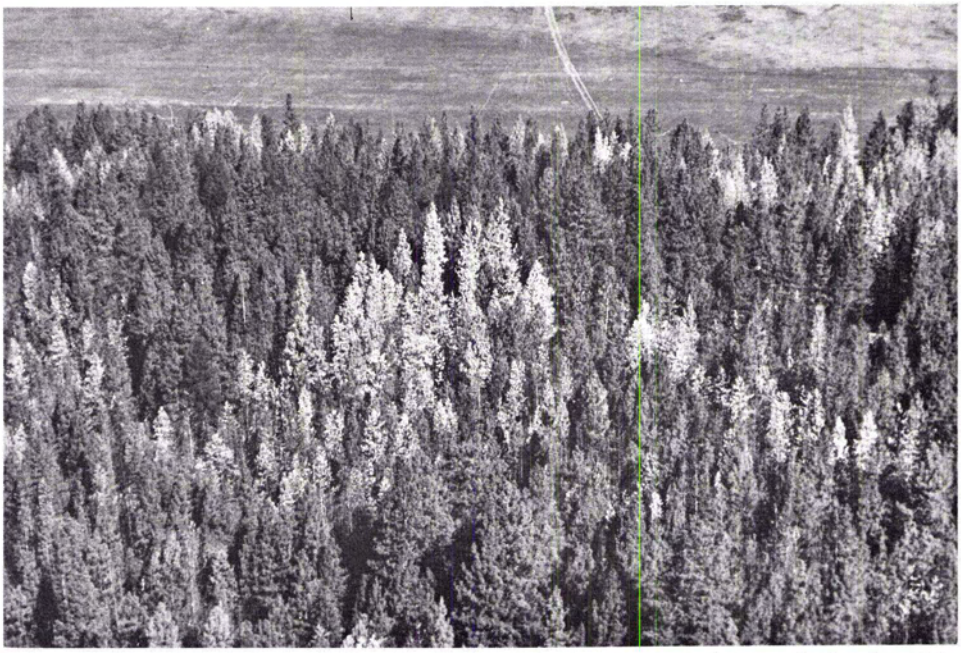

FIG. 1. Oblique view of ponderosa pine stand in the Ninemile Creek watershed infested by mountain pine beetle. Light-colored crowns are trees which have been attacked and killed.

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Forest Insect Damage from High-Altitude Color-IR Photos

ERTS-1 underflight photos taken from a U-2 were evaluated for detection capability.

(Abstract on next page)

INTRODUCTION

NUMEROUS PAPERS have appeared in literature describing use of color and color-IR aerial photographs for the detection and evaluation of damage caused by various forest insects (Aldrich and Drooz 1967; Ciesla, et al. 1967, 1971; Wert and Roettgering 1968; Wert and Wickman 1970). Manuals have been published describing survey methods for forest insects using aerial photographs (Anon. 1970, Wear et al. 1966) and recently an interpretation guide for detecting forest damage on aerial photos has been published (Murtha 1972). Heller (1971) reports that most successful uses of aerial photographs for detecting forest insect damage have been at large (1:600-1:2,000) or medium

(1:4,000-1:12,000) photo scales although multiple tree infestations of mountain pine beetle, *Dendroctonus ponderosae* Hopk., have been accurately mapped at scales as small as 1:32,000.

It has been suggested that forest insect damage could be detected on small-scale photographs and that Earth-orbiting satellites may be of value in monitoring forest insect damage (Luney and Dill 1970). Photos taken of a NASA test site during July 1972 in western Montana provided an opportunity to evaluate ultrasmall-scale photos for mapping forest insect damage. Results of this evaluation are described in this paper.

METHODS

SOURCE OF PHOTOS

Photos were provided as a result of a U-2 flight of NASA test site 354 A&C encompassing portions of the Bitter Root and Lolo National Forests in Missoula and Ravalli Counties, Montana, and were taken for the University of Montana Geology ERTS project. The film type was Kodak Aerochrome infrared 2443, and photo scale was approximately 1:126,720 (½ inch = 1 mile). The camera system was a Wild RC-10 with 6-inch focal-length lens. The date of photography was July 26, 1972.

ABSTRACT: *High-altitude color-infrared ERTS-1 underflight photos of a NASA test site in western Montana taken from a U-2 were evaluated for capability to resolve forest insect damage. Three insect outbreaks were known to occur within the test site: a bark beetle, mountain pine beetle* Dendroctonus ponderosae *Hopk.; and two defoliators–pine butterfly* Neophasia menapia *F. and F., and western spruce budworm* Choristoneura occidentalis *Free. Defoliation of ponderosa pine forests by pine butterfly was readily discernible on color IR positive transparencies. Detection of mountain pine beetle damage was only partially successful. Defoliation of current year's foliage by western spruce budworm was not resolved.*

INSECT DAMAGE EVALUATED

Photography included forested regions which are surveyed annually from small aircraft by personnel of the Forest Insect and Disease Branch, Division of State and Private Forestry, Northern Region, U. S. Forest Service, for insect and disease detection. As a result of surveys the following outbreaks were known to occur within the test site:

★ MOUNTAIN PINE BEETLE, *Dendroctonus ponderosae* Hopk.—An epidemic of mountain pine beetle occurred over a gross area of approximately 30,000 acres of young second-growth ponderosa pine, *Pinus ponderosa* Laws, stands on the Lolo National Forest and adjoining State and private lands in the Ninemile Creek drainage approximately 20 miles northwest of Missoula. Detailed evaluation of this outbreak indicated 16 stands encompassing 2,592 acres were heavily infested with an average of 31.26 trees killed per acre over a 3-year period. (Bousfield et al. 1973). The level of infestation in 1971 was 7.43 trees per acre. Trees attacked in 1971 or before had sorrel or red crowns by July 1972 and were visible on photos taken at that time (Figure 1).

★ PINE BUTTERFLY, *Neophasia menapia* (F. and F.).—An extensive outbreak of pine butterfly occurred over portions of the Bitterroot National Forest and adjoining State and private lands in 1972. The larval stage of this insect defoliates ponderosa pine. In heavily infested stands all but the current year's growth is removed by the larvae (Figure 2). At the time of peak defoliation, the current year's growth is not fully elongated and developed; therefore, heavily damaged trees appear completely stripped of their foliage. Defoliated stands have a brown or gray cast to them and can be seen for distances of several miles. Larvae are active in June and July and usually complete their feeding by late July; consequently, peak defoliation coincided with this underflight. Aerial and ground surveys revealed approximately 40,000 acres of ponderosa pine forests in the Bitter Root Valley suffered varying degrees of foliar damage by this insect (Bousfield and Dewey 1972). Heaviest feeding injury tends to occur on south-facing slopes.

★ WESTERN SPRUCE BUDWORM, *Choristoneura occidentalis* Freeman.—This insect was in epidemic status over much of the test site. The larval stage feeds on buds and new growth of Douglas-fir, *Pseudotsuga menziesii* (Mirb.) Franco; subalpine fir, *Abies lasiocarpa* (Hook.) Nutt.; grand fir, *A. grandis* (Dougl.) Lindl.; and Engelmann spruce, *Picea engelmanni* Parry. Defoliation is most conspicuous dur-

ing late July or early August. Heavily damaged stands tend to take on a brownish cast if viewed from a distance.

PHOTO INTERPRETATION AND GROUND-TRUTH ACQUISITION

Aerial photos containing forested areas with known insect damage were examined using a Bausch and Lomb zoom stereoscope. The presence or absence of insect damage was determined by color patterns on the photos. For example, red-topped and fading pines dying from bark-beetle attack typically register as beige or yellow on color-IR film. Defoliated trees register as a grey or grey-green color as compared to healthy foliage which appears in various tones of red, red-brown, or magenta. Where color changes suggestive of damage were detected, attempts were made to classify intensities of damage and establish infestation boundaries.

Ground truth was acquired from several sources. A multi-stage aerial photo-ground survey (Bousfield et al. 1973) provided the ground truth for the mountain pine beetle infestation. Ground truth for the two defoliators was taken from existing survey records with supplemental aerial and ground examination of specific stands which were located on the U-2 photographs.

FIG. 2. Ponderosa pine stand in the Bitter Root Valley suffering from heavy defoliation by pine butterfly. All but current year's foliage has been removed.

RESULTS

Three U-2 photographs encompassed stands infested by mountain pine beetle in Ninemile Creek watershed west of Missoula. Stereoscopic examination of these frames revealed traces of yellow coloration typical of bark-beetle infested pine on color-IR film in one of the 16 stands classified as heavily infested by earlier multistage aerial photo-ground survey (Bousfield et al. 1973). This stand contained solid areas of pines with discolored foliage as opposed to more scattered attacks in the other infested stands, perhaps making it more visible on high-altitude photographs.

Two frames of U-2 imagery encompassed portions of Sweeney, Bass, and Kootenai Creek drainages in the Bitter Root Valley (Plate 1). These drainages contain stands of ponderosa pine which suffered heavy defoliation by pine butterfly in 1972. Heavily defoliated stands registered in tones of grey on the imagery and were clearly visible without the aid of magnification or stereoscopic viewing. Detailed examination of the photos and subsequent ground observation indicate that defoliated stands of pure or nearly pure ponderosa pine with a grass understory can readily be detected on high-altitude photographs. Presence of nonhost trees such as Douglas-fir which register as dark red or understory herbaceous vegetation such as ninebark, *Physocarpus malvaceus;* willow, *Salix* sp.; or snowberry, *Symphoricarpos albus,* which registered as brilliant red, tended to mask the grey color of the defoliated pine.

In an attempt to map stands defoliated by pine butterfly from the U-2 imagery, a total of 5,080 acres were classified as defoliated. This compares to a total of 7,320 acres classified as having aerially visible defoliation when the same area was mapped by conventional aerial sketchmap-ground survey techniques currently used in the Region (Figure 3). The lower acreage estimate from the U-2 imagery is believed to be primarily due to the masking effect of nonhost trees and herbaceous vegetation in mixed ponderosa pine-Douglas-fir stands.

Defoliation of Douglas-fir and true fir by western spruce budworm occurred in varying degrees over much of the test site. However, examination of stands known to be heavily damaged in 1972 on the U-2 photos failed to reveal presence of discoloration indicative of spruce budworm defoliation.

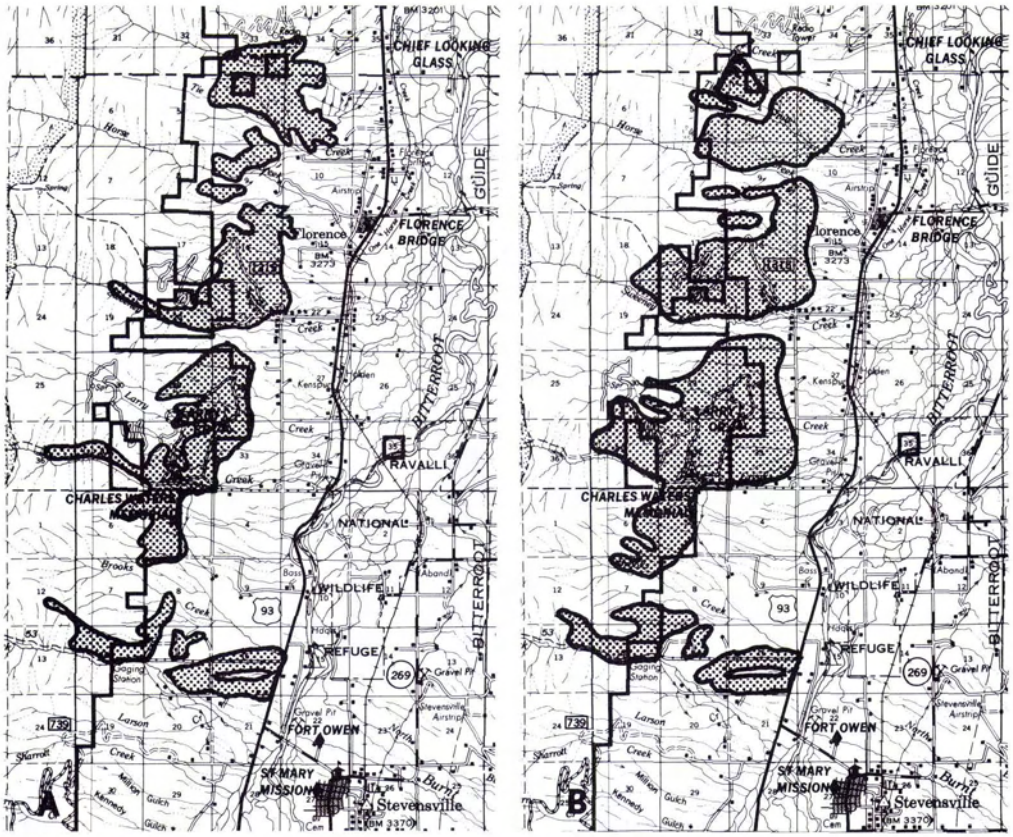

FIG. 3. Maps showing location of stands defoliated by pine butterfly made from *A*, interpretation of U-2 photos, and *B*, conventional aerial sketchmap and ground survey methods. (Original scale ½ inch = 1 mile).

DISCUSSION AND CONCLUSIONS

Insect damage evaluated on U-2 imagery is representative of types of damage which are currently mapped from either low-flying aircraft or large-scale color photography; i.e., tree mortality, defoliation of virtually all foliage, and defoliation of only current year's foliage. Of the three, it is generally agreed that defoliation of virtually all foliage such as caused by epidemic populations of pine butterfly is the most conspicuous form of insect damage, particularly where vast areas of pure or nearly pure stands of host trees are involved. This study shows that ultrasmall-scale color-IR photographs comprise a potential tool for detecting and mapping this type of damage as long as it is restricted to nearly pure stands of host type with little or no herbaceous vegetation in the understory to mask feeding injury.

These photos were only partially effective in registering stands suffering heavy tree mortality due to bark-beetle infestations and were not capable of registering defoliation of current year's foliage caused by western spruce budworm. Perhaps techniques such as image enhancement or densitometer scanning of infested and uninfested stands may prove effective for detecting and mapping these types of damage.

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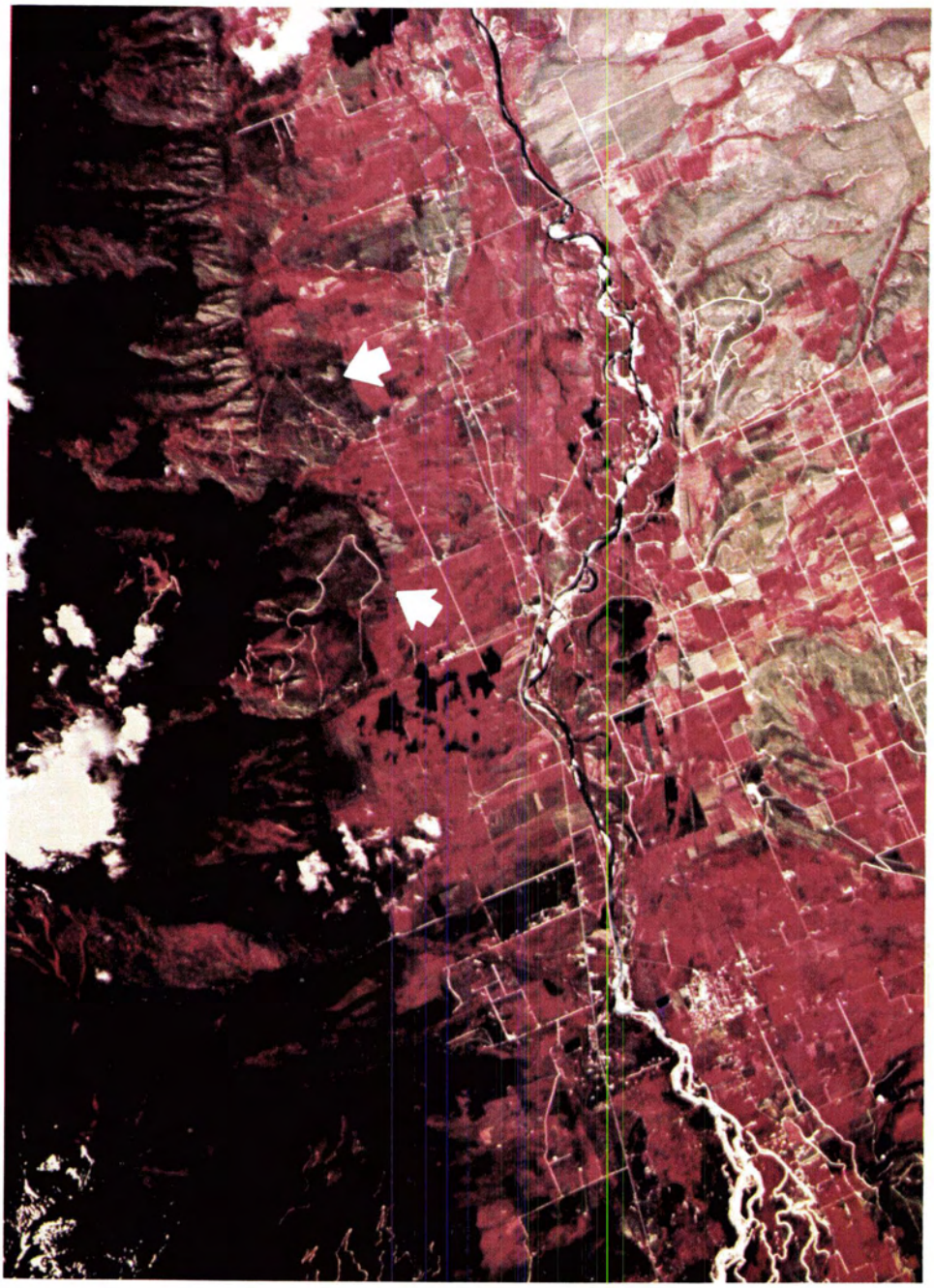

PLATE 1. Portion of U-2 color-IR photo showing ponderosa pine stands defoliated by pine butterfly in the Bitter Root Valley. Arrows denote locations of infested stands in the Sweeney and Bass Creek drainages (scale ½ inch = 1 mile).

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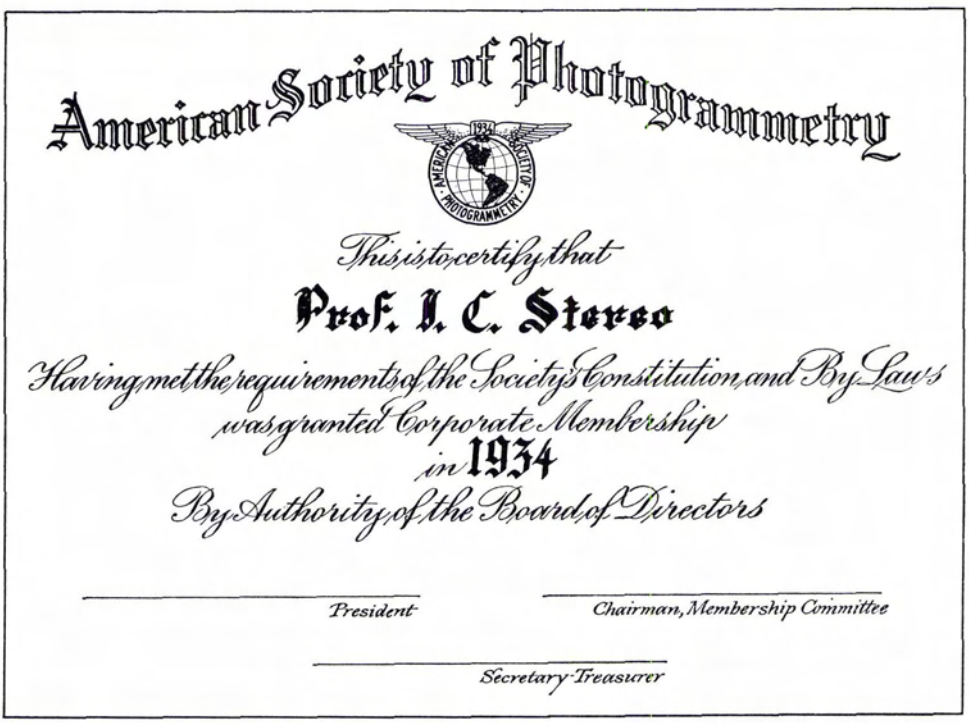

Illustrated above is the certificate that is available to members of the American Society of Photogrammetry. The original, suitable for framing, is 8½ by 11 inches with the name of the member attractively hand engrossed. The price is $2. Orders should be sent to ASP, 105 N. Virginia Ave., Falls Church, Va. 22046.