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An Evaluation of the use of Erts-1 Satellite Imagery for Grizzly Bear Habitat Analysis

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INTRODUCTION

Considerable data on grizzly bear, *Ursus arctos*, ecology have been gathered during the course of a 13-year study in the Yellowstone ecosystem (Craighead and Craighead 1970, 1971; Craighead *et al.* 1960, 1967, 1969; Craighead *et al.* in prep; Hornocker 1962). This population constitutes one of the few sizeable populations remaining in the United States outside of Alaska.

Recent research at the Montana Cooperative Wildlife Research Unit has emphasized habitat evaluation and integration of this data with accumulated knowledge of the grizzly's food habits, home range, movements and population dynamics. The result will be a better understanding of habitat usage and requirements. It will also permit more accurate estimates of population density and distribution and allow wildlife managers to predict the effects of land use changes (logging, road construction, etc.) on existing bear populations. Habitat can be evaluated to determine if grizzlies can be reintroduced and survive where they have been eliminated.

The development of remote sensing techniques using aerial photography, multispectral scanning sidelooking radar, microwave imaging, and other methods to evaluate land uses and natural resources has been rapid in recent years. These techniques have great potential for reducing the logistical effort of surveying by conventional methods extensive wilderness areas used by grizzly bears.

This report evaluates one of these techniques, multispectral imaging from earth-orbiting satellites. Viewing equipment for analyzing ERTS-1 multispectral images was recently acquired by the University of Montana Geology Department as part of an Earth Resources Program contract with the National Aeronautics and Space Administration (Applicability of ERTS-1 to Montana Geology, NAS5-21826). This provided an opportunity to compare ERTS-1 imagery with data gathered for the U.S. Forest Service and Montana State Fish and Game Department during the summer of 1972 (Sumner and Craighead 1973). Our comparison of multispectral images with habitat data have enabled us to come to some conclusions about the usefulness of this technique and to identify some promising areas for further investigation.

The imagery analysis described in this report was supported by National Aeronautics and Space Administration grant NGR 27-002-006. Dr. Robert Weidman made available to us the multispectral viewing and cartographic equipment and provided much assistance and helpful advice. Ground truth was obtained from a habitat survey of the Scapegoat Wilderness Area sponsored by the U.S. Forest Service and the Montana State Fish and Game Department, and conducted by the Montana Cooperative Wildlife Research Unit.

STUDY AREA

The 135 sq. km (52 sq. miles) study area is in the center of the newly-formed 970 sq. km (240, 500 acre) Lincoln-Scapegoat Wilderness which is 120 km (75 miles) west of Great Falls, Montana. It lies within the Lolo National Forest, bordered by the Bob Marshall Wilderness area on the northwest. Elevations range from 1700 to 2800 m (5600 to 9200 ft), with over half the area above 2400 m (8000 ft). Relative isolation and light use, combined with specific vegetation and topographic characteristics, make the area favorable habitat for grizzlies. Between 29 July and 15 September 1972, the area was type-mapped for food plants utilized by grizzlies. A population survey of grizzlies, black bear, *Ursus americanus*, and other mammals and birds was made over a somewhat larger area at the same time (Sumner and Craighead 1973).

A recent food habits and habitat requirement study indicated that the following criteria are important to maintain the grizzly population of the Yellowstone ecosystem (Craighead *et al.* in prep):

1. Space.

The home ranges of grizzly bears may encompass areas up to 3900 sq. km (1500 sq. miles). Large undeveloped or *de facto* wilderness areas of national parks and national forests meet this requirement.

2. Isolation

Grizzlies conflict with man and his livestock, and have been eliminated from developed areas. Areas where bears remain and potential habitat for reintroduction of grizzlies is isolated, receiving only light public use. Roads and extensive trails degrade grizzly habitat.

3. Food

An abundance of natural foods must be available from April to November, and must be sufficiently varied so that intermittent deficiences of one or more sources do not jeopardize the population. Basic foods are carrion, ungulates, rodents, berries, pine nuts, green vegetation, bulbs and tubers and, in some situations, fish.

4. Vegetation types

A wide range of vegetational types characterize prime grizzly bear habitat. A mixture of timber and alpine meadows provide places to forage, socialize and breed. Alder thickets *Alnus* spp., lodgepole *Pinus contorta*, downfalls and other dense vegetation are preferred bedding sites. Large tracts of undisturbed timber provide protection and seclusion.

While other factors may influence a population in a particular situation, those above were given primary consideration in our investigation.

METHODS

The coverage of ERTS-1 MSS imagery develops for Montana as the satellite moves from north to south along the paths shown as dotted lines in Figure 1.

Images are taken at approximately 160 km (100 mile) intervals along each path with adjacent paths covered on successive days moving from east to west. The same orbit path is repeated at 18-day intervals.

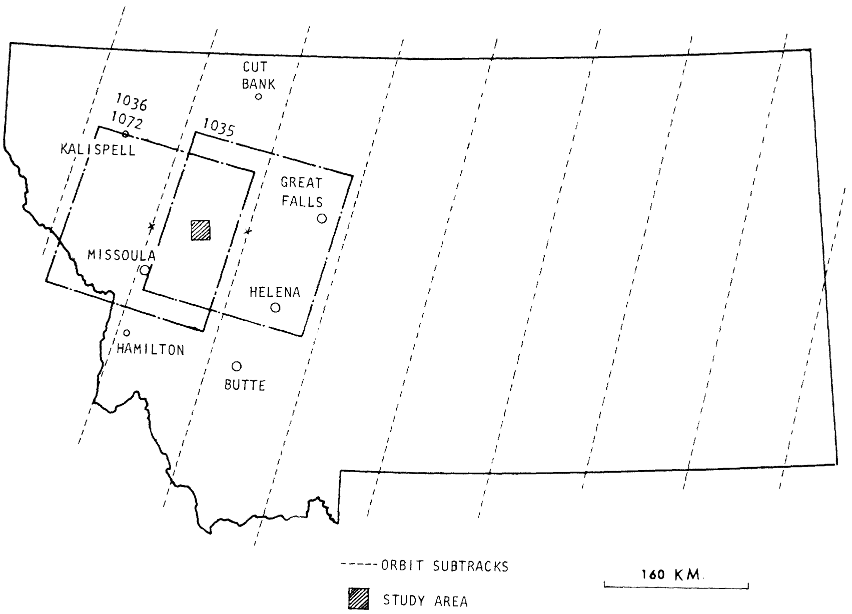

Fig. 1 ERTS-1 Coverage of Montana and study area.

TABLE 1. ERTS-1 IMAGERY OF STUDY AREA JULY-NOVEMBER 1972.

Date	Frame	Percent Cloud Cover	Subsatellite Point		Sun Angle	
					Elev.	Az.
8-10	1018-17571	10	47.12°N	113.88°W	51.7°	137.3°
8-27*	1035-17513	0	47.28	112.43	47.1	142.7
8-28*	1036-17571	0	47.30	113.80	46.0	143.0
9-15	1054-17571	60	47-33	113.77	41.2	148.6
10-2	1071-17513	10	47.51	112.23	35.3	153.3
10-3*	1072-17571	10	47.43	113.72	35.0	153.5
10-20	1089-17515	0	47.38	112.35	29.3	156.8
10-21	1090-17574	70	47.33	113.80	29.0	156.9
11-7	1107-17521	30	47.26	112.45	23.8	158.7
11-8	1108-17575	40	47.26	113.85	23.5	158.8
11-25	1125-17522	40	47.32	112.46	19.3	159.2

*Frames selected for evaluation

Each image is roughly square and covers an area measuring 185 km (115 miles) on each side, so there is about 10% north-south overlap on successive frames taken in each orbit, and about 40% overlap on frames taken on successive days from adjacent orbits. It is thus possible to obtain side-lap stereo viewing of most areas with images taken in adjacent orbits.

The images used in our evaluation were selected by checking the NASA indexes (ERTS U.S. Standard Catalog, NAS1.48:872) and by examining the print file maintained by the Geology Department. Coverage began after launch of the satellite in July 1972 and continues at present. The time from July to

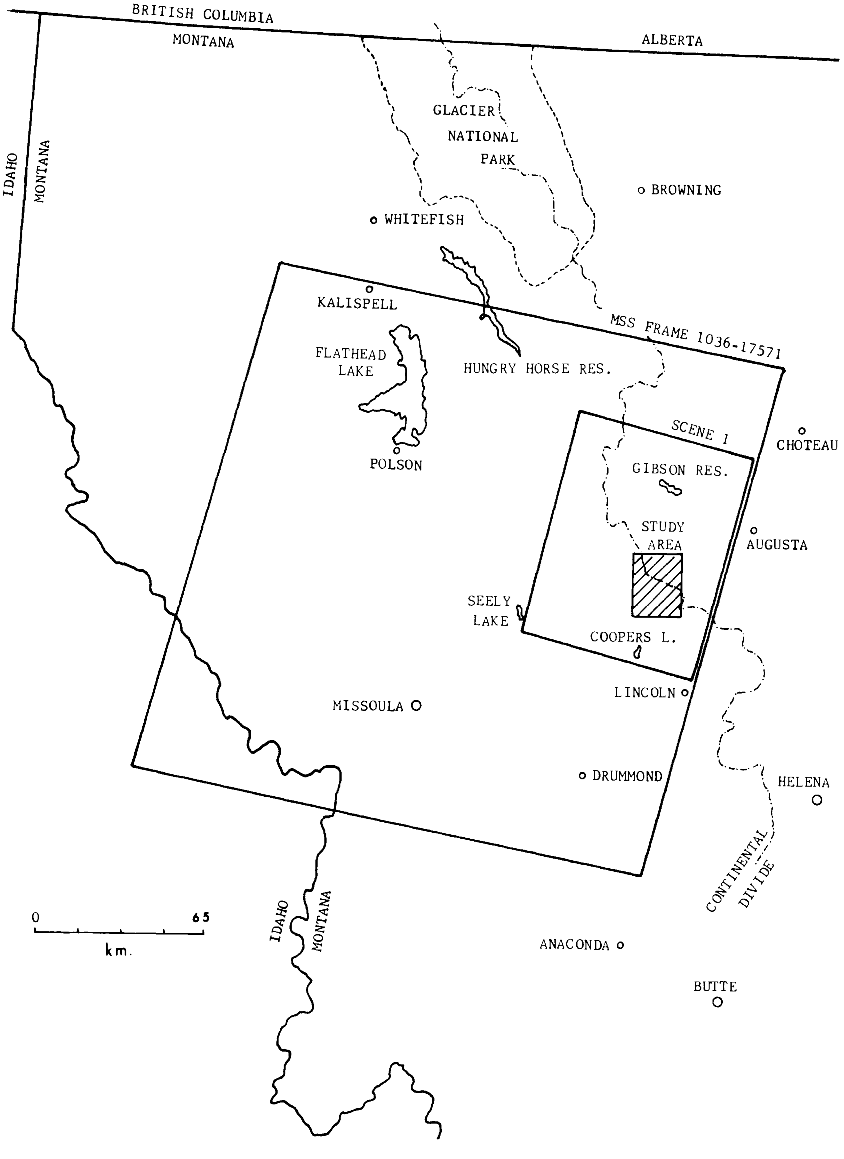

Fig. 2 Boundaries of MSS frame, area displayed on color additive viewer (Scene 1), and study area.

November 1972 was of greatest interest. This included the period when personnel were afield obtaining ground truth data. Satellite imagery obtained is listed in Table 1. Although study area coverage occurred every 18 days, many images were unusable because of cloud cover. One cloud-free set obtained in August, and another in October, were selected for evaluation. Frame 1036-17571 (28 Aug.) was used for most of the vegetation analysis. This frame and frame 1072-17571 (3 Oct.) were used together to examine time-lapse effects in appearances of vegetation and snow cover. Frame 1035-17513 (27 Aug.) and frame 1036-17571 (28 Aug.) were used together for side-lap stereo viewing.

Most image analysis was done with a color-additive viewer using positive transparency enlargements (23 × 23 cm, scale 1:1, 000, 000) of multispectral scanner scenes. Portions of these transparencies encompassing the study area, 8 × 10 cm in size, were cut out and mounted in 70 mm glass and metal slide holders. The area covered, designated Scene 1, is illustrated in Fig. 2.

The prepared slides for each of the four MSS bands were then placed in a Spectral Data Corporation Model 64 Multispectral Viewer. Red, green, blue, or white light of variable intensity was projected through each transparency to form a color composite image on a 23 × 23 cm ground glass viewing screen. The viewer optics provide a ×37. 37 enlargement of the slide, giving an image scale of 1:297, 000 on the viewing screen. After adjustments to place all four images in register, various combinations of band, color and light intensities can be sent up to give maximum enhancement to features of interest in the composite image.

After obtaining the desired scene display adjustments, the image was permanently recorded by photographing the viewing screen with a 35 mm camera and Type B High Speed Ektachrome film. The resulting slides could later be examined, projected or used to make prints as required.

A 23 × 23 cm transparent overlay was prepared for the viewer screen to aid in identifying major topographic features and landmarks. A convenient and low cost method of making such overlays consisted of copying a portion of a 1:250, 000 scale USGS topographic map on a Xerox 7000 electrostatic copying machine at a #2 reduction setting (84. 5%) and then making a 1:1 thermographic overhead projection transparency from this reduced-size copy. The resulting overlay matched the image scale on the viewing screen within 1% and allowed forest boundaries, drainages, mountains, and other features to be easily identified.

A composite aerial photograph map of the study area was also prepared from Forest Service 1:15, 840 black and white panchromatic photographs to aid in identifying small features not shown on the topographic map.

A Bauch & Lomb model ZT-4 Zoom Transfer Scope was used to draw vegetation maps from the 35mm slides of color composite images and to superimpose topographic maps on images for identification of major features and determination of snow cover elevation.

RESULTS

Image color effects

Conclusions similar to those of other investigators (Heller *et al.* 1973, Barnes & Bowley 1973, Tueller 1973) were reached after evaluating the comparative utility of the four MSS images, both individually and in combinations.

The two infrared bands (band 6, 0. 7 to 0. 8 um; band 7, 0. 8 to 1. 1 um) were very similar in appearance, with rivers and lakes showing black and growing plants in light tones. They reduced the dark tones of forested areas normally apparent in visible light so that scene topography was very clear. Band 5 images (0. 6 to 0. 7 um, red) closely approached the appearance of normal aerial photographs; forests and growing vegetation appeared in dark tones and dry vegetation in light tones. Band 4 images (0. 5 to 0. 6 um, green) were the least useful for vegetative mapping and had a slightly hazy appearance due to atmospheric scattering, but were the best for identifying snow cover.

A combination of bands 5 and 7 gave the finest detail for vegetative mapping. Adding band 4 to these two gave greater subtlety of color but resulted in a slight reduction in detail, because of both haze effect and the additional difficulty of adjusting three images for perfect registration instead of two.

Simulated false-color infrared images were obtained by illuminating band 4 with blue light, band 5 with green, and band 7 with red. Usually band 6 was not used because of its similarity to band 7. In these images growing vegetation appears in various shades of red. A simulated normal-color image could be obtained by projecting band 4 in blue, band 5 in red, and band 7 in green. The resulting image shows growing vegetation in exaggerated shades of green and was easier for inexperienced observers to classify accurately.

Scene illumination effects

The transparencies supplied by the EROS data center are photometrically accurate, having densities which correspond to absolute scene brightness. As a result, scenes obtained during winter months at high latitudes are often very dark. Two effects are responsible for this darkening: one is the lower average illumination level due to oblique lighting; the other is the presence of many more shadows in areas of uneven topography. Sun angles above the horizon for imagery of the study area (summarized in Table 1) vary from 52° on 10 August to 19° on 25 November.

We found that vegetation mapping was more difficult in mountainous areas with November imagery than with August imagery. North- and northwest-facing slopes received much less light at low sun angles than south-facing ones, resulting in tone variations larger than those used to discriminate between vegetation types in bright evenly-illuminated areas. Discrimination within large sloping areas illuminated at very low angles was poor because of the general dark tone, and no details could be distinguished in full shadow.

Determination of general vegetation character

High alpine meadows appear in light red or pink in the simulated false-color infrared images and can be easily identified and distinguished from the darker red or grayish-red timbered areas. Large areas can be quickly examined on the images and those portions with combinations of forest and meadow (favorable grizzly bear habitat) can be noted for further examination.

Classification of habitat quality by type and intensity of land use

Areas identified as potential bear habitat based on vegetation character can be classified by eliminating portions heavily used by man and grading the remaining area by a measure of land use intensity.

An overlay can be prepared to show all settlements, agricultural land, grazing land, logging or mining activity roads and trails in the area. Land in use for agricultural or livestock production, areas within a certain radius of settlements and residences, and a strip (with width proportional to traffic volume) adjacent to roads and trails, are excluded. Grizzlies avoid such areas or are eliminated as a result of eventual bear-man conflicts. A simple example of an overlay is shown in Fig. 3. Urban, agricultural and grazing areas are identifiable on satellite imagery by color characteristic and can be directly mapped. Roads and trails are generally not visible; their locations must be obtained from maps. The width of adjacent strips can be determined from traffic counts, visitor statistics and other sources.

Before this method can be used it will be necessary to approximate a scale factor to exclude high-use areas; on trails, for example, the width of the exclusion would be a certain number of meters per visitor man-day. Such scales would be rather arbitrary. An analysis of Yellowstone Park visitation may provide a starting point since better distribution records, both bear and human, exist there than any other area. The scales would need to be modified for habitat evaluation outside national parks. This could not be expected to be accurate in any absolute sense, but would permit use intensities to be compared with one another and the ranking of habitat by quality.

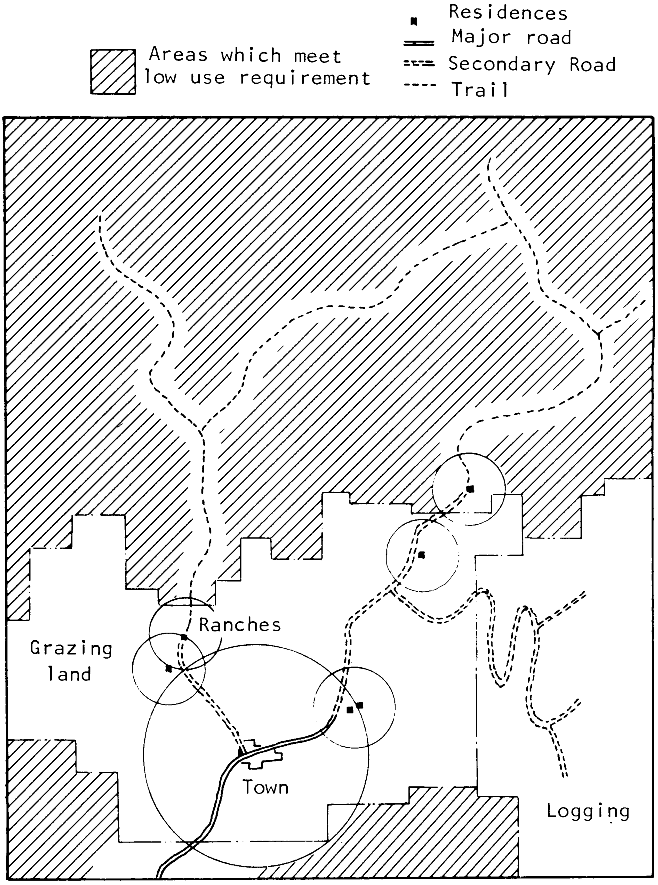

Fig. 3 Example of a use-intensity overlay.

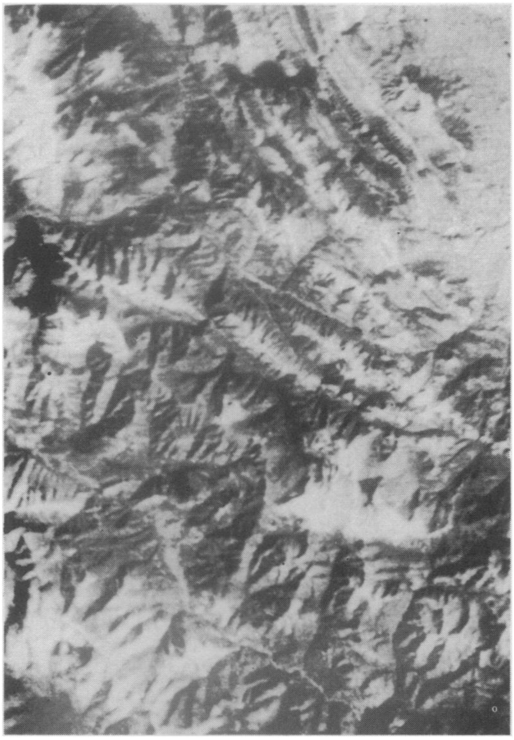

Fig. 4 Simulated false-color infrared image of Scene 1 as displayed on color additive viewer. Growing vegetation appears in shades of red in viewer and shades of grey in this photo.

Fig. 5 Scene 1 with high-altitude overlay superimposed in white light. Only the areas above 2100 m remain visible.

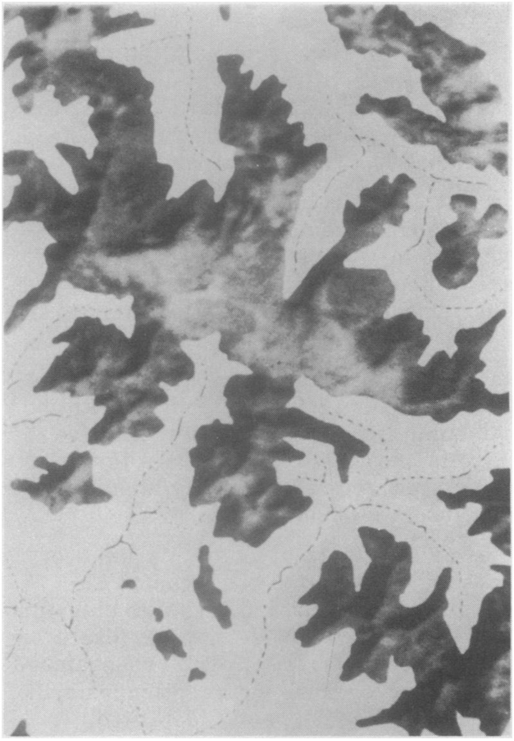

Fig. 6 Enlarged view of study area with altitude overlay. Darker areas are vegetation.

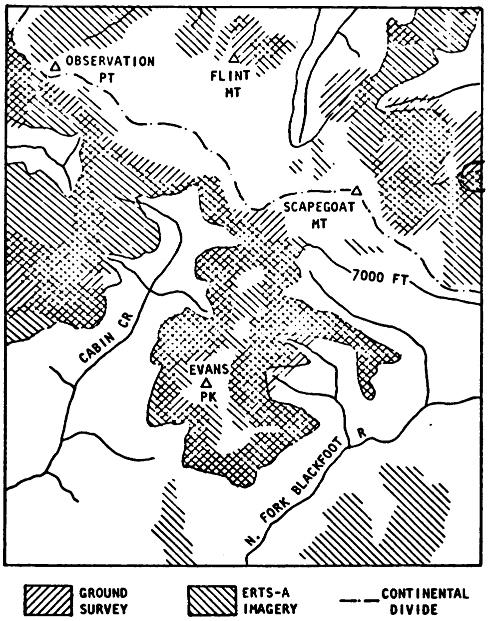

Fig. 7 Distribution of whitebark pine observed on the ground compared with high-altitude timbered areas mapped from satellite imagery.

Identification of whitebark pine

Examination of the color composite image of the study area with the color-additive viewer did not reveal any distinctive variations that would permit differentiation of various tree species. However, we found that a combination of tree cover imagery and altitude information permitted identification of whitebark *Pinus albicaulis* and limber pine *Pinus flexilis*, important food species of grizzly bears.

The ground survey showed that whitebark and limber pine occurred predominantly on higher ridges, usually above 2100 m (7000 ft) elevation. The approximate distribution of these pines is shown in Fig. 3 of Sumner and Craighead (1973). Both species were considered as whitebark pine for classification purposes.

A projection mask was prepared from a topographic map which showed areas above 2100 m in black. This image was combined (using white light) with the false-color infrared (Fig. 4) or normal-color images in the color-additive viewer. The resulting false-color image is shown in Fig. 5. In this image timbered areas above 2100 m appear dark red, and can be easily identified and mapped. A simulated normal-color image is shown in Fig. 6.

Timbered areas mapped from the false-color or normal-color images are shown in Fig. 7 in relation to whitebark pine distribution observed on the ground. The area covered by whitebark pine is 30.6 sq km, and high elevation timbered areas identified from satellite imagery cover 44.3 sq.km (excluding two southernmost areas, not checked in the ground survey). The crosshatched common area is 25.4 sq km. If the ground survey were entirely accurate, the results indicate that 83% of the whitebark pine was correctly identified.

Additional area amounting to 45% of that classified as whitebark pine was actually other species. This is a good result especially considering the simplicity of the method and limited accuracy of the ground survey.

Other factors influencing whitebark pine distribution include aspect, exposure, soil type and available moisture. On north-facing slopes it was often found at lower elevations than on south-facing slopes. More accurate estimates could be made from satellite imagery by incorporating such factors into the discrimination process.

Identification of shrubs, grasses, and herbs

Other important plant food items in the study area utilized by the grizzly include huckleberry and grouseberry, *Vaccinium* spp., tubers of *Claytonia* spp. and *Lomatium* spp., and several other herbs and grasses. These occur as a low shrub understory among larger trees or small plants in open areas.

It was not possible to identify these species from the satellite imagery alone. Open alpine meadows could be easily distinguished from timber stands, but particular species could not be separated. Mapping meadows may provide data to estimate the amount of tuberous and other foods since composition of alpine meadow vegetation is stable. It can be assumed, for example, that the amount and distribution of *Claytonia* spp. and *Lomatium* spp. determined by sampling in one location would represent other alpine areas within the ecosystem.

Understory species, *Vaccinium* spp., were not visible, and their typing would probably be limited to identifying likely areas for ground sampling.

Some discrimination between visible vegetation types should be possible based on their association with indentifiable species (whitebark pine), or other factors as altitude, soil type, topography or a combination of these.

Since green plants are distinguished from dry or dead ones by higher reflectance in the infrared bands, a series of scenes at 18-day intervals can be used to determine phenological differences during spring late summer and fall. To the extent that this is species-specific, it provides a promising technique for distinguishing coniferous trees from hardwoods, and for identifying some hardwood species and agricultural crops (Dethier 1973).

Mapping snow cover

Information about snow conditions is helpful in grizzly studies since it affects behavior and seasonal availability of food.

Snow appeared distinctively in bands 4 & 5, where it has highest contrast with surrounding snow-free terrain. Although clouds and snow had about the same brightness, they could be distinguished because of differences in shape and the shadows that accompanied clouds. Boundaries of snowcovered areas are easily distinguished on bare or lightly-vegetated terrain, but become more difficult to recognize in heavy timber. These findings agree with those of other investigators (Barnes and Bowley 1973; Meier 1973; Weller 1973).

A time-lapse technique proved useful in determining changes in snow cover. Two band 4 images of the same area, one taken in August and one in October. were superimposed on the viewer. The August image was illuminated with green light, the October image with red. In areas where no changes in tone had occurred between the time images were taken, the resulting composite was a neutral greenish-gray. Areas that were lighter in the October image appeared red, and areas that were darker appeared green.

Areas covered with snow in October and not in August were bright red and easily distinguishable. Examination of this image with a topographic map overlay showed that the snow level on 3 October was at 3400 m (2300 m on north-facing slopes) in the study area.

Additional data for vegetation type mapping can be obtained from snow cover information, since it is closely related to moisture conditions. Differential melting rates and changes in snow field boundaries provide exposure and average temperature data that helps discriminate between some vegetation types indistinguishable by appearance alone. Appearance and flowering of certain plant species is closely related to snow field boundaries, so the location of these boundaries indicate vegetation type and general phenology.

DISCUSSION

The results of this preliminary investigation show that ERTS-1 multispectral scanner imagery can be of value in habitat analysis. Useful information about grizzly habitat can be obtained with minimal cost and effort. The authors have not had prior photointerpretation experience, so information may have been overlooked that could be obtained from the imagery. We plan to continue evaluating this technique in ongoing programs where habitat data are needed.

We feel that satellite imagery is most valuable at present as a supplement to, not a replacement for, field observations by personnel on the ground. Limitations in image resolution and kinds of information that can be obtained from multispectral scanning allow errors if used alone. The imagery can be used, however, to perform initial screening and to select these areas where field effort can be productively concentrated. In surveying wilderness areas to locate suitable reintroduction habitat, large portions could, for example, be eliminated on the basis of the imagery alone. Field work can then be focused on remaining locations which appear to meet minimum requirements. Examination of satellite imagery early in a study should thus allow an effective sampling strategy to be developed to minimize field effort and overall program cost.

Computer-assisted analysis of multispectral scanner images offers several advantages over the visual methods described in this paper, and we are investigating this technique to minimize subjective factors and reduce time required to classify larger areas. The general approach involves displaying a 3-band color composite image of the area under investigation on a CRT screen. The image is derived by transferring picture-element data from ERTS computer-compatible digital magnetic tapes to a buffer-storage system, which is in turn scanned to produce a periodically-refreshed color image on the CRT. The digital form of the image data permits a computer to be used to perform decision functions or computational algorithms upon each image element before it is displayed. This allows a variety of operations to be performed on the image such as density slicing, color enhancement, selective color display, and false-color display. It also permits 'learning' techniques to be applied in which a small portion of the image, for which ground truth is available, can be analyzed by the computer; similar areas in the remaining scene are then identified and displayed as one color on the CRT. This is a powerful method for developing land classification maps. The computer-enhanced images and type maps can then be compared with vegetation type maps obtained by selective ground sampling to validate the classifications.

Using techniques described, we could rapidly survey the three largest ecosystems in the western United States (Yellowstone, Selway-Bitterroot and Bob Marshall) to classify favorable grizzly habitat, to assist in making more accurate estimates of the present grizzly population and to locate the most promising sites for reintroduction. Such information is badly needed and could be obtained with comparatively modest funding. Together with extensive data on grizzly food habits, movements, ranges and bear ecology that has already been gathered, such a survey could provide several western states the means to evaluate hunting regulations and harvest, and better data than is now available for making management and land use decisions.

Satellite remote sensing methods are a valuable addition to the tools of the wildlife researcher and manager. The usefulness of ERTS-1 imagery will expand in the near future as other researchers develop analysis methods to increase types and quality of data obtained from the images. This should result in additional techniques useful in habitat analysis. Remote sensing will become increasingly valuable as equipment with improved resolution and additional spectral bands becomes available on future satellites.

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