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APPLICATION OF ERTS IMAGERY TO THE STUDY OF
CARIBOU MOVEMENTS AND WINTER HABITAT

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PREFACE

The objectives of the investigation were to determine feasibility of applying ERTS-1 data to caribou management problems in northern Alaska.

Specific tasks included assessment of snow conditions in relation to annual migratory movements, detection of disturbed snowcover in wintering areas, detection of large aggregations of animals, detection of major trail systems, and winter habitat mapping and analysis.

Conclusions indicate feasibility for mapping snowcover, monitoring phenology of snowcover changes in relation to caribou movements, and illustrate potential for application to long term studies of the influence of snow conditions on the routing and rate of migratory movements.

Habitat mapping and analysis is feasible with bulk MSS digital tape data. Broad application potential wildlife management is indicated.

No conclusive results were obtained with regard to detection of disturbed snowcover on wintering areas, large animals aggregations, and trail systems because of a combination of unfavorable circumstances.

Summarizing recommendations, our most immediate general need is development or local implementation of a software package for direct processing of digital tapes at local computer facilities. Because of the inefficiency of CDU-200 tape format for algorithmic multiband classification analyses, direct processing software utilizing available disc memory capability and efficient language is required to minimize costs for broad scale application. Therefore, local implementation of one or more algorithmic classifiers using maximallly efficient software for our facilities is the greatest current research priority. Next, further organized cooperative efforts with wildlife and fisheries management agencies is required for operational use in habitat evaluation and mapping. Finally, integration of data in a comprehensive classification analysis on a state-wide basis should be accomplished as soon as possible. Because the wildlife resources of Alaska are among the most important in the State, this comprehensive inventory should receive high priority particularly in light of the rapid pace of development and land selection by governmental and private groups.

Increased ability to monitor ephemeral events and phenological changes of biological importance will require satellites with more frequent overpasses of the state.

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16. Abstract

The project investigated the feasibility of applying ERTS-1 data to wildlife management tasks in Alaska, with particular reference to caribou biology. Research effort was confined to Arctic Alaska and addressed the following objectives: 1. Mapping of seasonal snowcover conditions, 2. Detection of disturbed snowcover in caribou feeding areas, 3. Detection of heavily used caribou trail systems, 4. Detection of large caribou aggregations, and 5. Analysis and mapping of caribou winter range. Results indicate strong potential for application of ERTS data to understanding snow-related factors influencing migrations of caribou and winter range use by caribou and muskox. The VP-8 image analyzer was found to be a highly useful tool for rapid snowcover mapping. Supervised classifications with heuristic algorithms were applied to ERTS digital data for habitat analyses and aspect-ratio corrected computer printed habitat maps were produced. Feature extraction analyses for specific vegetation-related habitat factors indicate potential broad scale application to wildlife habitat analysis and mapping in Alaska. Recent wildfire burn areas are easily identified and mapped using these techniques. Analyses for trail systems, winter feeding areas, and caribou aggregations were impeded by equipment failures and lack of adequate ground-truth and results of these analyses remain inconclusive.

17. Key Words (Selected by Author(s)) ERTS, Alaska, Snow, Caribou, Habitat, Wildlife	18. Distribution Statement

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LIST OF ABBREVIATIONS

ACWRU = Alaska Cooperative Wildlife Research Unit

ADF&G = Alaska Department of Fish and Game

ANWR = Arctic National Wildlife Range

BSF&W = Bureau of Sport Fisheries & Wildlife

CDU 200 = Digital color display system manufactured by Interpretation Systems, Inc.

MSS = Multispectral Scanner

NDPF = NASA Data Processing Facility

USFS = United States Forest Service

VP-8 = Image analyzer with density slicing capabilities manufactured by Interpretation Systems, Inc.

CAV = Color Additive Viewer

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APPLICATION OF ERTS IMAGERY TO THE STUDY OF CARIBOU MOVEMENTS AND WINTER HABITAT

INTRODUCTION

The purpose of this investigation was to determine the feasibility of applying ERTS-1 data to problems of caribou biology and management in northern Alaska. Specific goals of the investigation included assessment of snow conditions in relation to caribou migrations, detection of disturbed snowcover in wintering areas, detection of large aggregations of animals, detection of major trail systems, and habitat analyses on caribou winter range.

Field work was confined primarily to northeast Alaska north of the Porcupine River and east of the Sagavanirktok and Chandalar drainages. However, two reconnaissance flights were made to northwest Alaska in June and July of 1973. Activity in the field consisted of aerial reconnaissance of caribou distribution, air and ground reconnaissance of winter range areas, and detailed studies of vegetative composition in habitat types.

The initial analytic effort emphasized determinations of the practicality and effectiveness of attempting various feature discriminations. For each task the feasibility and information retrieval capability of a variety of analytic techniques was tested. These techniques ranged from simple direct visual interpretation of single band or color composite products to multiband discriminate analyses of digital tapes. This testing of a variety of techniques was considered an important aspect of the investigation in order to evaluate the level of training and equipment necessary to make the use of ERTS imagery operational in resource management agencies.

MAIN TEXT

I. Data used in the investigation

Summaries of the data used or obtained in connection with the investigation are shown in Tables 1, 2 and 3. Most of the ground truth and low level aircraft data was gathered with the financial or logistic support of agencies other than NASA, primarily the U.S. Bureau of Sport Fisheries and Wildlife.

II. General methods of data analysis

Preliminary processing of incoming data involved visual examination of 70mm positive transparencies. Based on this examination, specific scenes were selected for analysis and an order was placed with NDPF for 9.5" positive transparencies, a 9.5" false color composite transparency, and a digital tape.

When these products arrived, a CDU tape was produced for a selected portion of the scene. Next, a frequency histogram program was applied to the CDU tape to determine density distribution in the various bands. Based upon results of this determination, a tape printout of digital densities was produced in one output of coded format or , if the histogram indicated the range was too great, two outputs were produced, namely, a "tens" and a "units" printout.

Printouts were analysed by locating feature target areas and extracting

TABLE I

ERTS Data Utilized in the Investigation

Scene ID	Date	Location	Visual	Type of Analysis & Processing			Gaussian Linear Discriminant	Heuristic Algorithm
				CAV	VP-8	CDU		
1016-21052	8 Aug 72	Barter I.	X					
1030-20424	22 Aug 72	Demarcation	X					
1050-20541	11 Sep 72	Demarcation	X	X	X			
1051-21002	12 Sep 72	Arctic	X	X	X	X	X	
1063-20271	24 Sep 72	Taylor Hwy	X	X				
1086-20543	17 Oct	Mt. Michelson	X	X				
1086-20545	17 Oct	Arctic Quad.	X					
1087-21004	18 Oct 72	Arctic Quad	X	X				
1087-21010	18 Oct 72	Chandalar	X					
1088-21062	19 Oct 72	Arctic	X					
1102-20434	2 Nov 72	Colleen	X					
1102-21441	2 Nov 72	Fort Yukon	X					
1103-20493	3 Nov 72	Arctic-Colleen	X					
1103-20495	3 Nov 72	Fort Yukon	X					
1103-20502	3 Nov 72	Fairbanks	X	X				
1105-21010	5 Nov 72	Arctic Quad	X	X				
1247-20500	27 Mar 73	Arctic -						
	27 Mar 73	Table Mtn.	X		X	X	X	
1277-21584	26 Apr 73	DeLong Mtns.	X		X			
1301-20494	20 May 73	Arctic -						
	20 May 73	Christian-Colleen			X			
1313-21582	1 Jun 73	Noatak R.			X			
1375-20595	2 Aug 73	Arctic-						
		Sagavanirktok	X			X	X	
1375-21002	2 Aug 73	Arctic Quad.	X		X	X	X	X
1407-20371	3 Sep 73	Fort Yukon	X		X	X	X	X

TABLE 2

Aircraft Data Utilized in the Investigation

Source	Dates	Mission Objective	Map Scale	Photo Products
ADF&G	Jul-Aug 72	Air Recon. mapping of caribou trail systems	1:63,360	35mm
ADF&G	Jul-Aug 72	Air Recon. mapping of selected habitat types	1:250,000	None
ANWR (BSF&W)	8 Oct 72	Air recon. of caribou distribution in the Sheenjek Valley	1:250,000	35mm
ADF&G	20 Nov 72	Air recon. of caribou distribution southwest of Arctic Village	1:250,000	None
ACWRU	27 Nov 72 28 Nov 72	Air recon. & photography of caribou distribution on south slope of Philip Smith Mtns.	1:250,000	35mm 70mm
ACWRU	27 Mar 73 27 Mar 73 29 Mar 73	Air recon. & photography of caribou wintering areas	1:250,000	35mm
ACWRU	21 May 73	Air recon. & photography of snowmelt conditions on caribou wintering areas	1:250,000	35mm 70mm
ACWRU	Jun 73	Air recon & photography in NW Alaska - calving grounds	1:250,000	35mm 70mm
ANWR (BSF&W)	26 Jun 73	Air recon of habitat types and ground test site selection	1:250,000	None
ACWRU (BSF&W)	Jul 73	Air recon. of post calving groups in NW Alaska	None	None
ANWR (BSF&W)	9 Jul 73	Air recon. & photography of test sites; test site selection	1:250,000	70mm
ANWR (BSF&W)	17 Jul 73	Air recon. & photography of test sites; test site selection	1:250,000	70mm
ANWR (BSF&W)	25 Jul 73	SAME AS ABOVE (17 Jul 73)	1:250,000	70mm
ANWR (BSF&W)	7 Aug 73	SAME AS ABOVE	1:250,000	70mm
ANWR (BSF&W)	8 Aug 73	SAME AS ABOVE	1:250,000	70mm
ANWR (BSF&W)	16 Aug 73	SAME AS ABOVE	1:250,000	None
Renewable Resources	16 Aug 73	SAME AS ABOVE	1:250,000	70mm
Renewable Resources	19 Aug 73	SAME AS ABOVE	1:250,000	None
ANWR (BSF&W)	20 Aug 73	SAME AS ABOVE	1:250,000	None
ANWR (BSF&W)	30 Aug 73	SAME AS ABOVE	1:250,000	70mm

TABLE 3

Ground truth data obtained during the investigation

Source	Dates	Type	Location
ACWRU	8-12 Apr 72	Measurement of nival characteristics on wintering areas	Anvil Lake (68°23'N - 145°38'W)
ACWRU/ ANWR	11 May 72 to 8 Jun 72	Ground observation of caribou migrational progress	VABM Gwen (69°36'N - 142°10'W)
ADF&G & ACWRU	16 Jun 72 to 5 Jul 72	Formation and sex-age composition of post calving aggregation.	Beaufort Lagoon - Camden Bay
ACWRU	27-29 Mar 73	Measurement of nival characteristics on winter range	Selected locations in NE Alaska
ACWRU/ ANWR	26 Jun 73 to 9 Jul 73	Vegetative analysis of forested and unforested valley bottom sites	Vettatrin Lake (68°29'N-145°08'W)
ACWRU/ ANWR	10 Jul 73 to 17 Jul 73	Vegetative analysis of forested site SE of Old John Lake	(68°02'n - 144°54'W)
ACWRU/ ANWR	18 Jul 73 to 25 Jul 73	Vegetative analysis of forested and unforested valley bottom sites	Anvil Lake (68°23'N - 145°38'W)
ACWRU/ ANWR	26 Jul 73 to 7 Aug 73	Vegetative analysis of upland site near Windy Lake and valley site on peninsula of Old John Lake	Windy Lake (68°01'N - 145°11'W) Old John Lake (68°04'N - 144°58'W)
ACWRU/ ANWR	8 Aug 73 to 16 Aug 73	Vegetative analysis of alpine tundra site	Porcupine Lake (68°47'N - 146°32'W)
ACWRU/ Renewable Resources	17 Aug 73 to 19 Aug 73	Vegetative analysis of upland brush site	Deadman Creek (68°21'N - 145°55'W)
ACWRU/ ANWR	20 Aug 73 to 30 Aug 73	Vegetative analysis of unburned bottomland spruce-poplar forest and recent wildfire burns	Gailey Lake (66°49'N - 144°22'W)

training set data. These data were used in discriminant analyses evaluating the feasibility of particular discriminations.

Having established that the desired feature discrimination was feasible, we attempted to determine the power of anlaysis required to produce satisfactory feature extraction. Four basic techniques were employed to produce feature maps.

First, direct visual interpretation of 9.5" single band positive transparencies was used in feature mapping. The most useful band for the discriminations involved was selected and placed in a zoom Transfer Scope. Transparencies were registered to 1:250,000 scale overlays prepared from U.S.G.S. maps. The overlays were prepared by inking in outlines of major lakes and drainage features and these outlines were used as registration references in the zoom transfer process. After achieving satisfactory registration, the interpreter delineated feature boundaries on the overlay using a #4 hard pencil. Upon completion, overlay information was transcribed to a 1:250,000 scale map by using a light table.

Second, direct visual interpretation of 9.5" false color composite positive transparencies was used in feature mapping following the same procedures described above.

Third, VP-8 analyses of 9.5" single band positive transparencies were performed using the optimal band for the desired discrimination. Feature displays were photographed in black and white or color and these products were transferred to a 1:250,000 overlay and then transcribed to a 1:250,000 U.S.G.S. topographic map.

Finally, the fourth technique used in feature mapping was a heuristic algorithm applied to CDU digital tape data. Classification schemes were formulated from training set data and results of discriminant analyses. These classification criteria were then applied to the CDU tape and a "classified" output was produced. In the output format, various alphabetic designations were used to represent each of the feature categories. Each character on the output represents feature mapping for approximately 1.2 acres. Initial outputs were considerably distorted by the printout process and time consuming zoom transfer correction to 1:63,360 overlays was required. However, we have recently carried out program modifications to correct for aspect ratio and reduce distortion to the 0.3% inherent to ERTS MSS data. Consequently, recent outputs are direct feature mapping at roughly 1:18,540 scale.

III. Discussion of data analyses

Of the four methods utilized, we feel that computer processed algorithmic classifications from digital tape data are the least subjective and most useful. Although fully automated theme extractions are not entirely tenable with heuristic methods, the amount of interpretation required is greatly reduced. Moreover, the final interpretative decisions involved are normally limited to specific misclassifications which have been anticipated and, in most cases, these decisions are not difficult. For example, in the classification of scene 1375-21002, final interpretations of output required deciding whether particular areas were riverbeds, shallow lakes, or bare mountain rock.

The other methods utilized produced less satisfactory results primarily because the photographic data sources contained less information than the digital tapes. Even in the case of color composite transparencies, one band must be omitted and the information contained in that band is not available to the analyst. Additionally, we found it most difficult to consistently identify features using visual interpretation and have little confidence in these analyses. Because they are subjective, their value is entirely a function of the skill and insight of the individual interpreter.

The VP-8 analyses of single band products were less subjective but the usefulness of this type of analysis is, in our opinion, limited to very straightforward discriminations such as detection of snow free areas or lake mapping (see Section IV C).

While better results could no doubt be realized by local implementation of more sophisticated algorithmic classifier programs such as maximum likelihood, linear multiband feature mappings represent considerable improvement over habitat maps currently available for most of the state.

IV. Results

Our activities in the overall investigation are divisable into five distinct tasks, as follows:

A. Detection of large caribou aggregations
B. Detection and mapping of caribou trail systems
C. Mapping of snow cover in relation to caribou movements
D. Identification and mapping of winter feeding areas (cratered and trampled snow)
E. Identification and mapping of habitat types, including burns, on caribou winter range.

In this section we will treat the results achieved, if any, in connection with each of these tasks. In addition, special techniques and field work carried out in connection with each specific task are described.

A. Detection of large caribou aggregations

At the request of NASA we agreed to attempt to detect large caribou aggregations on ERTS imagery. The Northwest Alaska "Arctic" caribou population was selected for this task because it forms the largest aggregations of caribou in Alaska (up to 30,000 animals or more in the post-calving period; see Lent, 1966).

Two aerial reconnaissance missions, from Kotzebue were attempted on June 21 and July 7, 1973 to coincide with the ERTS overpasses during the post-calving season.

The first flight revealed that large aggregations were only beginning to form on the Arctic Slope. None with over 500 animals were observed. Cloud cover was general over much of the Arctic Slope and no ERTS images were usable. The second flight was terminated because of extreme turbulence in the DeLong Mountains, therefore, no "ground truth" was obtained. Scenes available from that overpass did not include the area where large aggregations were likely to occur and further analysis was futile in the absence of ground truth.

As an alternative to useful data from northwest Alaska we have undertaken a cooperative effort with the Canadian Wildlife Service. Mr. Elmer DeBock of Canadian Wildlife Service has recently forwarded some of his 1973 data which may provide sufficient information for testing the capability of ERTS imagery for this task and will be the basis for our analysis. We selected a July 28th scene (1370-20314) for the analysis. A brief summary of Mr. DeBock's observation on that date are presented in Table 4. We have ordered a digital tape of this scene from NDPF and have requested Mr. DeBock provide us with airphotos, and other data which might be useful in the analysis. Supplementary data are in hand but NDPF refused to supply the digital tape, and,therefore, this analysis will not be completed under this contract.

TABLE 4

Observations by Canadian Wildlife Service of Caribou
Aggregations in the Northern Yukon
July 28, 1973

Estimated # of Caribou	Approximate Location	Remarks
6,000	68°14'N 137°29'W	Animals on ridge top
500	68°13'N 137°30W	Dense herd
2,500	68°13'N 137°37'W	Moving north
2,500	" "	" "
2,500	" "	" "
30,000	68°24'N 137°35'W	Dense herd
5,000	68°28'N 137° 29	Animals on high ridge
5,000	" "	" " " "
5,000	68°24'N 137°15'W	Dense herd
7,500	68°24'N 137°15'W	
1,500	68°22'N 137°15'W	Animals on ridge knoll

B. Detection and mapping of caribou trail systems

Habitually used caribou migration routes on the tundra are detectable from low-level aircraft by the effects of trampling and disturbance on the vegetative cover and substrate. Experienced observers can often distinguish between old trails established by repeated use in previous years and trails freshly used during the summer of observation. If such trail systems were detectable from satellite imagery the imagery would provide useful synoptic information on caribou use and movement patterns at relatively low cost.

To test the feasibility of such trail mapping, analysis of scene 1375-20545 was undertaken as a cooperative effort with Dr. Robert LeResche of Alaska Department of Fish and Game. In the summer of 1972,Dr. LeResche mapped caribou trail systems using light aircraft on the Arctic Slope between Camden Bay and the Canadian border. The purpose of this analysis was to detect and map heavily used caribou trail systems on the Alaskan Arctic coastal plain. Trail systems were not detectable using simple visual inspection and display techniques. Therefore, a printout of digital data was produced and feature training sets were selected based on Dr. LeResche's 1972 data. Discriminant analysis indicated that bands 6 and 7 would be the most useful in the analysis and suggested that density slicing in these bands might produce satisfactory results. Therefore, we produced displays with the CDU-200 but no satisfactory trail map displays were achieved.

C. Mapping of snow cover in relation to caribou movements

The distribution, depth and other physical parameters of snow cover are known to influence the routes of movements of caribou and their distribution during much of their annual cycle (Pruitt, 1959; Lent, 1966; Henshaw, 1968). The major problem encountered in investigating these caribou-snow relationships has been the inability to adequately sample and map these snow-cover features over the large areas within which caribou populations move.

Simple visual inspection and transfer of snow cover distribution from single band MSS photographic products to base maps is feasible. However, we have found density slicing techniques using single MSS band 70mm positives or larger black and white prints and a VP-8 display to be more useful.

The most important advantage of this density slicing is that it permits rapid outlining and, to a limited extent, contouring of snow cover. The operator makes initial decisions on how to slice the continuum of densities. He is thus not faced with making thousands of such decisions as occurs in a unaided visual classification and mapping process.

As an example of the usefulness of this technique we have selected two scenes from the Noatak River-DeLong Mountains are (1277-21584 and 1313-21582). This is an area through which up to 100,000 caribou or even more may pass in May on their way from winter ranges to the calving grounds on the Arctic Slope. Unfortunately, only the southern edge of the calving area is in the scenes. No usable scenes to the north were available for this period because of the extensive cloud cover.

Figure 1 shows a portion of the lower Noatak River drainage with the snow cover pattern as it existed on June 1, 1973. Superimposed on this VP-8 display are the typical pre-calving migration routes used during late May. The analysis clearly shows that caribou follow the drainages and passes where snow cover first melts off. For example, Trail Creek, a tributary of the Kugurok River is normally used by most caribou to gain access to the upper Utukok River calving area, rather than the main fork of the Kugurok River, which,for various reasons, normally melts off later (Lent, 1966). The same figure also clearly shows burns which occurred in dry tundra and open forest areas in the lower Noatak drainage in the summer of 1972.

Figure 2 shows the entire image No. 1313-21582 including the head of the Salmon River and a relatively snowfree corridor through the Baird Mountains to the Noatak River area.

Fig. 1. VP-8 image with density slicing to show snowcover and burns, lower Noatak R., June 1, 1973. Dark areas - snowfree, white - snowcovered, vertical lines - heavy snowcover, black - burns. Typical caribou migration routes

6

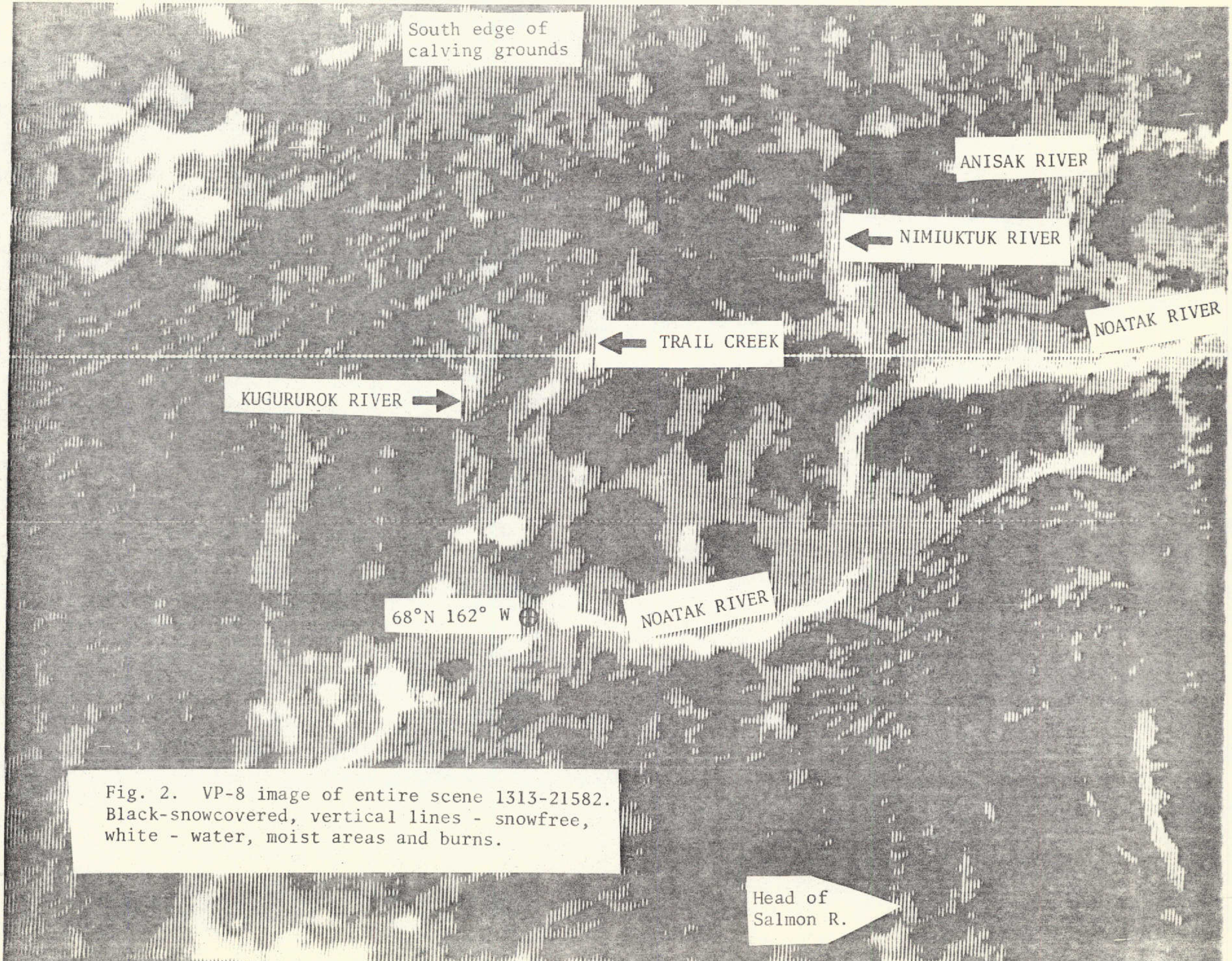


Fig. 2. VP-8 image of entire scene 1313-21582. Black-snowcovered, vertical lines - snowfree, white - water, moist areas and burns.

At the upper left hand corner of the picture the extreme southern edge of the calving area and upland plateaus used immediately after calving are visible but partially obscured by clouds. Nevertheless, major snow free areas are detectable. Lent (1966) concluded that these areas normally have less snowcover than the surrounding Arctic Slope region and this difference may account for their use by caribou during late May and June.

Repetitive satellite coverage and analyses of this type over a series of years will prove extremely useful in understanding and perhaps predicting annual variations in caribou migration and range use patterns.

The first autumn snowfalls in the tundra have been thought to have great influence on the timing of southward migrations in caribou (Lent, 1966). Early "dustings" of snow are not always detectable in a simple visual examination. They are, however, easily recognizable in multiband digital analysis (see Fig. 9, for example).

D. Identification and mapping of winter feeding areas (cratered and trampled snow)

We attempted detection of caribou snow cratering activity with ERTS imagery but our results were inconclusive. During the early March 1973 satellite overpass of northeast Alaska, we were prepared to launch aircraft and ground reconnaissance missions but these were cancelled on three successive days of regional overpass because of unfavorable weather conditions in the target areas. Therefore, neither usable ERTS imagery nor reconnaissance data was obtained for the early March 73 cycle.

Favorable weather existed in target areas on March 27th and our field reconnaissance team departed Fairbanks on that date. Ground truth data on cratering areas near selected landing sites were obtained on March 28th and 29th. Additionally, comparative snow depth and hardness values were obtained for two uncratered areas. Inacessible cratering areas where aircraft landings could not be made safely were noted on the map sheet and photographed. By mid-day on the 29th, weather conditions were rapidly deteriorating and the field team was forced to return to Fairbanks.

The ERTS-1 imagery resulting from this cycle was mostly cloud covered over cratering sites for which ground measurements had been obtained. Therefore, we attempted instead an analysis of scene 1247-20500 using as "ground truth" cratering areas observed only from the air. These areas were not immediately adjacent to landmarks recognizable on the image. Results were therefore inconclusive because we were unable to accurately locate these cratering sites on the digital printout data. Some density anomalies were noted in band 6. These consisted of patches with high reflectance (albedo) lying on an otherwise uniform open slope. These patches may or may not represent cratered areas. More definitive conclusions will require use of an ERTS image where sufficient land marks are recognizable to permit precise location of ground truth sites. Such sites should also be accessible so that on-the-ground location fixes can be obtained with surveying equipment.

Examination of the digital printout of the same scene suggests that variations in the amount of snow in the canopy of trees ("qali") in forested area may be detectable from ERTS images. Since the amount of qali is an indicator of snow density in an area it is therefore possible to use it as an index of snow conditions in various winter range areas. Again, we were hampered in pursuing this aspect further because the good spring 1973 imagery did not concide with our areas of intensive ground truth efforts.

E. Identification and mapping of habitat types, including burns, on caribou winter range.

Selected areas within the winter range of the "Porcupine" caribou population were used to determine the feasibility of using ERTS imagery as a tool for identifying and mapping habitat types.

Ground truth data on vegetation, soils and animal utilization indices were obtained at eleven sites in Northeast Alaska (see Table 5) during the summer of 1973. The sampling techniques employed followed those of Ohmann and Ream (1971) with some modifications to make them more suitable to our area and interests.

The sites were ground surveyed and corner points were tied into geographic reference points which could be readily located on ERTS data. These reference points were always hydrologic features such as a drainage confluence, small lakes, or a characteristic shoreline feature of larger lakes and several distance direction fixes were made from target corner points to selected reference points. Target areas were normally 28 hectares which we felt to be near minimum size necessary for training set data. Pertinent field data on vegetation, soils, and animal utilization were obtained on target areas. These target areas were first located and plotted on band 7 digital printouts then target boundaries were transcribed to digital outputs for bands 4, 5, & 6. Digital data within target area boundaries were the training set data base for later discriminations. Discriminant analyses were carried out on this data and, if particular discriminations were clearly impractical, analytic effort was redirected elsewhere.

More detailed analyses of tree density, tree seedlings, tall shrubs, ground cover, browse, soil, and other wildlife species utilization indices is still in progress. These analyses are being performed in cooperation with the Institute of Northern Forestry (USFS) and a duplicate set of the data is now at the Forest Service computer facility in Portland, Oregon.

Three photographs of typical stands are shown. Fig. 3 is a moderate density white spruce stand near Vettatrin Lake. Fig. 4 is a low density white spruce open valley bottom north of Anvil Lake. Fig. 5 is a recent burn area on the lower Sheenjek River.

Using these ground truth data as interpretive standards, or, as a basis for extraction of training sets, habitat feature maps were prepared using four different techniques.

Fig. 6 is a feature mapping based on direct visual interpretation of a 9.5" positive transparency of band 6. Fig 7 is a feature mapping prepared by VP-8 analysis of the same transparency. Fig. 8 is a feature mapping prepared by direct visual interpretation of a 9.5" color composite transparency of the same scene. Fig. 9 is a feature mapping produced by application of a heuristic

TABLE 5

Partial summary of results from intensive ground truth sites

Stand #	Classification Type ( )=Printout Character	Caribou Pellet Group Density per ha.	Primary Ground Cover (% cover)	Principal Tall Shrubs	Principal Tree Species	Major Ecosystem Category
201	White Spruce Forest (F)	.65	Litter 41.5% *Dryas integrifolia* 28.9% *Carex sp.* 28.8% Moss 27.7% *Cladonia sp.* 16.8% *Vaccinium uligonosum* 12.0% *Arctostaphylos rubra* 6.4%	*Betula glandulosa* *Salix alaxensis* *S. brachycarpa* *S. lanata*	*Picea glauca*/ Moderate density	Upland Spruce-hardwood
301	White Spruce Forest (F)	1.3	Litter 32.9% Moss 27.0% *Dryas integrifolia 17.1%* *Carex sp. 14.4%* *Vaccinium uligonosum 7.2%* *Caldonia sp. 6.7%* *Equisetum sp. 4.8%*	*Betula glandulosa* *Salix alaxensis* *S. brachycarpa* *S. lanata*	*Picea glauca* Moderate density	Upland Spruce-hardwood
202	Low density Spruce (0)	.60	Moss 38.7% Litter 24.3% *Carex sp. 18.2%* *Eriophorum sp. 10.7%* *Arctostaphylos rubra 5.8%* *Vaccinium uligonosum 4.3%* *Ledum decumbens 5.7%*	*Betula glandulosa* *Salix arbusculoides* *S. glauca* *S. hastata* *S. lanata* *S. planifolia*	*Picea glauca* low density	Low Brush
302	Low density Spruce (0)	.75	Moss 33% Litter 16.1% *Eriophorum 13.6%* *Carex sp. 10%* Standing water 8% *Dryas integrifolia 4.4%* *Ledum decumbens 4.0%*	*Betula glandulosa* *Salix planifolia*	*Picea glauca* low density	Low Brush

TABLE 5 (cont.)

Stand #	Classification Type ( )=Printout Character	Caribou Pellet Group Density per ha.	Primary Ground Cover (% cover)	Principal Tall Shrubs	Principal Tree Species	Major Ecosystem Category
203	White Spruce Forest (F)	.65	Moss 33.3% Litter 22.5% *Dryas integrifolia* 9.25% *Equisetum sp.* 7.5% *Arctostaphylos rubra* 7.3% *Vaccinium uligonosum* 6.5% *Salix reticulata* 4.6%	*Betula glandulosa* *Salix glauca* *S. lanata* *S. planifolia*	*Picea glauca* low density	Upland Spruce-Hardwood
303	White Spruce Forest (F)	1.05	Litter 26.8% Moss 22.3 *Dryas integrifolia* 8.8% *Arctostaphylos rubra* 8.8% *Equisetum sp.* 4.4% *Carex sp.* 3.9% *Salix reticulata* 4.6%	*Betula glandulosa* *Salix arbusculoides* *S. branchycarpa* *S. glauca* *S. lanata* *S. planifolia*	*Picea glauca* low density	Upland Spruce-Hardwood
204	White Spruce Forest (F)	2.65	Litter 19.0% *Dryas integrifolia* 10.3% Moss 10.2% *Fruticose lichen* 9.1% *Carex sp.* 7.8% *Vaccinium uligonosum* 6.4% *Arctostaphylos rubra* 5.8%	*Betula glandulosa* *Salix glauca* *S. lanata*	*Picea glauca* Moderate density	Upland Spruce-Hardwood
304	White Spruce Forest (F)	1.65	Litter 20.4% Moss 10.4% *Carex sp.* 8.3% *Fruticose lichen* 7.1% *Dryas integrifolia* 6.5% *Vaccinium uligonosum* 6.2% *Arctostaphylos rubra* 4.1%	*Betula glandulosa* *Salix glauca* *S. lanata*	*Picea glauca* Moderate density	Upland Spruce Hardwood

TABLE 5 (cont.)

Stand #	Classification Type ( )=Printout Character	Caribou Pellet Group Density per ha.	Primary Ground Cover (% cover)	Principal Tall Shrubs	Principal Tree Species	Major Ecosystem Category
205	Low density Spruce (0)	.10	Litter 20.2% Moss 12.6% *Carex sp. 10.0%* Standing water 7.9% *Eriophorum sp. 6.4%* *Arctostaphylos rubra 4.9%* *Dryas integrifolia 3.8%*	*Betula glandulosa* *Salix brachycarpa* *S. lanata*	*Picea glauca* low density	Low Brush
305	Low density Spruce (0)	.05	Litter 22.6% Moss 16.7% *Carex sp. 12.5%* Standing water 6.1% *Dryas integrifolia 2.7%* *Eriophorum sp. 2.7%* *Arctostaphylos rubra 2.4%*	*Betula glandulosa* *Salix brachycarpa* *S. lanata*	*Picea glauca*	Low Brush
206	*Eriophorum* Tussock Community (E)	.35	Moss 22.9% Litter 19.5 *Eriophorum vaginatum 14.8%* *Vaccinium uligonosum 6.7%* *Ledum decumbens 5.8%* *Vaccinium vitis-idaea 5.3%* *Foliose lichen 5.1*	*Betula glandulosa* *Salix brachycarpa* *S. glauca* *S. planifolia*	None or *Picea glauca* at very low density	Moist Tundra
306	*Eriophorum* Tussock Community (E)	.50	Moss 19.6% *Eriophorum vaginatum 18.0%* Litter 15.9% *Ledum decumbens 7.8%* *Vaccinium uligonosum 6.9%* *Vaccinium vitis-idaea 6.9%* *Foliose lichen 5.7%*	*Betula glandulosa* *Salix brachycarpa* *S. glauca* *S. planifolia*	None or *Picea glauca* at very low density	Moist Tundra

TABLE 5 (cont.)

Stand #	Classification Type ( )=Printout Character	Caribou Pellet Group Density per ha.	Primary Ground Cover (% cover)	Principal Tall Shrubs	Principal Tree Species	Major Ecosystem Category
207	Low density Spruce (0)	1.20	Moss 20.3 Litter 19.6 *Dryas integrifolia* 8.3% *Carex sp.* 6.3% *Fruticose lichen* 5.8% *Vaccinium uligonosum* 4.9% *Arctostaphylos ruba* 7.45%	*Betula glandulosa* *Salix brachycarpa* *S. glauca* *S. lanata*	*Picea glauca* low density	Low Brush
208	Alpine Tundra	2.15	Moss 24.6% *Vaccinium vitis-idaea* 13.9% Litter 10.6% *Foliose lichen* 8.7% *Fruticose lichen* 7.7% *Ledum decumbens* 6.3% *Cladonia sp.* 13.4%	*Betula glandulosa* *Salix glauca* *S. planifolia*	None	Alpine Tundra
308	Alpine Tundra	3.90	Moss 21.5 *Cladonia sp.* 13.7% Litter 10.6% *Vaccinium vitis-idaea* 8.5% *Foliose lichen* 6.7% *Favticose lichen* 6.0% *Ledum decumbens* 3.6%	*Betula glandulosa* *Salix glauca* *S. planifolia*	None	Alpine Tundra
209	Upland Shrub Willow (L)	.65	Litter 23.8% *Dryas integrifolia* 10.3% *Crex sp.* 9.1% Moss 8.6% *Fruticose lichen* 5.4% *Salix reticulata* 5.2% *Vaccinium uligonosum* 4.4%	*Salix glauca* *Salix lanata* *Betula glandulosa*	None	High Brush

TABLE 5 (cont.)

Stand #	Classification Type ( )=Printout Character	Caribou Pellet Group Density per ha.	Primary Ground Cover (% cover)	Principal Tall Shrubs	Principal Tree Species	Major Ecosystem Category
309	Upland Shrub birch (B)	.55	Litter 20.7 Moss 8.5% *Salix reticulata* 5.7% *Carex sp.* 5.7% *Arctostaphylos rubra* 4.9% *Fruticose lichen* 4.5% *Dryas integrifolia* 7.1%	*Betula glandulosa* *Salix glauca* *S. lanata*	None	High Brush
210	Recent Wildlife Burn (B)	0	Litter 29.4 *Marchantia sp.* 28.25 Moss 22.7% *Epilobium angustifolium* 10.1 *Equisetum sp.* 2.8% *Graminae sp.* 2.7% Mushrooms .75%	*Rosa acicularis* *Salix alaxensis* *S. arbusculoides* *S. glauca*	None but standing dead	---
310	Recent Wildlife Burn (B)	0	Moss 34.5% *Marchantia sp.* 21.8% Litter 18.0% *Epolibium angustifolium* 9.4% *Graminae sp.* 5.2% *Equisetum sp.* 1.0% *Senecio yukonensis* 1.0%	*Rosa acicularis* *Salix alaxensis* *S. arbusculoides* *S. glauca*	None but standing dead	
211	Spruce-Poplar Forest (F)	0		*Salix glauca* *S. arbusculoides* *Rosa acicularis* *Betula glandulosa*	*Picea glauca* *Populus balsamifera* *Populus tremuloides* High density	Bottomland Spruce - Poplar Forest

TABLE 5 (cont.)

Stand #	Classification Type ( )=Printout Character	Caribou Pellet Group Density per ha.	Primary Ground Cover (% cover)	Principal Tall Shrubs	Principal Tree Species	Major Ecosystem Category
311	Spruce-Poplar Forest (F)	0		*Betula glandulosa* *Rosa acicularis* *Alnus incanta* *Salix glauca* *S. arbusculoides*	*Picea glauca* *Populus balsamifera* *Populus tremuloides* High density	Bottomland Spruce-Poplar Forest
South end of Anvil Lake	Shallow water(s): 1 m or less	unknown	Open water	None	None	Lakes
South End of Vetta-trin Lake	Shallow water(s): 1 m or less	unknown	Open water	None	None	Lakes
Middle of Old John Lake	Deep water (D): 20 m or more	unknown	Open water	None	None	Lakes
Gravel Bar at conflu-ence of Water Creek and Junjik R.	Gravel (G)	unknown	Bare Gravel	None	None	Riverine

TABLE 5 (cont.)

Stand #	Classification Type ( )=Printout Character	Caribou Pellet Group Density per ha.	Primary Ground Cover (% cover)	Principal Tall Shrubs	Principal Tree Species	Major Ecosystem Category
Top of Nichen-thraw Mt.	Bare Rock (K)	Unknown	Bare rock or Scree	None	None	Alpine Tundra
Chan-dalar River	Intermediate Dept Water (I and/or R): 1 to 5 m	Unknown	Open water	None	None	Riverine
Large Stand of Wil-low ad-jacent to Water Creek	Willow (W)	Unknown	Bare Gravel	*Salix alaxensis*	None	High Brush
Unmelted snow-bank on ridge N. of old John Lake	Snow (A)	Unknown	Snow	None emergent	None	Glacier
Clouds NW of Old John L.	Clouds (C)	---	---	---	---	---

Fig. 3. White spruce forest in valley near Vettetrin
Lake (Upland spruce-hardwood ecosystem category,
See Fig. 12)

Fig. 4. Low density white spruce stand (low brush ecosystem category, see Fig. 12)

Fig. 5. Stand burned by wildfire in 1969 near Gailey Lake (see Fig. 15)

Descriptive legend for vegetation types used on feature maps
(figures 6, 7 & 8)

Type 1 - White spruce forest: pure stands of relatively evenly distributed white spruce at moderate density and with a tall shrub understory.

Type 2 - Open valley bottom areas with unevenly distributed low density white spruce; primary vegetative cover consists of tall shrubs (growth forms over 3 feet) and sedges.

Type 3 - Treeline spruce: upland areas of relatively evenly distributed white spruce at low density and in stunted growth form; understory of tall shrubs and an abundance of ericaceous ground cover.

Type 4 - Riparian willow: dense stands of tall willow especially *Salix alaxensis* along streams; occurs in both uplands and valley bottom areas.

Type 5 - *Eriophorum* tussock community: treeless or nearly treeless upland with relatively evenly distributed *Eriophorum* tussocks especially *Eriophorum vaginatum;* tall shrubs may or may not be present and the percentage of ericaceous ground cover is considerably less than in other upland vegetation types.

Type 6 - Upland brush: treeless upland with relatively evenly distributed tall shrubs and moderately high percentage of ericaceous ground cover.

Type 7 - Dryas: treeless upland with unevenly distributed dwarf shrubs at low density and moderately high percentage of ericaceous and Dryas ground cover

Type 8 - Alpine tundra: treeless upland with very low percent cover of dwarf shrubs; primary vegetative cover consists of moss, lichens, and sedges; bare ground and exposed rock occur more frequently than in other upland vegetation types.

Type 9 - Bare Mountain Rock: little vegetative cover occurring in widely scattered clumps; called rock desert by Spetzman.

Fig. 6: Habitat feature mapping based on direct visual interpretation of a 9.5" positive Band 6 transparency, scene 1375-21002. *Legend on facing page*

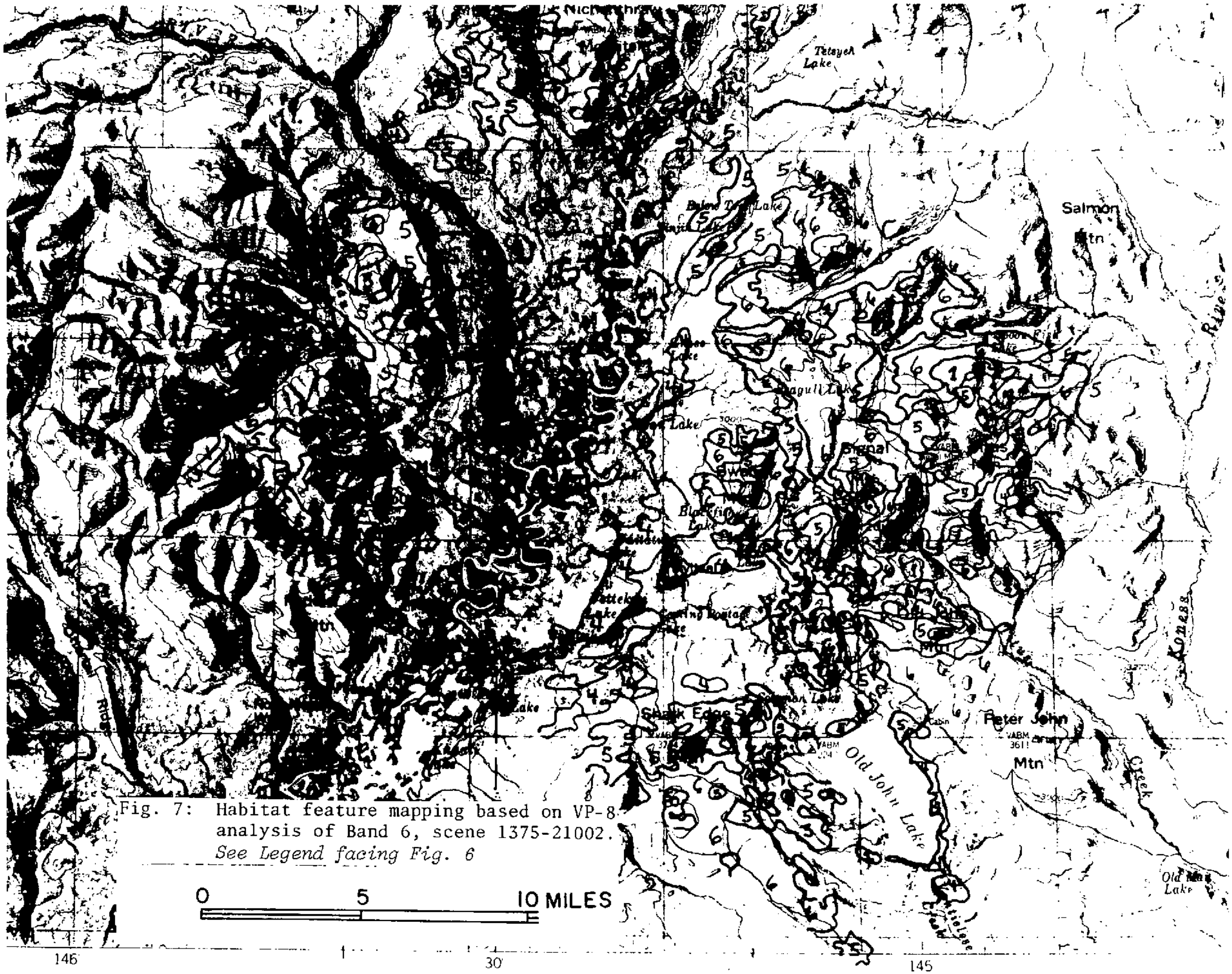


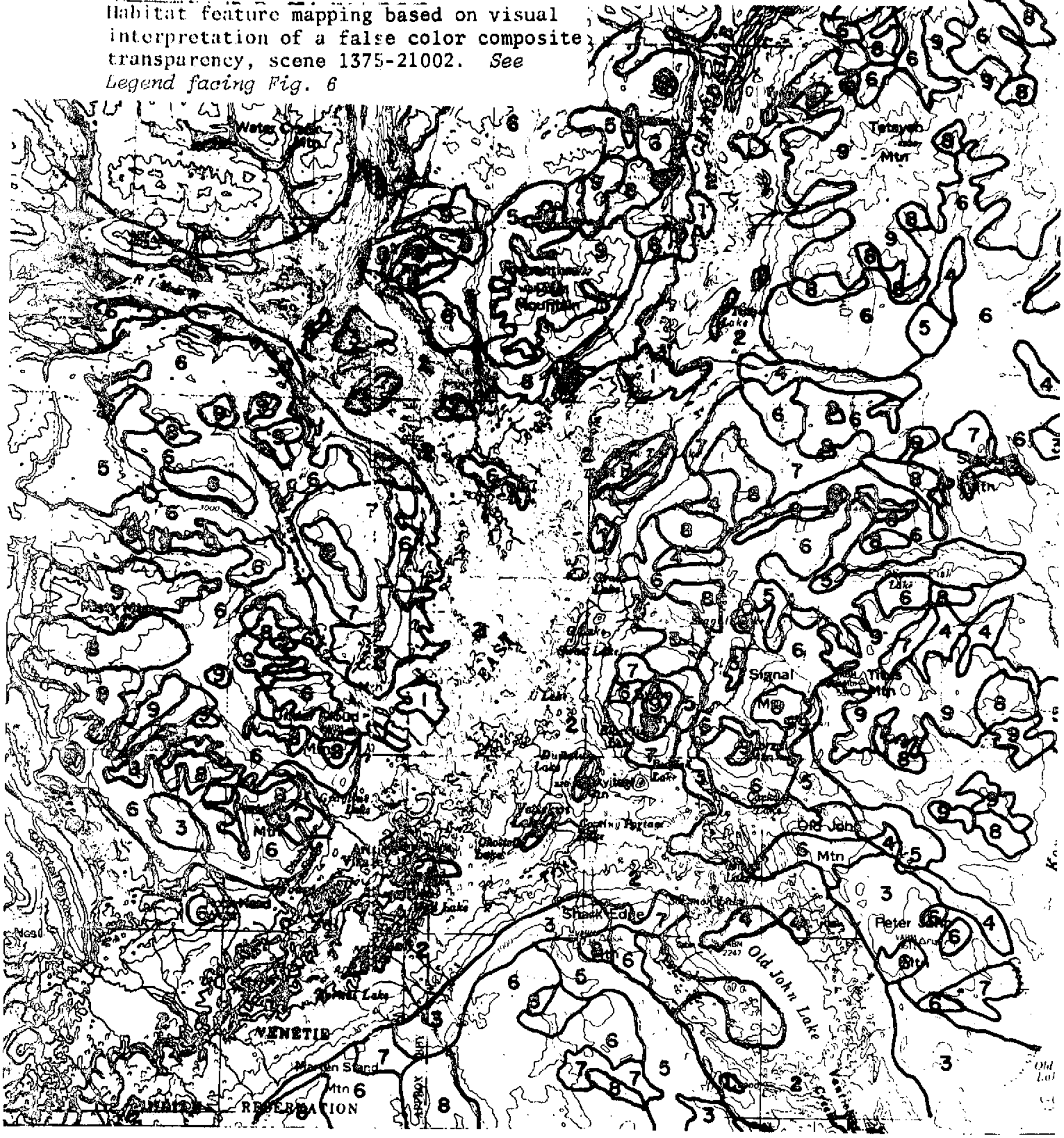
Fig. 7: Habitat feature mapping based on VP-8 analysis of Band 6, scene 1375-21002. *See Legend facing Fig. 6*

N

0 5 10 15 20 25 MILES

Fig. 8

Habitat feature mapping based on visual interpretation of a false color composite transparency, scene 1375-21002. *See Legend facing Fig. 6*



algorithm or linear signature classification scheme to digital tape data (Table 6).

Since this investigation was primarily a feasibility study, detailed color maps of the printout data have not been drafted or reproduced. However, such maps could be prepared from the feature categorized digital tapes generated as a result of our investigation. Portions of two aspect ratio corrected printout products are provided (fig. 10 and 11) with explanatory notations to depict the amount of detail possible with these digital analyses. Each output character on the printouts represent approximately 1.2 acres of surface area. The printouts are, therefore, feature maps at 1:18,540 scale.

This mapping is a supervised classification because supervision or interpretation of the output is required to some extent. For example, bare rock (K), gravel (G), and shallow water categories [(S) (I) (R)] are difficult to separate with a simple heuristic methods. Therefore, decisions must be made by an interpreter as to whether an area is bare rock, scree in the mountains, river bed, or lake. In almost all cases these decisions are not difficult to make with a reasonable degree of confidence.

Another problem arises in misclassification resulting from "bright banding" or spectral inconsistencies in the digital data. In this particular scheme, the only obvious and consistent misclassifications due to bright banding involves upland shrub willow and *Eriophorum* tussock areas. *Eriophorum* tussock areas are misclassified as upland willow shrub in the bright bands. In spite of these shortcomings, however, the classification represents feature mapping with a level of detail never before attempted in this part of Alaska. Fig. 12 is the most recent vegetation map of the area and was prepared by the Joint State Federal Land Use Planning Commission. Comparison with the map products presented in this report indicate the much greater detail possible with ERTS digital data. Therefore, enormous potential application to wildlife habitat inventory and general vegetation mapping is indicated. Table 7 lists the approximate acreages classified into each category. Most of the unclassified area is probably alpine tundra or wet sedge meadow which were not represented in the ground truth stands (Table 5) within the area covered by the generated CDU tapes.

A similar series of analyses was performed for a portion of scene 1407-20371. The features in this analysis were confined to unburned bottomland, spruce-poplar forest of some commercial potential, recent wildfire burns, unvegetated alluvial gravel, rivers and lakes. Fig. 13 is a feature mapping prepared by visual interpretation of a 9.5" band 7 positive transparency. Fig. 14 is a feature mapping prepared by visual interpretation of a 9.5" false color composite transparency. Fig. 15 is a feature mapping produced by application of a linear multiband classification scheme to the digital data. The scheme is shown in Table 8. Because it is not possible to fully reproduce the detail in the output, a sample of the output is shown (Fig. 16). This output, however, is distorted and laterally compressed by the printing process which prints 10 characters to the inch laterally but only six lines per inch in the vertical. This problem was resolved by minor program modifications to correct for aspect ratio and subsequent outputs such as those for scene 1375-21002 (Fig. 10 and 11) are undistorted except for distorations inherent to ERTS MSS data. Results of this classification are shown in Table 9.

TABLE 6

Multiband Classification Scheme for
Scene 1375-21002

Features	Density Ranges			
	Band 4	Band 5	Band 6	Band 7
Open Spruce Forest (F)	21-24	14-19	25-28	13-17
Low Density Spruce (O)	19-24	14-19	29-32	12-18
Eriophorum Tussocks (E)	22-23	15-18	30-35	19-20
Upland Shrub community (willow) (L)	17-21	11-16	31-36	19-20
Riparian willow (W)	25-29	20-22	23-30	14-15
WATER				
Shallow Lakes (S)	16-32	20-27	9-18	1-4
Streams (I)	17-20	10-15	9-22	3-8
Rivers (R)	22-27	14-19	10-18	3-7
Deep Lakes (D)	16-20	8-11	6-8	0-3
Bare Mountain Rock (K)	22-33	20-29	11-22	5-12
Alluvial Gravel (G)	29-35	25-30	23-29	9-13
Unmelted Snowbanks (A)	20-23	15-20	37-44	21-25
Clouds (C)	27+	22+	36+	21+
Upland Shrub Community (Birch) (B)	24-26	11-16	31-36	19-20

TABLE 7

Linear multiband classification of a portion of ERTS scene 1375-21002

Feature	# of pixels Classified	% of Total	Approximate Acreage	Caribou Use Index Value
White spruce Forest	61,258	11.65	73,509	1.33
Upland Brush	21,673	4.11	26,007	.60
Low density Spruce	68,303	12.99	81,963	.54
Eriophorum Tussock Community	41,168	7.82	49,401	.42
Deep Lake Water	5,117	0.96	6,212	Unknown
Bare Rock, Gravel, and Shallow H_2O*	36,209	7.20	113,686	Unknown
Cloud	22,093	4.18	26,512	---
Cloud Shadow	22,335	4.25	26,802	---
Snow	29,274	5.55	35,129	Unknown
Riparian Willow	5,292	0.97	6,350	Unknown
Unclassified	211,506	40.31	253,807	Unknown
Total	524,288	100.00	629,146	

* In this analysis, interpreter decision was required on final output to separate these features.

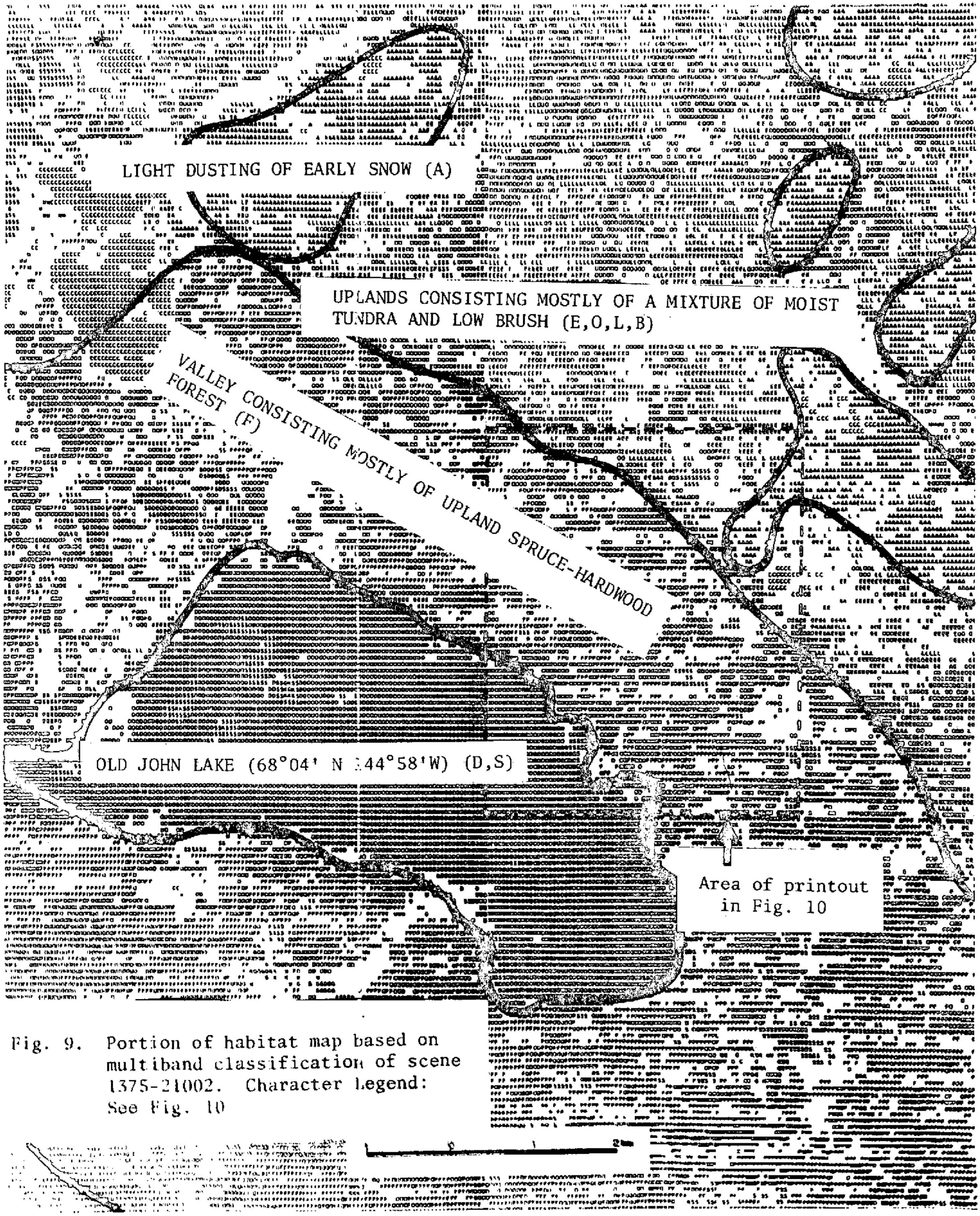


Fig. 9. Portion of habitat map based on multiband classification of scene 1375-21002. Character Legend: See Fig. 10

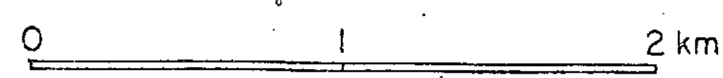


Fig. 10. Printout showing Portion of Habitat map shown in Fig. 9. Linear reduction of original printout ca. 30%

Legend:

F- White spruce forest (upland spruce-hardwood)

O- low density white spruce (low brush)

E- *Eriophorum* tussock community (moist tundra)

L- Upland shrub willow (low brush)

W- High brush willow (High brush)

B- upland shrub birch (low brush)

S- shallow water

I- stream

R- river

D- deep lake water

K- bare rock

G- gravel

A- snow

C- cloud

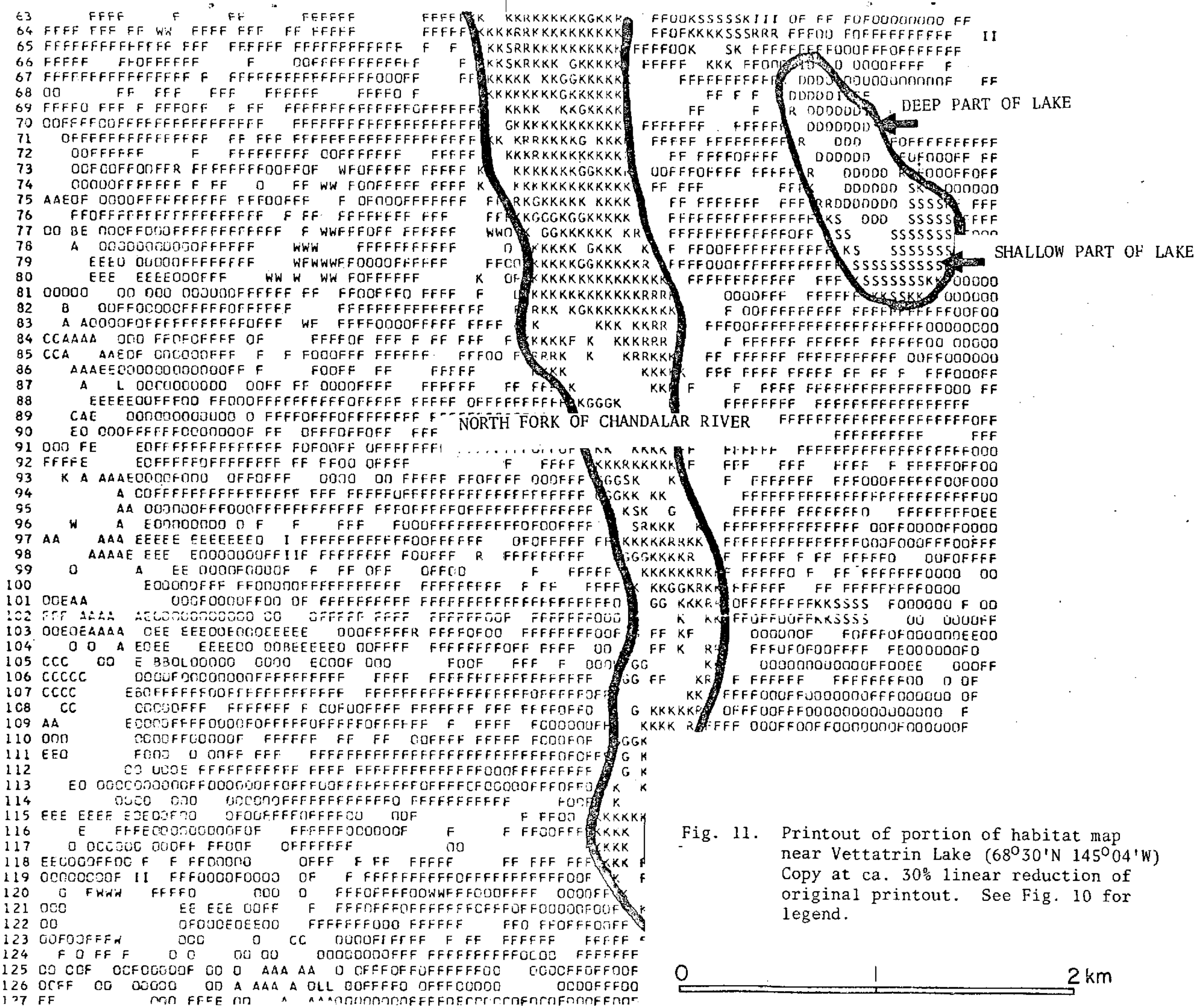


Fig. 11. Printout of portion of habitat map near Vettatrin Lake ($68^{o}30'N$ $145^{o}04'W$) Copy at ca. 30% linear reduction of original printout. See Fig. 10 for legend.

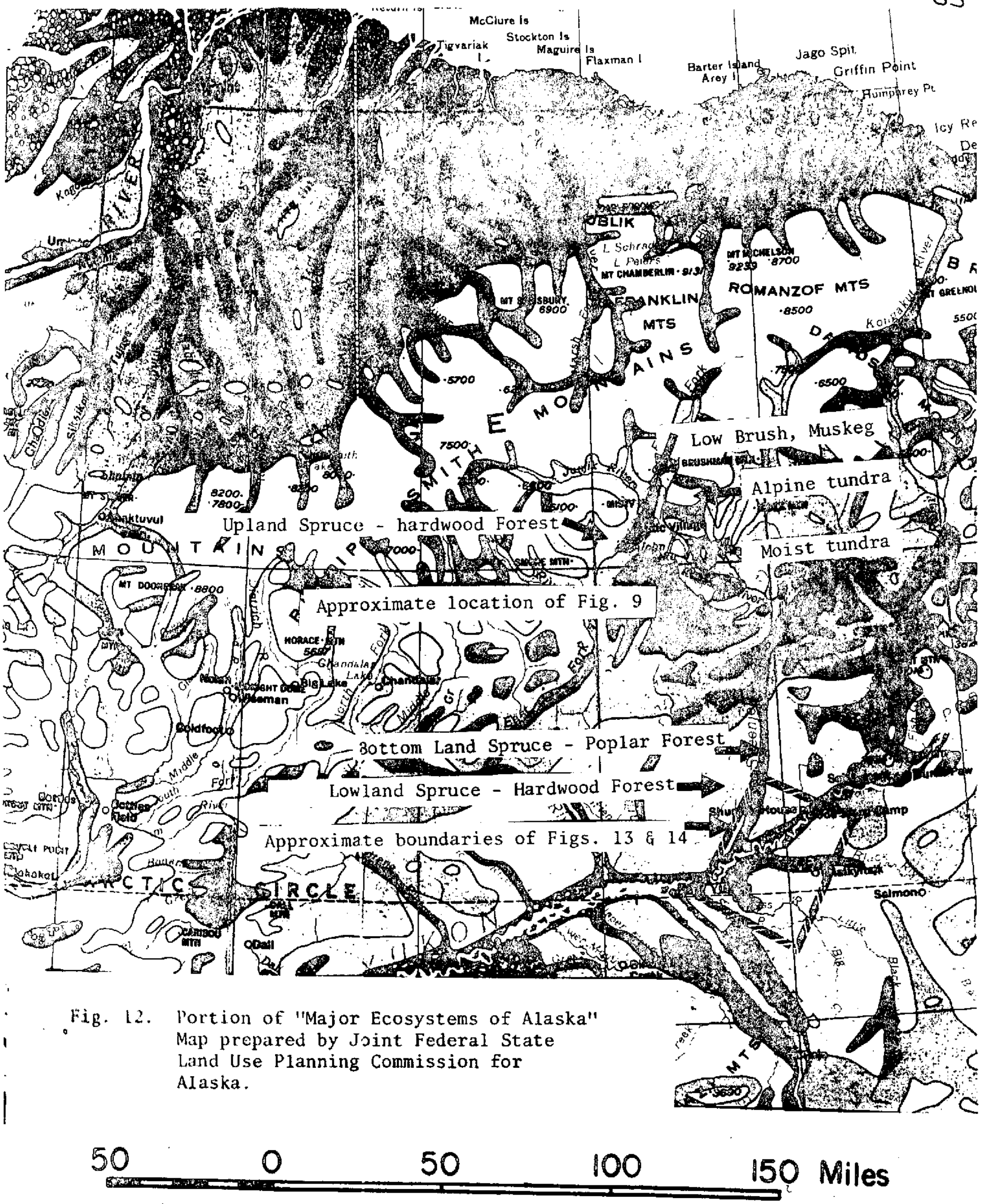


Fig. 12. Portion of "Major Ecosystems of Alaska" Map prepared by Joint Federal State Land Use Planning Commission for Alaska.

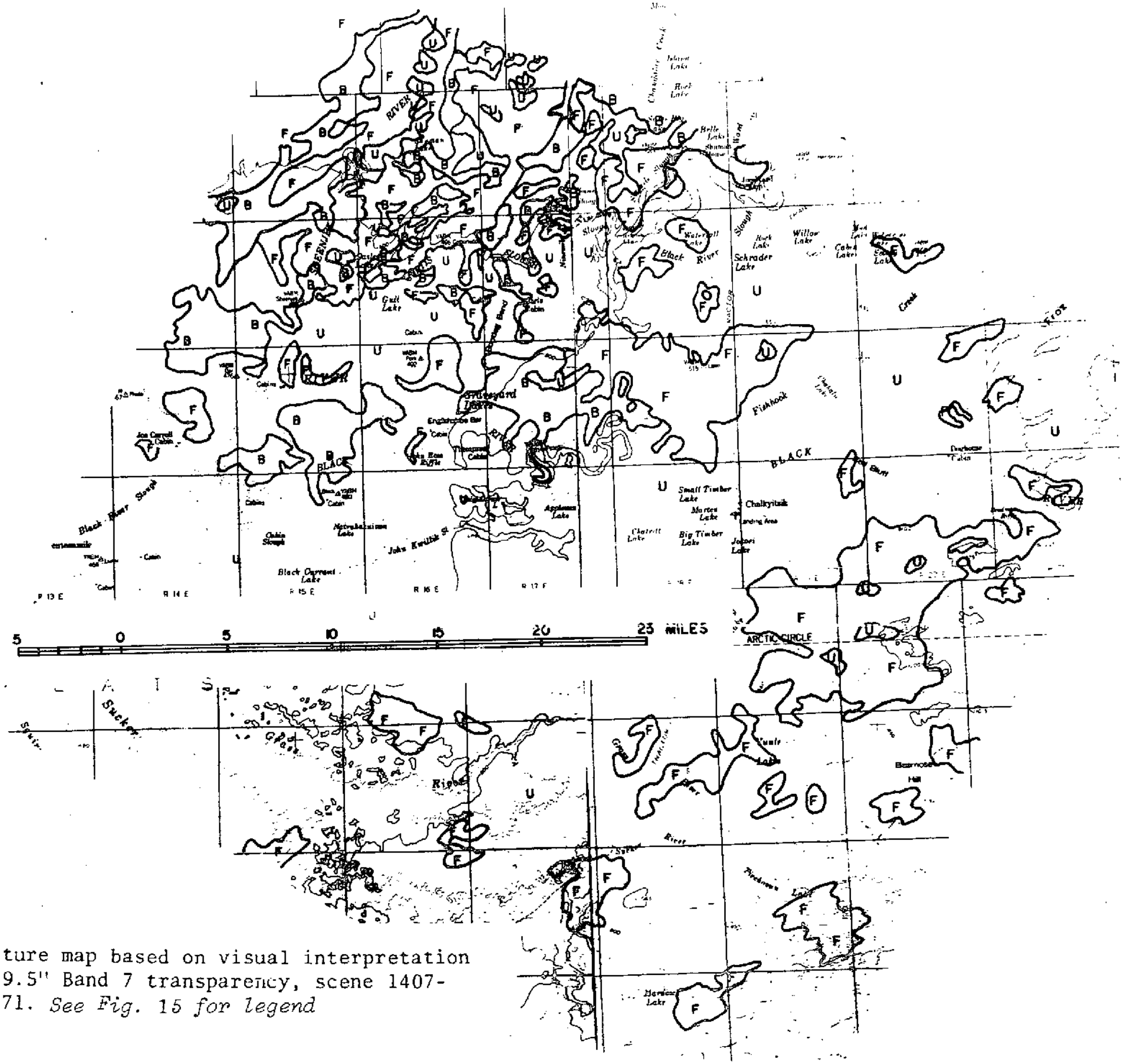


Fig. 13: Feature map based on visual interpretation of 9.5" Band 7 transparency, scene 1407-20371. *See Fig. 15 for legend*

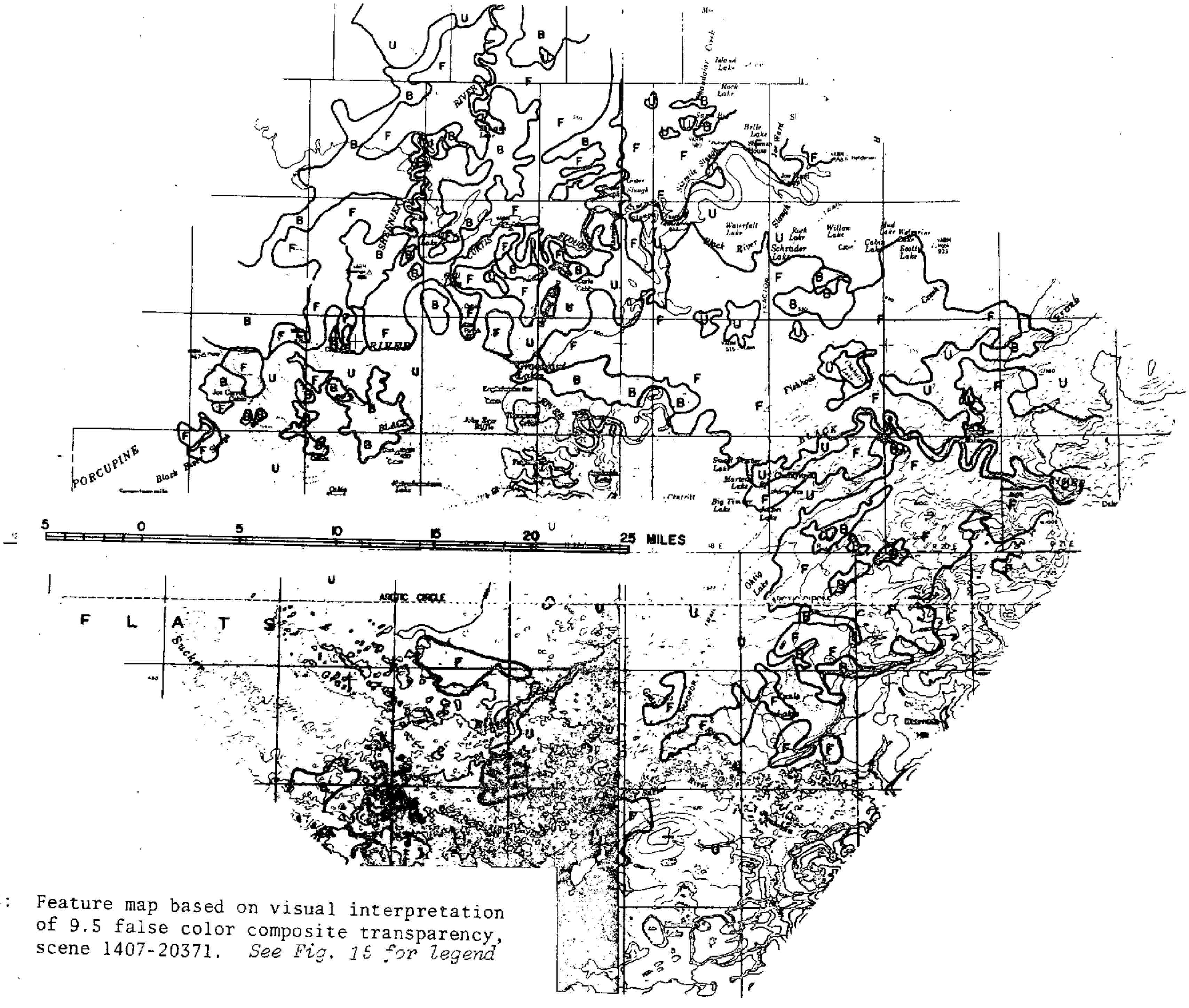


Fig. 14: Feature map based on visual interpretation of 9.5 false color composite transparency, scene 1407-20371. *See Fig. 15 for legend*

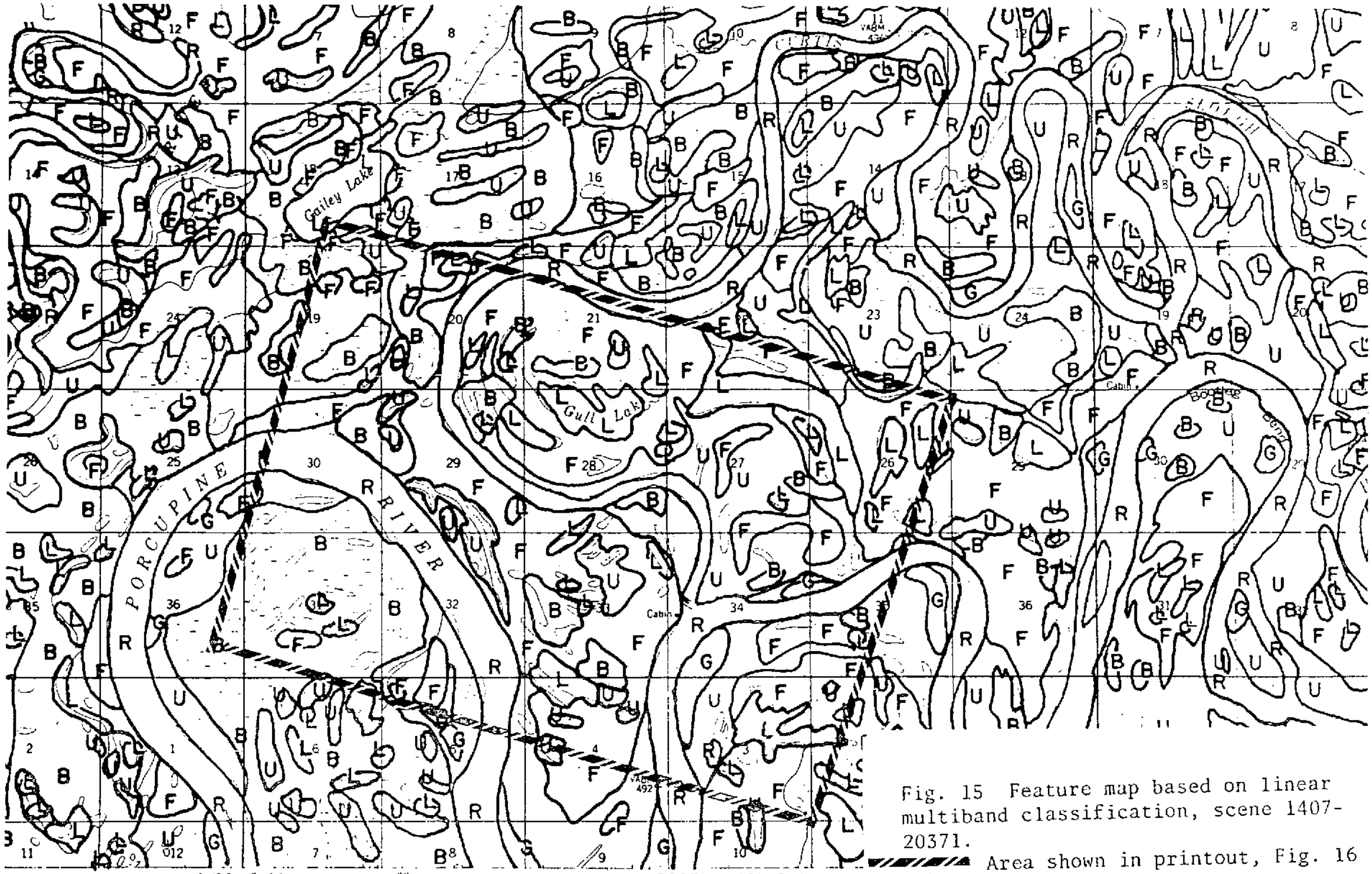


Fig. 15 Feature map based on linear multiband classification, scene 1407-20371.

Area shown in printout, Fig. 16

Legend:

B - Recent Burn
F - Mature Bottomland Spruce-Poplar Forest
L - Lake
R - River
G - Unvegetated Gravel
U - Unclassified (Blank on

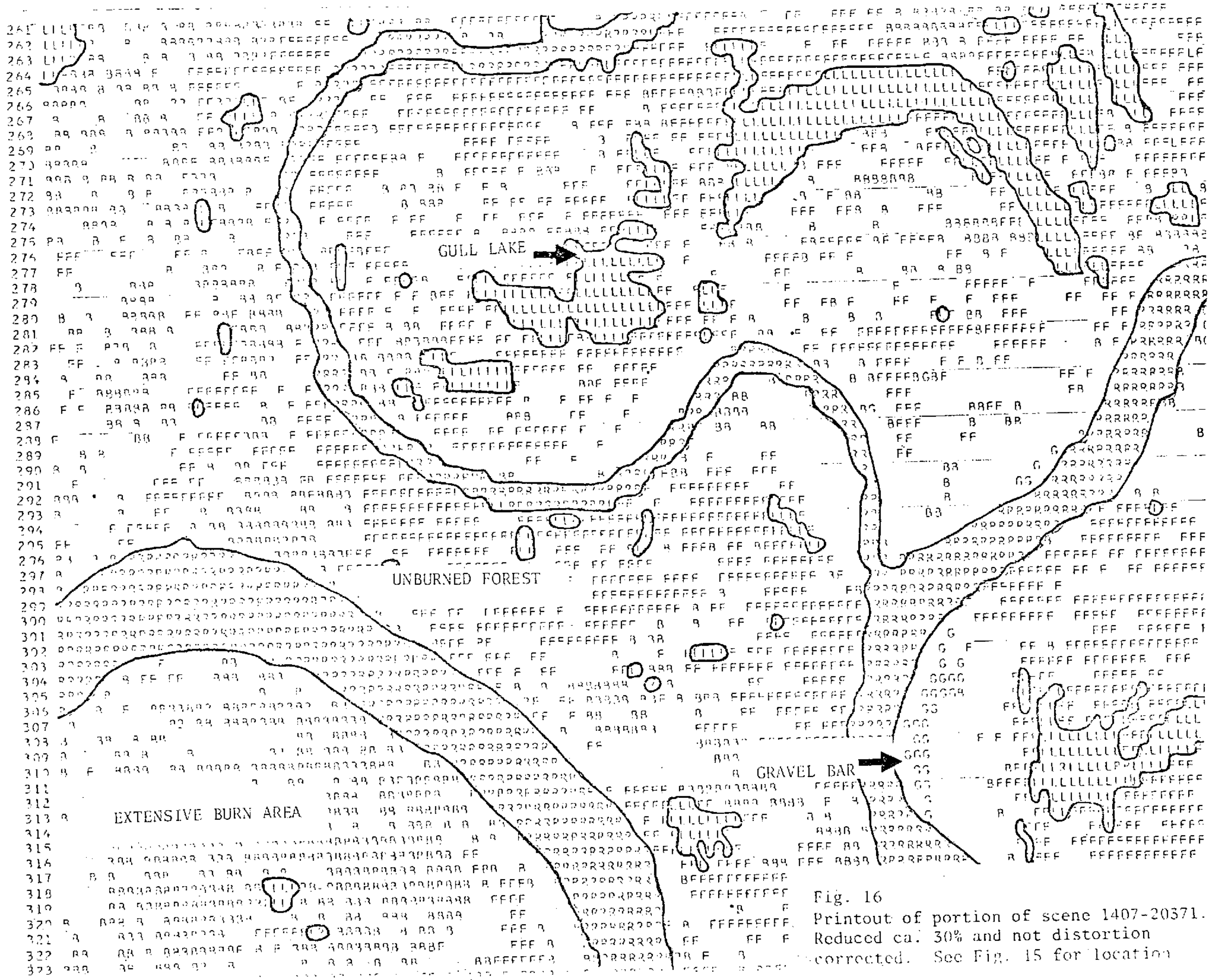


Fig. 16
Printout of portion of scene 1407-20371. Reduced ca. 30% and not distortion corrected. See Fig. 15 for location

TABLE 8

Linear multiband classification scheme applied to Scene 1407-20371

Feature	Band 5 Density Range	Band 7 Density Range
Recent Wildlife Burn	12-15	9-11
Mature Bottomland Spruce-Poplar Forest	8-10	5-8
Lakes and Potholes	5-9	0-5
Rivers	10-16	0-4
Unvegetated Gravel	20-32	12-15

TABLE 9

Linear multiband classification of a portion of ERTS scene 1407-20371

Feature	# of Pixels Classified	% of Total	Approximate Acreage
Spruce-Poplar Forest	45,420	17.35	54,576
Recent Wildfire Burn	72,445	27.64	86,934
Lakes	8,954	3.42	10,745
Rivers	9,885	3.77	11,862
Unvegetated Alluvial Gravel	1,446	0.55	1,735
Unclassified	123,934	47.28	148,721
Total	262,144	100.00	314,573

In their major ecosystem mapping of the State, the Joint State-Federal Land Use Planning Commission divided Alaska into six regions. Our multiband analyses of scenes 1375-21002 and 1408-20371 both fall within the Yukon region. Therefore, our analyses cover just under one million acres of this 130 million acre region. Our analyses indicate the extent of the following major types is: Upland Spruce Hardwood - 24.6%, Bottomland spruce poplar - 17.4%, High brush - 0.9%, Low brush - 4.1%, Lakes - 3.4%, and Riverine - 3.7%. The Commission's analysis of the region is as follows: Upland spruce hardwood 33.4%, Bottomland spruce poplar - 9.2%, High brush - 0.7%, low brush - 7.1%, Lakes - 1.5% and Riverine - 2.0%. This comparison is of limited value because our areas represent less than 1% of the total region but the comparison does indicate our analysis is reasonably compatible with that of the Ecosystem map. Our percentage for Upland spruce-hardwood is about 10% lower than the Commission's. This is reasonable because the area of our analysis (1375-21002) is in the northernmost extent of the region where white spruce is reaching the northern limits of it's distribution. Consequently, the extent of this type would be expected to be somewhat less than for the region as a whole. Our percentage figure for Bottomland spruce-poplar is about 8% higher than the Commission's figure. This too is reasonable because our area of analysis (1408-20371) included portions of the Porcupine River. Since this ecosystem type is confined to major flood plains, one would expect this analysis to produce a percentage figure higher than for the total region. Similarly, our figures for Lakes and Riverine systems are somewhat higher than that on the Ecosystem Map. Again this is to be expected because of the specific area selected for our analysis.

V. Practical applications of results of the investigation

Results obtained for snow distribution feature mapping have important application potential for range studies involving caribou, muskox, and Dall sheep. For example, Pruitt (1959) and others have demonstrated that migratory movements of caribou are influenced by snow conditions. Our results indicate that a synoptic view of snow conditions over large areas can be achieved with ERTS imagery. These analyses can be used in connection with long term studies of caribou distribution and migration patterns. Such a synoptic coverage cannot be achieved by any "conventional" means.

Caribou and moose habitat in Alaska and the Canadian north is greatly influenced by wildfires. Maximum moose utilization occurs 11 to 30 years after burning whereas maximum caribou utilization in winter occurs in mature spruce forest which has not burned for 120 or more years (Scotter 1970). Moose, in contrast, obtain maximum benefit from burn areas only a few years after the fire. Therefore, the extent and distribution of range resources for each species changes with each fire season. Until now, there has been no practical, low-cost means of monitoring these changes. Our analysis of scene 1407-20371, however, indicates this can be accomplished with ERTS-1 data at reasonable cost. Analyses of this type can be used effectively in management decisions regarding emphasis of firefighting effort during a particular fire season. It should also provide a powerful and economical tool to aid in estimating the effect of a given fire season on the welfare of various ungulate populations, particularly moose and caribou.

Specific vegetation types or botanical associations have differential habitat value to different wildlife species. Our analysis of scene 1375-21002 indicates such type mapping is possible with ERTS data and at a level of detail not attempted over most of Alaska. Economic considerations previously made such detailed feature mapping impractical but our results were achieved with an initial processing cost of about $.64 per square mile. This amount does not include the cost of ground truth data but considerable ground truth data is available in the files of various state and federal agencies. Additionally, processing was accomplished with software requiring a CDU-200 tape format. This is much less efficient than direct processing of the original NASA tape. Therefore, development and/or implementation of a cost optimized software package for direct processing at our computer facility would result in much lower classification costs. Consequently, broad-scale application potential in habitat analysis of scene 1375-21002 (Figs. 9, 10, 11) suggests that lakes can frequently be classified by depth. Separation of deep lakes from shallow lakes has important application in fisheries and waterfowl biology because the shallow lakes are most important as waterfowl breeding habitat. Annual variation in the amount of wet lands in various areas can also be monitored.

In summary, our results demonstrate the broad-scale application potential of ERTS data to wildlife biology and management. In particular, applications to research and management for waterfowl, Dall sheep, muskox, moose, and caribou are clearly indicated.

VI. Use of the results and their applications by operational agencies

Techniques developed as a result of this investigation are currently being applied to an ecological study of muskoxen on Nunivak Island, Alaska. This study, being done under contract with Bureau of Sport Fisheries and Wildlife, will make recommendations on the management of the muskox population. The winter range available to muskoxen on the island is critically limited by the pattern of deep snowcover that develops each winter on the island (Spencer and Lensink, 1970; Lent, 1972). Our ability to compare seasonal and annual changes in snowcover over the entire island will greatly aid in understanding the long-term ecological implications of the phenomenon. Density slicing using the VP-8 will provide the basis for such comparisons.

In an investigation of Dall sheep in the Brooks Range by Alaska Cooperative Wildlife Research Unit for Alaska Department of Fish and Game, the use of similar techniques for mapping preferred Dall sheep winter range has also been attempted. In this case the rugged, highly dissected range area, with the attendant problems of shadows in the imagery, has prevented successful use of the VP-8. Direct visual mapping is being attempted.

Within the Bureau of Sport Fish and Wildlife, there is considerable interest in application of ERTS data for habitat analysis and mapping. Immediate needs are for rapid assessment of D-2 lands tentatively selected under the Native Land Claims Settlement Act. Long term research interests address specific applications to waterfowl biology and management, and systematic State-wide habitat assessment. The results produced by this investigation are directly and immediately useful to the Bureau because the areas mapped are on D-2 lands which are proposed additions to the Arctic National Wildlife Range.

Additionally, our results with algorithmic classifiers should have broad application to realization of the Bureau's long term objectives on a State-wide scale.

The Alaskan native regional corporations also have land selection and management problems which require identification of wildlife habitat. One regional corporation has already indicated strong interest in applying this ERTS technology to their tasks.

We are currently performing cooperative analyses with the Alaska Department of Fish and Game. Our analysis of scene 1375-20595 is directed at detection and mapping of heavily used caribou trail system. Analysis of scene 1408-20435 is currently is progress. The purpose of this analysis is mapping of moose range on the Tanana Flats, particularly several stages of fire recovery succession. Alaska Department of Fish and Game will obtain further ground truth this summer and analysis of the scene will be expanded to include the foothills of the Alaska Range. This analysis represents a joint effort between Alaska Department of Fish and Game, University of Alaska ERTS project 1, and Alaska Cooperative Wildlife Research Unit.

NEW TECHNOLOGY

See results and applications section of the main text.

CONCLUSIONS

ERTS data has broad scale application potential to wildlife biology and management in Alaska. Specific applications of clearly established value include the use of ERTS data to identify snow free areas comprising winter range and movement corridors for several game species as well as habitat mapping of vegetation types. Areas of potential application where feasibility has not been established include detection and mapping of heavily used trail systems, snow disturbance areas associated with caribou winter feeding, and detection of caribou aggregations themselves.

Multiple methods are possible for feature extraction and all of these are considerably less expensive per unit of information return than conventional feature mapping with aerial reconnaissance and photography. Further evaluation of results produced by each method is required but preliminary indications suggest a general ranking according to increasing power of analysis as follows: 1) visual interpretation of single band products, 2) VP-8 analysis of single band products, 3) visual interpretation of false color imagery, and 4) algorithmic classification of digital tape data.

For small areas, the first of these methods is the least expensive and the last is the most expensive, but the amount of detail produced with algorithmic classification is much greater than with other methods. The choice of a method depends entirely upon the volume of processing and the difficulty of the feature discrimination involved. Relatively easy discrimination such as extraction of snow-free areas can be satisfactorily effected by direct visual interpretation to VP-8 analysis of a single band product (usually Band 5 or 6). More difficult discriminations involving habitat types require algorithmic classification of digital data for adequate feature extraction. Most useful wildlife applications require algorithmic classification for valid results.

It is believed that the computer printouts generated with supervised multiband classifications represent reasonably accurate habitat map products. However, more detailed ground-truth verification is required before routine application by operational agencies can be achieved. The Alaska Cooperative Wildlife Research Unit proposes to further test the relative accuracy of the various map products appearing in this report through additional field work in the summer of 1974.

RECOMMENDATIONS

Detailed ground-truth verification of map products should be undertaken in the next field season and a full comparative evaluation made of each analytic method used in the investigation with regard to habitat typing. Additional verification of this type is considered necessary to "convince" personnel of operational agencies that ERTS imagery can be applied to their practical needs.

Development of cost optimized software for direct processing of ERTS digital tape data is strongly recommended. Specifically, development and/or implementation of the following programs at our local computer facility is recommended. First, a program for transfer and internal storage of ERTS tape data on the disc memory capability of the local system. Second, a program for retrieval of specific data at specific latitude-longitude points. This program should provide sufficient flexibility such that the amount of ERTS data desired can be efficiently retrieved at or about whatever geographical points desired. Third, implementation of one or more algorithmic classification schemes. Used in connection with the above programs, the analyst could apply classification to whatever specific scene portion desired. This type of program package would permit efficient retrieval of specific training set data permitting rapid evaluation of feature discrimination capabilities for the scene. Subsequent application of algorithmic classifiers could be made efficiently to specific areas of interest. This would greatly reduce current processing costs and we consider such a program package necessary for efficient use of ERTS data by operational user agencies in Alaska.

Various biological phenomena of interest in Alaska (such as large caribou aggregations) are ephemeral in nature. This quality together with the logistic and weather problems encountered in Alaska has precluded full investigation of the application of ERTS imagery to their identification during the time span of this ERTS-1 investigation. Therefore further feasibility studies related to such phenomena are recommended.

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PUBLICATIONS

None to date. These will be postponed until after an additional summer of field work directed towards confirming map products.

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