOUTHERN PINE BEETLE, OAK RIDGE, TENNESSEE, AUGUST 1965

Photo Count		*Ground Count*		
Spot Size Class (Trees)	*Discolored Crowns (Number)*	*Red-topped & Fading Pines (Number)*	*Green Infested Trees (Number)*	*Trees with Active Infestation (Number)*
Singles	1	2	2	2
2–5	2	3	1	2
	2	3	0	1
	2	6	2	6
	4	3	0	2
	4	5	1	2
6–20	6	1	4	4
	6	18	43	57
	9	6	8	12
	9	8	0	2
	13	14	10	24
	16	8	1	1
	19	42	104	142
21–50	30	40	46	71
	33	44	33	55
	48	46	1	17
50+	56	110	44	144
	59	103	24	73
	63	126	48	144
	70	71	150	184
	81	187	223	326
	129	120	89	161

stocked stands where individual crowns were difficult to distinguish and a considerable number of the trees were in the intermediate and suppressed crown classes. This had little effect on the survey design because estimates of the number of infested trees per spot are obtained entirely from ground surveys in the sampling procedure used. This is necessary because there is little or no relationship between the number of red-topped and fading pines in a spot and the number of green infested trees (Table 1). In addition, only a portion of the red-topped and fading pines still contain brood at the time they are detected.

TABLE 2

OMISSION AND COMMISSION ERROR ON PHOTO COUNTS OF DISCOLORED CROWNS ON EKTACHROME INFRARED AERO FILM COMPARED TO GROUND COUNTS OF RED-TOPPED AND FADING PINES ON 22 SPOTS INFESTED BY THE SOUTHERN PINE BEETLE, OAK RIDGE, TENNESSEE, AUGUST 1965

Spot Size Class (Trees)	*Number of Spots*	*Ground Count (Trees)*	*Photo Count (Trees)*	*Interpretation Accuracy (Trees)*		
				Correct	*Omission Error*	*Commission Error*
Singles	1	2	1	1	1	0
2–5	5	20	14	13	7	1
6–20	7	97	78	61	36	17
21–50	3	130	111	109	21	2
50+	6	717	458	449	268	9

TABLE 3

COST ANALYSIS OF FOUR AERIAL PHOTOGRAPHIC SURVEYS DESIGNED TO APPRAISE THE LEVEL OF SOUTHERN PINE BEETLE INFESTATIONS

Survey	*Area Surveyed (M Acres)*	*Scale of Photography*	*Size of Sample Plot (Acres)*	*No. Photo Plots*	*No. Rolls Film Exposed*	*Total Cost*[1] *(Dollars)*	*Cost/Acre (Dollars)*
Andrew Pickens District, S. C.	178	1:3960	50	86	2	1063.53	0.0059
Francis Marion National Forest, S. C.	255	1:7920	200	117	3	1408.36	0.0055
Oak Ridge, Tenn. (June)	60	1:3960	50	81	2	1142.20	0.019
Oak Ridge, Tenn. (August)	60	1:3960	50	96	2	1153.43	0.019

[1] Based on a rental rate of $40.00/hour for a U. S. Forest Service owned Aero-Commander, $15.00 /day pilot's per diem, Ektachrome Infrared Aero film at $129.04/75 ft. roll and Kodak E2-E3 processing kits at $13.79/kit. Labor costs include one GS-9 entomologist ($3.70/hour) for 64 man hours and two GS-5 forestry technicians ($2.65/hour) for 96 man hours per survey. Labor costs include time spent on photography, processing, photo interpretation, ground surveys, analysis of data and reporting of results.

However, even a rough estimate of the number of discolored crowns in a spot helps field crews insure they are tallying the spot selected for ground checking.

Final results of the survey indicated that there were 28.7 ± 10.5[†] spots and 1262.8 ± 512.5 trees actively infested by the southern pine beetle per 1,000 acres host type over the 60,000 acre area surveyed in August 1965.

OPERATIONAL ASPECTS

Aerial photographic surveys were conducted over three southern pine beetle outbreak areas in Tennessee and South Carolina during 1966 to determine the operational feasibility and costs of conducting this type of survey. Ektachrome Infrared Aero film was used exclusively in these surveys, which were conducted in the identical manner described in the previous section with two minor exceptions; stereo pairs rather than triplets were taken at each plot location, reducing the volume of film required by one third, and sample plots were located off center on one photograph of the pair to permit full stereo coverage from the adjoining photograph. Rectangular 4×5-inch plots rather than square plots were used.

Photographic surveys conducted during 1966 were completed with minimum operational difficulties and all phases; photography, processing, photo interpretation, ground surveys, analysis of data and reporting of results were accomplished in three weeks. Photographs taken during June were taken during a period of excessive haze which reduced visibility to less than three-fourths mile, a condition typical of mid-summer in the Southern Appalachian Mountains. Excellent photographs were obtained with Ektachrome Infrared Aero film in spite of the hazy atmospheric conditions.

Survey costs were lower than anticipated and ranged from $0.0055 to $0.019 per acre depending upon the size of the area surveyed (Table 3). Ketcham (1964) reports that operation recorder survey costs range from $0.005 to $0.01 per acre. The costs of the two survey methods are equivalent. Aerial photography has the advantage of versatility and can be used in mountainous as well as level terrain.

CONCLUSIONS

Plots superimposed on color aerial photographs provide the survey entomologist with a method for sampling southern pine beetle infestations in areas of hilly and mountainous terrain as well as level terrain. Ektachrome Infrared Aero film does not have the ability to detect trees infested by the southern pine beetle before crown discoloration occurs but is superior to Anscochrome D200 film because of its ability to discriminate between pines and hardwoods and its ability to penetrate haze when used in combination with a Wratten #12 filter. Data obtained from aerial photographs and subsequent ground surveys provide estimates of the number of spots and number of trees actively infested by the southern pine beetle per 1,000 acres of host type with 90 per cent confidence limits.

The costs of conducting these aerial photo-

[†] Confidence limits of 90 per cent.

graphic surveys are low, ranging from $0.0055 to $0.0190 per acre, and not prohibitive. Aerial photographic surveys are more versatile then operation recorder surveys because they can be conducted over any outbreak area, regardless of the condition of the terrain.

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