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AERIAL SURVEYS

OF BLACK HILLS BEETLE INFESTATIONS

by

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Cover photo: Aerial survey plane, a Cessna 195, specially modified for lateral visibility and aerial photography

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Aircraft have been used since 1925 in detecting and appraising damage by the Black Hills beetle and other forest insects. In 1952, research to improve aerial surveys was begun. Two avenues of research seemed most promising: (1) to plot or count infested trees visually, and (2) to photograph infested areas and interpret the pictures.

The Black Hills beetle (Dendroctonus ponderosae Hopk.) is the most serious enemy of ponderosa pine in the central Rocky Mountain region. Epidemic infestations have been present in the region almost continuously since the insect was identified (Hopkins, 1905). The Black Hills beetle attacks and kills trees in groups (fig. 1). Each year as the infestation continues, more groups appear and more trees are killed in the groups already present (Beal, 1939; Knight and Yasinski, 1956).

The insect has one generation each year. It attacks trees in late summer. Larvae are partially grown when they hibernate for the winter. They continue to develop the following spring. At the same time, tree foliage begins to fade. By early August, the foliage of all trees is yellowish orange to brownish red, and the mature beetles are ready to fly and attack green trees. The faded trees are called red-tops.

Before a control operation can be adequately planned, pine stands must be surveyed to determine the extent and intensity of the outbreak. Data from ground surveys would be obtained from beetle-infested trees. However, from the air the observers must rely on the faded or red-top trees to provide data on the infestation.

The field phase of the study on aerial survey techniques was conducted in September 1952 and August 1953. A Cessna high-wing monoplane with no obstructing struts and a five-person capacity was used (see cover).

Two small areas (each more than 1,000 acres) on the Poudre District, Roosevelt National Forest, were selected. A 100-percent count of infested trees was made on the ground in each area in 1952 and in 1953. This provided the necessary ground control for an analysis of the various methods of aerial survey.

Several survey methods were tested with varying degrees of success. These were:

1. Visual aerial survey
   a. Sketch mapping on planimetric maps
   b. Sketch mapping on large-scale aerial photographs
   c. Strip counts on the operations recorder

2. Aerial photography at two scales (1:7,920 and 1:15,840)
   a. Panchromatic film
   b. Ektachrome color film

VISUAL AERIAL SURVEYING

During the three visual surveys, two observers worked from the rear seat of the airplane. Observation masks with a face piece of amber vinylite were worn to improve accuracy of observations, as recommended by Heller and Aldrich (1955). All visual surveys showed that better results were obtained as experience in aerial observation was gained. Visual aerial surveying should always be done by personnel experienced in aerial observation. They should also be familiar with the timber stands and the habits of the insect.

SKETCH MAPPING ON PLANIMETRIC MAPS

An attempt was made to sketch-map and count all faded trees in the study areas during 1952. Various maps were used including USGS maps (scale 1 inch = 1/4 mile), Forest Service type maps, and tracings containing less detail. The plane was flown approximately 1,000 feet above the ground at speeds of 70 to 90 miles an hour. This method was unsatisfactory for accurate counts in epidemic areas. The observers were able to tally only one-third of the total number of trees. The method might be useful in endemic situations. A map-rolling device such as suggested by Merkel et al.(1955) would be of value for such surveys.

SKETCH MAPPING ON LARGE-SCALE AERIAL PHOTOGRAPHS

Large-scale aerial photographs (1:7,920 enlargements of 1:20,000 negatives--measuring 20 by 25 inches) were also used in the sketch mapping study. An attempt was made to plot all groups of trees on the photographs and, on a second flight over the area, to count the trees in the plotted groups. Orientation was such an overwhelming problem at the speeds of flight that many groups were missed. The resulting counts of faded trees were as inaccurate as in the sketch-mapping method. But more accurate counts could be made on lighter infestations. This phase of the study was not continued in 1953.

STRIP COUNTS WITH THE OPERATION RECORDER

An aerial strip cruise, using the operation recorder technique developed by Heller, Bean, and Marsh (1952), was tried over the study area. On such a survey the observer is relieved of all orientation duties and is concerned only about the strip under his view. The operation recorder used in these studies has 20 electrically actuated pens, which can be used individually or in combination with each other to make a record on a moving chart. Two keyboards are used, one for each observer. Each has a bank of six momentary switches connected individually with one of the pens on the operations recorder. After a short practice period, an observer can keep his attention on the ground continuously without watching the keyboard. Each keyboard was keyed as follows:

Switch number	1	2	3	4	5	6
Number of red-tops	1	6	7	8	9	10

Figure 1. --Typical group killing of ponderosa pine (light-foliaged trees) by the Black Hills beetle.

The use of the switches is best explained by example. If 4 trees were counted, the number 1 switch would be depressed 4 times. If 24 trees were counted, the number 6 switch would be depressed 2 times and number 1 switch 4 times.

Two observers, each viewing a 10-chain strip, recorded the number of red-tops on the operation recorder. The 10-chain strip was calibrated before the actual survey by flying at 1,000 feet over 2 markers placed 10 chains apart. Two strips of masking tape were spaced on each plexiglas door so the observer could just see the ground markers along the inner edges of the tapes. The observer's eye distance from the plexiglas was held constant by a tripod chinrest. Using the tripod arrangement, the observer's view was limited to the 10-chain-wide strip when flying over any area at 1,000 feet. An improved strip viewer (Bailey, 1958), which can be attached by a suction cup to any aircraft window, is now available for this type of survey.

In flights over the study area the 1,000-foot elevation was difficult to maintain because of rough terrain. However, by flying with reference to radio altimeter indicator lights, the deviations were largely compensating. Flight lines were 1/2 mile apart. Consequently, 25 percent of the area was seen by each observer from each observation position.

Two entomologists, Bean and Knight, served as observers in 1952; all of their estimates were less than the actual count (table 1). Bean's greater experience in aerial observation may have accounted for his closer estimates. However, another factor was perhaps more important. The 1952 survey came in late September when the red-tops were not distinctive as to year of attack. Knight may have assumed that more of the trees were killed 2 years previous to the survey.

Table 1.--100-percent counts and estimates by operation-recorder surveys of red-tops made in two successive years, 1952 and 1953. Aerial observations covered 50 percent of area

Method and observer	Lewstone area		Redstone area	
	1952	1953	1952	1953
	---- No. dead trees ----			
100-percent ground count	569	1/ 732	584	641
Estimated red-tops				
Bean	508	564	480	544
Knight	404	630	264	696
Wilford	---	644	---	770
Smith	---	866	---	882

1/ This figure is not accurate and should be lower because part of the area was logged after the ground count was made but before the aerial estimate.

In 1953, four observers were flown over the study area early in August when all yellow-colored trees killed the previous fall could be distinguished from the older dark red trees. Observer Smith had had no experience on the ground or in the air. He evidently tallied not only the current red-tops but also some of the trees killed 2 years previous to the flight.

In general, the operation-recorder survey gave good results when individuals with both ground and air experience did the observing. Experienced personnel using this method at the proper time of year should produce estimates within 25 percent of the actual number.

In 1953, a survey using this method was made in the pine type on the Redfeather District, Roosevelt National Forest. Bean and Knight were the observers. A 5-percent ground survey of the major infested blocks resulted in an estimate of 3,610 $\pm$ 564 red-tops. The survey by operation recorder (50-percent coverage) gave an estimate of 5,540 trees. These estimates seem satisfactory because of the extensive additional area covered by the recorder.

AERIAL PHOTOGRAPHY

1952 FILM TESTS

Photo interpretation of aerial photographs frequently provides a means of evaluating insect damage. Trees with discolored foliage can be counted on black and white photographs or color transparencies by trained interpreters. For example, in southeastern United States, pines killed by the southern pine beetle (Dendroctonus frontalis Zimm.) were located on color photographs with a high degree of accuracy in less time and at less than one-fourth the cost of ground surveys (Heller et al., 1959).

In 1952, the study areas were photographed with two types of films (Super XX with an orange filter, and Ektachrome Aero) each at two scales (1:7,920 and 1:15,840). These photographs were interpreted by individuals using mirror stereoscopes and identical interpreting procedures (table 2).

When tested by analysis of variance the data revealed the following results:

1. No difference in accuracy occurred among photo interpreters.
2. Color film was significantly better than panchromatic film.
3. The 1:7,920 scale was a vast improvement over the 1:15,840 scale. Results were significantly different at the 1 percent level.

A second analysis was made of data from both study areas but without the black and white pictures at the 1:15,840 scale. The results again showed no significant difference among observers and a highly significant difference between films; the color film at 1:7,920 was the best combination.

The results (tables 2 and 3) were somewhat erratic even with color film at 1:7,920. The Lewstone estimates are all high; and the Redstone, all low. This variation is primarily due to lack of experience by the interpreters. Estimates were low where only the Black Hills beetle had killed trees (Redstone Creek) but high where mistletoe damage and dead Douglas-fir (Lewstone

Creek) were also present. The observers soon learned to recognize these factors, and after several months, made much better interpretations. Because of this time interval in examining the color pictures, there was probably no bias in making a second interpretation (table 3). During the first interpretations, the three men were together; during the second interpretations, they worked independently.

Table 2. --Estimates of trees killed (red-tops) in 2 study areas by use of 2 types of film and 2 scales, 1952

Area surveyed, map scale, and type of film	Acres	Ground count of dead trees	Estimated dead trees by photo interpretation		
			Bean	Knight	Heller
	No.	No.	No.	No.	No.
Lewstone Creek	1,188	569			
Map scale--1:7,920					
Ektachrome color			841	679	807
Super XX black and white			688	586	544
Map scale--1:15,840					
Ektachrome color			298	315	398
Super XX black and white			(1/)	(1/)	(1/)
Redstone Creek	1,538	584			
Map scale--1:7,920					
Ektachrome color			429	418	456
Super XX black and white			386	361	386
Map scale--1:15,840					
Ektachrome color			364	278	441
Super XX black and white			294	264	292

1/ After the extremely poor results in the Redstone Creek area the Super XX film was not considered worth evaluating at 1:15,840 in the Lewstone Creek area.

Table 3. --Results of two interpretations of Ektachrome transparencies (Scale 1:7,920), 1952

Area surveyed	Ground count of dead trees	Estimated dead trees by photo interpretation		
		Bean	Knight	Heller
	No.	No.	No.	No.
Lewstone Creek	569			
First interpretation		841	679	797
Second interpretation		586	593	682
Redstone Creek	584			
First interpretation		431	418	456
Second interpretation		577	551	624

1953 FILM TESTS

As a result of the 1952 findings, both areas were rephotographed in 1953 but only at the 1:7,920 scale with color film (Ektachrome Aero). As mentioned previously, the Lewstone Creek area was partially logged between the time of the 100-percent ground count and the aerial coverage; therefore, these ground counts were unreliable. However, the interpretation results in the Redstone Creek area were excellent as shown below:

	Dead trees (No.)
100-percent ground count	641
Estimate by photo interpretation:	
Bean	636
Knight	661
Heller	703
McCambridge	757

Results of these interpretations show that color film is excellent when handled by experienced personnel. As a comparative test of interpretation, five groups of trees were encircled on the color transparencies, and the number of trees in each were determined by Bean, Knight, and Heller. Their results were consistently good:

	Group 1	Group 2	Group 3	Group 4	Group 5
	- - - - - (No. dead trees) - - - - -				
100-percent ground count	49	120	25	42	5
Estimate by photo interpretation:					
Bean	44	111	24	44	5
Knight	46	107	24	38	5
Heller	51	116	35	45	5

When the actual number of trees was plotted over interpreted number of trees, a straight-line relation was shown. A regression analysis showed the coefficient of the slope of this line to be 0.9565, indicating an overall tendency toward slightly high estimates. This coefficient shows that the error averaged less than 5 percent.

SUMMARY AND DISCUSSION

Tests were made during 1952 and 1953 to determine whether the airplane might be used as a tool in estimating the number of trees killed by Black Hills beetles. The following general conclusions are made:

1. Sketch-mapping and marking trees on maps and aerial photographs gave poor estimates. In very light infestations, these techniques might be satisfactory.

2. Surveys covering 50 percent of the area and using the operations recorder were successful. Experienced observers can obtain satisfactory results with less than 25-percent error.

3. Aerial photography with Panchromatic film (Super XX with orange filter) and small scale (1:15,840) photography resulted in poor estimates. Ektachrome Aero (scale 1:7,920) film produced excellent results when experienced interpreters were available to count the faded trees on color transparencies. Experienced interpreters should be able to estimate within a 5-percent error.

4. Aerial surveys are most efficiently conducted during July or August, when all trees attacked the previous fall retain a full complement of needles with a coloring that can still be separated from that of older kills. If the survey is made too early, some trees will not have faded; if made too late, some trees begin to lose their needles and can be mistaken for older kills.

5. Color photography can be used in a practical way in conjunction with control projects. Photography completed in late May or June can be used as an aid in spotting infested trees. The fading trees show up clearly on the transparencies.

The value of the methods discussed here is in estimating the number of trees killed the preceding year, not the number of currently infested trees. Methods for converting the estimate of red-tops to an estimate of currently infested trees are being investigated.

LITERATURE CITED

Bailey, W. F.
1958. An oblique strip viewer for aerial sampling in forest insect surveys. U. S. Forest Serv. 3 pp. [Processed.]

Beal, J. A.
1939. The Black Hills beetle, a serious enemy of Rocky Mountain pines. U. S. Dept. Agr. Farmers' Bul. 1824, 22 pp., illus.

Heller, R. C., and Aldrich, R. C.
1955. Observation masks for aerial spotting of insect damaged trees. U. S. Forest Serv. 2 pp. [Processed.]

_____, Aldrich, R. C., and Bailey, W. F.
1959. An evaluation of aerial photography for detecting southern pine beetle damage. Photogrammetric Engin. 25: 595-606, illus.

_____, Bean, J. L., and Marsh, J. W.
1952. Aerial survey of spruce budworm damage in Maine in 1950. Jour. Forestry 50: 8-11, illus.

Hopkins, A. D.
1905. The Black Hills beetle with further notes on its distribution, life history, and methods of control. U. S. Bur. Ent. Bul. 56, 24 pp., illus.

Knight, F. B., and Yasinski, F. M.
1956. Incidence of trees infested by the Black Hills beetle. U. S. Forest Serv., Rocky Mountain Forest and Range Expt. Sta. Res. Note 21, 4 pp. [Processed.]

Merkel, E. P., Heller, R. C., Aldrich, R. C., and Bailey, W. F.
1955. Map rolling device for aerial sketch-mapping. U. S. Forest Serv. 2 pp. [Processed.]