# Large-Scale Sampling Photography for Forest Habitat-Type Identification

*Wm. Befort*
University of New Hampshire, Durham, NH 03824

ABSTRACT: To learn whether or not forest sites could be classified as to ecological habitat type by use of large-scale aerial sampling photography, 156 stands in northern Idaho and eastern Washington were photographed at scales around 1:1000. A type-identification key was assembled, and five interpreters were asked to assign habitat type labels to 111 stereophoto sample strips representing 16 field-identified habitat types. A success rate of approximately 75 percent was achieved. Extreme misclassifications were rare, and interpretations were highly correlated with the positions of the types along a bioclimatic gradient.

## INTRODUCTION

PRESENT TRENDS toward smaller aerial photograph scales make it doubtful that foresters will be able to measure such variables as tree height, crown diameter, and crown closure with acceptable precision on full-coverage stereophotography in the future. However, developments in small-format sampling photography at very large scales (1:2000 and larger) raise the possibility that, before long, many kinds of detailed resource data now ordinarily collected in the field will be obtained from airborne systems.

Small-format aerial photography has been with us for some time (Heller *et al.*, 1959, 1964); and large-scale sampling photos have been in use for years for special purposes such as forest damage surveys (Wear et al. 1966) and regeneration assessment (Aldrich *et al.*, 1959). Two important developments have taken place in the past decade: first, the number of "special purposes" has grown quite large; and second, equipment has been devised and standardized which permits exact determination of the scale of large-scale airphotos without reference to ground control (Nielsen *et al.*, 1979; Bradatsch *et al.*, 1981).

This "controlled-scale" photography, largely a Canadian achievement, has made possible a number of the newer applications. Apart from the timber-inventory purposes for which they were developed, controlled-scale systems have been employed in logging residue and fuels measurement, regeneration appraisal, forestry engineering, woodpile volume estimation, and development of growth simulation models. Availability of scale control may bring to general use a number of large-scale photo techniques developed for habitat analysis (e.g., Greentree and Aldrich, 1976). The present study was undertaken to find out if still another "special purpose" might be added to the growing list of applications.

## OBJECTIVE

The aim of the study was to learn whether the "habitat type" to which a forest site belongs can be reliably ascertained by interpretation of the vegetation on color aerial photography taken at a scale of about 1:1000.

A habitat type is defined as the set of all sites that produce similar plant communities at climax, i.e., at the theoretical endpoint of plant succession on those sites. Habitat-type systems allow resource managers to classify wildland sites as to capability and productivity by using existing or projected climax vegetation to epitomize the various environmental influences at work on the sites. The habitat-type label given to a forest site usually consists of the name of the dominant climax overstory species plus the name of a characteristic understory (usually shrub- or herb-layer) species. Thus, a common inland Northwest habitat type is *Pseudotsuga menziesii/Symphoricarpos albus* (Douglas-fir/snowberry).

In the years since habitat type classifications were developed by R.F. Daubenmire (1952, 1968, 1970) for forest and steppe vegetation of northern Idaho and eastern Washington, the principles of his system have been widely applied throughout the western United States by others (e.g., Steele *et al.*, 1981; Pfister *et al.*, 1977), and the system has been adopted by the U.S. Forest Service both for qualitative description of sites and as input to computer models for stand prognosis (Stage, 1973). The "management implications" pertaining to each type have been worked out in terms of species suitability and growth potential, optimum harvest and regeneration practices, response to disturbance, forage and browse productivity, and other considerations.

Habitat-type classification was devised on the as-

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sumption that it would be applied "on the ground," the forester visiting each site and examining vegetation composition and trends (Daubenmire, 1973). This is impracticable on large ownerships where field personnel are few; hence, various workers have attempted to map the distribution of types from topographic maps or conventional resource photography, first finding out by field investigation what elevations, slopes, and aspects are associated with particular habitat types, and then extrapolating the pattern to the area at large (Deitschman, 1973; Plumb, 1981). This approach has been less than completely successful, fundamentally because topographic maps and medium-scale resource photographs do not readily reveal all the environmental variables influencing the distribution of habitat types.

Other workers who have used medium-scale photography in ecological analysis (e.g., Bourne, 1931; Losee, 1942; Bajzak, 1960; Dechert *et al.*, 1981) have ordinarily employed this method of attempting to integrate various photointerpretable environmental factors into an expression of site capability. Daubenmire-style habitat-type analysis, in which the trend of vegetational development is itself used as the integrator of environmental variables, cannot realistically be performed on medium-scale photography, because such photography does not provide enough information about the composition, structure, and trend of vegetation communities. Even where the interpreter can identify overstory tree species with some accuracy, he cannot say whether the species represent climax or seral stages of succession.

If very large scale photography were to be used, on the other hand, an interpreter might be able to make habitat-type determination on much the same basis as if he visited the stand in person. Looking down into the stand, the interpreter could inspect the pattern of tree species regeneration and succession, and perhaps even distinguish—if only on the basis of gross morphology—among the shrub communities. Trained field workers ordinarily develop considerable facility at identifying the habitat type of non-climax stands by quite cursory examination of tree regeneration and shrub community physiognomy, and it seems possible that the same clues might be accessible from aerial photographs if the scale were large enough.

The question reduces to the fairly simple one of whether vegetation species, community structure, and successional trend can be adequately distinguished on such photography; and there is a good deal of evidence (Heller *et al.*, 1964; Driscoll *et al.*, 1970; Aldred and Lowe, 1978; Nielsen *et al.*, 1979; Bradatsch, 1980) in the affirmative. If habitat types can be identified with tolerable accuracy from large-scale photos, and if large-scale photography is about to come into general use for resource inventory purposes, the problem of habitat-type mapping is essentially solved, because even large ownerships can be heavily sampled in a short time and at low cost from the air.

## METHODS

The inquiry was conducted in five stages:

(1) About 150 sites representing various habitat types were located on the ground and then photographed from low altitudes;
(2) An aerial photo key to the types was prepared;
(3) Five interpreters were given preliminary training in habitat-type interpretation;
(4) Each interpreter was given a test set of 111 short strips of stereophotos, and were asked to identify the types shown; and
(5) The pattern of success and failure was analyzed.

There is no single habitat-type scheme covering the entire West; rather, there is a mosaic of somewhat different systems constructed at different times by different workers proceeding along the same general lines. The present study was confined by circumstances to the system established by R. and J. Daubenmire (1968) for the forest regions of eastern Washington and northern Idaho. There are 21 types in this system, ranging from the *Pinus ponderosa/Stipa comata* (ponderosa pine/needlegrass) type on droughty sites at low elevations to the *Pinus albicaulis/Abies lasiocarpa* (white-bark pine/subalpine fir) type at timberline. The total area covered by the Daubenmire system comprises some 400 7.5-minute topographic quadrangles. Of these, 44 were identified by reference to the Daubenmires' field notes as likely to contain sufficient representative examples of all types. Locations spanned 200 miles from the Clearwater River in Idaho to the Columbia River at the Canadian border in eastern Washington. In these quadrangles, field workers identified representative sites, recorded their locations on maps and orthophotoquads, documented them with terrestrial stereophotos, and sketched flight lines on the maps for aerial sampling. Sites could be in any stage of disturbance or succession, provided that they were positively identified as to type and large enough to be found and photographed from fixed-wing aircraft. Of the sites identified, 165 were selected for aerial photography, the number in each type being roughly proportional to the estimated acreage in that type across the entire region.

A total of 156 sites were photographed in late summer, with a Hulcher 70-mm camera equipped with a 360-mm Xenar lens, at an average scale of 1:900. Between six and 20 stereophotos were taken over each site, usually in a single strip. Two kinds of normal-color film were employed: Kodak Aerochrome MS 2448 and Kodak Aerocolor Negative 2445. Typical settings were *f*/4.5 and 1/700 second. After processing, the photos were taken to the field for positive identification of sites, plant species, and habitat types. Only 16 of the 21 types were well enough represented on the photography to be included in the identification test; some of the low-acreage types eluded photography.

A photographic key in looseleaf form was assembled from some of the sampling strips. For each habitat type, the key included a written description, a species list, at least one terrestrial stereogram, and at least one 70-mm aerial stereotriplet with all tree species labeled. The sites in the key were mostly "typical" near-climax examples of their habitat types, except that they possessed greater tree species diversity so that interpreters would have examples of all species. Sites in earlier successional stages of development were reserved for the identification test. The key was strictly descriptive and not dichotomously arranged. A typical double-page spread from the 47-page key appears as Plate 1. Plate 2 exemplifies the 70-mm photography used in the key and in the test.

All five interpreters had had formal training and field experience in applying habitat-type systems, and had completed at least a basic course in aerial photointerpretation. All either held or were candidates for advanced degrees in forestry. They were required to study the key and review the Daubenmires' (1968) habitat-type guide covering the region. Each went through a preparatory exercise in identifying species and habitat type on 12 non-test sites, followed by a critique. In training, interpreters were instructed to apply the Daubenmire classification system as if they were on the ground, comparing overstory composition with regeneration composition for evidence of successional processes, and using shrub- and forb-layer information as further classificatory data.

The test itself had three phases. In the first, the interpreter received the test set of 111 sampling strips (three to seven photos each), was told that each strip represented a single habitat type, and was asked to examine the strips stereoscopically (at up to 4X magnification) and to assign a habitat type label to each strip. In the third phase, the interpreter was additionally given, with each strip, two map segments showing its geographic location, physiographic setting, and precise topographic situation. Interposed between these two, partly in hopes of eliminating visual carryover between them, was another phase in which the interpreters used only the two maps for each site and attempted to predict habitat type from the geographic, physiographic, and topographic information on the maps alone, without photographs.

## DATA ANALYSIS

Test results were subjected to analysis of variance, error matrix analysis, and nonparametric correlation analysis. Befort (1983) gives full details of statistical treatment.

Interpretations were tabulated in 18 error matrices (confusion matrices), one for each interpreter in each test phase plus three all-interpreters matrices. Dimensions were 21 by 21, as interpreters had no knowledge that some types were not included in the test. One of the matrices appears as Table 1.

Various statistics were calculated from the matrices. For all habitat categories represented, percentages of correct classifications (PCC) were calculated for each interpreter and phase. For each matrix, Cohen's K coefficient of agreement was computed in order to correct matrix PCC's for the effects of chance agreement or "lucky guesses" (Cohen, 1960; Congalton and Mead, 1983). In order to obtain a similarly deflated PCC figure in each habitat category of each test phase, conditional agreement indices $K_i$ were computed according to Light's (1971) procedure. Table 2 gives combined-interpreter $K_i$ scores for each represented type in each test phase. Table 3 shows confidence intervals for matrix K values as calculated by Cohen's (1960) method, and for matrix PCC values as calculated by the method of Hord and Brooner (1976).

Analysis of variance performed on arcsine-transformed $K_i$ scores following the procedure of Rosenfield *et al.* (1980, 1981) showed highly significant differences attributable to all main effects (habitat type, interpreter, and test phase) and all two-way interactions. Comparison of least-squares means for the phase $x$ interpreter interaction showed the two photographic-phase scores significantly superior to the map-only scores for nearly all combinations of interpreters, but turned up few differences between the photographic phases. The same comparison was made by testing matrix K scores for differences (Congalton and Mead, 1983), with virtually identical results.

A salient feature of test results was that misclassifications, particularly in the photographic phases, were decidedly non-random. If a given site was misclassified, it was likely to be placed in a category not far removed (in ecological terms) from its true class. This tendency was obvious from the error matrices, wherein the types (see Table 1) were arranged in the order in which habitat-type workers (Daubenmire, 1966; Pfister, 1976; Johnson, 1981) rank them along an environmental gradient ranging from warm, droughty low-elevation conditions (*Pinus ponderosa* series) to cool, moist, high-elevation conditions (*Abies lasiocarpa* series). Accepting this arrangement, and assuming that the practical consequences of misclassification increase with the distance separating interpreted from actual type along this gradient, then the distance of a matrix entry from the diagonal is proportional to the seriousness of misclassification. This model, however approximate, suggested that some measure of linear correlation might provide an index of agreement as significant (in this case) as the standard K-related coefficients, because the latter, although they account well for chance agreement, treat all errors alike.

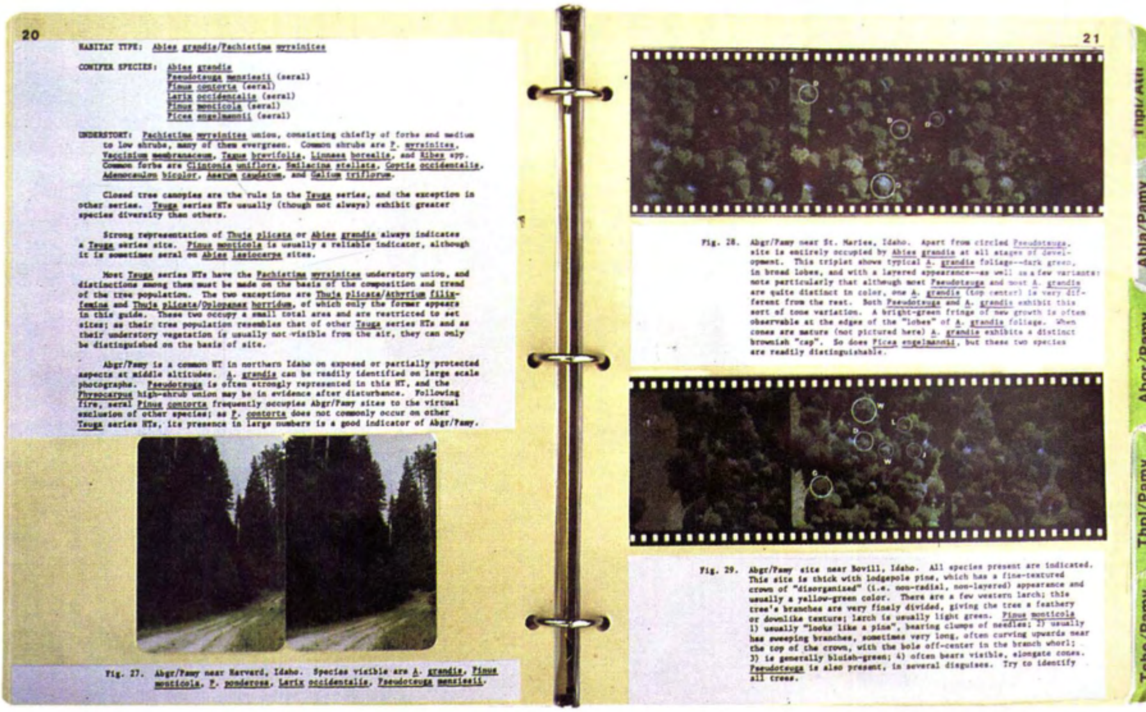


PLATE 1. The key gave each habitat type a double-page spread. On the left, a description of the type and its identifying characteristics, with a terrestrial stereogram; on the right, two 70-mm large-scale triplets, with examples of tree species encircled, together with descriptive captions. Key was thumb-indexed for interpreter convenience.

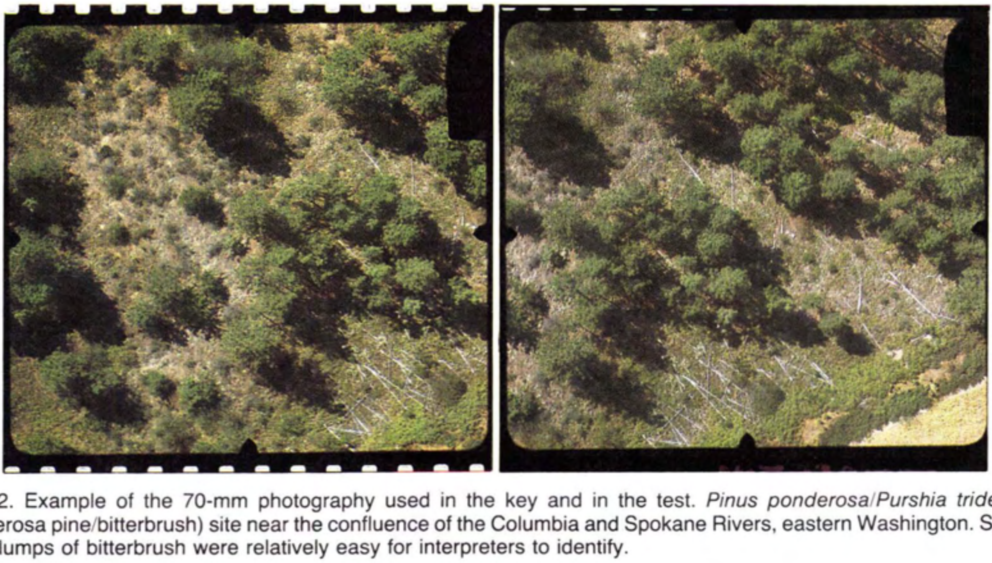

PLATE 2. Example of the 70-mm photography used in the key and in the test. *Pinus ponderosa/Purshia tridentata* (ponderosa pine/bitterbrush) site near the confluence of the Columbia and Spokane Rivers, eastern Washington. Sparse grey clumps of bitterbrush were relatively easy for interpreters to identify.

### TABLE 1. ERROR MATRIX, ALL INTERPRETERS, PHOTO + MAP PHASE

Distribution of habitat type labelings

| Actual Habitat Type | No. of plots | % Correct | Pipo/Stco | Pipo/Agsp | Pipo/Feid | Pipo/Putr | Pipo/Syal | Pipo/Phma | Psme/Syal | Psme/Phma | Psme/Caru | Abgr/Pamy | Thpl/Pamy | Tshe/Pamy | Thpl/Atfi | Thpl/Opho | Abla/Pamy | Abla/Xete | Abla/Mefe | Tsma/Xete | Tsme/Mefe | Abla/Vasc | Pial/Abla | $K_i$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pipo/Stco | 5 | 60 | 3 | | 1 | 1 | | | | | | | | | | | | | | | | | | 60 |
| Pipo/Agsp | 10 | 50 | | 5 | 2 | | | | 3 | | | | | | | | | | | | | | | 49 |
| Pipo/Feid | 15 | 53 | | 5 | 8 | 2 | | | | | | | | | | | | | | | | | | 52 |
| Pipo/Putr | 10 | 100 | | | | 10 | | | | | | | | | | | | | | | | | | 100 |
| Pipo/Syal | 15 | 73 | | | | | 11 | 4 | | | | | | | | | | | | | | | | 73 |
| Pipo/Phma | 10 | 80 | | | | | 1 | 8 | | 1 | | | | | | | | | | | | | | 79 |
| Psme/Syal | 20 | 60 | | | | | 2 | | 12 | 3 | 1 | 2 | | | | | | | | | | | | 59 |
| Psme/Phma | 60 | 42 | | | | | | 4 | 4 | 25 | | 25 | 2 | | | | | | | | | | | 38 |
| Psme/Caru | 0 | -- | | | | | | | | | | | | | | | | | | | | | | -- |
| Abgr/Pamy | 100 | 88 | | | | | | | | | | 88 | 11 | | | 1 | | | | | | | | 85 |
| Thpl/Pamy | 155 | 95 | | | | | | | | | | 4 | 148 | 3 | | | | | | | | | | 94 |
| Tshe/Pamy | 55 | 85 | | | | | | | | | | | 7 | 47 | 1 | | | | | | | | | 84 |
| Thpl/Atfi | 0 | -- | | | | | | | | | | | | | | | | | | | | | | -- |
| Thpl/Opho | 0 | -- | | | | | | | | | | | | | | | | | | | | | | -- |
| Abla/Pamy | 20 | 70 | | | | | | | | | | 2 | | | | | 14 | | 4 | | | | | 69 |
| Abla/Xete | 30 | 43 | | | | | | | | | | 2 | 1 | | | | 9 | 13 | 5 | | | | | 42 |
| Abla/Mefe | 10 | 80 | | | | | | | | | | | | | | | 1 | | 8 | | 1 | | | 79 |
| Tsme/Xete | 15 | 80 | | | | | | | | | | | | 1 | | | | | | 12 | 2 | | | 80 |
| Tsme/Mefe | 25 | 92 | | | | | | | | | | | | 1 | | | | | 1 | | 23 | | | 92 |
| Abla/Vasc | 0 | -- | | | | | | | | | | | | | | | | | | | | | | -- |
| Pial/Abla | 0 | -- | | | | | | | | | | | | | | | | | | | | | | -- |
| Percent correct labeling: | | | 100 | 50 | 73 | 77 | 79 | 50 | 63 | 86 | 0 | 72 | 88 | 90 | 0 | 0 | 58 | 100 | 44 | 100 | 88 | -- | -- | |

TABLE 2. $K_i$ SCORE BY TYPE AND PHASE, ALL INTERPRETERS (EXPRESSED AS PERCENTAGE CORRECT)

| Habitat Type | # Plots | Photo | Map | Photo & Map |
|---|---|---|---|---|
| Pinus ponderosa/Stipa comata | 5 | 80 | 0 | 60 |
| Pinus ponderosa/Agropyron spicatum | 10 | 29 | 29 | 49 |
| Pinus ponderosa/Festuca idahoensis | 15 | 46 | 18 | 52 |
| Pinus ponderosa/Purshia tridentata | 10 | 90 | 69 | 100 |
| Pinus ponderosa/Symphoricarpos albus | 15 | 73 | 45 | 73 |
| Pinus ponderosa/Physocarpus malvaceus | 10 | 79 | 29 | 79 |
| Pseudotsuga menziesii/Symphoricarpos albus | 20 | 64 | 33 | 59 |
| Pseudotsuga menziesii/Physocarpus malvaceus | 60 | 45 | 27 | 38 |
| Abies grandis/Pachistima myrsinites | 100 | 76 | 20 | 85 |
| Thuja plicata/Pachistima myrsinites | 155 | 84 | 37 | 94 |
| Tsuga heterophylla/Pachistima myrsinites | 55 | 88 | 22 | 84 |
| Abies lasiocarpa/Pachistima myrsinites | 20 | 58 | 1 | 69 |
| Abies lasiocarpa/Xerophyllum tenax | 30 | 35 | 51 | 42 |
| Abies lasiocarpa/Menziesia ferruginea | 10 | 69 | 59 | 79 |
| Tsuga mertensiana/Xerophyllum tenax | 15 | 59 | 19 | 80 |
| Tsuga mertensiana/Menziesia ferruginea | 25 | 79 | 18 | 92 |

TABLE 3. 95 PERCENT CONFIDENCE INTERVALS FOR AGREEMENT SCORES AND PERCENT-CORRECTLY-CLASSIFIED DATA (EXPRESSED AS PERCENTAGE CORRECT)

| | | | K Index (Cohen, 1960) | | | PCC Data (Hord and Brooner, 1976) | |
|---|---|---|---|---|---|---|---|
| Phase | Intp. | Lower | K | Upper | Lower | PCC | Upper |
| Photo | All | 65.0 | 69.3 | 73.6 | 70.1 | 73.9 | 77.4 |
| Map | All | 24.1 | 28.9 | 33.7 | 35.3 | 39.3 | 43.4 |
| Photo and Map | All | 70.6 | 74.6 | 78.6 | 74.8 | 78.4 | 81.6 |
| Photo | MH | 70.4 | 78.8 | 87.2 | 73.8 | 82.0 | 88.0 |
| | RB | 65.5 | 74.5 | 83.5 | 69.9 | 78.4 | 85.0 |
| | KS | 55.9 | 65.9 | 75.9 | 62.2 | 71.2 | 78.8 |
| | RR | 49.9 | 60.2 | 70.5 | 56.6 | 65.8 | 74.0 |
| | JU | 58.1 | 67.7 | 77.3 | 63.1 | 72.1 | 79.6 |
| Map | MH | 20.7 | 31.1 | 41.5 | 31.0 | 39.6 | 48.9 |
| | RB | 23.5 | 34.5 | 45.5 | 36.1 | 45.0 | 54.3 |
| | KS | 25.8 | 37.0 | 48.2 | 38.6 | 47.7 | 56.9 |
| | RR | 7.5 | 17.3 | 27.1 | 21.2 | 28.8 | 37.8 |
| | JU | 14.5 | 24.8 | 35.1 | 26.9 | 35.1 | 44.3 |
| Photo and Map | MH | 72.2 | 80.4 | 88.6 | 75.9 | 83.8 | 89.5 |
| | RB | 61.8 | 71.2 | 80.0 | 66.9 | 75.7 | 82.7 |
| | KS | 53.4 | 63.6 | 73.8 | 60.3 | 69.4 | 77.2 |
| | RR | 70.4 | 78.8 | 87.2 | 73.8 | 82.0 | 88.0 |
| | JU | 69.4 | 77.9 | 86.4 | 72.8 | 81.1 | 87.3 |

The habitat types were, therefore, ranked in order according to position on the habitat gradient, and two non-parametric correlation coefficients, Spearman's and Kendall's, were calculated for each matrix. These appear in Table 4; coefficients for the two photographic phases suggest that most interpreters could account for about 90 per cent of the between-type variability encountered in the test.

## RESULTS AND DISCUSSION

Several general conclusions seem warranted:

- Locational and topographic maps added little to the photointerpreters' ability to identify habitat types in this test;
- Achievable accuracy for beginning habitat-type interpreters probably lies somewhere within the confidence interval calculated for the K index in the third

TABLE 4. NONPARAMETRIC CORRELATION COEFFICIENTS, INTERPRETED VERSUS ACTUAL HABITAT TYPE

| Phase | Interpreter | Coefficients Spearman | Kendall |
|---|---|---|---|
| Photo | All | 0.916 | 0.863 |
| Map | All | 0.760 | 0.650 |
| Photo and Map | All | 0.958 | 0.921 |
| Photo | MH | 0.966 | 0.935 |
| | RB | 0.957 | 0.922 |
| | KS | 0.904 | 0.852 |
| | RR | 0.881 | 0.803 |
| | JU | 0.888 | 0.836 |
| Map | MH | 0.802 | 0.697 |
| | RB | 0.804 | 0.703 |
| | KS | 0.739 | 0.634 |
| | RR | 0.729 | 0.606 |
| | JU | 0.744 | 0.631 |
| Photo and Map | MH | 0.971 | 0.941 |
| | RB | 0.968 | 0.935 |
| | KS | 0.914 | 0.861 |
| | RR | 0.970 | 0.944 |
| | JU | 0.976 | 0.946 |

phase of the test (Table 3): i.e., 74.6 per cent correct, plus or minus 4 percent, after adjustment for chance agreement; and

- Photointerpreted identifications were highly correlated with the standard arrangement of types along a temperature/elevation/moisture gradient: i.e., most classification errors were not radical errors.

Whether 75 percent accuracy and 90 percent correlation with ground truth is "good enough" is, of course, debatable. The test was severe, in that interpreters worked under significant handicaps which would not be present in an operational situation. The test area was very large, no interpreter was familiar with all of it, interpreters lacked experience in this kind of photointerpretation, and sites were considered in isolation from one another, without any comparisons, collation, or corrective feedback.

The habitat type system in the West is not in finished form. Classification criteria differ among regions, and new systems supersede old ones; proliferation of types is the rule. However, in any local area (such as a National Forest district) only a dozen out of the scores of catalogued types are likely to be present; thus, the multiplicity and variety of types now recognized need not deter photointerpreters. Seriously disturbed sites will, of course, pose problems for the interpreter, much as they do for the field worker.

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### Washington, D.C.

*24–26 March 1986—Digital Geographic Information Systems*

The course concentrates on the requirements and techniques for managing and controlling geographic data within digital geographic information systems. It introduces the concepts of geographic analysis and emphasizes the need to assess simultaneously point, polygon, and raster (image) data. These concepts and the forthcoming interchange format family to be used for Landsat-D data (already in use in Canada for Landsat and polygon data) are explained.

*31 March–3 April 1986—Video Disk Technology with Business and Government Applications*

This course enables participants to apply video disk technology to the rapidly expanding information revolution in the business and government sectors. It is an introduction to video disk technology and its application for data storage and retrieval of various information types.

For further information please contact Darold Aldridge, (202) 676-6106 or toll-free (800) 424-9773.