Section 2: Land Cover

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Vegetation Mapping of the Arctic Refuge Coastal Plain

Documenting the distribution of land-cover types on the Arctic National Wildlife Refuge coastal plain is the foundation for impact assessment and mitigation of potential oil exploration and development. Vegetation maps facilitate wildlife studies by allowing biologists to quantify the availability of important wildlife habitats, investigate the relationships between animal locations and the distribution or juxtaposition of habitat types, and assess or extrapolate habitat characteristics across regional areas.

To meet the needs of refuge managers and biologists, satellite imagery was chosen as the most cost-effective method for mapping the large, remote landscape of the 1002 Area.

Objectives of our study were the following: 1) evaluate a vegetation classification scheme for use in mapping; 2) determine optimal methods for producing a satellite-based vegetation map that adequately met the needs of the wildlife research and management objectives; 3) produce a digital vegetation map for the Arctic Refuge coastal plain using Landsat-Thematic Mapper (TM) satellite imagery, existing geobotanical classifications, ground data, and aerial photographs; and 4) perform an accuracy assessment of the map.

The land-cover classification scheme developed for the mapping project was based on Walker's hierarchical vegetation classification system for northern Alaska (Walker 1983). During the development of the map, the scheme was altered slightly to provide a group of land-cover classes that were more compatible with the information content of the Landsat-TM spectral data and ancillary data. Wildlife biologists were consulted to ensure that the system included land-cover types relevant to wildlife habitat studies.

We conducted a preliminary assessment of mapping tundra habitats with Landsat-TM and SPOT satellite image data. We used an integration of the 2 data sources for one study area and used Landsat-TM exclusively for another. Results indicated that the expense (at the time of the study) of integrating SPOT data would not be cost effective for the entire mapping project. Landsat-TM methods, however, could improve existing maps made previously with Landsat-MSS data due to TM's finer spatial resolution and additional spectral bands. Therefore, further studies focused on using the Landsat-TM data.

We evaluated 3 methods for producing a land-cover map from Landsat-TM data: 1) a supervised classification approach where spectral categories were defined by reference to field data; 2) an unsupervised approach where spectral categories were defined by a statistical clustering algorithm without reference to field data; and 3) a modeling approach where the unsupervised classification was combined with ancillary data about the landscape, such as terrain types, slope, and elevation (Joria and Jorgenson 1996). Accuracy assessments indicated that modeling was the best approach due to limited spectral differences among several tundra vegetation types.

Spatial data used to produce the land-cover map included 2 Landsat-TM multispectral images, digital elevation data (including derived slope and sun-illumination themes), and maps of riparian zones and terrain types (including hilly coastal plains, foothills, mountains, thaw-lake plains, and floodplains). Each of these data sources comprised a thematic layer in a geographic information system (GIS).

Field data were collected at 102 sites in the Arctic Refuge, with 5 to 20 plots established in different land-cover types at each site over 4 years. The sampling locations were digitized and a GIS theme of field-verified land-cover types was produced.

Field data were cross-referenced with the statistically generated spectral classes to determine the most common land-cover type associated with each of the spectral classes. Because many spectral classes represented more than one land-cover type, the ancillary, non-spectral data layers were used to improve the classification (Hutchison 1982). Each spectral class was cross-tabulated with the field land-cover, terrain type, elevation, sun-illumination, and slope layers. These tables were used to guide the modeling of decision rules for splitting confounded spectral classes into separate land-cover types.

The land-cover class assigned to each unit area on the map (30-m^2 pixel) depended on its spectral class and associated ancillary data, most commonly slope and terrain type. Preliminary land-cover maps were produced, and then the distribution of each land-cover class was viewed in conjunction with color-infrared aerial photographs showing vegetation to judge the map accuracy. Additional field data were gathered for problem areas, and the decision rules were modified as necessary. The process was repeated through several iterations before the final map was produced.

The mapping methods, data, summary statistics, and an accuracy assessment were presented in a map user's guide (Jorgenson et al. 1994). The image processing methods were presented in more detail in Joria and Jorgenson 1996. Sixteen land-cover classes were mapped (Fig. 2.1). They included: 1) wet graminoid tundra, 2) wet graminoid tundra with 10-50% moist inclusions, 3) moist

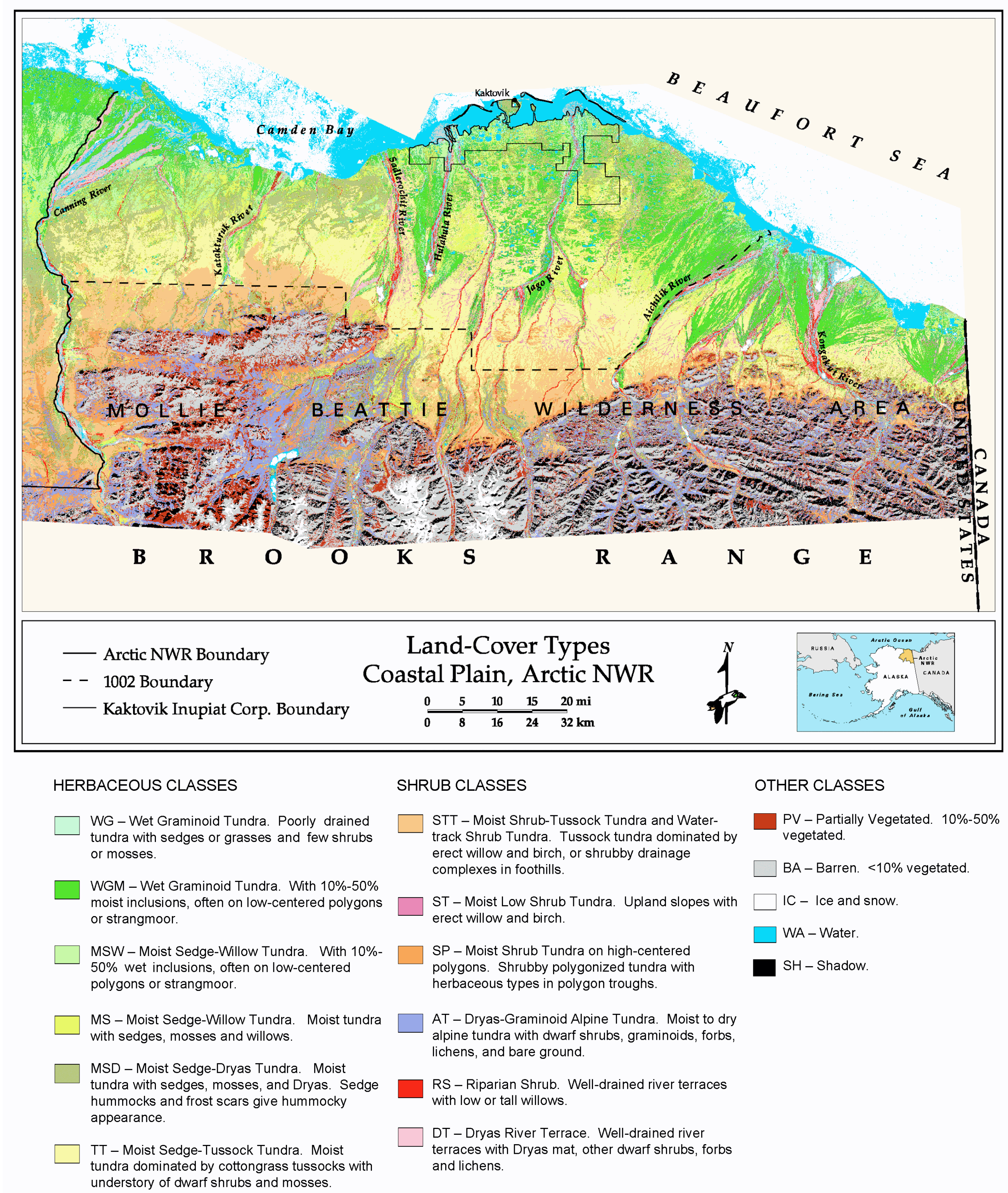

Figure 2.1. Land-cover map of the 1002 Area with corresponding vegetation class names, descriptions, and class codes, Arctic National Wildlife Refuge, Alaska.

sedge-willow tundra with 10-50% wet inclusions, 4) moist sedge-willow tundra, 5) moist sedge-Dryas tundra, 6) moist sedge-tussock tundra, 7) moist shrub-tussock tundra, 8) moist low-shrub tundra, 9) moist shrub tundra on high-centered polygons, 10) Dryas-graminoid alpine tundra, 11) riparian shrub, 12) Dryas river terrace, 13) partially vegetated, 14) barren, 15) ice, and 16) water.

The land-cover classes are described in detail in the map user's guide, which includes quantitative vegetation cover data, species lists of typical plant communities occurring in each land-cover class, photographs, and cross-reference to 7 other classification systems used in northern Alaska.

An accuracy assessment was performed with an independent data set of 318 vegetation plots that were not used to make the map. The plots were systematically located across the coastal plain and foothills but not across the mountains. Point-by-point overall agreement between the mapped land-cover classes and the field-assigned classes was 50% (Table 2.1).

Although land-cover types in the classification system were distinct, land-cover types in the field occurred across a continuum. Almost all of the vegetation in the mapped area was less than 0.5 meters tall and the structural and floristic differences among related types were not great. Subtle transition zones between land-cover types are characteristic of the vegetation of low arctic tundra. Most errors reported in the accuracy assessment were between closely related types that were typically adjacent and interspersed in the field.

Approximately 86% of the assessment points were classified as the correct type or one of the most closely related other types. Agreement is higher when similar classes are combined into the fewer, more general classes typically used in wildlife studies. For example, when the map was combined into 6 or 7 more generalized classes for ungulate habitat studies, over 70% agreement was obtained. The greater initial detail of the 16-class map was preserved, however, because it allows adaptability to a wider range of studies.

Proportional occurrences of the vegetation classes across the entire coastal plain and within various terrain types were roughly similar between the mapped classes and the independent ground-truth data set (Table 2.2), again with the majority of discrepancy arising between closely-related vegetation communities.

The final land-cover map is available to the public in digital format at http://agdc.usgs.gov. The ancillary GIS data layers (topographic data, digitized field data, accuracy assessment point locations, terrain types, and riparian zones) are archived at the Arctic National Wildlife Refuge headquarters in Fairbanks, Alaska.

Because the land-cover map and its associated landscape themes have compatible digital formats, they can easily be applied to a variety of future GIS applications. Additional themes can easily be incorporated as more resource information becomes available, or as new management or mitigation needs are identified.

Table 2.1. Contingency table used to assess the accuracy of the land-cover map of the coastal plain of the Arctic National Wildlife Refuge, Alaska. Table compares the map's coastal plain and foothill land-cover classes (rows, ordered by ecological continuum) with field-assigned classes (columns) from an *independent* systematically-sampled data set of 318 points. Land-cover class codes are defined in Fig. 2.1.

Land Cover Class	WG	WGM	MSW	MS	MSD	TT	STT	SP	ST	AT	RS	DT	PV	BA	WA	TOT	% Agree
WG	**2**	1	1									1				5	40
WGM	7	**19**	4	4	6			1			1	2				44	43
MSW	4	9	**12**	8				2								35	34
MS			4	**15**	4	5										28	54
MSD		5	4	11	**18**	14	1			2		1				56	32
TT		1	6	2	8	**51**	3	6								77	66
STT		1		1	1	5	**13**		2	2						25	52
SP		1				1		**6**								8	75
ST				1			1		**2**							4	50
AT									1	**1**						2	50
RS											**2**	3			1	6	33
DT											1	**6**				7	86
PV		2								1		1	**1**	1		6	17
BA		1												**8**		9	89
WA											1			1	**4**	6	67
TOTAL	13	40	31	42	37	76	18	15	5	6	5	14	1	10	5	318	
%Agree	15	47	39	36	49	67	72	40	40	17	40	43	100	80	80		**50**

Table 2.2. Percent of each land-cover class in the land-cover map of the coastal plain of the Arctic National Wildlife Refuge, Alaska, and the percent partitioned among various terrain types. Land-cover class codes are defined in Fig. 2.1.

Land Cover Class	Entire Map	Entire Coastal Plain[a]	Mountain	Foothill	Hilly Coastal Plain	Thaw Lake Plain	Flood-plain	Riparian Zone[b]
WG	1	2 (4)[c]	<1	<1 (0)	4 (5)	18	3 (5)	1
WGM	9	13 (9)	<1	1 (0)	21 (9)	23	39 (20)	
MSW	6	9 (10)	<1	4 (7)	10 (10)	23	17 (13)	2
MS	6	9 (20)	1	8 (17)	16 (36)	6	9 (16)	2
MSD	10	13 (12)	3	17 (12)	20 (5)	8	6 (14)	
TT	14	21 (22)	<1	32 (33)	23 (29)	<1	4 (2)	1
STT	9	12 (6)	2	24 (11)	<1 (0)	0	<1 (0)	2
ST	5	3 (1)	8	6 (2)	0 (0)	0	<1 (0)	
SP	1	1 (4)	<1	1 (5)	1 (0)	<1	1 (0)	
AT	1	2 (1)	20	3 (4)	0 (0)	0	<1 (0)	
RS	1	1 (2)	<1	1 (0)	<1 (0)	<1	4 (4)	18
DT	1	2 (3)	<1	<1 (0)	<1 (0)	<1	5 (10)	14
PV	6	2 (2)	14	1 (1)	<1 (0)	<1	2 (6)	8
BA	15	7 (2)	32	1 (0)	<1 (0)	2	9 (6)	33
IC			3	<1 (0)	<1 (0)	4	1 (0)	3
WA			<1	<1 (0)	2 (1)	16	5 (5)	13
SH	6	<1 (0)	16	<1 (0)	<1 (0)	<1	<1 (0)	
Sq-km[d]	18501	12145	7073	6397	1810	271	3523	1038

a Entire map excluding the mountain terrain type.
b Riparian zone is included within the floodplain terrain type.
c Number in parentheses is the percent cover for each land-cover type as estimated by an *independent* systematic field sample of 756 points.
d Number of square-kilometers in each terrain type.

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