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Mapping Effectiveness of Insecticide Treatments against Pandora Moth with Color-IR Photos*

Medium scale color-IR photos were used to classify defoliation in treated and untreated ponderosa pine stands.

Introduction

The pandora moth, *Coloradia pandora* Blake, periodically causes severe defoliation of pine forests in the western United States. The insect has one generation every two years, with defoliation occurring in alternative years. Outbreaks occur at 20 to 30 year intervals, and have been reported to last up to eight years (Carolin and Knopf, 1968).

Abstract: *Color-IR photos were used to help assess effectiveness of aerial applications of the insecticide acephate against pandora moth,* Coloradia pandora *Blake, a defoliator of ponderosa pine, on the Kaibab Plateau in northern Arizona. Defoliation was classified into three intensity classes, and a map was prepared showing intensity relative to spray block boundary. Defoliation, as mapped from aerial photographs, provided 74 percent agreement with ground classification. In blocks where the insect population was significantly reduced by insecticide treatment, the aerial photos showed a corresponding area of reduced feeding injury.*

In 1979 the pandora moth reached epidemic levels in ponderosa pine, *Pinus ponderosa* Laws, forests on the Kaibab National Forest in northern Arizona, when 5120 acres suffered varying degrees of defoliation. Subsequent surveys by personnel of the Southwestern Region, USDA Forest Service, Albuquerque, New Mexico predicted that the infestation would continue in 1981 with approximately 10,000 acres suffering defoliation. No registered pesticides were available for direct control of this insect, therefore a pilot control project was initiated in 1981 to evaluate the insecticide acephate† to protect key scenic, timber, and wildlife resources in a scenic corridor leading to the North Rim of Grand Canyon National Park from defoliation (Bennett and Ragenovitch, 1982). This paper describes the use of

* This paper reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here are registered. All uses of pesticides must be registered by appropriate state and/or Federal agencies before they can be recommended.

† An organophosphate insecticide marketed as Orthene by Chevron Chemical Company. Use of trade names is for convenience only and does not imply endorsement by USDA.

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color-IR aerial photographs to evaluate foliage protected by the insecticide application.

Medium scale color-IR aerial photos have been used successfully to assess foliage protection achieved by application of chemical and microbial insecticide against insect defoliators of hardwood forests. Color-IR film at a scale of 1:15,000 was superior to color film for classification of defoliation by forest tent caterpillar, *Malacosoma disstria* Hbn., in southwestern Alabama (Ciesla *et al.*, 1971). Oblique color-IR photos taken with 35-mm or 70-mm cameras have been used to demonstrate foliage protection due to experimental sprays in hardwood forests of the northeastern United States infested by gypsy moth, *Lymantria dispar* L. (White *et al.*, 1978).

The pandora moth pilot project provided the opportunity to evaluate large and medium scale color-IR photos to assess foliage protection achieved from direct chemical treatment of a coniferous defoliator. Earlier work with pine butterfly, *Neophasia menapia* F. and F., an insect which causes similar damage to ponderosa pine forests, showed that heavy defoliation could be resolved on 1:126,700 scale color-IR photos (Ciesla, 1974).

METHODS

DESCRIPTION OF TEST SITE

The test site was located near the community of Jacob Lake on the Kaibab National Forest of Northern Arizona in Coconino County. The Kaibab Plateau is an essentially flat-topped ovoid land mass 20-miles wide and 60-miles long with its long axis lying NNW-SSE. Topography is gently rolling and dissected by numerous narrow canyons. Elevations range from 7,500 feet to 9,200 feet, with the elevation at Jacob Lake, the only community in the area, being 7,920 feet. The middle portions of the plateau are generally higher and slope downward in all directions.

Ponderosa pine is the predominant tree species in the area and comprises 51 to 100 percent of the infested stands. This species occurs in open grown, park like stands with a grass understory (Figure 1). Other tree species present include quaking aspen, *Populus tremuloides* Michx., white fir, *Abies concolor* (Gord. & Glend) Lindl., Douglas-fir, *Pseudotsusa menziesii* var. *glauca* (Beissn.) Franco, pinyon pine, *Pinus edulis* Engelm., Utah juniper, *Juniperus osteosperma* (Torr.) Little, Rocky Mountain juniper, *Juniperus scopulorum* Sarg, gambel oak, *Quercus gambelii* Nutt., and New Mexico locust, *Robinia neomexicana* A. Gray (Bennett and Ragenovitch, 1982).

DESCRIPTION OF SPRAY TEST

Eight blocks, 500 to 700 acres in size, were established within the area predicted to have noticeable defoliation in 1981. Five blocks (Numbers 1 to 5) were treated with an aerial application of 0.75 lbs acephate in one gallon of water per acre (Figure 2). The remaining blocks (6 to 8) served as untreated checks. Spray was applied during mid May 1981 when the larvae were about half grown. Blocks 1 and 2 received heavy rain and wet snow from a late winter storm $7^{1}/_{2}$ and 24 hours after treatment, respectively.

FIG. 1. Ponderosa pine stand near Jacob Lake, Arizona—typical of stand conditions within the test site.

AERIAL PHOTOGRAPHY

Three spray blocks (blocks 1,3, and 5) and one untreated check (block 8) were included in the photo mission. These were selected because they occurred outside of the area defoliated in 1979 and would therefore not contain areas of prior damage which might mask treatment effects (Figure 2).

Each block was photographed with Kodak Aerochrome Infrared Film 2443 (Estar base) with a Zeiss RMK A 21/23 aerial camera equipped with an $8^{1}/_{4}$-inch focal length lens. The camera platform was a USDA Forest Service Aero-Commander 500B. Photos were taken at scales of 1:6,000 and 1:15,000. The test site was photographed on 6 May 1981, immediately prior to treatment, and on 26 June when larval feeding was completed and defoliation was at its peak level (Figure 3).

The May photographs provided baseline data to which subsequent changes in foliage density could

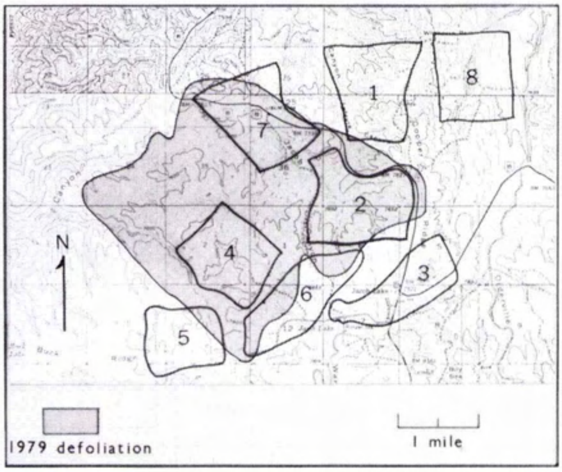


FIG. 2. Location of treatment and check blocks relative to pandora moth defoliation boundaries in 1979. Blocks 1 to 5 were treated by spraying acephate; blocks 6 to 8 served as untreated checks.

be related. This was important because defoliation damage prior to 1981 had to be accounted for. Because conifers normally retain their foliage for several years, any accumulated damage from previous years larval feeding might still be visible and not distinguishable from damage caused by the 1981 generation of insects.

PHOTO INTERPRETATION

Transparencies of each photo scale were examined in stereo with an Old Delft scanning stereoscope at 1.5 × magnification. Forest vegetation was classified into one of three defoliation classes:

Undamaged— No evidence of defoliation, crown color magenta to red (National Bureau of Standards centroid color chips 15 M Red or 12 S Red).

Partial— Visible thinning of crowns, crown color grey-red to pink (color chips 19 G Red, 6 D Pink, or 5 M Pink).

Heavy— All foliage removed, crown color grey (color chips 23 DR Grey or 266 D Grey).

Class boundaries were transferred to a 1:15,000 scale topographic map of the test site containing the approximate boundaries of the spray blocks by using a simple sketchmap procedure. Proportion of defoliation classes within each block was determined with a dot grid.

FIG. 3. Heavy feeding injury on ponderosa pine near Jacob Lake, Arizona caused by pandora moth.

GROUND DATA

Defoliation was classified on 14 to 15 ground plots within each block on 24 and 25 June. These served as points where defoliation estimates made independently by aerial photo interpretation and ground methods could be compared in an error matrix. Ground plots consisted of six dominant or codominant ponderosa pines. Two raters classified each tree into one of six defoliation classes (Table 1). A plot rating was computed from an average of the

TABLE 1. PANDORA MOTH DEFOLIATION CLASSES USED IN AERIAL PHOTO INTERPRETATION AND GROUND CHECKS—1981 PANDORA MOTH PILOT PROJECT, KAIBAB NATIONAL FOREST, ARIZONA

Photo Interpretation Class	Ground Rating Class	Description of Ground Rating Class
Undamaged	0	No visible defoliation
	1	Up to 25% of the foliage removed
Partial	2	26–50% of the foliage removed
	3	51–75% of the foliage removed
Heavy	4	76–99% of the foliage removed
	5	100% of the foliage removed

TABLE 2. PERCENT OF AREA IN EACH DEFOLIATION CLASS BY TEST BLOCK AS DETERMINED FROM AERIAL PHOTO INTERPRETATION—1981 PANDORA MOTH PILOT PROJECT; KAIBAB NATIONAL FOREST, ARIZONA

Treatment	Block	Percent of Area by Defoliation Class		
		Undamaged	Partial	Heavy
0.75 acephate/acre. Precipitation within 7½ to 24 hr.	1	7.1	37.6	55.3
	2	12.1	51.6	36.3
0.75 acephate/acre. No precipitation for at least 48 hr.	3	68.4	30.3	1.3
	5	74.8	25.2	0.0
Untreated	8	18.6	73.6	7.9

individual tree ratings rounded to the nearest whole number.

Defoliation class data from the ground plots were compared to photointerpreted defoliation classes. Ground defoliation classes 0 and 1 were equated to the "undamaged" aerial classification, classes 2 and 3 to "partial", and 4 and 5 to "heavy" (Table 1).

RESULTS

AERIAL PHOTO INTERPRETATION

Photo quality was excellent for both photo missions and both scales, although color balance varied slightly between flight dates.

Defoliation by the 1979 generation of pandora moth was not confused with 1981 defoliation or treatments as originally anticipated. The pandora moth is somewhat atypical of forest defoliators indigenous to North America in that feeding larvae are present only in alternate years. In addition, because feeding is generally completed before the current year's foliage is fully expanded, new foliage escapes injury. Therefore, trees within the area defoliated in 1979 contained two years of foliage, 1979 and 1980, when the May 1981 photographs were taken and appeared similar to stands which were not defoliated in 1979.

Defoliation by the 1981 generation of pandora moth was visually similiar at both photo scales. An entire spray block and a sufficient area of surrounding untreated forest appeared on a single frame at a scale of 1:15,000 whereas only a portion of a spray block appeared on the 1:6,000 scale photo. Thus, 1:15,000 scale photos were more convenient to interpret because we were looking for defoliation patterns relative to spray blocks. A defoliation map was prepared from the 1:15,000 scale photos. Because spray block 2 was in the flight path between blocks 1 and 3 and was present in its entirety on the 1:15,000 scale photos, and we had concluded that defoliation from the 1979 generation of pandora moth did not confuse the interpretation of 1981 defoliation, it was included in the evaluation.

Spray blocks 1 and 2 received moderate or heavy defoliation over most of their respective area. A greater proportion of the areas of spray blocks 1 and 2 was classified as heavier than block 8 which was an untreated check (Table 2, Figure 4). Block 5 showed a considerable area of undamaged foliage. However, because the southern boundary of this block roughly conformed to the boundary of uninfested areas to the south, we could not conclude from aerial photointerpretation alone that the lack of damage was due to a treatment effect (Figure 4).

An area of undamaged foliage occurred in block 3 that roughly conformed to the spray block boundary. This was almost completely surrounded by areas of partial and some heavy defoliation (Figure 4 and Plate 1). Block 3 was the only block in the test site where foliage protection due to treatment could be discerned solely from aerial photointerpretation.

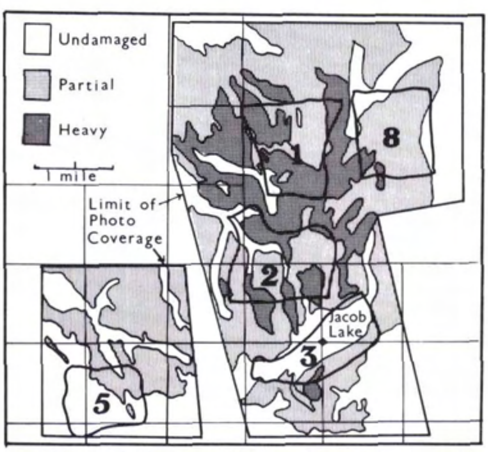


FIG. 4. Map of 1981 pandora moth defoliation relative to test blocks. Blocks 1, 2, 3, and 5 were treated with acephate, block 8 was an untreated check, and blocks 4, 6, and 7 were not included in the aerial photo evaluation. Blocks 1 and 2 received heavy rain and snow 7½ and 24 hrs. after treatment.

TABLE 3. ERROR MATRIX COMPARING AERIAL AND GROUND DEFOLIATION ESTIMATES IN SPRAY AND CHECK BLOCKS—1981 PANDORA MOTH PILOT PROJECT—KAIBAB NATIONAL FOREST, ARIZONA

Intensity Class on Ground Plots %	Intensity Class on Aerial Photos (%)			
	Undamaged	Partial	Heavy	Subtotal
0–1	24a	3	0	27
2–3	4	15a	2	21
4–5	0	10	16a	26
Subtotal	28	28	18	74

a—Denotes agreement between aerial and ground classification.

COMPARISON WITH GROUND DATA

Ground and aerial estimates of defoliation agreed in 55 cases, or 74 percent of the time (Table 3). Significance was tested by using a 2 by 2 Chi-square test with one degree of freedom and assuming an expected probability of 33.3 percent of correct classification by chance alone. The computed Chi-square was 56.27, indicating that classification was significantly better than random chance at a 99 percent level of probability. Part of the incorrect classification is attributed to the spotty nature of defoliation. No attempt was made to map small patches (less than one acre) of one defoliation class within a larger area of another class.

Pre- and post-spray insect population data that were collected as part of the overall pilot project evaluation (Bennett and Ragenovitch, 1982) explain differences in intensities of defoliation observed on the 26 June aerial photos. When pre-spray insect population densities from all blocks were subjected to a single classification analysis of variance (4 and 70 d.f.), an F of 0.034 indicated no significant differences between blocks. Therefore, we conclude that the pre-spray population of pandora moth was relatively homogeneous, capable of causing the same degree of defoliation in all blocks. When post-spray population densities were subjected to the same analysis F was 3.86, indicating that differences between blocks occurred at the 99 percent level of probability. Post-spray data were subjected to an *a posteriori* analysis for testing homogeniety of means known as Sum of Squares-Simultaneous Test Procedure (SS-STP), developed by Gabriel (1964) and described by Sokal and Rohlf (1973). This analysis showed that there were no significant differences between blocks 1, 2, and 8 or blocks 3 and 5 but that the two groups were significantly different at the 95 percent level of probability (Table 4). The difference is attributed to a treatment related population reduction, which can be seen on the aerial photos as less intense defoliation. We conclude that the lack of foliage protection seen on photos of blocks 1 and 2 is due to a washing of insecticide residue from the foliage by the rain and snow which fell shortly after application. This conclusion is substantiated by the insect population data, which show only slight reductions in these blocks.

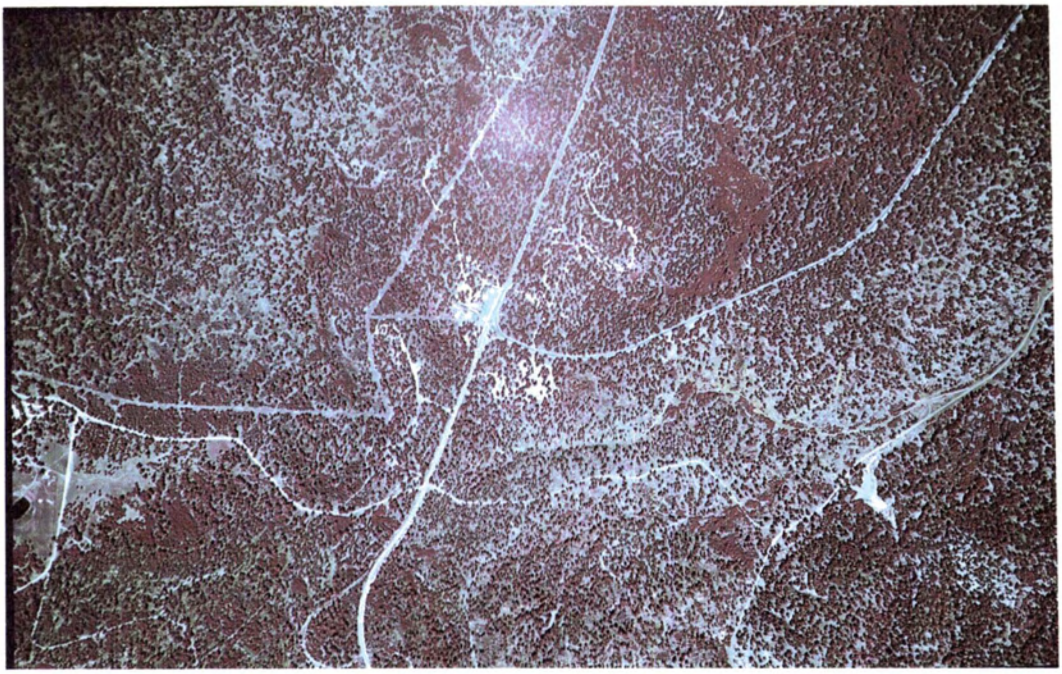
DISCUSSION AND CONCLUSION

Evidence of foliage protection is as meaningful as insect mortality to land managers trying to protect

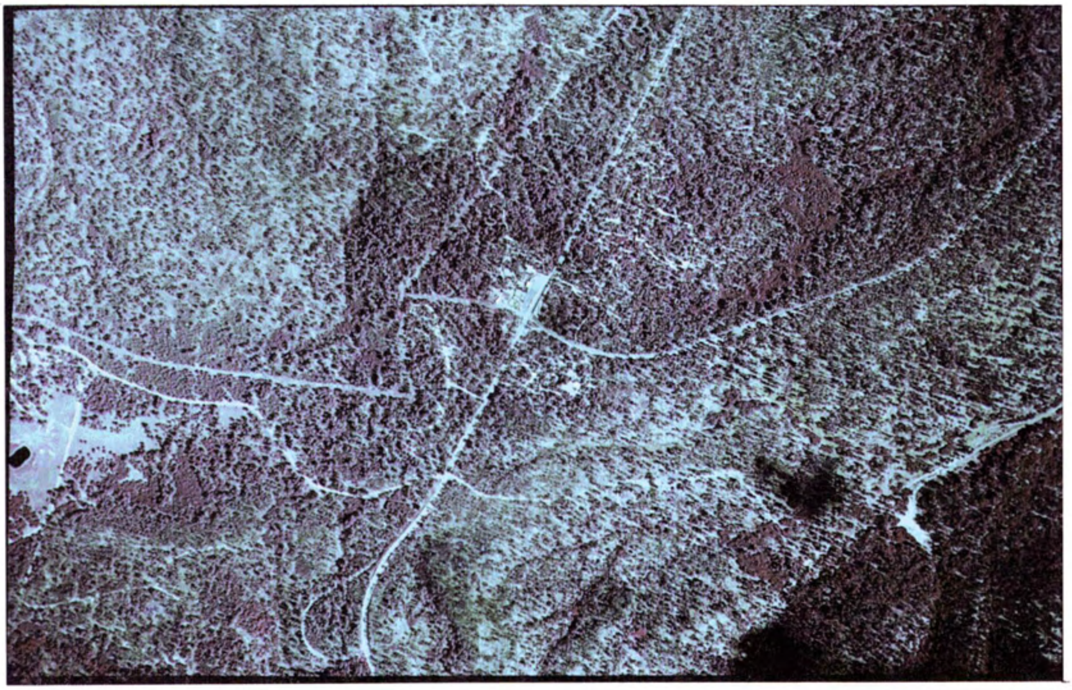
TABLE 4. PRE AND POST SPRAY PANDORA MOTH POPULATION DENSITIES FROM BLOCKS INCLUDED IN THE AERIAL PHOTO EVALUATION 1981 PANDORA MOTH PILOT PROJECT—KAIBAB NATIONAL FOREST, ARIZONA. (DATA FROM BENNETT AND RAGENOVITCH (1982)).

Treatment	Block	Mean Insects per Branch[1]		% Mortality After 15 Days
		Prespray	15 Day Post Spray	
0.75 acephate/acre. Precipitation within $7^1/_2$ to 24 hr.	1	3.38	2.75a[2]	18.6
	2	3.07	2.34a	23.8
0.75 acephate/acre. No precipitation for at least 48 hr.	3	2.98	1.50b	49.7
	5	3.19	1.41b	55.8
Untreated	8	2.84	2.01a	29.2

[1] Branch samples varied from 12 to 28 inches in length.
[2] Means followed by different letters are significantly different from one another at the 95 percent level of probability.



(a)



(b)

PLATE 1. Color-IR photos of block 3; community of Jacob Lake is near photo center. Photo (a) was taken 6 May 1981, prior to treatment and appearance of defoliation by the 1981 generation of pandora moth. Photo (b) was taken 26 June 1981, at peak defoliation. Magenta to red areas are undamaged, grey-red or pink areas received partial defoliation, and grey areas received heavy defoliation. Areas of undamaged foliage on the 26 June photo conform roughly to spray block boundaries. (Original photo scale = 1:15,000)

resource values and to pesticide manufacturers attempting to secure registration for their products. Use of 1:15,000 color IR aerial photographs in combination with ground data on insect mortality can provide an effective assessment of aerial sprays applied to the pandora moth in coniferous forests. A single photo mission timed to coincide with peak defoliation will provide adequate coverage. Aerial photos permit classification of defoliation over an entire block of land and, in addition, they provide a permanent visible record of foliage protection, or lack thereof, pursuant to treatment.

A problem inherent in using aerial photos alone is that variations in insect population density or condition of the host plant could mask treatment effects. These must be accounted for with ground sampling. A disadvantage of reliance solely on defoliation data from ground plots is that the data from isolated points within a block will vary greatly from each other and from the average value of the block as a whole. Proper combination of photo and ground plot techniques gives a broader and more detailed understanding of treatment effects.

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United Nations International Meeting of Experts on Remote Sensing Information Systems

Feldafing and Oberpfaffenhofen, Federal Republic of Germany 7-11 May 1984

This meeting is a follow-up action on the United Nations General Assembly resolution 37/90 which directed that an international space information service be established in the Outer Space Affairs Division of the Organization which should have the capability to provide information, on request, on all aspects of space science and technology. Accordingly, the meeting will focus its attention on (1) identifying the mechanisms for establishing a viable clearinghouse on remote sensing information systems and (2) recommending appropriate action programs for achieving this goal.

A limited number of authoritative papers are being invited for presentation at the meeting. Such papers will focus on the objective of the United Nations space information service; elements of a remote sensing information system; current status and future of remote sensing information systems; and information aspects of remote sensing data, training and research opportunities, remote sensing equipment (both soft- and hardware), and literature. These presentations will be followed by a series of working group sessions. Further information on this meeting can be obtained from

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