ANALYSIS OF WINTER HABITAT BY MULTISPECTRAL REMOTE SENSING

by

Ralph R. Root, Graduate Research Assistant
Department of Watershed Sciences
Colorado State University

ABSTRACT

Remote sensing will prove to be a valuable tool for mountain sheep researchers in the near future. Multispectral sensing is the process of collecting and interpreting information from electromagnetic energy detected from a scene in several discrete wavelength bands from the ultraviolet, visible, and infrared regions. This technique can be used for evaluating important characteristics of bighorn sheep habitat, specifically the winter range, since this may be the time of greatest population stress. A description of the technique of multispectral sensing is given, along with a brief explanation of a method for automatically interpreting the sensor data by computer. Automatic interpretation of multispectral data has been done over a 12 square mile area in Yellowstone National Park with an overall accuracy of 86 percent correct identification of eight different mountain terrain types (Smedes et al. 1969). The success of the Yellowstone experiment suggests using a similar approach over bighorn sheep habitat to evaluate habitat characteristics considered important for maintenance of herd populations. Although present multispectral remote sensing surveys are costly, it might be possible to obtain data through other agencies which have collected imagery over bighorn habitat areas for other purposes. Imagery might also be collected on a cost share basis by several agencies, each with a specific interest in the data and target area. Multispectral imagery will soon be collected from satellite and will be available to researchers at a much lower direct cost than data obtained from aircraft. As remote sensing data collecting systems improve, and as interpretation techniques become more advanced, higher quality data will be available at increasingly lower cost.

Remote sensing is the process by which materials on the ground are recognized and mapped from a remote location by their reflection or emission of electromagnetic energy. Methods currently being developed in the field of remote sensing promise to be a valuable asset to mountain sheep researchers needing rapid analysis of terrain and vegetation features of winter and summer habitats. The technique of multispectral sensing and computerized image analysis is briefly discussed, and a study in Yellowstone National Park using these methods is reviewed. Application of remote sensing methods to the analysis of bighorn sheep winter range is suggested, as populations may often be under great stress during the winter months.

I am indebted to Dale Hein and Eugene Decker for initial suggestions pertaining to this paper, and I wish also to express my appreciation to Lee Miller, Alex Cringan, and James A. Smith for their advice and assistance in reviewing the manuscript.

MULTISPECTRAL REMOTE SENSING TECHNIQUES

Visible light represents only a small portion of the total electromagnetic spectrum, which ranges from very short wavelength gamma rays to very long wavelength radio waves (Fig. 1). Photographic sensors are capable of utilizing only that portion of the spectrum immediately adjacent to and including the range of human vision, extending short distances into the ultraviolet and infrared wavelengths. A recent development in photographic sensors is the multiband camera which simultaneously uses several lenses, each filtered to sense electromagnetic energy only in one discreet portion of the photographable spectrum. A simultaneous multiple set of images of the same scene is the result, and differences in character of the energy reflected from objects in the scene may be utilized by comparing the objects in each of the narrow wavelength band images produced. This is much the same method used in mapping materials on the ground with color film, but is not limited to one single wide spectral interval as with color film.

A much broader portion of the electromagnetic spectrum can be utilized by other non-photographic sensors. One important such instrument, called a multispectral scanner, measures levels of incoming energy in a number of discreet segments of the electromagnetic spectrum, called spectral or wavelength bands, over the range of .3 to 15 micrometers ($10^6 \mu m$ = 1 meter). This device collects data by rotating a mirror-telescope combination which scans the scene by sweeping out strips along the ground perpendicular to the line of flight (Fig. 2). At an instant of time the mirror receives energy from a spot along its current scan line called the instantaneous-field-of-view. The incoming energy is averaged over each instantaneous-field-of-view. Current scanners produce an instantaneous-field-of-view of 1 to 3 feet in diameter at 1000 feet above terrain, and sweep out scan lines 1000 feet wide. Successive scan lines are swept out as the plane advances forward, resulting in the coverage of a continuous strip of terrain 1000 feet wide below the aircraft, flying 1000 feet above terrain. The incoming energy received by the scanning mirror and telescope at each instant is directed into a prism or into a grating where it is broken up into a continuous wavelength spectrum. Discreet portions of this spectrum, called wavelength bands, are sensed by detectors which convert the energy received into electrical currents which are then recorded as parallel tracks on magnetic tape, each channel on the tape corresponding to a wavelength band in the sensor.

A schematic diagram shows the instrument response, where each vertical bar represents the level of energy sensed in each of the wavelength bands (Fig. 3). A curve is defined by these different energy levels measured in each wavelength band, and is called a

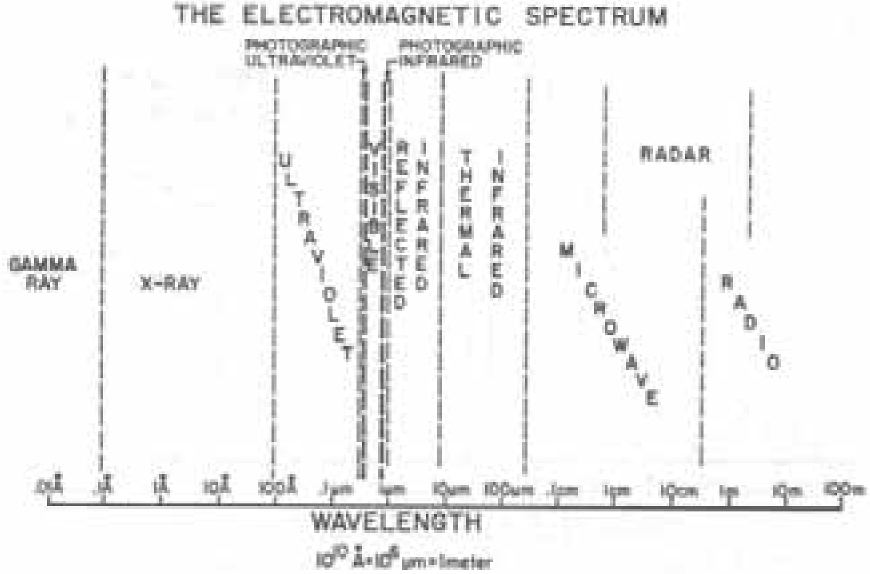


Fig. 1 ILLUSTRATION OF RELATIVE NARROWNESS OF THE VISIBLE PORTION OF THE ELECTROMAGNETIC SPECTRUM. Compare the visible band with the entire electromagnetic spectrum, from gamma rays to long wavelength radio waves. Note that wavelength is shown on a logarithmic scale.

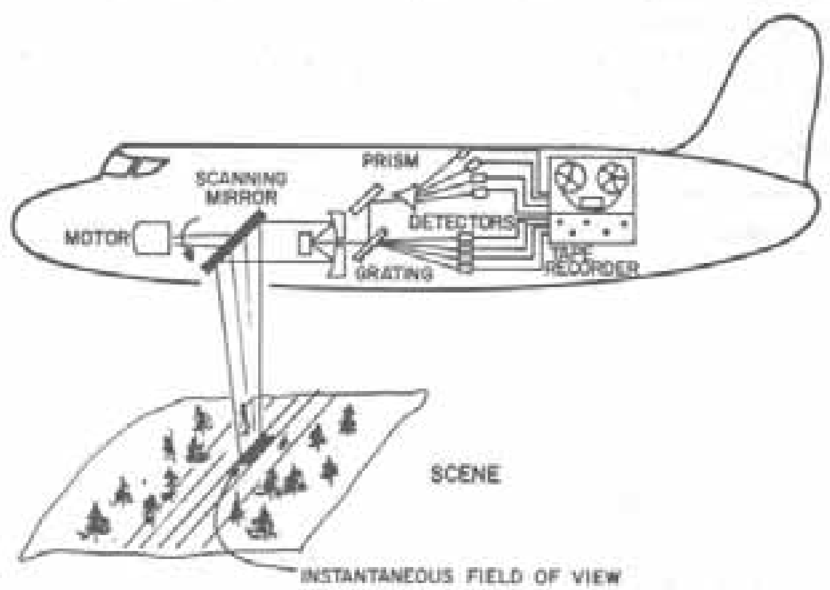


Fig. 2. SCHEMATIC DIAGRAM OF A MULTISPECTRAL SCANNER IN OPERATION. A rotating mirror and reflective telescope combination sweep out successive strips along the ground perpendicular to the line of flight, called scan lines. At any one instant on a given scan line the scanning mirror receives and averages energy from a spot in the scene called the instantaneous-field-of-view (IFOV). The energy received from each IFOV is broken down into a number of discreet wavelength bands by optical dispersing elements. The energy levels in each band are converted to electrical currents by detectors, and recorded on respective channels on magnetic tape for each successive IFOV sensed by the scanner. (Courtesy of Willow Run Laboratories, University of Michigan).

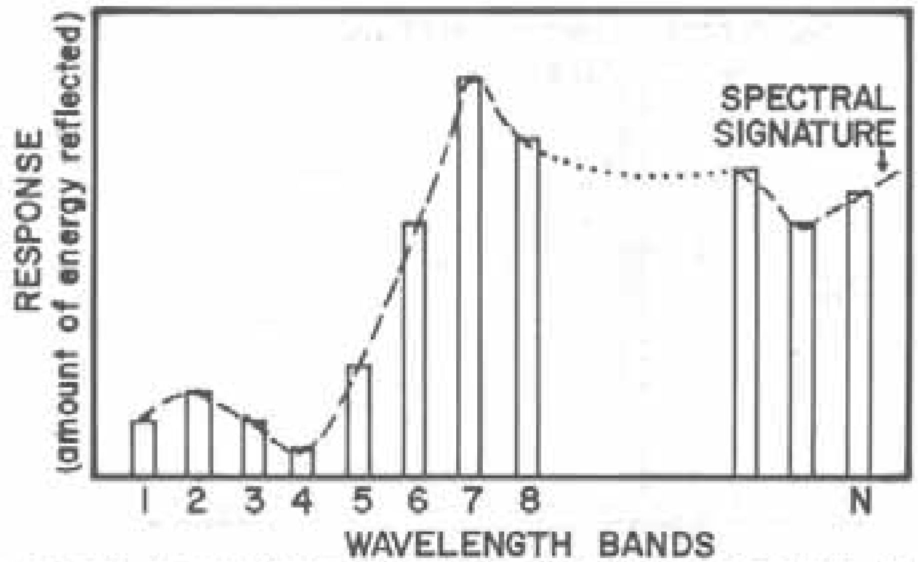


Fig. 3. GRAPHIC ILLUSTRATION OF SCANNER RESPONSE AS RECORDED ON MAGNETIC TAPE. Each vertical bar represents a wavelength band over which simultaneous data was collected. Bar height represents recorded detector output, which is directly proportional to the amount of energy received from the scene in that particular wavelength interval. The curve formed by the energy levels of all bands is the spectral signature received by the scanner for the instantaneous field-of-view currently being sensed. N = 12 channels for a multispectral scanner widely used at the present time. (Courtesy of Willow Run Laboratories, University of Michigan).

SPECTRAL SIGNATURES OF SOME GENERAL LAND COVER TYPES

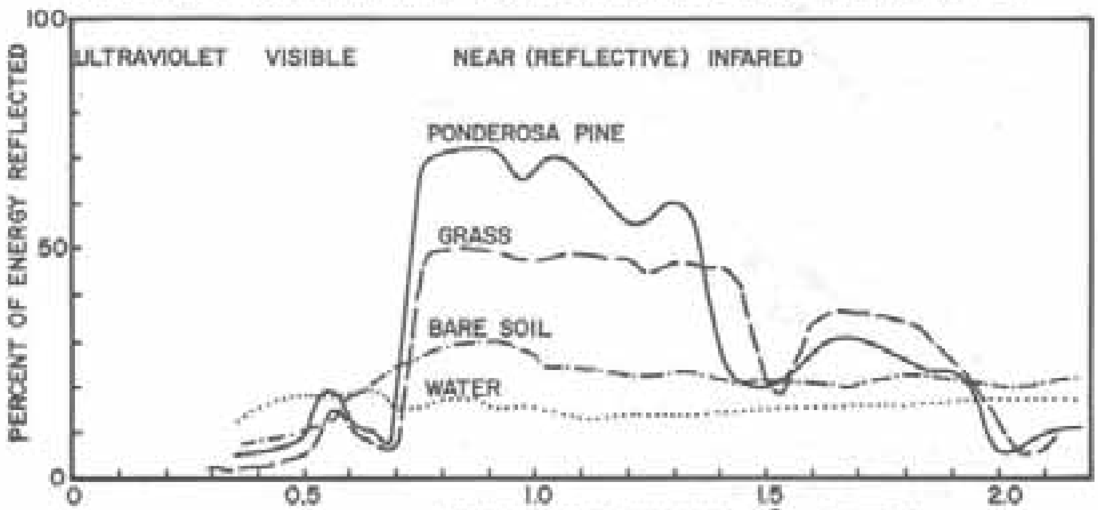


Fig. 4. SPECTRAL SIGNATURES OF SEVERAL MATERIALS COMMONLY FOUND IN WESTERN MOUNTAIN TERRAIN. Percent energy reflected, called reflectance, shown on the vertical scale is a ratio of the energy received from the scene to the energy incident upon the scene. Multispectral scanners measure only the energy reflected back from the scene, and in order to calculate reflectance the incident solar radiation must be simultaneously measured. (Courtesy of D. Earing, 1968).

wavelength or spectral signature. Every material has its own characteristic spectral signature, some being more similar or different than others (Fig. 4). The recorded levels of energy in the several wavelength bands of the multispectral scanner approximate spectral signatures. Different materials in the scene can be identified from the data after determining their spectral signatures. This is done by a computerized analysis technique known as spectrum matching in the following manner.

1. Decide what objects in the scene are to be identified, and go to the site on the ground to visually inspect and photograph typical examples of these objects and areas. No matter how sophisticated remote sensors become, there is no substitute for accurate ground truth data.

2. Collect multispectral imagery of the site at the optimal time of day and season, and also obtain aerial photographs of the area if no previous air photos are available.

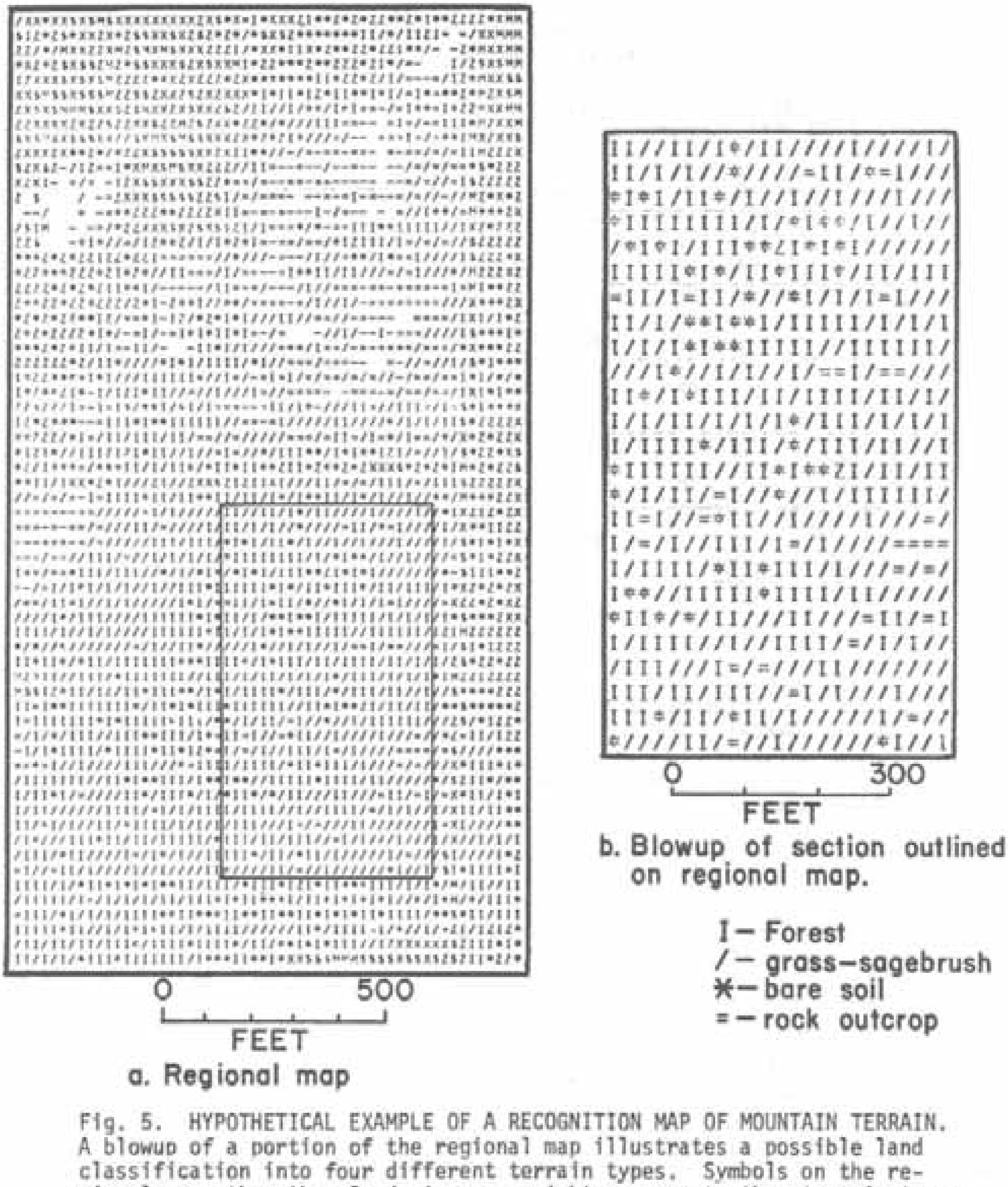
3. On the air photos locate objects which are representative of those chosen to be identified in the prior ground inspection reconnaissance. Locate these same objects and areas in the multispectral scanner data and determine the scanner response at these locations (i.e. the spectral signature) for each object and area.

4. Store the spectral signatures for each of the objects in the computer.

5. Have the computer go through all the scanner data along the flight line point by point, comparing the spectral signature at each unknown image point with the known spectral signatures determined above and representing the objects to be identified. If the signature of the unknown point matches a catalogued known signature, have the computer print out our appropriate identifying symbol at the location of the unknown point, on the computer line printer.

6. Repeat this process for all unknown image points in the scanner imagery. The final result is the computer printout of the identified points, called a recognition map (Fig. 5).

The multispectral scanner has a distinct advantage over photographic sensors in that it utilizes a much broader portion of the electromagnetic spectrum for making identifications. Spectral signatures determined by the multispectral scanner are longer curves, and therefore the potential for differentiating them is increased. New multispectral scanners are currently being tested which utilize more and more wavelength bands, and the total portion of the spectrum covered is continually increasing, which will make it possible for the process of pattern recognition to make very subtile distinctions between objects appearing similar to the human eye and camera in the visible band.



a. Regional map

Fig. 5. HYPOTHETICAL EXAMPLE OF A RECOGNITION MAP OF MOUNTAIN TERRAIN. A blowup of a portion of the regional map illustrates a possible land classification into four different terrain types. Symbols on the regional map other than I, /, *, or =, might represent other terrain types not classified in the enlargened region, such as snowfields, water, bog, etc.

EXPERIMENTAL APPLICATION OF THE PATTERN RECOGNITION PROCESS

A study of the effectiveness of computerized image analysis was completed recently on 12-band multispectral data collected over a 12 square mile area with 1800 feet of relief in northcentral Yellowstone Park (Smedes et al. 1969). Computer analysis was carried out in the manner described above to map eight terrain types, namely bedrock exposures, talus, vegetated rock rubble, glacial kame, glacial till, forest, bog, and water. Shadows cast by cliffs and cloud cover were also readily recognized. Overall accuracy of the results using four optimum wavelength bands of the 12 available bands was 86% correct identification of all image points. A recognition map of a portion of the 12 square mile area is shown in Figure 6.

Even though automatic image analysis techniques are still presently in the experimental stage with a few problems yet to be worked out, the success of the Yellowstone study suggests that a similar approach be applied to mapping bighorn sheep habitat. Human interpretation of air photos, although presently more accurate than automatic computer image analysis, is time consuming, tedious, and subjective. Computerized interpretation is much faster, less subjective, and can be repeated frequently in time, which is not possible with human interpretation.

APPLICATION TO HABITAT STUDY

Terrain types which are of importance to wintering herds of mountain sheep could be rapidly mapped in a manner similar to that employed in the Yellowstone study and the results used as an aid in making timely management recommendations. Examples of terrain types that represent winter sheep habitat in Colorado that might be mapped are rock outcrops, talus, vegetated rock rubble, snow, grass slope or meadow, sagebrush and grass, bare soil, lakes, and streams. However, the terrain types chosen will vary with geographic location, and within the same areas there might be variance among researchers as to what terrain types are of greatest significance to the maintenance of bighorn sheep populations. Rapid computer analysis of multispectral scanner imagery would enable several interpretations to be made of the same habitat area essentially simultaneously, allowing comparisons of different combinations of habitat factors.

Analysis of terrain types comprising bighorn sheep winter habitat and mapping by the proposed method have a number of potential applications. Range quality could be determined, perhaps by using a numerical index which is a ratio of grass to bare soil and rock. The greater the percent grass cover, the higher the quality of the range. Present multispectral sensors are capable of distinguishing vegetated areas containing as little as 20% difference in exposed bare soil. Thus when grassy areas are overgrazed to the extent that 20% more bare soil is exposed, a change in range quality can be detected, from the point of view of quantity of grasses present.

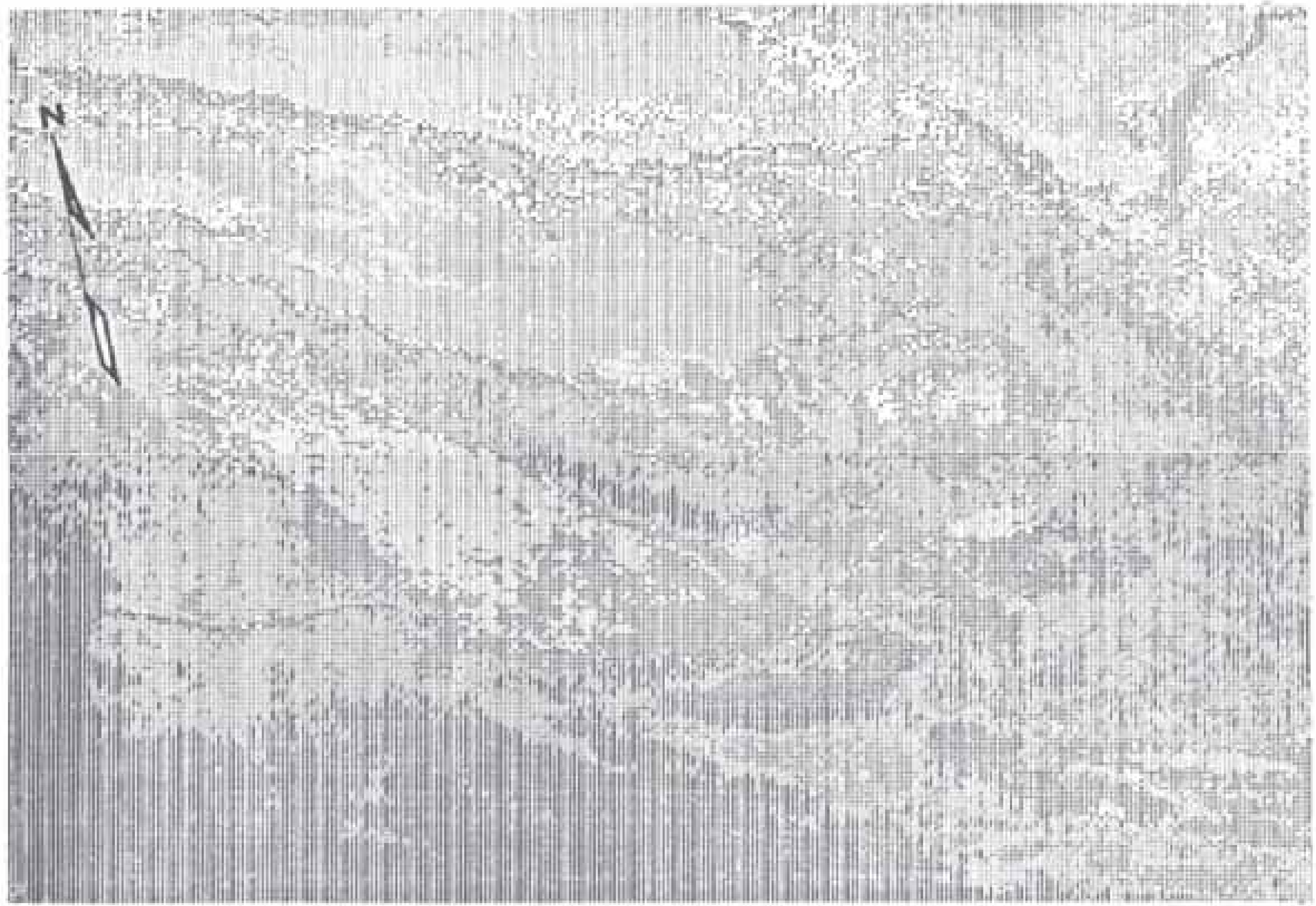


Figure 6. Recognition Map of a Segment of the Yellowstone Study Area (Courtesy of H. W. Smedes, 1969)

Symbols representing terrain classes are:

· Bedrock exposures	H. Shadows
$ Vegetated rock rubble	8 Talus
- Glacial till meadows	= Glacial kame meadows
: Bog	/ Forest
W Surface water	(Blank) Other

More intense habit study might lead to a better understanding of the lungworm life cycle by indicating a relationship between the incidence of carrier snails and particular habitat types or conditions. Perhaps the snails are found in certain definable areas from which the sheep could be exclosed, or the areas might be treated for the extermination of the lungworm.

Rapid analyses of ranges where transplants are proposed might indicate the chances for transplant success. Furthermore it may be necessary at times to quickly appraise areas for transplants if mountain sheep should become available on short notice from overpopulated herds in other locations.

In early 1972 the ERTS-A (Earth Resources Technology Satellite) will be orbiting the earth, collecting 4-band multispectral data completely covering North America every 18 days. The four wavelength bands to be used in the ERTS-A scanner were simulated in the experiment previously described (Smedes et al. 1969) to classify the eight terrain types in the Yellowstone study area, with an overall result of 80% correct identification, as opposed to the 86% accuracy obtained by using the optimum four wavelength bands from the aircraft scanner. The ERTS-A will be capable of resolving data elements of 230 feet in diameter (one acre) at an altitude of 500 nautical miles (Goldberg 1969), but in spite of this, relatively coarse instantaneous-field-of-view changes in vegetation condition over bighorn sheep habitat could be monitored nearly twice monthly, when cloud free. ERTS-B, to be orbited a year later than ERTS-A, will contain a similar scanner, but with an additional wavelength band in the thermal infrared. The manned Skylab missions in the mid to late 1970's will carry multispectral scanners capable of resolving 1/2 acre, and will utilize even more wavelength bands. Within five years it is probable that higher resolution sensors with a greater number of wavelength bands will be available for use in natural resource inventory programs. The ERTS-A satellite data will be made available to researchers who have submitted proposals to the National Aeronautics and Space Administration which are approved but not necessarily funded by NASA. Data might also be obtained through research projects sponsored by government agencies which have already made arrangements with NASA for procuring the satellite data.

At present, multispectral data collected by aircraft has much better ground resolution than orbital data, and is being collected over more and more of the Rocky Mountain West, as scanners become available to more organizations. Cooperation with other researchers and agencies interested in collecting multispectral data in or near mountain sheep habitat can make such imagery available at reasonable cost. As data collecting techniques have become more sophisticated and more costly the importance of cooperation between researchers for maximum economy and benefit becomes apparent. Researchers in most fields, including wildlife management, are presently in a position where emphasis should be placed on communication and cooperation, to take advantage of modern technology, rather than on independent study of their own disciplines.

LITERATURE CITED

Earing, D. 1968. Target signature analysis center/ data compilation. University of Michigan. Infrared and Optical Sensor Lab. Report 8492-16-B. Ann Arbor, Michigan. 3 volumes.

Goldberg, I. L. 1969. Design considerations for a multispectral scanner for ERTS. Purdue University. Symposium on Information Processing. pp. 658-672.

Smedes, H. W., K. L. Pierce, M. G. Tanguay, and R. M. Hoffer. 1969. Digital computer terrain mapping from multispectral data, and evaluation of proposed Earth Resources Technology Satellite (ERTS) data channels, Yellowstone National Park: preliminary report. National Aeronautics and Space Administration. Second Annual Earth Resources Aircraft Program Status Review. Volume 1, Section 1.

DISCUSSION

QUESTION BY WARREN KELLY, USFS CALIFORNIA: Is there any possibility of determining species of grasses with this method?

REPLY BY ROOT: I seriously doubt it. The field of view that we can look at is probably not small enough that we can isolate certain species and tell what their curves look like.

There is a project which is part of the International Biological Program which involves a spectral radiometer. This is a ground instrument that produces the spectral curves or the signatures that we are talking about. This radiometer can be focused on a particular species. We could look at, say blue grama, and get a curve for blue grama. It might be possible that you could match data in the air with the curve on the ground. We have problems in that we are looking at it from the ground. The angle of illumination might be a little different. The atmospheric conditions if we are flying over it might cause some interference. There might be possibilities but my answer right now is no, it cannot be done.

REPLY BY KELLY: I question whether or not you could get very good results on range quality unless you could determine species of range grasses which would be more prefereable to different species of animals.

REPLY BY ROOT: This is a good point. What I was really trying to refer to here more than anything is the idea of how much bare soil is showing through. If there is an area which the sheep do like and they do graze it heavily, then more and more bare soil will show through if they have to graze in that particular area. As the condition of the range deteriorates, we might be able to detect this.

QUESTION BY GENE DECKER, CSU: How available is the satellite information?

REPLY BY ROOT: It hasn't been collected yet, so that is a hard question to answer. I am sure that a well thought out research proposal from a University would be considered, but there will be red tape.

QUESTION BY KELLY: Is this the same satellite that they are going to use to determine some of this pollution that exists around the world?

REPLY BY ROOT: I am not sure offhand, but I would think so.

DISCUSSION FOLLOWING PANEL

QUESTION FROM DALE JONES, USFS, NEW MEXICO: I don't have any surefire method of censusing game, but I did have an opportunity to talk with a retired military man. He claims that right now the service has infra-red or another heat sensitive type films that he feels will someday be used to count wildlife. It will differentiate between species by heat emission, respiration rate and quite a few other things. He claims that right now they can tell you where just about every one of the humans are in Viet Nam, down to sex, creed and color. I am not so sure that the day of counting big game isn't too far off. Then I don't know what we are going to use for an excuse.

REPLY BY RALPH ROOT, CSU: I'd like to make a comment on that. A study has already been done using an infra-red scanner for censusing big game in Michigan. This was the same plane that flies the 12 channel scanner that flew the thermal infra-red scanner. It flew over a game preserve where there were roughly 100 deer which had been previously censused by ground methods. They were then counted by the thermal imagery. They show up as little white spots. The hotter the object is, the whiter it looks. The count from the air was as accurate or possibly more accurate than the one from the ground because a lot of the deer were in swamps or in other areas inaccessible to ground counting. I might add a word of caution. The conditions for this were ideal. There was an 8 inch snow cover and there were very uniform atmospheric conditions. It couldn't have been better.

Snow cover is very important because it allowed a very large difference between the background and the animal. In other words, a greater temperature differential will more readily be seen. In bighorn sheep studies, especially in Alaska where we are counting white Dall sheep against white snow, it might be of some benefit to census with infra-red scanners.

REPLY BY LYMAN NICHOLS, G & F ALASKA: We already tried it. I had an opportunity last year to run a test with a Daedalus scanner. We were trying initially to find whether we could locate moose in timber. I tried over a known number of moose in enclosures under a number of different conditions in the winter where the background was below freezing. I tried it at night, early in the morning and during the day. We could not differentiate them from the background at all in the timbered areas. We were able to pick out moose in the open during the day when they were actually reflecting the sun's heat.

I tried it over sheep and caribou. The sheep were right out in the open tundra before the sun came up. It was a cold background with everything very even. We flew right over the sheep but couldn't see a thing on the film.

Northern species are apparently so well insulated from the cold that they are not radiating enough heat to be detectable.

COMMENT BY RICHARD HANSEN, CSU: I would like to plead with everybody to devise methods which make work more efficient. But when it comes to these spectral signatures, which we will undoubtedly start to use in the future, I hope we have something besides grass and trees to put into the computer scheme. I think we need to put in the important factors that concern the productivity of the animal that we wish to perpetuate. These include the food sources as well as other protective sources. This is going to require people to go back and get down to the nitty gritty of actually measuring what species of plants are present and how much of each is present and the same with the diets. I hope when we do get to a computerized scheme of spectral scanning, the important things will be present.

COMMENT BY AL WOOLF, RACHELWOOD PENNSYLVANIA: In regard to censusing, I must make one comment concerning infra-red film. There is no such thing as an infra-red film that detects heat, nor will there be one. Infra-red film has just that narrow little band in the spectrum that he showed you. This is not heat-sensitive. In some items you get a color distinction but not in all. We are trying this with white-tailed deer and different films. There is no easy solution to censusing in sight right now.

In regards to thermal scanning even with something like deer, it's not a multi-spectoral scanning. We are just searching for the heat response. They can select the signature they want to record. How about if you have a deer lying there and he suddenly gets up and walks away? Are you going to pick up the bed and the deer? These types of problems exist.

In addition, in most cases, it's a real difficult interpretive job to look at this imagery and know what you are getting. It takes a real skilled person to do it.

COMMENT BY JERRY LIGHT, USFS, CALIFORNIA: Those of us who work for the United States Government have an opportunity to utilize, for training purposes, the photo labs of the Air Force. This has been done by some of us already. Those of us that haven't been doing it out to try it.

COMMENT FROM BRUCE GILL, G & F COLORADO: We've been working in cooperation with Dick Driscoll of the Rocky Mountain Forest and Range Experiment Station. We are concerned with how to census dead deer in Middle Park. The first question we ask is can you see a deer carcass using remote sensing techniques? We were flying over some experimental areas with colored infra-red anyway so we salted the area with carcasses at known locations. I put some under sagebrush, so they were partially covered by the crown, and some in the open. We were able to locate every carcass we put on the flight line. Not only were we able to locate the carcasses, but we could tell this year's dead deer from last year's because as the animal's decay, the nutrients that are leached out of the carcass are picked up by the plants. These show up as a pink ring around a two year old or older carcass. Now we are in the process of testing remote sensing against a known number of carcasses under a variety of conditions. Unfortunately, you cannot get the age structure of dead deer with remote sensing.

COMMENT BY H. DENNISON PARKER, G & F COLORADO: We have been trying for two years to get radiometer ground truth data to determine the delta T or temperature contrast which exist between mule deer and various objects in the background: snow, vegetation, rock and bare soil. All I can say at this point is that the technique would work quite well if you have 100% snow cover and I mean literally 100%. That is a limitation we cannot count on.

Further analysis will show what delta T's we can expect under various conditions. Next winter we hope to participate in a study to try a flight over the Middle Park area to test some of the results of this radiometry data. At the present time, we are doing statistical analysis on the delta T's that exist and the change of delta T's that exist as a function of environmental conditions to determine what is the best time to fly.

There is no question, theoretically or practically, that a body which differs from its background by a couple of degrees centigrade can be detected by the equipment we now have. The question is, as the man from Alaska eluded to a few minutes ago, is the delta T dependable when the animal has, for instance, the heavy insulation in the wintertime? I can't say it is at this time. We are still working on it.