Agroborealis

RECEIVED
APR 11 1991

Volume 23, Number 1, January 1991

Agricultural and Forestry Experiment Station
School of Agriculture and Land Resources Management
University of Alaska Fairbanks

Today's Research Will Answer Questions in 1995

Diversification, specialization, change—how many times a week do we hear those words? Television, newspapers and magazines bombard us with these challenging and alarming words. We hear how we have to diversify our economy. We hear that we must find new specialized niches for Alaskan businesses. We hear how we must change to meet today's challenges with tomorrow's skills.

Within the Agricultural and Forestry Experiment Station and the School of Agriculture and Land Resources Management, we've listened to these prophecies. Only we heard them and started addressing them more than a decade ago. We listened when they were only whispers. We did so that we could respond when the whispers became issues needing answers.

Just look at the diversity of articles in this issue of Agroborealis and see how we've responded over the years. And then take a few minutes and review the list of publications in the back. Notice the diversity of topics explored. See how so many of them answer some of the questions we ask today. Significantly, many of these publications report studies initiated three, five or more years ago. Reporting findings from our studies continues to be one of the most important responsibilities of our researchers. But research takes time. That's why today, we're still listening to whispers. And from those whispers, we plan our research programs to have answers in 1996 or 1997 or even 2006.

With our talented staff and faculty, we'll continue to explore Alaska's many diverse opportunities and problems in natural resources management, agriculture and forestry. This issue of Agroborealis illustrates research in projects ranging from reindeer to arctic tundra rehabilitation.

In closing I'd like to thank both ARCO Alaska, Inc. and BP Exploration (Alaska) for their generous grants to underwrite the costs of color photography in Arctic Tundra Rehabilitation—Observations of Progress and Benefits to Alaska. The article, begins on page 29. This summer, the companies will be giving reprints of the article to Prudhoe Bay visitors. Incidentally, Dr. McKendrick started his work on the North Slope in 1972.

We'd also like you to know that this issue of Agroborealis is printed on recycled paper. That's another of our responses to the world's changes.

James V. Drew

James V. Drew
Dean, School of Agriculture and Land Resources Management
Director, Agricultural and Forestry Experiment Station

ISSN: 0002-1822

Agroborealis

January 1991

Volume 23 ..... Number 1

Agricultural and Forestry Experiment Station

School of Agriculture and Land Resources Management

University of Alaska Fairbanks

ADMINISTRATION

J.V. Drew, Ph.D .... Fairbanks
Dean, SALRM, and Director, AFES

G.A. Mitchell, Ph.D. .... Palmer
Assoc. Dean, SALRM, and Assoc. Director, AFES

C.W. Hartman, B.S. .... Fairbanks
Executive Officer, SALRM

C.E. Lewis, Ph.D. .... Fairbanks
Head, Div. of Resources Management

K. VanCleve, Ph.D. .... Fairbanks
Head, Div. of Forest Sciences

F.J. Wooding, Ph.D. .... Fairbanks
Head, Div. of Plant and Animal Sciences

V.L. Cochran, M.S. .... Fairbanks
Location Coordinator, USDA-ARS

Scientists from the Agricultural Research Service, U.S. Department of Agriculture, cooperate with the Agricultural and Forestry Experiment Station, University of Alaska Fairbanks.

Agroborealis is published by the Agricultural and Forestry Experiment Station, University of Alaska Fairbanks. A written request will include you on the mailing list. Please address all correspondence regarding the magazine to: Publications, Agricultural and Forestry Experiment Station, University of Alaska Fairbanks, Fairbanks, Alaska, 99775-0080.

Managing Editor .... J. Stephen Lay
Composition .... Scott L. Penwell
Printed by Printing and Duplicating Services, University of Alaska Fairbanks.

The Agricultural and Forestry Experiment Station at the University of Alaska Fairbanks provides station publications and equal educational and employment opportunities to all without regard to race, color, religion, national origin, sex, age, physical handicap, or veteran status.

To simplify terminology, trade names of products or equipment may have been used in this publication. No endorsement of products or firms mentioned is intended, nor is criticism implied of those not mentioned.

Material appearing herein may be reprinted provided no such endorsements are stated or implied. Please credit the researchers involved and the University of Alaska Agricultural and Forestry Experiment Station.

With the exception of the cover, this publication is printed on recycled paper.

Table of Contents

ABOUT THE COVER ... *Helicopters replace herders during reindeer handlings on the Seward Peninsula. Skilled pilots can collect and drive thousands of animals without overstressing the animals. Helicopters collect the deer in the early evening for nighttime handling. Bringing the reindeer into the herding pens at night allows vaccination, deantlering and counting during the cooler hours which protects the animals from getting overheated during handlings.*

AFES Notes

Four new faculty members have joined the School of Agriculture and Land Resources Management.

Assistant professor **Dr. Lyle A. Renecker** came to UAF from the University of Alberta to head the reindeer program. He graduated from Canada's Wilfred Laurier University. Renecker earned his master's in wildlife management from Laurentian University and his doctorate in wildlife productivity and management from the University of Alberta. Renecker replaced Bob Dieterich who retired.

Harry R. Bader rejoined the faculty as an assistant professor of natural resources management. During the 1988-89 academic year he was a visiting faculty member while Bob Weeden was on sabbatical. Weeden retired last spring and Bader was appointed to the permanent position. Bader earned his doctorate of jurisprudence from Harvard Law School. He has a bachelor's degree emphasizing range and wildlife management from Washington State University.

Dr. Joshua A. Greenberg has joined the faculty as an assistant professor of resource economics. He replaces Drs. Bill Workman and Wayne Thomas who retired. Greenberg is a graduate of the University of Connecticut. He earned his master's from the University of Alaska Fairbanks and his doctorate from Washington State University.

Visiting Assistant Professor **Susan Todd** replaces Dr. Tom Gallagher who is on a one year special research leave. Todd is a graduate of Bryn Mawr College and earned her master's degree from the University of Michigan. She is currently completing the dissertation for her doctorate from Michigan.

Sixty of the 101 permanent AFES/SALRM employees were honored in December for longevity of service to the University of Alaska. Five of the recipients received gift certificates for books from the University of Alaska Press for their service of between 20 and 25 years. Honored for 15 to 20 years of service were eight employees. They were awarded a pen and pencil set. Specially designed mugs were presented to the 18 employees with between 10 and 15 years of service. Twenty-seven employees received lapel pins recognizing their service of five to 10 years.

	20-25 Years of Service	
Mary Boyd	Keith Van Cleve	Chick Hartman
Lola Oliver	Frank Wooding	
	15-20 Years of Service	
Jay McKendrick	Peter Scorup	Carolyne Wallace
Carol Lewis	John Fox	Joe Offner
Pat Wagner	Fredric Husby	
	10-15 Years of Service	
John Muth	James Drew	Bob Schlentner
Jenifer McBeath	Charlie Knight	John Yarie
Laurie Wilson	Tim Quintal	Alan Jubenville
Grant Matheke	Wilder Simpson	Cathy Birklid
Bob Van Veldhuizen	Julia Moor	Jan Hanscom
Donald Brainard	Dot Helm	Gary Michaelson
	5-10 Years of Service	
Wayne Bouwens	Stephen Sparrow	Carla Kirts
Bill Thompson	Glenn Juday	Mary Lou Herlugson
Donald Carling	Roy Erickson	Pat Mayer
Janey Wineinger	Larry Burke	Chien-Lu Ping
Roseann Leiner	Edmond Packee	Tom Malone
K.C. Christensen	Steve Blake	Tom Gallagher
Alan Tonne	Heather McIntyre	Allen Mitchell
Pat Holloway	Darleen Masiak	Kathy Wells
Ben Bruce	Mary Ann Peters	Barbara Pierson

Five AFES/SALRM employees received meritorious service awards honoring them for outstanding work. A committee, comprised of previous meritorious service award recipients, selected the winners from written nominations submitted by AFES/SALRM employees. Honored were: **Dr. John D. Fox,** assistant professor of resources management; **Donald Gossett**, Palmer farm maintenance mechanic; **J. Stephen Lay,** publications supervisor; **Timothy Quintal**, forest soils lab technician; and **Dr. Stephen D. Sparrow**, associate professor of agronomy. Each recipient was awarded a plaque honoring him for his dedicated service and a check for $1,200.

... Continued on page 25

Economics of Reindeer Rangeland

William G. Workman, Wayne C. Thomas, and Joshua A. Greenberg

COMMERCIAL production of reindeer (Rangifer tarandus) occurs in northwest Alaska, primarily on public lands on the Seward Peninsula. The industry has been in existence since 1892 and was a major economic activity in the region through the 1920s (Stern *et al.*, 1980). It has since declined in importance, but remains the only commercial use of the range resource on the peninsula. Reindeer enterprises are typically family-run operations with herd sizes varying from fewer than 1,000 to 7,000 animals. Herd ownership is restricted by U.S. Federal law (Public Law 75-413) to Native people of Alaska. Currently there are 19 herds containing, in total, 33,000 reindeer. In the Seward Peninsula region, where 13 of the herds are located, there are 16,012,080 acres of available rangeland, with individual range permit areas averaging 1,000,755 acres.

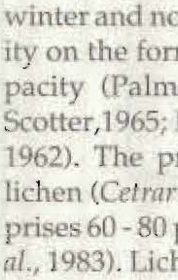
The reindeer rangelands can be divided into winter and non-winter areas, with forage availability on the former determining overall carrying capacity (Palmer, 1944; Palmer and Rouse, 1945; Scotter,1965; Klein ,1964; Pegau, 1968; Wood *et al.*, 1962). The primary winter forage of reindeer is lichen (*Cetraria* spp. and *Cladina* spp.), which comprises 60 - 80 percent of the winter diet (Swanson *et al.*, 1983). Lichen is a fungal algal symbiont characterized by a very slow rate of growth. The slow growth rate leads to long recovery periods for grazed winter lichen range, thus limiting range productivity.

Three types of management plans have been designed, in consultation with herders, for most Seward Peninsula reindeer herds (Swanson and Pendelton, 1984). These plans can be referred to as intensive, semi-intensive and extensive management. The common practice of managers of reindeer herds is to employ extensive management, which is characterized by an absence of rotational grazing and infrequent and sporadic herder contact, resulting in the herd being unsupervised for lengthy periods of time. The absence of close herd supervision requires that the permit areas be stocked at a low density to prevent reindeer from straying beyond area boundaries and to prevent the severe depletion of the forage resource. Semi-intensive and intensive management systems feature denser stocking rates and increased herder supervision of the deer, and result in shorter recovery periods for the winter range lichen.

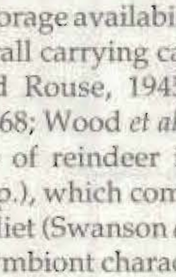
It has been suggested that under traditional management methods, the range is not being utilized at its biological capacity (Swanson and Pendelton, 1984; Pegau, 1968). Of greater interest is whether economic returns from use of the available forage resources can be increased through use of alternative herd management methods. To this end, this paper considers the effects of more intensive management and rotational grazing on net returns from reindeer herding operations. The information generated through our simulations is of potential interest not only to herders but to government agencies responsible for managing these public lands. Policy issues of current interest include the state's move toward adjusting grazing fees and the conflicts between caribou and reindeer use of specific rangelands in northwest Alaska. The results reported here can improve the background on which to base related policy decisions.

Methods

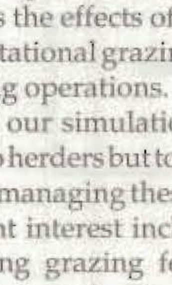
Linear programming (LP) is a technique that allows one to systematically relate the goals of an enterprise or organization to the constraints that limit the ability to achieve these goals. This ana-



William G. Workman, Associate Professor of Economics, retired, Agricultural and Forestry Experiment Station, School of Agriculture and Land Resources Management, University of Alaska Fairbanks.



Wayne C. Thomas, Professor of Economics, Emeritus, Agricultural and Forestry Experiment Station, School of Agriculture and Land Resources Management, University of Alaska Fairbanks.



Joshua A. Greenberg, Assistant Professor of Resource Economics, Agricultural and Forestry Experiment Station, School of Agriculture and Land Resources Management, University of Alaska Fairbanks.

lytical tool has been applied to numerous range-livestock situations (e.g., D'Aquino, 1974; Bartlett *et al.*, 1974; Hewlett and Workman, 1978; and Torell *et al.*, 1982). It was used in the present application to build on two previous studies of Alaska reindeer enterprises (Arobio *et al.*, 1979; Thomas *et al.*, 1983). Range management decisions were not explicitly considered in either of these previous cases. The LP model developed for the present research was formulated to consider such decisions.

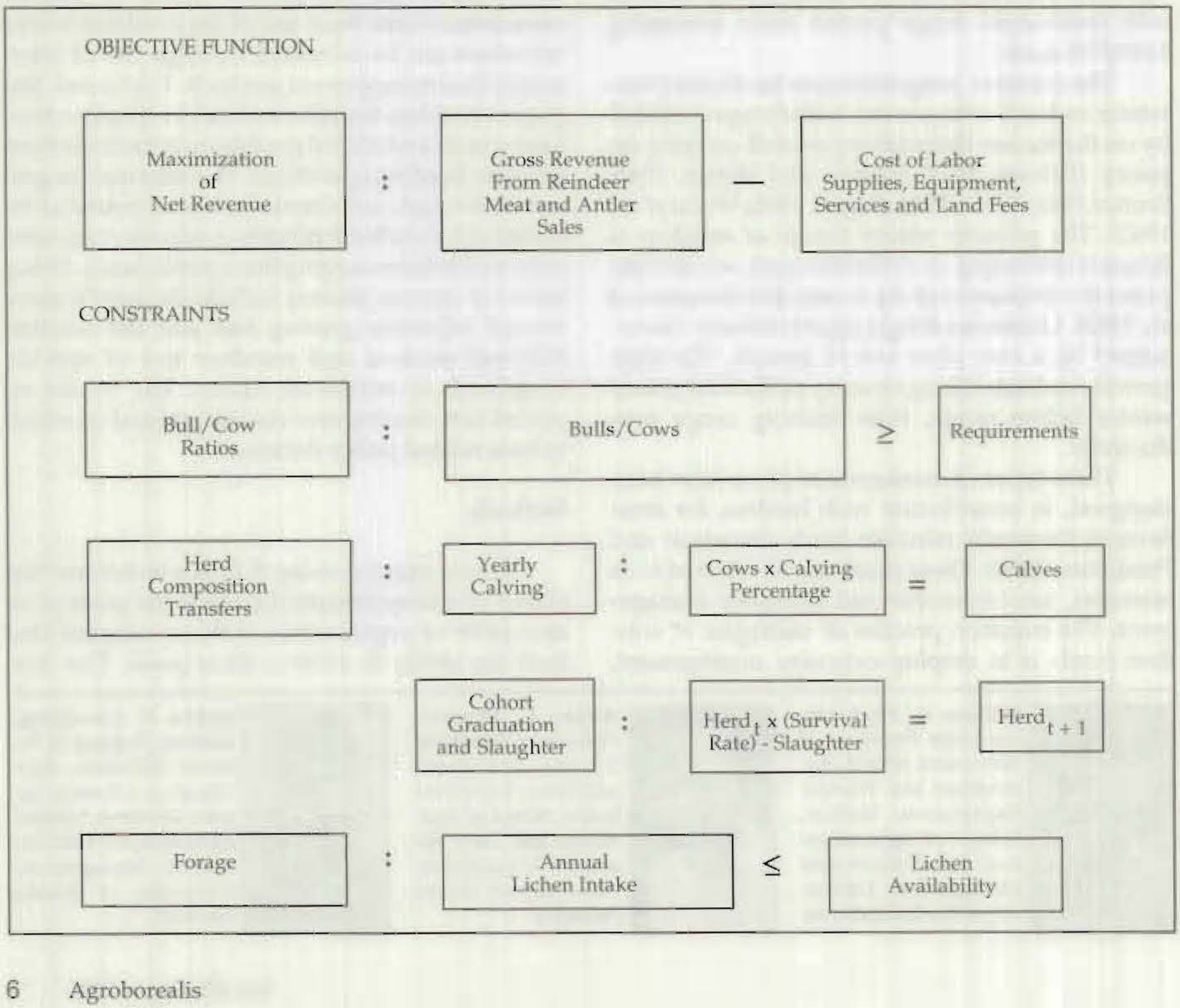
Model Development

Reindeer herd owners are assumed to attempt to maximize net returns, subject to a set of operating and biological constraints. These constraints fall into three broad categories: 1) bull/cow ratio requirements; 2) transfer restrictions representing annual changes in herd composition due to age progression, calving, death loss, and slaughter; and 3) winter forage availability. Three management systems were embedded into the model to represent different labor-management intensities. These management alternatives defined the three options available on a specified range permit area. The model was constructed to solve for the optimal herd structure for each management system and then to identify the system that achieved the greatest net returns. Figure 1 shows a simple schematic of the model structure.

Objective Function

Revenue is derived from antler and meat sales.

Figure 1. Schematic of Model Structure.



Costs are associated with labor for summer and winter handlings and with the purchase of supplies, snowmobiles, fuel, helicopter and air charter services, and repairs of cabins and corrals. While these expenditure categories are common to all management systems, magnitudes varied across systems. Semi-intensive and intensive management regimes also incorporated additional costs due to increased herding labor.

Animal production activities yield velvet antlers and herd replacements as reindeer graduate to older age classes, die or are slaughtered. These activities were further divided into male and female cohorts which were assumed to be present in the herd from calves to 10-year-olds. Culling occurred at age 10 because of decreasing fecundity and increasing mortality rates of deer beyond this age. Slaughter activities allowed for the butchering of bulls, steers, and cows, three years of age and older. A separate set of animal production and slaughter activities was present in the model for each management system.

The market for velvet antler is the orient, primarily South Korea. Antler production in Alaska constitutes a minor portion of the total world export market, and, therefore, prices were assumed independent of production levels. The market recognizes two principal reindeer antler grades which are believed to be unaffected by management. Recent prices of \$25/lb and \$8/lb for grades A and B, respectively, were used in the analysis. Grade distributions were determined from discussions with the primary antler buyer. Since grade is based in part on antler size, it was assumed that grade A antler was produced only by males and females 3 years and older. Male and female 1- and 2-year-olds produced grade B antler. Antlers produced by steers are deformed and lighter than those produced by non-castrated males. Males were assumed to be castrated in the summer after antler removal and slaughtered the following winter, consistent with industry practices. Per animal antler production was held constant across management systems. Antler weights for cohorts were determined from industry sources and Luick (1979).

A carcass meat price of \$1.75/lb, reflecting the average price recently received by herders in smaller villages on the Seward Peninsula, was used in the analysis. There is no grading system for carcass meat, and carcass weights were assumed to be independent of management system. Most of the meat is presently sold regionally. The virtually untapped export markets in other regions of Alaska and in the contiguous United States were assumed to be of sufficient size to prevent meat prices from being affected by changes in production levels.

Variable costs were estimated from data provided by individual herders, the Reindeer Herders Association (RHA), and Stern *et al.* (1980). Individual budgets and herding labor schedules were constructed for each management system, in consultation with herders and the RHA. It was assumed that a single herder could provide 90 days of herding supervision during the 180 day winter season (Oct. 15 - April 15). Hired herders were required only under the semi-intensive and intensive management systems; the herd owner or members of his family conduct all herding for the extensive system. The rotational grazing plan associated with semi-intensive management required one herder per 2,000 reindeer during the winter and calving season (April 15 - May 15). The intensive management system and its associated rotational grazing plan required the highest level of herder supervision: two herders per 2,000 reindeer during the winter and calving season. Both of the latter systems required one herder to be employed year-round to assist in the supervision of the herd during the summer season and to help with summer operational activities, in addition to winter herding duties. Slaughter costs were estimated based on an assumed production rate of a crew of four being able to butcher 24 reindeer per six-hour day.

Constraints

The assumed bull/cow ratios were based on the number of cows a single bull, five years or older, could be expected to service. A separate bull/cow ratio constraint was included for each management system. For semi-intensive and intensive management, the ratio was set at 1:15 (Baskin, 1983). For extensive management, the ratio was set at 1:10 (Luick, 1978). Differences in this ratio between management plans was due to the level of herd supervision.

The LP model employed here was a single-period framework, requiring a constant herd size and composition. It did, nonetheless, reflect annual changes that occurred as cohorts graduated to older

Table 1. Assumed Annual Herd Mortality Rates and Calving Percentages. Sources: Luick, 1978; Thomas et al., 1983; Greenberg, 1984.

	Extensive Management	Semi-intensive Management	Intensive Management
		Mortality Rates(%)	
Calves	30	20	10
1-year old	15	10	5
2-year old	6	4	2
Adult	3	2	1
		Calving Percentage	
	60	68	68

age classes, or left the herd due to mortality or slaughter. Sets of transfer constraints for each management system accommodated introduction of a yearly calf crop, graduation of cohorts to the next oldest age class, and the effects of slaughter and mortality. Assumed mortality rates and calving percentages are shown in Table 1. Mortality rates decreased and calving percentages increased with increased herd supervision as predation and straying were better controlled. Additionally, increased supervision allowed reindeer to be directed away from rangelands with severe surface icing and crusting and/or high snow cover.

The focus of the forage constraint was the available lichen supply on winter range since it is this component of the reindeer's diet that limits carrying capacity of the rangelands. To increase the utilization of winter lichen range, intensive and semi-intensive management employ rotational grazing systems. These systems were based on research conducted by Andreev (1954 and 1976) concerning lichen physiology and on field work by the Soil Conservation Service (SCS), U.S. Department of Agriculture.

Andreev's studies indicated a direct non-linear relationship between the portion of the lichen podetium cropped and the necessary recovery period before a lichen range could be re-grazed. By Andreev's estimates, a two- to five-year recovery period (depending on species, age, and weather conditions) is necessary when the upper one-fourth to one-third of the lichen podetium is cropped (45 percent of the live lichen biomass). The recovery period is lengthened to 10 years if the upper two-thirds to three-quarters of the podetium is cropped (70-80 percent of the live lichen biomass). Palmer and Rouse (1945) estimated that if the lichen range were severely depleted, the recovery period increased to 20 - 40 years.

The grazing system assumed under intensive management used a five-year rotation of the winter range, which requires restricting grazing during most of the winter season (Oct. 15 - Apr. 15), to the upper one-third to one-quarter of the lichen podetium. For this to occur, the reindeer need to be slowly directed by herders along a grazing path. This would necessitate daily supervision during the winter season, weather permitting. Semi-intensive management was assumed to use a 10-year rotational grazing system that restricted the reindeer cropping to, at most, two-thirds to three-quarters of the lichen podetium during most of the winter season. (Andreev estimated this to be the portion that reindeer harvest when grazing normally, in the absence of herder interference and deep snow cover.)

For the semi-intensive system, the winter range was divided into ten winter management units (WMU), with the reindeer to be confined to a single WMU during a winter season. This restriction would necessitate that the reindeer herd be checked by herders every two to three days. As indicated previously, for both intensive and semi-intensive management, it was assumed that the increased supervision of the herd would require the owner/operator to hire herding labor.

Extensive management is characterized by an absence of a rotational grazing system. Reindeer are able to return annually to favorite winter ranges. To protect against the severe depletion of winter forages, relatively low stocking rates would have to be maintained. In the calculation of annual lichen availability on winter range, a 25-year recovery period for winter lichen range was assumed. All herding labor is supplied by the herd owner/operator or by members of his family.

A representative range permit area was chosen for use in construction of the forage constraint. The SCS has identified six ecological site types (coastal tundra, tussock tundra, dryas limestone slope, lichen granite slope, bald limestone slope, and lichen meadow) on this permit area which are suitable for winter grazing. In total, the permit area contains 118,793 acres of winter grazing lands. SCS compiled total dry lichen biomass on a per acre basis for each site. This estimate was adjusted to account for desirability of the ecological site for grazing, the portion of the podetium grazed, and reindeer grazing habits. Desirability factors ranged from 100 percent (high quality winter grazing site) to 50 percent (poor quality winter grazing site). The portion of the lichen live biomass grazed are 45 percent, 75 percent, 100 percent, for intensive, semi-intensive, and extensive management, respectively. Finally, available lichen was reduced by 50 percent to account for foraging losses from trampling and reindeer grazing habits (Pegau, 1968). These adjustments yielded annual total usable dry lichen per acre. Total area for each winter ecological site was calculated using the gravametric method (Greenberg, 1984) and then adjusted to account for length of rotational or recovery period and for inaccessibility due to snow cover. Total annual net live lichen biomass (dry weight) was calculated for each management system as the summation of the annual net live lichen biomass per unit area times the annual net land area for each ecological site.

The winter lichen requirements per animal were specified as coefficients in the forage constraint. Holleman *et al.* (1979) estimated daily winter intake rates of lichen to be .5 ounce per lb of animal body weight. Animal body weights were calculated as a percentage of carcass weights. Ringberg *et al.* (1981) found carcass weights to vary from 49.6 to 58.9 percent of body weight for calves to 3-year-olds, irrespective of sex. The low figure of 49.6 percent was used to purposely protect against overgrazing.

Results

Model Solutions

Initially, the model was allowed to consider only the extensive management plan. The solution for the extensively managed operation produced as optimal a herd size of 1,436 animals (Table 2) and annual net returns above variable costs of $57,418 (Table 3). Deducting fixed herd and facilities investment costs (interest and depreciation on the cabin and corrals and interest on the reindeer), along with the required $10 annual filing fee for the grazing allotment, yields $25,700 as the return to the owner/operator for labor and management input. This solution reflects, to a large degree, the present production system except that it shows a higher proportion of bulls than is typical in current operations. Given the assumed relative velvet antler and meat prices, the slaughtering of males is delayed until bulls reach culling age since they are more valuable as antler producers than as producers of carcass meat.

In the second case, the model was allowed to consider both extensive and semi-intensive management. Given these options, the model indicated that semi-intensive management should be exclusively employed by the reindeer operation. Optimal herd size was 3,010 animals, with annual returns above variable cost of $129,680, and returns to herd owner/operator equalling $72,186 (Tables 2

*Table 2. Optimal Herd Composition for an Alaskan Reindeer Range Unit.**

Cohort Group	Extensive Management Number	Extensive Management %	Semi-intensive Management Number	Semi-intensive Management %	Intensive Management Number	Intensive Management %
Calf (F)	122	8.50	229	7.61	262	6.71
1 Year (F)	85	5.92	183	6.08	236	6.04
2 Year (F)	72	5.01	165	5.48	224	5.73
3+ (F)	405	28.20	674	22.39	769	19.68
Calf (M)	122	8.50	229	7.61	262	6.71
1 Year (M)	85	5.92	183	6.08	236	6.04
2 Year (M)	72	5.01	165	5.48	224	5.73
3 Year (M)	68	4.74	159	5.28	219	5.61
4 Year (M)	65	4.53	155	5.15	217	5.55
5+ (M)	340	23.69	868	28.84	1,258	32.20
End of Winter Herd Size	1,436	100.00	3,010	100.00	3,907	100.00

* Errors from rounding may cause the percent columns not to total to 100 percent.

and 3.) The proportion of bulls under semi-intensive management increased over that in the extensive management system. This adjustment was made possible by decreased animal mortality rates and increased calving percentage. These two factors allowed for a constant herd structure to be maintained with a smaller calf crop, as a percentage of total herd size.

Finally, the model was allowed to consider all management options, wherein it indicated that the maximum net returns were achieved by exclusively employing intensive management. Herd size was 3,907 animals, with returns above variable costs equaling $191,295, and returns net of both variable and fixed costs equaling $118,098. Decreased animal mortality rates assumed in an intensively managed herd *vis-a-vis* a semi-intensively managed herd permitted an increase in the proportion of bulls present in the optimally structured herd.

Earnings projected here from reindeer herding operations may appear somewhat large in comparison with those of range livestock enterprises in western North America. However, efficient reindeer operations should be able to achieve these comparatively favorable results since income taxes, range fees and other land costs typically present in cattle and sheep ranch operations are absent in a reindeer enterprise. The nontaxable status of earnings from a reindeer operation stems from the 1937 Reindeer Act (U.S. Public Law 75-413). Under this act, the reindeer technically are not owned by the herders, but rather are held in trust by the U.S. Bureau of Indian Affairs (BIA). Except for an annual $10 filing fee per allotment, grazing fees are not charged on federal reindeer range in Alaska.

With such potentially attractive returns available from more intensive management, one would expect herders to adopt these systems. The only significant investment cost would be that for deer acquisition. These animals can be obtained through purchase from other herders, a BIA-sponsored loan program, or natural increase. Indeed, the recent

Table 3. Slaughter Schedule, Objective Function Values and Returns to Owner for an Alaskan Reindeer Range Unit.

Slaughter Schedule	Extensive Management Number	Semi-intensive Management Number	Intensive Management Number
5 Year (F)	-	-	94
6 Year (F)	-	87	117
7 Year (F)	-	58	-
8 Year (F)	17	-	-
9 Year (F)	35	-	-
10 Year (Steer)	49	135	202
Total Meat Production (lb.)	2,430	6,729	9,952
Total Antler Production Grade A (lb.)	440	1,095	1,654
Total Antler Production Grade B (lb.)	335	686	939
Objection Function Value (Net Revenue in $)	57,418	129,680	191,295
Fixed Cost ($) *	31,718	57,494	73,197
Returns to Owner/ Operator ($)	25,700	72,186	118,098

* Interest and depreciation on the cabin and corrals for all three management systems was $9,318.52 using straight line depreciation and an 8% interest rate. Interest on herd investment was $22,389.26, $48,165.07 and $63,868.59 for the extensive, semi-intensive and intensive systems, respectively. The rate of interest used was 10%. A $10 annual filing fee was also included as a fixed cost.

industry pattern suggests an interest in more intensive management as deer numbers have grown by almost a third in the past eight years with no increase in grazing land (Alaska Agricultural Statistics Service, 1989.) The opportunity cost of time spent away from traditional subsistence activities may, however, continue to temper herders' interests in becoming involved in more time-demanding herding methods (Thomas, *et al.*, 1983.)

Forage Values

Results from the model showed that available lichen supply on winter range was the only binding constraint in any of the three management plans. Correspondingly, "shadow prices," or marginal contributions of winter forage to the reindeer herder's net earnings, were computed at $.01, $.03, and $.05 per lb per year for the extensive, semi-intensive and intensive management plans, respectively. These figures can be used to determine the marginal value of an acre of rangeland with a given biological productivity employed under the different management options. The following formula was used to make this conversion:

$$RV = \frac{SP \times [NL \times (1-SL)]}{RP}$$

where

RV=Annual per acre rental value
SP=Shadow price
NL=Net live lichen lb/ac
SL=Snow loss percentage
RP=Rotational period

The annual rental rates (marginal net returns) on various ecological sites and for the different management options are shown in Table 4. Again, the differing rental values demonstrate the simulated effect of intensified management on the net economic productivity of the range.

Some Land Management Implications

Rangelands of Northwest Alaska historically have been administered by the Bureau of Land Management (BLM), U.S Department of the Interior. The policy of the BLM has been to collect an annual $10 filing fee on each allotment but with no additional use charge. This policy has effectively accommodated the herders' desires for extensively managed operations. The rangeland resources represent not only forage for the animals but potentially large buffer zones between herds on different permit areas. Thus, the vastness and the pricing of the permit areas provide a low cost substitute for the herding efforts that might be required to keep herds separated and to prevent overgrazing on smaller tracts. As a result, the forage on the permit areas remains vastly under utilized since the owner/operator has no obligation to compensate the public for the value of the carrying capacity of the land if it were to be used more intensively. Further, given the restrictions on transferring permits, there is no

Table 4. Annual Rental Values for Range Ecological Sites.

Winter Ecological Site	Net Live Lichen Biomass (lb/ac)*	Rental Values ($/ac)/year
Lichen Sedge (Coastal Tundra)		
Extensive	555	.21
Semi-intensive	417	.90
Intensive	250	1.60
Lichen (Tussock Tundra)		
Extensive	498	.19
Semi-intensive	374	.93
Intensive	224	1.84
Dryas Limestone Slope		
Extensive	86	.03
Semi-intensive	65	.16
Intensive	39	.32
Lichen Granite Slope (Alpine)		
Extensive	324	.13
Semi-intensive	243	.60
Intensive	146	1.20
Bald Limestone Slope		
Extensive	13	.00
Semi-intensive	10	.02
Intensive	6	.05
Lichen Meadow (Mountain)		
Extensive	647	.25
Semi-intensive	484	1.20
Intensive	292	2.40

* These values correspond to the amount of lichen available per unit area once each rotational period, i.e. once every 5, 10 and 25 years for an operation practicing intensive, semi-intensive, and extensive management, respectively.

economic mechanism at work to encourage the use of allotments by more efficient operators since individual herders have no incentive to relinquish claims to portions of their allotments which are not utilized.

Shifting land ownership patterns have followed the Alaska Statehood Act (U.S. Public Law 85-508) and Alaska Native Claims Settlement Act (U.S. Public Law 92-203), and part of the rangeland in Northwest Alaska is now owned by the state and managed by the Alaska Department of Natural Resources. This agency is introducing a new system of grazing fees on rangelands across the state. One of the considerations given in establishing these charges is that they approximate the fair market rental value of the forage. Thus, the economic rent earned by the resource would be transferred from the herder to the land owner, i.e., the citizens of Alaska. In the context of the Northwest Alaska rangelands, the figures given in Table 4 might be considered as the annual per acre grazing fees on various winter ecological sites. However, adjustments would need to be made to the figures to allow for a return to management input.

While a grazing fee based on the value of range when it is used to capacity may be consistent with a policy of promoting "highest and best use," it may not provide for a socially desirable outcome. Society may deem that the reindeer industry provides benefits in addition to its financial return and that the government's role should be to help promote a healthy reindeer industry. The introduction of a grazing fee based on intensive management may lead to an opposite result by reducing the present size of the industry, and even possibly by causing its demise. This result would occur if there were not a sufficient number of individuals willing to utilize rangelands which become available due to any current members of the industry's inability to pay the grazing fee. An alternative would be to base the grazing fee on returns associated with current management practices in the industry. A basis for setting such a fee is represented in Table 4 by values given for extensive management. While this fee may not provide the incentive for individuals to manage their operations at highest efficiency, it does limit the impact of the fee on the reindeer operations. For any grazing fee, it may be desirable to follow the recommendation of Arobio and Workman (1981) to implement the grazing fee over a number of years to mitigate its effect on reindeer enterprises.

A related issue concerns the competition between caribou and reindeer in the use of rangelands on the Seward Peninsula. Given the relatively poor economic performance of the reindeer industry in the past, public lands agencies have been reluctant to restrict caribou access to the reindeer grazing allotments. The results of this study, however, demonstrate a potential for vast improvement in that performance. Thus, the opportunity cost of allowing caribou to roam freely on the allotments may be much more significant than is currently felt. The more socially efficient mix of uses of the range can be identified only by considering the *potential* net benefits associated with each use. It may be that the reindeer industry is indeed currently being undervalued in public land debates. Huffaker, *et al.* (1989) argue for the introduction of incentive-based fee systems — a combination of grazing fees and compensation payments — on public rangelands in the Western U. S. as a means of promoting a more efficient mix of multiple uses. This recommendation may also hold potential as an instrument for fostering improved resource allocation in Northwest Alaska.

Summary

In this paper a net returns maximizing linear programming framework was used to model an Alaskan reindeer operation. Incorporated in the model were three herd management options, each representing a separate type of grazing system. When management methods were altered from extensive management, using no rotational grazing, to intensive management, using a 5-year rotational grazing system, returns above variable costs were increased by 333 percent.

The only binding resource constraint within the linear programming model was lichen supply on winter range. Using shadow prices of this forage, annual rental values for the various types of winter ecological sites were calculated. The results demonstrated that Seward Peninsula rangeland has the potential for earning increased financial returns for both the reindeer herders and the land owner.

The introduction of range fees based on annual rental values was discussed. Policy makers who wish to implement such grazing fees must determine their exact purpose. If the primary purpose is to

provide incentives for rangelands to be used efficiently, and thereby earn for the government a return on these ranges when they are used to capacity, then grazing fees would best be based on the returns associated with intensive management practices. If, however, the primary purpose is to earn for the government some return, without disturbing the status quo, then the extensive set of rental values should be considered as a basis for setting grazing fees. In addition, the estimated rental values can provide information for a more complete evaluation of the range use trade-off between reindeer and caribou. ❑

References

Alaska Agricultural Statistics Service. 1989. Alaska Agricultural Statistics. Palmer.

Andreev, V.N. 1954. The growth of forage lichens and methods for their regulation. Translated from Russian. Bot. Inst. An SSSR, Ser. III, Geobotanika, 9:11-74.

Andreev, V.N. 1976. Recommendations for the rational use of reindeer pastures. V.I. Lenin All-Union Academy of Agriculture, RSFSR, Moscow, 1976. (Translated from Russian, ed. J.R. Luick. Inst. Arctic Biol., Univ. of Alaska, Fairbanks. 1981.)

Arobio, E.L., W. Thomas, and W.G. Workman. 1979. Mathematical programming for considering management options in Alaska reindeer herding." Proc. 2nd Int. Reindeer/Caribou Symp. Roros, Norway. 690-699.

Arobio, E.L. and W.G. Workman. 1981. Economic issues in establishing grazing fees on state lands in Alaska. Report submitted to Dept. of Natural Resources, State of Alaska. Agr. Exp. Sta. Univ. of Alaska, Fairbanks.

Bartlett, E.T., G.R. Evans, R.E. Bement. 1974. A serial optimization model for ranch management. J. Range Manage. 27:233-239.

Baskin, L.M. 1983. The causes of calf reindeer mortality. Acta Zool. Fennica. 175:133-134.

D'Aquino, S.A. 1974. A case study for optimal allocation of range resources. J. Range. Manage. 27:228-233.

Greenberg, J.A. 1984. The economics of reindeer herd management. Unpublished M.S. thesis. Univ. of Alaska, Fairbanks.

Hewlett, D.B., and J.P. Workman. 1978. An economic analysis of retention of yearlings on range and potential effects on beef production. J. Range Manage. 31:125-128.

Holleman, D.F., J.R. Luick, and R.G. White. 1979. Lichen intake estimates for reindeer and caribou during winter. J. Wildlife Manage. 43:192-201.

Huffaker, R.G., J.E. Wilen, and B.D. Gardner. 1989. Multiple use benefits on public rangelands: an incentive-based fee system. Am. J. Agr. Econ. 71:670-678.

Klein, D.R. 1964. Range related differences in growth of deer reflected in skeletal ratios. J. Mammology. 45:226-335.

Luick, J.R. 1978. Antlers, aphrodisiacs and the Alaska reindeer industry. In: Reindeer Herders Newsletter, Luick, J.R. ed. Inst. of Arctic Biol. Univ. of Alaska, Fairbanks. 3(4).

Luick, J.R. 1979. Herd statistics, research report, and news of New Zealand deer farming industry. Reindeer Herders Newsletter. Inst. of Arctic Biol. Univ. of Alaska, Fairbanks. 4(2).

Palmer, L.J. 1944. Food requirements of some Alaskan game mammals. J. Mammology. 25:49-54.

Palmer, L.J. and M.H. Rouse. 1945. Study of the Alaskan Tundra with references to its situation to reindeer and other grazing. U.S. Fish and Wildlife Research Report 10.

Pegau, R.E. 1968. Reindeer range appraisals in Alaska. Unpublished M.S. Thesis. Univ. of Alaska, Fairbanks.

Ringberg, T.M., R.G. White, D.F. Holleman, and J.R. Luick. 1981. Body growth and Carcass composition of lean reindeer (Rangifer tarandus tarandus L.) from birth to sexual maturity. Ca. J. Zool. 59:1040-1044.

Scotter, G.W. 1965. Reindeer ranching in Fennoscandia. J. Range Manage. 18:301-305.

Stern, R., E. Arobio, L. Naylor, and W. Thomas. 1980. Eskimos, reindeer and land. Agr. Exp. Sta. Univ. of Alaska, Fairbanks. Bull. 59.

Swanson, J.D., M.P. Kinney, and P.C. Scorup. 1983. Reindeer range vegetation inventory procedures. Acta Zool. Fennica. 175:39-41.

Swanson, J.D. and D. Pendelton. 1984. Range management plans for Alaskan reindeer. Proc. 2nd. Int. Rangeland Cong. Adelaide, Australia.

Thomas, W.C., E.L. Arobio, L. Naylor, and R. Stern. 1983. An alternative management system for Alaskan reindeer herds. Agri. Systems. 11:1-16.

Torrell, T.A., C.F. Speth, and C.T.K. Ching. 1982. Effects of calf crop on net income of a Nevada range cattle operation. J. Range Manage. 35:519-21.

Wood, A.J., I.M. Cowna, and H.C. Nordan. 1962. Periodicity of growth in ungulates as shown by deer of the genus odocoileus. Ca. J. Zool. 40:593-603.

Reindeer Meat: Relationship Among Dietary Fat, Flavor and Acceptability

Ruthann B. Swanson and Marjorie P. Penfield *

Health-conscious consumers are concerned about their dietary fat intake (FMI, 1989). This concern is reflected in products available in supermarkets. In Alaska, one major supermarket chain offers predominantly USDA Select beef, a lower fat alternative to the traditionally purchased USDA Choice beef. All major supermarket chains in urban Alaska now carry a wide variety of fresh and previously frozen fish and shellfish in their in-store fish markets. The selection of poultry has also been expanded. Both poultry and fish are frequent low-fat replacers of domestic red meats in American diets (Breidenstein, 1988). Reindeer, another low-fat potential alternative to domestic red meats (Swanson et al., 1990), is also available in limited amounts in both restaurants and supermarkets. This low-fat exotic meat (USDA-FSIS, 1989), should also appeal to many Alaskans, the majority of whom enjoy trying new foods (Swanson and Lewis, 1991).

Consumer interest in dietary fat intake, particularly saturated fat content, is linked to associations between high dietary fat consumption and increased incidence of chronic diseases. Both heart disease and cancer (US DHHS, 1988) have been linked to dietary fat intake. Domestic red meats (beef, pork and lamb) are among the major contributors of fat in the American diet (NRC, 1989). In a recent national consumer survey, 33 percent of the respondents reported their red meat consumption had decreased because of health concerns (FMI, 1989).

The total fat content of reindeer meat is similar to the fat content of meat from game animals such as hunt-killed mule deer (Miller et al., 1986) and caribou (Novakowski and Solman, 1975). A four ounce (113.5 g) serving of reindeer meat provides about 132 kilocalories with only about one-third of this energy from fat (Swanson et al., 1990). For comparison, four ounces (113.5 g) of USDA Select beef completely trimmed of visible fat, provides 166 kilocalories and 47 percent of these kilocalories are from fat. Further, when serving sizes are equal, the amount of saturated fat consumed by individuals who enjoy reindeer (Swanson et al., 1990) is within the range reported for fish and poultry (Linscheer and Vergroesen, 1988). Reindeer is a suitable low-fat red meat choice for health-conscious consumers who prefer red meats.

Not only is reindeer meat low in fat (Swanson et al., 1990), it is also high in iron (Sjenneberg and Slagsvold, 1968). Beef and pork are the major sources of the most absorbable form of iron in the American diet (USDA, 1988). When chicken and fish replace beef, pork and lamb in the diet (Breidenstein, 1988), substantially lower levels of iron as well as fat (Adams, 1975) are consumed. For many Americans, including Alaskans, dietary iron is already present at marginal levels. Reindeer as a low-fat alternative to poultry and fish may help domestic red meat consumers maintain their iron intake while decreasing their fat intake.

If current production trends continue (USDA, Alaska Agricultural Statistics Service, 1990), reindeer meat will be increasingly available in Alaska and elsewhere. Most of the reindeer available for sale is field-slaughtered between mid-September and the end of March. Zhigunov (1961) implies that fat content varies with time of slaughter. Effects on fatty acid composition are unknown.

Ruthann B. Swanson, Assistant Professor of Food Science, School of Agriculture and Land Resources Management, University of Alaska Fairbanks.

* **Marjorie P. Penfield**, Professor, Department of Food Technology and Science, Agricultural Experiment Station, The University of Tennessee.

Differences in fat content and composition may also affect flavor of reindeer meat. Total fat content as well as the specific fatty acids present have been related to the flavor of domestic red meats (Miller et al., 1986). Red meats which have high levels of polyunsaturated fatty acids have a flavor which is less acceptable to many consumers. Many game and exotic meats have higher levels of polyunsaturated fatty acids than are found in domestic red meats (Miller et al., 1986). For these reasons, fat extracted from muscles of the reindeer forequarter harvested in March and September was compared. Flavor variability was also assessed.

Materials and Methods

Representative reindeer forequarters were purchased from commercial sources in two lots. Six forequarters harvested on the Seward Peninsula in March, 1989 and five forequarters harvested in September, 1989 were shipped to The University of Tennessee, Knoxville, Tennessee, for study. The forequarters in each lot were allowed to thaw at two degrees C for 48 hours prior to chemical analysis.

Chemical Analysis

Composite samples from the chuck blade muscles (shoulder muscles) were analyzed for moisture and fat content (AOAC, 1984). Two replicates were obtained on samples from the March handling and replicates for the September handling were three for moisture and two for fat. Fatty acid composition was also determined (AOCS, 1975).

Sensory Evaluation

An experienced sensory panel evaluated the gamey flavor of reindeer samples grilled to an endpoint temperature of 158-165 degrees F (70-74 degrees C) from both slaughter dates. Ten panelists who were consumers of hunt-killed deer evaluated the samples. A 15-point non-structured linear intensity scale, where 1 equals "none" and 15 equals "intense", was used. Overall acceptability was also evaluated on a scale where 1 equaled "not acceptable" and 15 equaled "extremely acceptable." During both sensory sessions, samples were evaluated in individual booths under white light. Single samples were presented on white plates within 30 minutes of cooking. Room temperature water was provided for rinsing between samples. Presentation order was random.

A sensory paired comparison test (Larmond, 1977) was also conducted to assess differences in flavor due to slaughter date. Four pairs of reindeer meat samples were evaluated by 24 experienced sensory panelists. Two of the four pairs of samples were matched to test for the placebo effect. These meat samples which were also cooked to an endpoint temperature of 158-165 degrees F (70-74 degrees C), were chopped in a food processor to reduce appearance and textural differences. Evaluation occurred under red light to minimize color differences. Other testing conditions were identical to those previously described. Prior to testing, the reindeer meat samples from the March harvest had been stored frozen, at zero degrees F (minus 18 degrees C), for 12 months and the samples from the September harvest had been held under identical storage conditions for six months.

Statistical Analysis

Means and standard deviations were calculated for the chemical analyses; fatty acids present were classified as saturated, monounsaturated, and

A sensory panelist evaluates reindeer samples.

Slaughter date	Moisture (%)	Fat (%)
March	74.7 ± 0.12^{a}	3.56 ± 0.08^{a}
September	75.1 ± 0.45^{b}	3.37 ± 0.06^{a}

[a]Means + or – standard deviation from two composite replicates from six and five reindeer chuck blade muscles from animals harvested in March and September, respectively.
[b]Means + or – standard deviation from three composite replicates from five reindeer chuck blade muscles.

Table 1. Composition of reindeer meat harvested on two dates in 1989.

polyunsaturated and the percentage in each class was determined. The percentage of panelists who rated for overall acceptability in the acceptable range and gamey flavor below midpoint on the sensory attribute scales were determined. The flavor paired comparison test data were analyzed with Chi-Square.

Results and Discussion

Total Fat Content

Fat and moisture content of the reindeer from both slaughter periods is reported in Table 1. No differences were found among the samples. This probably reflects the limited external fat cover and intermuscular fat present. Total fat content reflects the intramuscular fat present.

Total fat content of reindeer from both slaughter periods is less than half that of the lean from comparable cuts of USDA Select beef (USDA, 1986). The level present is about the same as medium-fat fish such as swordfish or bluefish. Salmon, a high-fat fish, is actually higher in fat than reindeer meat (Harsila and Hansen, 1989). Thus, from a nutritional perspective, reindeer is an exotic meat which offers a low-fat alternative to domestic red meats, poultry and fish throughout the year.

Fatty Acid Composition

The relative amounts of specific types of fatty acids present in the total diet as well as overall fat content are important in the development of chronic diseases. Percentages of saturated, monounsaturated and polyunsaturated fatty acids in reindeer meat harvested during the two slaughter periods are depicted in Figure 1. Muscles from both slaughter periods were rich in long-chained saturated and monounsaturated fatty acids. Only small amounts of polyunsaturated fatty acids were present. Clearly, differences due to slaughter date occur. This difference reflects the higher levels of myristic acid (14:0), a medium-chained saturated fatty acid and lower levels of oleic acid (18:1) in animals harvested in March. Oleic acid is a long-chained monounsaturated fatty acid. Fatty acid composition of domestic red meat animals is influenced by animal age, diet and environment (Dugan, 1987). It appears that similar fatty acid composition effects occur in reindeer. In the period immediately preceding slaughter, reindeer from the two harvest periods consumed different diets and endured different environmental conditions (Stern et al., 1980).

Despite the higher proportion of saturated fatty acids in muscles from the reindeer slaughtered in March, consumers of equal-sized servings of beef or pork will still consume much higher levels of saturated fats. Because the total fat content of the reindeer is so low, reindeer, like poultry and fish, contribute relatively small amounts of saturated fats to the diet. Thus, when considering reindeer, the variation in saturated fat content is probably unimportant within a total diet.

Flavor

Total fat content as well as the degree of fatty acid unsaturation has been reported to influence acceptability of meat flavor by consumers. A mini-

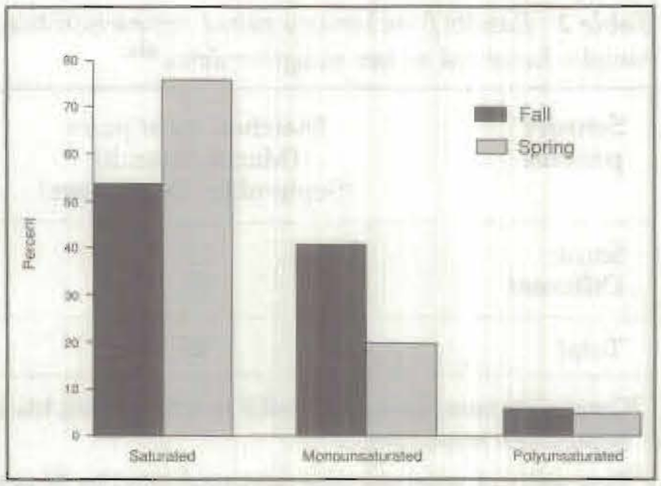


Figure 1. Percentage of fatty acids in reindeer meat from two harvest periods.

mum fat content of two to three percent for domestic red meats has been recommended to ensure acceptable palatability among American consumers. Lower fat levels are necessary for palatability of meat cuts from the forequarter than the hindquarter from these animals (Savell and Cross, 1988). The total fat content of the reindeer muscles studied (Table 1) approximates the range recommended for palatability of domestic red meat species.

Species-specific flavors are associated with volatile compounds produced when the fat present is heated (Judge et al., 1989). Miller et al.(1986) suggest that the relatively high levels of polyunsaturated fatty acids in game meats are responsible for the gamey flavor that many consumers find objectionable. The gamey flavor inherent to these species may be characteristic of the volatiles produced by heating the specific fatty acids present. However, this gamey flavor may also be due to off-flavors which develop during storage. The high levels of polyunsaturates present makes these meats more susceptible to oxidative changes. Despite the cause, the lower levels of polyunsaturates present in reindeer, a semi-domesticated animal, may produce a less gamey flavor that more consumers may find desirable. Variation in polyunsaturated fatty acid content was less than one percent (Figure 1).

No differences in the flavor of reindeer meat samples from the two slaughter periods (Table 2) despite differences in fatty acid composition (Figure 1) were detected by the experienced sensory panelists. Therefore, the variation in fatty acid composition did not alter the flavor of the meat.

Three quarters of the panelists rated gaminess of these samples below mid-point on the scale. These ratings indicate that a mild gamey flavor was present. Previously, flavor desirability of reindeer meat was found to be inversely related to flavor intensity (Blaylock et al., 1967). Approximately two-thirds of the panelists rated overall acceptability of these reindeer samples in the acceptable range.

Conclusions

For consumers concerned about the health effects of their dietary fat intake, selection of reindeer throughout the year can be an alternative choice. This exotic meat, a low-fat alternative to poultry and fish, should appeal to health-conscious consumers who prefer red meats. The reindeer meat evaluated in this study had a mild gamey flavor. The mild gamey flavor may increase its appeal among consumers who are not typical consumers of game or exotic meats.

Although slaughter date did not affect total fat content, the array of fatty acids present varied. A higher percentage of saturated fatty acids were found in meat samples from the March handling. However, these differences have little practical nutritional significance because the low overall fat content of reindeer ensures a low consumption of saturated fats, despite variation in fat composition. Although reindeer can be a healthy meat choice, it, like other entrees, is only one part of a healthy and nutritious diet. A variety of foods from all food groups are required to maximize the positive effects of diet on health status. The reindeer forequarters evaluated in this study were representative of ani-

Table 2. *Results from sensory paired comparison test for flavor differences between pairs of reindeer chuck blade samples harvested on two slaughter dates.*[abc]

Sensory panelist	Matched meat pairs (March/March) (September/September)	Unmatched meat pairs (March/September) (September/March)	Total meat pairs evaluated
Same	25	24	49
Different	23	24	47
Total	48	48	96

[a]Composite samples from 6 and 5 reindeer chuck blade muscles from animals harvested in March and September, respectively.

[b]Four pairs of meat samples were evaluated by 24 panelists.

[c]No significant difference in flavor between slaughter dates according to Chi-square analysis (X^2=1.64, p=0.2002).

mals harvested during the 1989 March and September handlings. However, additional work is needed to verify these effects over time. ❑

References

AOAC. 1984. *Official Methods of Analysis*, 14th ed. Association of Official Analytical Chemists. Washington, DC.

AOCS. 1975. *Official and Tentative Methods of the American Oil Chemists Society*, American Oil Chemists Society, Champaign, IL.

Adams, C.F. 1975. "Nutritive Values of American Foods," In *Agriculture Handbook 456*. Agricultural Research Service, United States Dept., Agriculture, Washington, DC.

Blaylock, D.M., Cramer, D.A. and Wookey, L.E. 1967. Effect of animal age and sex on certain qualities of reindeer meat. In *Proceedings 18th Alaskan Science Conference*, College, AK.

Breidenstein, B.C. 1988. Changes in consumer attitudes toward red meat and their effect on marketing strategy. *Food Technology* 42(1):112.

Dugan, L.R., Jr. 1987. "Chemistry of animals tissues. Part 2. Fats." In *The Science of Meat and Meat Products*, 3rd ed. ed. Price, J.F. and Schweigert, B.S. Food and Nutrition Press, Inc., Westport, CT.

FMI. 1989. *Consumer Attitudes and the Supermarket. Trends 1989*. Food Marketing Institute, Washington, DC.

Harsila, J. and Hansen, E. 1989. *Light-Hearted Seafood*. National Seafood Educators, Richmond Beach, WA.

Judge, M., Aberle, E., Forrest, J., Hedrick, H. and Merkel, R. 1989. *Principles of Meat Science*, 2nd ed. Kendall/Hunt Publishing Co., Dubeque.

Larmond, E. 1977. *Laboratory Methods for Sensory Evaluation of Food*. Agriculture Canada Publication 1637, Canada Dept. of Agriculture, Research Branch, Ottawa, Ont.

Linscheer, W.G. and Vergroesen, A.J. 1988. "Lipids." In *Modern Nutrition in Health and Disease*, 7th ed. ed.Shils, M.E. and Young, V.R. Lea & Febiger, Philadelphia.

Miller, G.J., Field, R.A. and Riley, M.L. 1986. Lipids in wild ruminant animals and steers. *J. Food Quality* 9:331.

NRC. 1989. *Recommended Dietary Allowances*. 10th ed., National Academy Press, Washington, DC.

Novakowski, N.S. and Solman, V.E.F. 1975. Potential of wildlife as a protein source. *J. Animal Science* 40:1016.

Savell, J.W. and Cross, H.R. 1988. The role of fat in the palatability of beef, pork, and lamb. In *Designing Foods: Animal Product Options in the Marketplace*. National Academy Press, Washington, DC.

Sjenneberg, S. and Slagsvold, L. 1968. *Reindeer Husbandry and Ecological Principles*. (translated from the Norwegian). Universitetsforlaget, Oslo.

Stern, R.O., Arobio, E.L., Naylor, L.L. and Thomas, W.C. 1980. *Eskimos, Reindeer and Land*. Agricultural and Forestry Experiment Station Bulletin 59. University of Alaska Fairbanks.

Swanson, R.B. and Lewis, C.E. 1991. Food Acquisition: Effects of resource availability and allocation in urban Alaska. *Home Economics Research Journal* (in press).

Swanson, R.B., Penfield, M.P., Mitchell, D., Reimann, M.J. and Loveday, H.D. 1990. *Quality Assessment of Reindeer Meat*. Agricultural and Forestry Experiment Station Circular 78, University of Alaska, Fairbanks.

USDA, Alaska Agricultural Statistics Service. 1990. *Alaska Agricultural Statistics*. Palmer, AK.

USDA. 1986. "Composition of foods. Beef Products—Raw, Processed, Prepared," In *Agricultural Handbook 8-13*. Human Nutrition Information Service, United States Dept. Agriculture, Washington, DC.

USDA. 1988. *Nationwide Food Consumption Survey Continuing Survey of Food Intakes by Individuals. Women 19-50 Years and Their Children 1-5 Years, 4 Days 1986*, NFCS, CSFII Report No. 86-3. Human Nutrition Information Service, United States Dept. Agriculture, Washington, DC.

USDA-FSIS. 1989. Voluntary inspection of exotic animals—Final rule. *Federal Register* 54(9): 1328.

US DHHS. 1988. *The Surgeon General's Report on Nutrition and Health*. US Government Printing Office, Washington, DC.

Zhigunov, P.S., ed. 1961. Slaughter of reindeer, primary processing, storage and transportation of the products. In: *Reindeer Husbandry* (translated from the Russian). Published for the United States Sept. of the Interior and National Science Foundation. Washington, DC. Published by the Israel Program for Scientific Translations.

Game Production: Agricultural Diversification For Alaska?

Lyle A. Renecker

It has become abundantly clear in recent years that agricultural enterprises must diversify if they hope to survive. North America has wrestled with the concept of alternative agricultural practices for over 20 years. Farmers no longer want to approach this business of agriculture with all "their peas in one pod." Political subsidy wars, stabilization plans, depressed commodity prices, and over-production are among the reasons why traditional farming is less profitable and why farmers are diversifying their conventional farm businesses. To the real people in the agricultural sector—the farmers—any change must offer a positive cash flow. More importantly, it must gain the confidence and general interest of farmers.

Consumer trends have been towards healthier and leaner meat products. Meat from native wild ungulates is a natural candidate because of its lean qualities, low percentage of intramuscular fat, and low energy content. In 1986, a conference was held in Des Moines, Iowa which provided 100 options for diversification of the farming community. Deer farming was among them. Commercial game farming would seem a natural alternative to conventional agricultural enterprises that choose to diversify and attempt to meet the greater demand for leaner meats. Here, I describe some of the history behind game production in North America, important political and conservation considerations that involve the game industry and private sector, and how Alaska may fit into the greater global picture.

Historical Perspective

Lyle A. Renecker, Assistant Professor of Animal Science (Reindeer), School of Agriculture and Land Resources Management, University of Alaska Fairbanks.

Man has been associated with the use of native wild herbivores in North America since Paleolithic times more than 100,000 years ago. Prior to the arrival of European fur traders, the Great Plains of North America were abound with wildlife. An estimated 35-75 million plains bison and about 10 million wapiti lived on the continent.

In historic times, native ungulates were utilized as an available source of food first by indigenous Indians and then by explorers and later by settlers who arrived in North America in search of new homes. From his explorations in western Canada, Samuel Hearne in 1770 stated that "moose were the easiest of the deer kind to tame." Homesteaders quickly recognized the favorable disposition of moose and often trained them as beasts of burden or for light farm chores (Figure 1).

However, as this new civilization pushed westward, populations of wild ungulates were slaughtered because of the unprecedented need for food by the frontier settlements and loss of habitat to conventional agriculture. Bison herds were soon decimated in such numbers that between 1873 and 1875 approximately 6.75 million head were killed (most in the United States Midwest). By 1889, William Hornaday estimated that only 635 bison remained in North America. Existence of plains bison today stems from the private efforts of a Flathead Indian and seven ranchers. The roots of plains bison populations were largely derived from 54 wild calves that were caught and raised by these private individuals. This historical event was of great consequence in the conservation of the species and delivers a message about the role of the farmer in wildlife management.

Interest in the commercial production of native herbivores continued to thrive in Canada. In 1915, the Federal Department of Agriculture established a program to evaluate the potential of plains bison x cattle crosses. The purpose was to develop a breed that retained the natural adaptive characteristics of bison to extreme environmental conditions, but maintain the favorable meat characteristics and

Errata

Game Production:
Agricultural Diversification For Alaska?

Industry Development in Alaska

Definitions: Are they important as we decide?

It may seem trivial, but is it important to define what we do or propose to do in this new agricultural industry of game production? Is it a farm or ranch that we operate and are the animals domestic, tame, or habituated to humans? Is this need for clarification even important? These definitions are critically important from an educational, political, and industry perspective. It is imperative that a new industry have clear goals that are uncluttered by the subjective opinion of the public or government. This step deserves enough attention to provide definitions and examples of how confusion can arise or be avoided.

Game Farming — This strategy will only occur on private, deeded land that is fenced to define ownership. Animals are stocked at carrying capacity on productive or marginal pastures to offset the limitations of a smaller land base and offered full or partial feed supplements in various seasons. This operation takes advantage of all economic opportunities (in the case of wapiti farming - velvet antler sales, meat sales, and sale of breeding stock). To avoid hobby - subdivision farming, government agencies often apply a minimum land base restriction (in Alberta, Canada the minimum is 59 acres).

Game Ranching — This type of extensive enterprise also applies to private land bases or communal properties that are owned by Native people and are fenced. Commonly, this management system exploits the adaptive traits of native ungulates that are stocked at or just below carrying capacity and then harvested as a surplus occurs. However, a productive ecosystem such as the prairie/parklands of western Canada, rangelands of Texas, or plains of Kenya and the Republic of South Africa are necessary in order to maintain the live animal biomass (lb of animal/ac) that is necessary to offset the high cost of fencing. This is a low-labor input strategy and no supplemental feed is offered. Economic opportunities are limited to when animals can be baited into corrals during winter and then surplus animals are sold as breeding stock or slaughtered for meat. Owners could also choose to exploit hunting opportunities on the ranch. This system utilizes a mixed-species grazing system in which several ungulates are included that generally, do not use the same food resources.

Game Herding — Animals are loosely herded at or below carrying capacity on open range and occasionally, are moved between ranges to encourage more efficient utilization of forage. Animals are often collected and herded into a facility and handled for routine management and slaughter. The land is not fenced or deeded but grazing rights have been leased. With this strategy, it is of utmost importance to maintain the most productive herd structure possible because loss of food to barren individuals can not only influence economics, but range conditions and future carrying capacity and animal productivity long into the future. The reindeer industry in Alaska's Seward Peninsula, Scandinavia, and Soviet Union are classic examples of herding operations.

Game Cropping — This applies to wild herds of native ungulates that are occasionally harvested on a commercial basis (with the cooperation of government agencies) to remove surplus animals. These animals forage on public land. Commercial harvests of muskox in the Northwest Territories and the George River Caribou held in Labrador, Canada and the bison in Custer State Park, South Dakota are examples of game cropping.

Clearly, there is no need for confusion in the meaning of game production strategies. If commercial game farming is legalized within a political jurisdiction then the only additional unknown is simply what products can be legally marketed. The regulatory process should be rather simple if consistency is maintained, however, discrepancies among definitions soon creates doubt and suspicion in the minds of the public about what hidden ideas or agendas are buried within the regulations. The public soon becomes confused about what exactly is proposed and what will be gained or even lost.

The use of the term **domestic** is another term that is often applied out of context and can result in the perception that a practice is not aesthetically acceptable. The Oxford dictionary defines domestication as "bringing an animal into the dependence of man." The game farming industry is often criticized because wild animals are transformed into domestic stock once they are placed behind a fence. It is difficult to establish a precise definition of domestic, however, one thing is for sure — it takes about 10,000 years for this process to occur. The new industry must make a clear distinction between domestic and semi-domestic animals and those that are merely tame or can be tamed. ❑

temperament of cattle. The program was terminated in 1973. Based on the research findings over the years of the program, it was determined that cross breeding the two species would not be as successful as concentrating on improving the bison or cattle.

Figure 1. Moose pulling an Indian travois in north central Alberta (c. 1899). Photograph by C.W. Mathers; permission granted by Saskatchewan Archives (Renecker et al. 1989).

Early Interest in Production Strategies

With establishment of Elk Island National Park, a working model of a mixed-species grazing system was initiated. This production strategy utilized an assemblage of a grazer (bison), mixed feeder (wapiti), and browser (moose) which have minimal overlap in their winter food habits. The Kikino Metis Settlement, in North Central Alberta, Canada was the first to apply this large-scale (game ranch) management system to a commercial operation. This strategy dilutes the cost of fencing by increasing the size of the land base to more than 9 ½ miles square and minimizes the labor-input by stocking animals at carrying capacity with no supplementary feeding. However, the experience of the Kikino Wildlife Ranch was one of little control over animal movement and economic opportunities were limited to winter when animals can be baited into corrals or traps. The decision of the Kikino operation was a change in direction to more intensive management.

Few private land owners possess the large contiguous tract of land that is necessary for an extensive game ranch. As a result, most commercial operations have been intensive game farms, on smaller properties, with supplementary feeding, which orchestrates a farm management program that exploits all economic opportunities.

Game farming in some Canadian provinces has been increasing at a rate of 30% per year. There are about 17,700 wapiti and 82,600 plains bison on commercial farms and ranches in Canada and the United States. At this stage of development, the game/bison farm industries are largely constrained by availability of breeding stock. It is logical to predict that it will require about 15-20 years for the industry to grow and reach a stable level that is based on the price of meat. For example, if the commercial population of wapiti in Canada continued to grow with the assumptions of good management and normal harvest of products and animals, by 2004, a respectable over-wintering herd of more than 200,000 head would be present on farms (Figure 2). This stock would produce annually 10,500 tons live weight of wapiti for meat production and 133 tons of velvet antlers (Figure 3) for total gross returns of about $62 million (US).

Industry Development in Alaska at a Glance

Physical Environment

The climate of Alaska is extremely pulsed with short warm summers from June to September and typically cold winters with a mean January minimum temperature of about -19° F in the Interior. The vegetation varies from temperate forest to montane and tundra types. Only a small proportion of Alaska has a climate and soil base that is suitable for cultivation and crop production. These areas consist of the Cook Inlet-Susitna Lowland and the Tanana Valley of the Interior Alaska Lowlands. Where agriculture is practiced, the principal crops grown in Alaska are cereals (barley and oats), grasses for hay and silage, and potatoes. Because of extremely cold winters and frost conditions forage legume crops are not widely grown in Alaska.

Generally, crop production and grazing in these regions are limited by a growing season which varies from three to four months. However, on Kodiak Island and the Aleutians, grazing can be maintained year round with some supplemental feeding. The best soils for grass production are those with good drainage, have a natural vegetation cover of grasses and forbs, and receive adequate precipitation. Organic soils are poorly drained and susceptible to flooding and erosion. Tundra soils are generally limited in depth and by the environment and not good for intensive agricultural production.

Commercial Game Production

Under the current game farm regulations in Alaska, commercial game production is permissible with bison, musk oxen, reindeer, or wapiti. Commercial reindeer herding has been practiced by indigenous people in the state of Alaska since the turn of the century. During the industry's development, health, management, and marketing programs have been developed and applied. The result has been an extremely important industry to both the Seward Peninsula, where much of the industry is concentrated, and the state as a whole. Because of their adaptive behavior and tolerance to harsh environments, wapiti and bison are other target species that could be easily farmed by the private sector in the agricultural regions of Alaska. For example, wapiti eat less than cattle, adjust quickly to conventional feedstuffs, and their gregarious behavior is compatible with intensive production. Each of these species has adapted to northern environments. With interest in alternative agriculture systems, ecological, physiological, and behavioral adaptations of these wild or semi-domestic species could

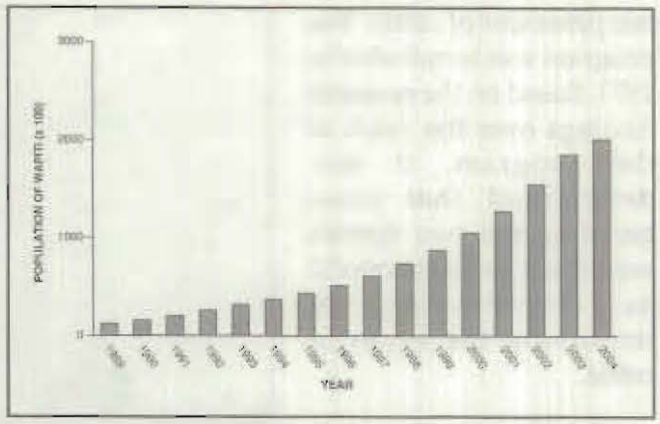


Figure 2. Projected growth of the population of wapiti on Canadian game farms until 2004.

be deployed with an advantage to the farmer. These species have growth cycles adapted to the seasonal food supply and cold tolerance and digestive systems to efficiently utilize native, as well as, domestic forages. For example, bison have adapted to more efficient utilization of low quality feedstuffs than cattle, wapiti are very productive with high growth rates, and reindeer have adapted to both extensive herding in the tundra and, as with other species, they have shown promise for intensive farm operations.

The Private Land Issue

Perhaps the greatest challenge that faces government wildlife agencies is management of resources on private lands. It is difficult to convince a farmer that he should not drain a wetland, clear a forest, or plow a grassland if it translates into more cash returns and less disparity in his annual budget. The farmer requires a tangible benefit in order to fully appreciate the importance of these marginal agricultural lands. Game and bison farming may have created that tangible benefit.

During the winter of 1986-87, there was an estimated 1 million acres of topsoil lost in Western Canada from wind erosion. From pre-settlement to 1985, about 40% of the prairie wetlands disappeared, and during 1984-85, some calculations have shown that forests were being removed at a rate of 80 ac/hr in Western Canada. These areas, like many in Alaska, are marginal, fragile, and probably should never have been altered. They were excellent habitats and range for wapiti and bison and with proper management, could provide reasonable returns for investments.

Although bison, reindeer, or wapiti may be the target species for a potential game farm industry in Alaska, other beneficiaries would be wildlife and waterfowl that utilize these pastures, wetlands, and forests (for example, rodents, ducks, game birds, shore birds, etc.). The marginal agricultural land that once seemed valueless, unless altered, now offers potential habitat and food resources for a high value commodity—commercially-raised game. This results from the realization that for the privately-held land:

VALUE = IMPORTANCE = CONSERVATION.

What are the potential problems and is there a basis for opposition? Some individuals have insisted that by legalizing the sale of commercially-raised game meat, it will increase the motivation to poach. However, this conclusion assumes that flow of meat, velvet antlers, or other by-products into the marketplace would be impossible to control and that by controlling supply there is a strong hold placed on demand. However, farm-raised venison and velvet antlers are already sold on the world market. Studies have shown that both venders and consumers demand a high quality, consistent product. High quality is obtained through proper timing of harvest and selection of animals of the proper age. It would be impossible to reproduce these conditions in wild herds. In addition, markets can be controlled by requiring live delivery for ante/post-mortem inspection, and carcasses could be stamped, wrapped in cryovac, and chilled for retail. This would effectively eliminate illicit trade and ensure a consistent quality in the marketplace.

We must also remember that the best way to eliminate poaching—a concern of everyone—is through public response. Interestingly, if Alaska's statistics are similar to other jurisdictions, much of the current poaching probably occurs under the umbrella of the hunting season.

All interest groups realize disease can be a potential problem if the industry is not implemented properly. However, movement of farm-raised game is subject to the same constraints as domestic cattle. It is also in the farmer's best interest to maintain the best health conditions to ensure high productivity. Whether a species is being managed in the wild or on a farm setting, as the stocking rate increases there is potential for higher parasite loads and incidence of disease. The farmer or manager must employ appropriate grazing management and animal husbandry strategies to maintain a healthy herd.

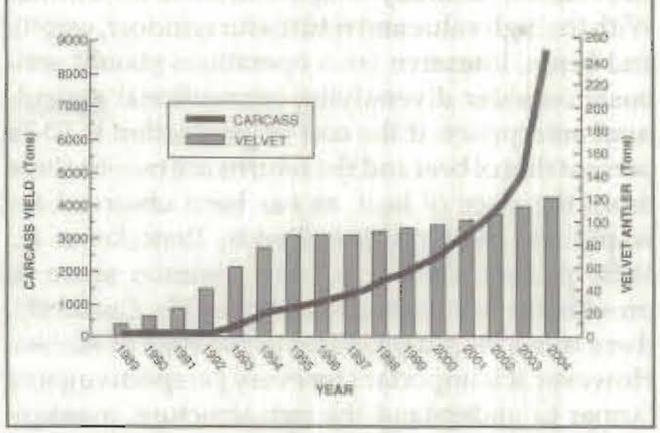


Figure 3. Projected growth in the yield of carcass and velvet antler production of the population of wapiti on Canadian game farms until 2004.

There is concern that adequate protection and consideration should be given to control potential movement of animals to and from the wild. This is a concern of farmers, ranchers, and wildlife biologists. From the experience of others, we can implement fence specifications and inventory controls that require tagging of animals and reporting. It is in the best financial interest of any game or conventional farmer to maintain detailed records of all animals, because, it translates into high returns either as high quality breeding stock or greater productivity.

Finally, there is issue of how to control wildlife management on private land. We must approach this problem as one of understanding the choices. Wild ungulates may be "better" than farmed ungulates, but farmed ungulates are better than cultivated and drained wetlands and meadows. Wildlife policy has changed little since the 19th century when there was a need to control harvests. Today, our concern is about habitat destruction and how to manage land more holistically.

Conclusions

Financial opportunities can be enhanced on marginal or productive lands or in areas with harsh environmental conditions through selection of species that are naturally adapted to these conditions. With the high value and returns for reindeer, wapiti, and bison, intensive farm operations should seriously consider diversifying conventional agricultural enterprises. If the cost of production is 70-76 percent that of beef and the returns are two-to-three times the price of beef, as has been observed for wapiti and bison (as described by Renecker et al., 1989: p. 264), then it is only common sense to provide the best management possible. Currently, there is one wapiti producer in the state of Alaska. However, it is important for every perspective game farmer to understand the infrastructure, management, and production needs of the species to be farmed and the markets where they can sell their products. But, a new industry must remember that strong public support is maintained through developments that are ethical and logical. There must also be a clear direction in the regulatory procedures of the industry and this originates from consistent definitions mentioned earlier. This new industry of game farming could offer a method of agricultural diversification for Alaskan farmers, however, we will never know unless we conduct the necessary research on which to develop the industry. In a capsule, the needed research is: a) a study of relocation and nutritional stress; b) herd health programs; c) pasture management; d) herd management and productivity; and e) market development, product consistency, supply consolidation. ❑

References

Anon. 1986. Adapt 100: Ag diversification adds profit today, 100 ideas for farmers. Conf. Proc. Des Moines. 168 pp.

Hewitt, C.G. 1921. The Conservation of Wildlife in Canada. Charles Scribner's Sons, New York. 344 pp.

Hudson, R.J., and C.B. Blyth. 1986. Mixed grazing systems of the aspen boreal forest. *In*: Rangelands: A Resource Under Siege. P.J. Joss, P.W. Lynch, and O.B. Williams, eds., Australian Acad. of Sci., Canberra. p. 380-383.

Johnson, P.R. and C.W. Hartman. 1969. Environmental Atlas of Alaska. Inst. of Water Resources, Univ. of Alaska Fairbanks. 111 pp.

Martin, P.S. 1973. The discovery of America. Science 179: 969-974.

Millar, J.B. 1986. Perspectives on the status of Canadian prairie wetlands. Can. Wildl. Ser. Rept., Saskatoon.

Moodie, D.W. and B. Kaye. 1976. Taming and domesticating the native animals of Rupert's Land. Beaver 307 (winter): 10-19.

Renecker, L.A. (ed.). 1987. Focus on a New Industry. Proc. of 1st Alberta Game Growers' Assoc. Conf., Red Deer. 110 pp.

Renecker, L.A. 1988. Wapiti farming in Canada. *In*: Proc. of 1st Inter. Wildl. Ranching Symp., R. Valdez, ed., Cooperative Extension Service - Wildl., New Mexico State Univ., Las Cruces p. 118-140.

Renecker, L.A. 1990. Reindeer production and game farming in North America. *In*: The Game Industry —A Holistic Approach. Proc. of South African National Game Organization Conference, Kimberly, Republic of South Africa. p. 3-31.

Renecker, L.A. and H.M. Kozak. 1987. Game ranching in western Canada. Rangelands. 9: 213-216.

Renecker, L.A. C.B. Blyth, and C.C. Gates. 1989. Game production in western Canada. *In*: Wildlife Production Systems: Economic utilization of wild ungulates, R.J. Hudson, K.R. Drew, and L.M. Baskin, eds., Cambridge Univ. Press, Cambridge. p. 248-267.

Roe, F.G. 1970. The North American Buffalo: A Critical Study of the Species in its Wild State. 2nd ed., Univ. of Toronto Press, Toronto. 991 pp.

Seton, E. 1929. Lives of Game Animals. Doubleday, Doran and Co., Garden City. 703 pp.

Syroechkovsky, E.E., E.V. Rogacheva, and L.A. Renecker. 1989. Moose husbandry. *In*: Wildlife Production Systems: Economic utilization of wild ungulates, R.J. Hudson, K.R. Drew, and L.M. Baskin, eds., Cambridge Univ. Press, Cambridge. p. 369-386.

Telfer, E.S., and G.W. Scotter. 1975. Potential for game ranching in boreal aspen forests of western Canada. J. Range Manage. 28: 172-180.

AFES Notes ... Continued from page 4

Graduate student **Cheryl Chetkiewicz** received a $300 travel grant to give a poster presentation at the North American Wildlife and Natural Resources Conference in Edmonton, Alberta, Canada, March 22-27.

Dr. Fred Husby was a member of the steering committee that developed an international conference on Alaska's marine by-products and was both a session chair and an invited speaker at the conference *Alaska's Billion Pounds of Protein: An International Conference About Fish By-Product Opportunities*, sponsored by the Alaska Fisheries Development Foundation and the Alaska Sea Grant College Program. The conference was held in Anchorage April 25-27. Husby also received a grant of $11,740 from the Alaska Fisheries Development Foundation for a project to determine the *Nutritional and Feeding Value of a Salmon Head Protein Hydrolysate in Diets for Weanling Pigs*.

Dr. Jenifer McBeath presented a paper, *Biotechnology in the North*, at the Western Plant Board 71st Annual Conference in Anchorage May 8-10. In her paper, McBeath examined the effects of snow molds in Alaska. Snow mold fungi are parasitic organisms which proliferate under the snow during the winter. The molds destroy grasses and winter grain crops. McBeath is working to find a biological control agent to combat the molds.

Dr. Chien-Lu Ping coordinated and chaired the 1990 Western Regional Cooperative Soil Survey Conference, June 18-22, 1990 at the UAF campus. The conference was hosted by SALRM and co-sponsored by USDA-Soil Conservation Service and USDA-Forest Service. Delegates representing land-grant universities, Forest Service and Soil Conservation Service, Bureau of Land Management from western states and national offices discussed common concerns on soil survey interpretation, data management and technology transfer. Faculties and staff from SALRM, Geophysical Institute and Department of Mining and Geological Engineering also contributed programs and field trips. Ping also attended the VIII International Soil Correlation Meeting on Classification and Management of Wet Soils in Louisiana and Texas, Oct. 6-21, 1990.

Dr. Lyle A. Renecker was a special invited guest, sponsored by the USSR Academy of Sciences, Institute of Evolutionary Animal Morphology and Ecology, from August 12 - September 8. Renecker presented two papers at the International Baikal Symposium on Hunting, Game Management, and Conservation of Wildlife, Irkutsk and was North American Convener and co-Chairman for the session on Physiology and Nutrition at the Third International Moose Symposium, Syktyvkar. While in the USSR Renecker visited an experimental moose farm at Yaksha, a commercial reindeer camp in the Ural Mountains, toured Lake Baikal and viewed its unique flora and fauna, and was shown hunting management strategies in the taiga of south central Siberia. Renecker also appeared on the Komi State Television network in a discussion on moose management. In October, he was a guest sponsored by the National Game Organization of the South African Agricultural Union to give the opening address at their biennial conference. While in South Africa he appeared on the television program *"Good Morning South Africa"* and discussed reindeer production and game ranching. He was shown numerous public and private game reserves and ranches and discussed management strategies in their mixed-species grazing systems. Renecker was chairman on the Second International Wildlife Ranching Symposium held in Edmonton, Alberta in June and will be senior editor of the book *"Conservation and Sustainable Development."*

Dr. Wayne Thomas was awarded emeritus status as a professor of economics at UAF's 1990 Commencement. Thomas joined the UAF faculty in 1971.

Dr. Robert Weeden was named professor of wildlife emeritus at the 1990 Commencement. At the time of his retirement he held a joint appointment with the School of Agriculture and Land Resources Management and the College of Natural Sciences. Weeden started his career at UAF in 1967.

The National Forage Testing Association certified the **Palmer Service Lab** for the third year in a row. As a certified laboratory UAF's lab consistently meets the association's quality guidelines. In the neutral detergent fiber testing program, also run by the association, the UAF laboratory has regularly been recognized as one of the best in the nation. ❑

A Return to Green Island

Glenn P. Juday* and Nora Foster**

In August 1989 we investigated the effects of the *Exxon Valdez* oil spill on Green Island Research Natural Area (RNA) in Prince William Sound (Juday and Foster, 1990) as part of a long-term monitoring study. Our first-year findings at Green Island revealed that:

1. the natural background condition of shoreline and intertidal ecosystems is exceptionally dynamic; there is no stable background condition;
2. oil spill effects were concentrated in predictable portions of the intertidal and lower beach zone that relate to tidal heights on the day the oil arrived and the time shortly after;
3. the oil spill reduced the abundance (measured as cover) of live plants and animals in direct proportion to the amount of oil that coated the beaches; and
4. not all organisms have been affected equally by the spill.

In June 1990 we had the opportunity to go back to Green Island RNA. We wanted to find answers to several questions related to the oil spill. How had the area changed? Was the oil still visible? Had the shoreline, marine plants and animals started to recover?

Condition of Beaches in 1990

We found that most beaches exposed to pounding winter storms at Green and Little Green Island appeared dramatically cleaner in 1990 than the summer before. Few traces of oil or tar remained at the surface of these high-energy beaches. Quick removal of oil on high-energy beaches has been seen in most spills (Baker et al., 1990; Gundlach and Hayes, 1978).

How was the oil removed? Figure 1 shows one of our permanent study plots at the upper intertidal range in 1989; Figure 2 shows the same location in 1990. We found three basketball-sized boulders—not present in 1989—on the plot in 1990. The winter surf bounces boulders such as these on

Figure 1. Study plot in 1989.

Figure 2. Study plot in 1990.

*Glenn P. Juday, Assistant Professor of Forest Ecology and Alaska Ecological Reserves Coordinator School of Agriculture and Land Resources Management University of Alaska Fairbanks.

**Nora Foster, Coordinator of Aquatic Collections University of Alaska Museum, University of Alaska Fairbanks.

Figure 3. Black tar deposit is found buried at Lunch Point.

the bedrock shelf and grinds rock against rock on boulder-strewn beaches. The dried tar residue of the oil spill that coated the beach was probably pounded off in small flecks. The flecks are readily attacked by decomposer organisms in the well-oxygenated surf or buried in underwater sediments below the beachline.

At Lunch Point we searched for the oil and tar line that we had mapped on the gravel beach in late August 1989 and found that essentially it was not traceable at the surface. However, when we dug into the surface gravel we found shallow (2-9 cm [1-4 in] thick) tar deposits in all locations where our 1989 map depicted pools of oil from the spill. Figure 3 shows a typical puddle of the buried black tar, melted on a warm day at Lunch Point.

Why was the tar no longer on the surface? Each winter the beach is coated by a layer of gravel; the entire gravel beach at Lunch Point was built by natural forces since 1964 when the site was a bare bedrock shelf uplifted by the 1964 Great Alaska Earthquake (Plafker, 1965). The process by which oil and oil residues are sealed off from the oxygen-rich atmosphere, light, and energy at the earth's surface and preserved from decomposition is called sequestration. Sequestration can be very effective in preserving oil, as shown by the fact that sealed bedrock layers preserve oil for millions of years. Until humans drill oil fields and pump oil to the surface, crude oil remains essentially intact.

Death and Recolonization of Intertidal Plants and Animals

Remonitoring of our intertidal permanent study plots revealed two processes happening. First, many attached intertidal plants and animals, especially those that occupy the zone from +2.0 to +3.4 meters (6-11 ft) tidal elevation, died between our August 1989 and June 1990 visits. Second, many of the common species had begun to recolonize the site. Figure 4 shows a blue mussel in June 1990 literally "hanging on by a thread." This species attaches itself to rock and other hard surfaces by a natural cement that is reinforced by strong natural fibers (Amato, 1991). Many blue mussels on and near our plots that were still relatively well-attached in 1989 were dead, removed, or in the last stages of loosing their attachment and clung to rock only by a few remaining fibers in 1990. Nearly all these mussels had a flecked black varnish of tar residues on them.

On the other hand, most of our study locations supported colonies of tiny new barnacles (called barnacle sets) that had arrived since the oil spill in late March of 1989, and a vigorous growth of new small *Fucus* (rockweed) plants.

Risk of Further Oil Damage

One of the greatest risks of continuing damage from oil spills is the remobilization of buried oil. Crude oil that still contains volatile (easily evaporated) toxic components damages plants and animals. However, oil in the open atmosphere quickly looses many volatile components and the remnants are readily attacked by microscopic decomposer organisms. Buried oil that leaks out causes, in effect,

Figure 4. A blue mussel is in the last stage of loosing its attachment to a rock.

a new spill. The risk of continuing damage from an oil spill, then, is a function of:

1. the timing and amount of leakage from buried deposits; and
2. the quality of the oil or oil residue that escapes.

We established that the high tide that placed oil on the shoreline at Green Island reached an elevation of about +3.4 meters (11 ft) above tidal datum (Juday and Foster, 1990); it appears that storms and surf action pushed the oil higher. We hypothesized that tides rising to +4.4 meters (14 ft) or higher would refloat buried oil and move a sheen of oil residue across the beach and intertidal community as the tide withdraws. During the highest tides of June 1990 we observed the surf washing over pools of oil, causing a sheen. Figure 5 shows the dates and frequency of high tides during 1990. There were 12 days with tides equal to or greater than the critical 4.63 meter (15 ft) elevation, including exceptionally high tides associated with the "blue moon" in early December.

We have established that oil has been remobilized by the processes we hypothesized at Green Island, but we do not know the effect the sheens will have on the plants and animals in our study area. However, even the buried oil at Green Island has been exposed and weathered into a tar-like residue, so the effects are unlikely to be as severe as oil leaking from fine sediment.

Conclusions

In summary, our 1990-season remonitoring work revealed that:

1. nearly all the beach oil and tar of 1989 was naturally removed or buried in accreting gravel zones;
2. the recolonization of intertidal organisms, especially barnacle sets and *Fucus* plants, was underway;
3. changes in the intertidal community, especially delayed mortality probably due to the oil spill, were still occurring in 1990, so that **both** recovery and oil spill effects were interacting; and
4. remobilization of buried oil may cause additional damage, although the risk in our study area would not be as great as leakage of unweathered oil sealed in fine sediments. ❑

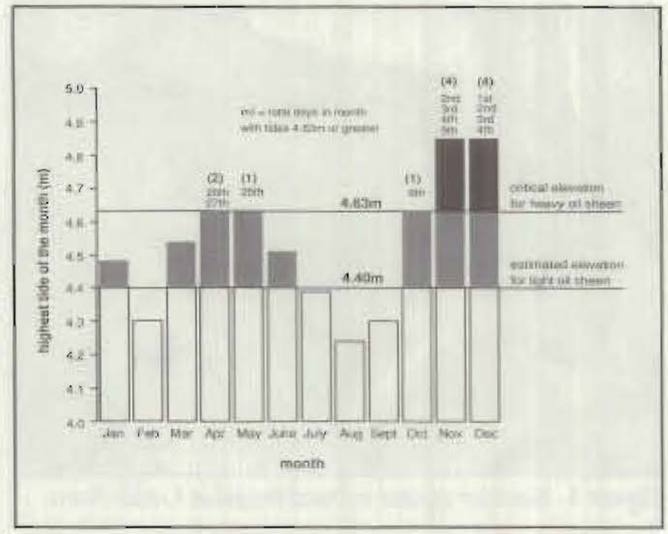


Figure 5. Critical high tides for re-oiling at Green Island, Alaska in 1990.

Acknowledgment

This article is the result of research sponsored by Alaska Sea Grant with funds from the National Oceanic and Atmospheric Administration, Office of Sea Grant, Department of Commerce under grant number NA90AA-D-SG066 (project number M/81-01) and from the University of Alaska with funds appropriated by the state. Rob Solomon, Judy Blakeman, Lisa Stuby, Anthony Whitworth and Bob Benda assisted in field work and data collection. David Hall assisted in arranging transportation. Sandy Wyllie-Echeverria contributed a number of ideas and designed a seagrass study component. Ron Dearborn provided support and encouragement.

References

Amato, I. 1991. Stuck on Mussels. *Science News*. 139:8-9, 15.

Baker, J.M., R.B. Clark, P.F. Kingston, and R.H. Jenkins. 1990. Natural recovery of cold water marine environments after an oil spill. Manuscript of paper presented at the Thirteenth Annual Arctic and Marine Oil Spill Program Technical Seminar.

Gundlach, E.R. and M.O. Hayes. 1978. Vulnerability of coastal environments to oil spill impacts. *Marine Technology Society Journal*. 12:18-27.

Juday, G.P. and N.R. Foster. 1990. A Preliminary Look at Effects of the *Exxon Valdez* Oil Spill on Green Island Research Natural Area. *Agroborealis*. 22(1):10-17.

Plafker, G. 1965. Tectonic deformation associated with the 1964 Alaska earthquake. *Science*. 148:1675-1687.

Workers are collecting arctic pendant grass (Arctophila fulva), an emergent aquatic plant considered important for bird habitat in the Arctic (August 29, 1985). The Central Power Station (CPS), operated by BP Exploration (Alaska), Inc., provides electricity to operate the Prudhoe Bay and satellite oil fields of the region is visible in the background.

Arctic Tundra Rehabilitation — Observations of Progress and Benefits to Alaska

Jay D. McKendrick

Progress with the way construction activities are designed and carried out and with the methods used in rehabilitating disturbed sites in Alaska's Arctic regions during the past two decades has largely gone unnoticed by those not directly involved with developments in the Arctic.

Jay D. McKendrick, Professor of Agronomy, School of Agriculture and Land Resources Management, University of Alaska Fairbanks.

Compared to the way things were done in the early 1970s, when development of the Prudhoe Bay Oil Field began, these changes have substantially reduced the amount of land surface affected per oil well and per mile of pipeline. These improvements are direct responses to environmental concerns. Such progress means impacts on the Arctic ecosystem can be reduced while Alaskans gain economic benefits from exploration and development of mineral resources. In this article some significant advancements in the technology for site protection and rehabilitation in the Alaska Arctic are described. These observations span a period of nearly 20 years and conclude with speculations of anticipated practices and improvements not yet realized.

At this point some definitions may be useful. Land rehabilitation refers to transforming an area that is considered unable to support plant life to one that supports a functioning plant community. Restoration refers to returning a site that has been either damaged or altered to its former state. Enhancement means elevating the value or usefulness of a site for a particular purpose, such as aesthetics or wildlife. Bioremediation is a term used to describe enhancement of site quality with biological entities.

Fertilizers have been used to encourage population increases of microorganisms that decompose crude oil, i.e., bioremediation of oil spills. Revegetation is the process where vegetation is planted and encouraged to occupy land that is either barren or partially barren of plant cover.

A worker rototills the surface of a 'peat' road (constructed from soil) south of Drill Site No. 2 in the Prudhoe Bay Oil Field (June 27, 1972). In the early 1970s these abandoned roads provided barren sites for revegetation research in the Prudhoe Bay region. This type of road was used for moving equipment among exploratory sites in the late 1960s. Such roads were only serviceable when the ground was frozen. When thawed, these roads were too unstable to support heavy traffic.

When Arctic tundra revegetation and rehabilitation were first seriously considered, little was known about plant succession for that ecosystem. Many misconceptions abounded. For example, it was believed that because the Alaska Arctic was free from either industrial or agricultural developments, plant and animal species living there were unadapted to surviving those kinds of human activities. It was believed because tundra plants reproduced mainly by vegetative means in the Arctic those plants had somehow lost their capacities to produce seed. Plants need seeds to quickly invade extensive barren sites. Some believed that continuous sunlight during the summer months inhibited seed germination even if seeds were present. Others theorized that in the Arctic's cold soil conditions, seed could not germinate and seedlings could not survive. All those speculations required testing to either substantiate or disprove them. Investigations of tundra plants and soils—both our's and others'—looked for answers to these theories.

Thermokarst, which is the subsidence of land surfaces when subterranean ice masses in permafrost regions melt, was a primary worry at that time. Thermokarst is a natural occurrence.

Soil slumping along road cuts and settling of ground around structures threatened facilities. It appeared to be a major hazard to any development in this region of continuous permafrost. The process of thermokarst begins when the thermal stability of the soil is altered, i.e., the insulating mat of mosses and accumulations of dead plant material (primarily peat) has been disturbed. Deepening of the annual thaw penetration increases melting of subterranean ice masses that have formed gradually over long time spans and which are balanced with the annual freeze-thaw cycle. Disturbances as slight as compacting the organic surface mat with vehicle traffic are sufficient to initiate thermokarst, but removing the insulation layer invokes even greater reactions. Reversing thermokarst was presumed in itself justification sufficient for a tundra revegetation research program.

An engineering solution to the thermokarst problem is to build gravel roads and pads. These gravel structures are approximately five to seven feet thick. Additionally all Prudhoe Bay buildings and pipelines are supported above ground on either wooden posts or steel pipes to prevent heat from these facilities penetrating the soil. For a large oil field, this required huge amounts of gravel, which was first mined from river channels in the Prudhoe Bay vicinity. Later, surface-mined pits became the main sources of gravel.

Our arctic work commenced in the early 1970s with a three-year tundra revegetation experiment in the Prudhoe Bay Oil Field. This was a problem-solving research project to determine the kinds of fertilizer needed and the species of grasses most useful for revegetating disturbed sites. The tests were conducted on the only available barren sites at that time, which were abandoned 'peat roads' constructed from silt loam soils on site. These experimental sites represented soil conditions intermediate in moistness (mesic) and organic matter contents. The applied research was sponsored primarily by Atlantic Richfield Co. (now ARCO Alaska, Inc.) (Mitchell, et al., 1974). Results from these and other studies were largely reported directly to the sponsoring organizations and are now sometimes difficult to locate. Concurrently, we were also studying oil spill revegetation. Findings from oil spill revegetation studies at Prudhoe Bay were publicly reported in the open literature (McKendrick and Mitchell, 1978a, 1978b; Mitchell et al., 1979).

Other intensive, short-term studies, which were not necessarily directed at problem solving, were developed to expand the knowledge of how the plant and animals of this region function. These studies were sponsored by the National Science Foundation, other public agencies, and private industry under the Tundra Biome Program. Results from Tundra Biome projects can be found in Brown, (1975), Tieszen (1978), Brown et al. (1980), and Hobbie (1980) as well as other scientific literature sources.

Both industry- and government-sponsored research provided information about the components and functioning of the Arctic's terrestrial and aquatic ecosystems. From the industry-sponsored studies, it was soon learned that phosphorus fertilization greatly benefits the establishment of grass seedlings on barren sites. Without fertilizing soils, vegetation reestablished slowly. It was obvious that seeding grasses could help stabilize barren slopes but it would neither stop nor reverse thermokarst in the short-term. On disturbed sites, a new thermal balance in the soil profile is reached long before the seeded grasses provide significant insulating effects. Natural formation of moss layers at the soil surface appear more useful in arresting thermokarst than seeded grasses and other higher plants.

After testing many species and ecotypes within species, three grasses were identified by Dr. William W. Mitchell as reliable species for seeding in the Alaska Arctic. These were: *Poa glauca* (glaucous bluegrass) variety 'Tundra', *Arctagrostis latifolia* (polargrass) variety 'Alyeska', and *Festuca rubra* (red fescue) variety 'Arctared'. Each of these varieties was selected on the basis of adaptation to the Arctic as well as potential for seed production outside the Arctic. Some Alaska farms are producing seeds, and supplies of certified seed can be purchased for site revegetation and rehabilitation projects.

A seeding of glaucous bluegrass (Poa glauca), variety 'Tundra' on the campsite pad (August 7, 1979) at Inigok Testwell No. 1, National Petroleum Reserve in Alaska (NPRA). This is a variety of native grass that was selected for revegetation purposes. The grass is grown in fields of southcental and interior Alaska to generate certified seed for use in the Arctic.

After the Prudhoe Bay Oil Field went into production in 1976, financial support waned for revegetation and rehabilitation research. My own interest in long-term monitoring of disturbed sites was not dimmed by this quiescence in research support. I was able to maintain a small degree of field work, i.e., periodically sampling soil to determine persistence of applied fertilizers and rephotographing study sites at Prudhoe Bay locations by 'piggy-backing' the work on consulting projects that took me to the Arctic.

During the early 1980s, industry

began developing smaller satellite oil fields in the vicinity of the Prudhoe Bay and Kuparuk reservoirs. These fields include Milne Point, Lisburne, and Endicott. As permit applications for these developments were reviewed, renewed environmental concern prompted rethinking of not only engineering approaches but also site protection and disturbance mitigation methods. Among the engineering advancements were:

1. limiting pad construction;
2. reducing distances between wells with a concomitant reduction in well pad size; and
3. centralizing housing and storage for subcontractors.

Permanent workpads along pipelines have been totally eliminated. Instead of constructing a permanent gravel workpad along the entire route of a pipeline, a temporary ice road is built during winter. Pipeline supports and pipe are installed from the ice road. With spring, the ice road melts and evidence of it soon disappears, leaving only the elevated pipeline on the landscape. Low-pressure vehicles (Rolligons) can be used to service the pipeline during summer months if needed. All pipelines are now constructed with at least a five-foot clearance to permit free movement of caribou beneath the pipe. In the past, these lines were constructed lower to the ground and special gravel crossings for caribou were mandated in permits. These gravel crossings were very expensive to construct—each costing in the hundreds of thousands of dollars—and they proved mostly ineffective. Caribou trailed along the pipe until they found a suitable place to pass under.

Drilling rigs have been redesigned to allow wells to be located as close as 10 feet from each other. Directional drilling had been used for some time in the Arctic. It enabled oil field

Note the changes along the surface of a 'peat' road near Drill Site No. 5 in the Prudhoe Bay Oil Field about two months (August 28, 1973) after a series of revegetation test plots had been planted to various grass species. Notice the pools of water formed in the barrow pits along the margins of the road and the lack of vegetation on the road, except in the seeded plots. The road is five years old.

Time changes the surface of the same 'peat' road near Drill Site No. 5 on September 7, 1989. The seeded plots have existed for 18 growing seasons, and the road is now 21 years old. Notice the natural colonization of plants in the margins of the barrow pits and on the road surface inside as well as beyond the borders of the revegetation plots.

A drilling rig operates on a gravel pad near the Kuparuk River, just west of the Prudhoe Bay Oil Field (September 22, 1989). Observe the thickness of gravel used to provide a stable surface for operating heavy equipment in this region of continuous permafrost.

operators to consolidate wells on fewer drilling pads. Even with the concentration of wells to a central location, there was still need for a sizeable pad because wells had to be at least 50 feet apart, because of drilling rig configuration. That meant large gravel pads had to be constructed to accommodate a number of wells. Fifteen years ago a 20 well pad covered more than 25 acres of the landscape. Now the same 20 wells can be drilled from a 10-12 acre pad.

When Prudhoe Bay was first being developed, subcontractors were located at Deadhorse, outside the jurisdiction of the oil field operators (ARCO Alaska, Inc. and BP Exploration (Alaska), Inc.). Permits for those businesses and contractors at Deadhorse were not always closely monitored. Many of the companies were on site only for a short time before their work was completed. Little concern for environmental consequences resulted from the quick turnaround by some of these companies. This resulted in unsightliness and environmental problems. Many writers and commentators have used this as evidence against further development in the Alaska Arctic. After offending companies left Deadhorse and perhaps even the state, there was little recourse for either the oil field operators or the permitting agencies to recover costs for damages. Later, when the Kuparuk Field was constructed, all subcontractors were housed in facilities provided by the field operator (ARCO Alaska, Inc.). Endicott (BP Explorations (Alaska), Inc.) is a more recent example of consolidating contractors on an offshore site. This centralizing of facilities ensures permit compliance and results in a much cleaner and more aesthetically acceptable development.

As these engineering changes were occurring, there was also a rethinking of how damage mitigation and rehabilitation of the landscape should be done. During the development of these oil fields, it became clear that, except for pre-development disturbances prior to and during the 1960s, a few accidents involving vehicles leaving the road, gravel washouts, and overburden stockpiles around gravel mines, there has been minimal need to revegetate the mesic (mid-range in moistness) silt loam soils in this region. Fortunately, there have been very few oil spills affecting significantly large areas of the landscape on the Coastal Plain. Natural recolonization of small disturbances can occur relatively soon if soil conditions are suitable. For crude oil-damaged sites, plant recovery has been relatively successful, especially if soils are naturally wet and have been fertilized to improve nutrient supplies to plants and microorganisms.

Thus, interest in site rehabilitation shifted toward habitat enhancement for wildlife. Truett and Kertell (1990) reviewed the literature and classified disturbances from oil field operations into three categories:

1. surface disturbances (including spills of contaminants);
2. burying tundra vegetation with gravel fill for roads and pads; and
3. altering drainage that resulted in water impoundments and flooding (temporary as well as permanent).

They also identified eight guilds (groups) of wildlife in the region based on how the animals used various components of the ecosystem and rated man-made disturbances according to impacts on those wildlife guilds. This was one of the first attempts to relate site alterations to specific effects on animals in the region. Previously, any alteration of habitat was assumed by many to result in a total loss to wildlife.

One of the first efforts to determine feasibility for improving habitats flooded by impounded water started in 1985, with our five-year investigation in the life history and habitat characteristics of *Arctophila fulva* (arctic pendant grass). This was a pivotal departure from focusing revegetation and site rehabilitation on mesic habitats and selecting grasses for revegetation that had to be grown outside the Arctic for seed production (Brown and McKendrick, 1987).

Arctophila fulva, an indigenous species, was identified as closely associated with prime habitat for migratory waterfowl. Waterfowl nest abundantly in the oil producing area on the North Slope as well as other locations on the Arctic Coastal Plain. This grass occurs in shallow water along the margins of ponds, lakes and slow-moving streams. A strikingly beautiful plant, *Arctophila fulva* usually turns a dark red to purple-red as the growing season advances.

Newly seeded area for fertilizer test plots is shown above on September 21, 1974. During late winter of 1971-72 after examining aerial photography, this area was selected for research because it appeared to represent relatively dry soils suitable for priority revegetation experiments at that time. The location is near Flow Station 1 in the Prudhoe Bay Oil Field. The area was scraped with a bulldozer to remove the surface vegetation mat then rototilled repeatedly for two summers to eradicate all plants. These test plots were then established, and the entire area seeded to a native alkali grass, Puccinellia sp.

Apparently, it provides not only forage for geese and swan, but also contributes to the organic detritus food for invertebrates (insects) and other small organisms. These, in turn, are eaten by ducks and other birds. Results of our *Arctophila fulva* work are still forthcoming. It appears this grass transplants very easily, and it does produce viable seed (McKendrick, 1990). We've found that, if it is desirable to introduce *Arctophila fulva* into new locations, reliable methods are available. The addition of phosphorus fertilizer significantly improves its vegetative reproduction rate.

Even before the wetland study on *Arctophila fulva* was completed, research on the use of disturbed sites—abandoned peat roads and gravel pads—by wildlife was underway. These sites, especially the gravel pads, are xeric (dry) environments which contrast sharply with the surrounding wet tundra and contain few of the silt-size and finer soil particles, necessary to support vascular plants (McKendrick and Holmes, 1989). They are considered to have a negative value for three of the eight wildlife guilds in this region (Truett and Kertell, 1990). Plant colonization of these sites can be accomplished only by species adapted to dry soil, gravel, and rocky slopes. The natural process of wind- and animal-carried seeds to these locations occurs very slowly if the gravel pad is a great distance from natural seed sources (Cargill and Chapin, 1987). Consequently, we began a 10-year research project to determine ways of vegetating gravel sites began in 1989 under sponsorship of BP Exploration (Alaska), Inc. It may be the first 10-year study ever undertaken for environmental rehabilitation in the Alaskan Arctic. It represents a significant redirection in not only problem solving research but also an unprecedented level of commitment by industry toward environmental research. ARCO Alaska, Inc. has also started sponsoring long-term environmental studies in the area. In terms of time, these commitments are probably unmatched by any public agency sponsored research in the Arctic.

Our project includes modification of an abandoned gravel pad to create various thicknesses of gravel, top soil additions, compaction and loosening of the gravel surface, and capturing snow to provide added moisture and winter protection for

Fifteen growing seasons (photo taken on September 7, 1989) have passed since the area was seeded and fertilized. The alkali grass planted has largely died and been replaced with natural colonizing species. Pools of water now appear where thermokarst occurred as subterranean ice masses thawed, permitting the soil surface to subside. Notice in the background a portion of barren soil is still visible where neither seeding nor fertilizing occurred. The vegetation that has formed on these plots is typical for tundra communities in this region and represents habitat that wildlife are accustomed to using. During late August and early September, geese feed heavily on the stem bases of robust watersedge (Carex aquatilis) and cottongrass (Eriophorum angustifolium) shoots that occur along the margins of thermokarst pools in disturbed sites, such as this one.

new seedlings. The usefulness of a number of indigenous plant species for colonizing gravel pads is also being assessed. The project is coordinated with wildlife studies documenting animal (bird and mammal) uses, gravel pads and other disturbances (Pollard et al., 1990; Troy and Carpenter, 1990). The objective is to gather information on plant species for site rehabilitation that would develop the kinds of plant communities most useful to wildlife. This represents a major departure from revegetating only with grasses which mainly provide plant cover and protect soils from erosion. Protecting soil by establishing grass cover is still a valid goal. However, including other plant life forms such as forbs and shrubs which are especially useful to wildlife means conscientiously developing plant communities of immediate value to the region's animals.

Another area of improvement in environmental protection is with the handling of drilling wastes. Originally wastes (drilling muds and rock cuttings) were deposited and left indefinitely in reserve pits. These pits were constructed by piling gravel to form a berm to contain the solids and fluids ejected from the drilling rig. It was assumed that the gravel berms would have a continuously frozen core, which would prevent fluids leaking from these pits. That assumption proved incorrect because not all berms retained a frozen core, and fluids leaked in many instances. Berm core thawing varied among years depending on summer temperature conditions and water levels in the pits. Thus, locating and controlling leaks was difficult.

Drilling muds are mainly clays conditioned with different substances to meet drilling needs. Fluids seeped from the reserve pits, carrying dissolved substances from the drilling muds onto the adjacent tundra. When enough of these materials have soaked into the soil tundra plants usually died, generating concern for the cause. Attention focused on heavy metals as the culprit since high concentrations of some of these elements are fatal to plants. However, data obtained on water and mud collected from reserve pits in our studies and unpublished data from others that we have reviewed indicate the pH levels in those pits are high, rendering all heavy metals, except molybdenum, weakly soluble and biologically unavailable. For instance, barium sulfate, a common component used to increase the specific weight of drilling muds, is quite insoluble in water.

The background levels for available barium in soils at more than 50 locations sampled in the Prudhoe Bay region ranged between 3 and 78 ppm (parts per million) and averaged 28 ppm. In comparison, 13 samples of reserve pit muds contained less than 30 ppm available barium. Interestingly, we found the highest level of available barium (nearly 90 ppm) was in sediments from a natural lake in the foothills of the Brooks Range. That lake is many miles from any source of drilling mud, and contains barium entirely from natural rock sources. We and others have concluded that heavy metals are not killing the tundra plants. Instead it is salt (sodium chloride, NaCl), the common substance used to flavor food. Sodium ions are used to disperse the clays so they remain in suspension during the drilling process. High concentrations sodium and chloride ions in soil reduce water availability to plant roots. Sodium in high concentrations can also disrupt soil structure and reduce aeration, water movement, etc. Instead of heavy metals, the damage to plant life comes primarily from physiological drought induced by salt. Testing is now underway to identify methods for flushing these salts from effected soils and/or diluting them to innocuous concentrations where leaks have occurred.

Peter C. Scorup, University of Alaska Fairbanks research associate, and Dr. Maynard A. Fosberg, University of Idaho soil scientist, collect mud cores for a soil characterization study of pond muds in Lake Patrawke, Prudhoe Bay Oil Field (September 3, 1989).

To prevent future drilling waste problems, industry engineers are developing disposal methods that will send some of the materials back in to the wells. Eventually, all the reusable material will be recycled. Clean rock cuttings and gravel from the first several thousand feet of drilling will be washed and could be used either in the place of, or in conjunction with, gravel for pad and road construction. Cuttings containing drilling muds and other potential contaminates will be ground at a specially designed facility and reinjected into designated wells. In addition to reducing risks from drilling wastes escaping to the surrounding environment, these improvements will allow a further reduction in the size of well pads, because there will be no need for long-term storage of drilling wastes in reserve pits. However, drilling pads will still require facilities to temporarily contain wastes in case of emergencies and for short-term holding until they are moved to the reinjection site. But overall, less gravel will be needed for each well drilled. There will also be no long-term storage of drilling wastes which are sources of salts that can affect survival and growth of surrounding vegetation.

In conclusion, our observations along with those from others researching long term aspects of vegetation and wildlife in the Alaska Arctic indicate there are a number of options for site rehabilitation that can suit a variety of purposes (Jorgenson et al., 1990). Barren soils can be planted with grasses for quick results to stabilize soils against erosion and meet short-term needs to improve aesthetics. A mixture of seeds from native plants need only to be planted strategically on dry sites not threatened by erosion, and then through natural processes will eventually develop into communities attractive to wildlife. Shallow ponds and impoundments can be enhanced for birds by transplanting *Arctophila fulva*. And, if it is desirable, wetlands can be improved by altering drainage and inducing thermokarst, fertilizing and introducing desirable vegetation species. Soil can be stripped from some areas to create wetlands, ponds, and lakes for waterfowl and other aquatic life forms.

The removed soils can be used on sites lacking suitable soil, i.e., to cover salt-damaged soils and gravel pads. Based on our recent studies with native plant seed collections, it appears indigenous plants may be cultivated in the Arctic for seed production on abandoned exploration or production sites in the region.

The losses of habitat in this region to excavation from gravel mines, and fills for roads and pads was calculated by Walker et al., 1987. It has been estimated that five percent of the land surface in the intensively developed portions of the oil field has been impacted (Walker et al., 1986). The aesthetic impairment to the landscape from the human perspective appears more significant than the presumed affects on wildlife. The early belief that

Oil spilled (July 9, 1985) across a wet site when a small pipeline leaked during the previous winter in the Prudhoe Bay Oil Field. Workers removed as much of the oil as possible in the winter by scraping up the snow. Barriers were erected in spring to prevent the oil from spreading during breakup, and a sump pump was used to remove oil collected at the lower end of the site. A set of fertilized plots was established in the central portion of the oil-affected area.

Five growing seasons have passed since the spill (September 4, 1989). Natural recolonization from primarily water sedge and a very minor amount of dupontia (Dupontia fisheri) and cottongrass provide vegetation cover to the damaged site. Although not visible in the photo, mosses have colonized the surface of the soil in the heavily damaged area where phosphorus fertilizer was applied.

alterations of natural environments by man is always harmful to wildlife is beginning to be reexamined. Pollard et al., (1990) studied animal uses on gravel pads and found several species used these sites more than they used either natural gravel areas of river channels or undisturbed tundra. Troy (1990) also discovered greater bird use of disturbed tundra than adjacent undisturbed tundra. Troy and Carpenter (1990) documented that site-tenacious birds displaced by gravel pad construction moved to adjacent locations and nested rather than curtailing nesting altogether. It was concluded that the habitat adjacent to the drilling pad was adequate to absorb these displaced birds with little, if any, infringement to birds already using the adjacent habitat. Gravel mines are now being flooded under supervision of the Alaska Department of Fish and Game to develop deep-water habitats for overwintering fish populations. These overwintering habitats are limited in Alaska's Arctic. Presumably increasing their abundance will have a positive influence on fish populations for the region.

Few have been daring enough to openly suggest some of the drastic land restructuring actions discussed above because they appear contrary to the very purposes of environmental protection, which is required for all oil industry operations in Alaska's Arctic regions. However, many of the original theories about what was proper for the Arctic, its soils, plants, and animals have changed as additional research has changed our theories (Truett and Kertell, 1990; Troy, 1990). Examining animal foraging and habitat preferences on disturbed sites as well as continued soil and plant studies will surely necessitate repeatedly reevaluating our perceptions and objectives for habitat rehabilitation, enhancement, bioremediation, and revegetation in the Arctic and other environments. Remaining receptive to new discoveries and concepts is vital to progress in both economic and environmental maintenance in Arctic Alaska. ❑

Acknowledgments

Support for the various Arctic projects from which these observations were derived include: The University of Alaska Agricultural and Forestry Experiment Station, National Science Foundation, USDA Cooperative State Research Service, ARCO Alaska Inc., BP Exploration (Alaska) Inc., and Husky Oil NPR-A Operations. The U.S. Fish and Wildlife Service is a cooperating partner in our *Arctophila* study. Numerous individuals assisted with field work over the years. One individual, Peter C. Scorup, has been involved from the beginning, and he is still working on these projects. His diligence and personal contributions are especially appreciated. Encouragement from various industry and agency personnel for continuing these long-term studies has been important to our persisting in the past and our commitment into the future. Appreciation is extended to LGL Research Associates, Inc. personnel (Joe Truett, Bob Pollard, and Bob Rodrigues) and Declan Troy of Troy Ecological Research Associates for providing information on wildlife uses of various tundra habitats.

This pad, Drill Site No. 1, was constructed in the early 1970s, and represents technology of that time. Each of the thirty green buildings on the pad covers a wellhead. Notice much of the pad consists of reserve pits for containing drilling wastes. Such large storage reservoirs are no longer required as a result of the elimination of reserve pits under new drilling procedures. Also notice the work pad road paralleling the pipelines in the foreground. Pipeline construction in the Arctic is now done during winter, eliminating need for permanent gravel work pads next to pipelines. (photo taken September 12, 1989)

This pipeline carries crude oil from the Lisburne Oil Field. The pipeline crosses the Little Putuligayuk River en route from the Lisburne Production Center, operated by ARCO Alaska, Inc., to Pump Station No. 1 of the Trans Alaska Pipeline, operated by Alyeska Pipeline Service Co. Notice the clearance under the pipeline provided for caribou and the absence of a work pad. This pipeline was constructed in the winter of 1985-86 and represents technology of the mid-1980s. (photo taken September 1, 1989)

This well, Inigok Testwell No. 1, NPRA, was drilled by Husky Oil Field Operations, Inc. under contract to the federal government during the second exploration of the reserve. The well location is visible on the right margin of the reserve pit. The small mound jutting outward from the margin of the gravel pad near the wellhead is solid waste from the drilling operation. Dark stains on the lower left berm of the reserve pit suggest a location where pit fluids have possibly escaped. Drifting snow that accumulates each winter in the pit maintains the water level. (photo taken July 11, 1984)

McKendrick, J.D, and W.W. Mitchell. 1978a. Effects of burning crude oil spilled onto six habitat types in Alaska. *Arctic*. 31(3):277-295.

McKendrick, J.D. and W.W. Mitchell. 1978b. Fertilizing and seeding oil-damaged tundra to effect vegetation recovery. *Arctic*. 31(3):296-304.

McKendrick, J.D. and K.W. Holmes. 1989. Plant species on dredge tailings of interior and gravel pads of arctic Alaska. In: *Mining in the Arctic. Proceedings of the 1st International Symposium on Mining in the Arctic*, ed. Bandophdhyay, Sukumar and Frank J. Skudrzyk. Fairbanks, Alaska, 17-19 July. A.A. Balkema, Rotterdam.

McKendrick, J.D. 1990. Seed formation by *Arctophila fulva* in Relation to Temperature, Arctic Coastal Plain, Alaska. June 11-15, 1990. International Conference on the Role of Polar Regions in Global Change, University of Alaska Fairbanks. (paper in review for proceedings)

Mitchell, W.W., J.D. McKendrick, F.J. Wooding, and M.A. Barzee. 1974. Agronomists on the banks of the Sagavanirktok. *Agroborealis*. 6(1):33-35.

References

Brown, A.L. and J.D. McKendrick. 1987. Joint Industry/Agency/University Revegetation Feasibility Project. Paper presented at The Fifth Symposium on Coastal and Ocean Management, May 26-29, Seattle, Washington.

Brown, J. (ed.). 1975. Ecological investigations of the tundra biome in the Prudhoe Bay region, Alaska. Biological papers of the University of Alaska, Special Report No. 2.

Brown, J., P.C. Miller, L.L. Tieszen, and F. Bunnell (eds.). 1980. An Arctic Ecosystem the coastal tundra at Barrow, Alaska. Dowden, Hutchenson & Ross, Inc. Stroudsburg, Pennsylvania.

Cargill, S.M. and F.S. Chapin III. 1987. Application of successional theory to tundra restoration: a review. *Arctic and Alpine Research* 19(4):366-372.

Hobbie, J.E. (ed.). 1980. *Limnology of tundra ponds Barrow, Alaska*. Dowden, Hutchenson & Ross, Inc. Stroudsburg, Pennsylvania.

Jorgenson, M.T., T.T. Heffernan and B.K. Lance. 1990. *Land rehabilitation studies in the Kuparuk Oilfield, Alaska, 1989*. ARCO Alaska, Inc. and Kuparuk River Unit, Anchorage, Alaska.

Mitchell, W.W., T.E. Loynachan, and J.D. McKendrick. 1979. Effects of tillage and fertilization on persistence of crude oil in a northern soil. *Journal of Environmental Quality* 8(4):525-532.

Pollard, R.H., R. Rodrigues, and R.C. Wilkinson. 1990. Wildlife use of disturbed habitats in Arctic Alaska 1989 In *Final Report* LGL Research Assoc., Inc./BP Exploration (Alaska), Inc., Anchorage, Alaska.

Tieszen, L.L. 1978. *Vegetation and production ecology of an Alaskan arctic tundra*. Springer-Verlag, N.Y.

Troy, D.M. 1990. *Bird use of disturbed habitats at Prudhoe Bay, Alaska: the abandoned peat roads.* (Abstract) North Slope Terrestrial Studies Workshop, (15-16 November 1990.) Environmental & Regulatory Affairs, BP Exploration (Alaska), Inc. Anchorage, Alaska.

Troy, D.M. and T.A. Carpenter. 1990. *The fate of birds displaced by the Prudhoe Bay Oilfield: The distribution of nesting birds before and after P-Pad construction.* Troy Ecological Research Associates./BP Exploration (Alaska), Inc., Anchorage.

Truett, J.C. and K. Kertell. 1990. *Effects of habitat disturbance on arctic wildlife a review and analysis*. LGL

Workers plant test plots June 26, 1990 on a gravel pad formerly used for an exploratory well (BP Put River No. 1) that was restructured in early spring of 1989 for a long-term research project (1989-99) to test native plants for revegetation and seed production possibilities in the Alaska Arctic.

Grass seedlings emerge from one of the test plots on the BP Put River No.1 pad (August 22, 1990). These plots were seeded to native plant species about two months earlier.

References (continued)

Research Associates, Inc./BP Exploration (Alaska), Inc. Anchorage.

Walker, D.A., E.F. Binnian, N.D. Lederer, E.A. Nordstrand, M.D. Walker, and P.J. Webber. 1986. *Cumulative landscape impacts in the Prudhoe Bay Oil Field, 1949-1983.* Institute of Arctic and Alpine Research/USDI Fish and Wildlife Service. Habitat Section, Anchorage, Alaska.

Walker, D.A., P.J. Webber, E.F. Binnian, K.R. Everett, N.D. Lederer, E.A. Nordstrand, and M.D. Walker. 1987. Cumulative impacts of oil fields on northern Alaska landscapes. *Science* 238:757-761.

Strip Mine Reclamation and Alaska's Big Game Wildlife

Charles L. Elliott* and Jay D. McKendrick**

The exploration and development of Alaska has been greatly affected by the region's mineral wealth. The development of the state's oil resources is the most recent example of how mineral-induced change has influenced the people and wildlife of Alaska. But the Last Frontier has another mineral resource which may play an important role in the state's future—coal.

Interest in Alaskan coal is nothing new; underground mining started in 1855 at Port Graham on the Kenai Peninsula (Naske and Triplehorn, 1980). As the demand for coal increased and new equipment was developed, underground mining was gradually replaced by open-pit or strip mining. At present there are few active coal mines in the state, but within the last decade the demand for domestically available energy and an expanding export market have refocused attention on Alaska coal.

Current strip mine reclamation techniques involve reseeding mined areas with native and/or approved plants, principally grasses. In 1980, the University of Alaska's Agricultural and Forestry Experiment Station began a study of revegetated strip mine spoils in interior Alaska.

We conducted our study on the Usibelli Coal Mine located near Healy, Alaska (Figure 1). Usibelli Mine is Alaska's largest coal strip mine operation and has been in operation since the 1940s. A reclamation program was instituted in 1972. After coal is removed, the excavated subsoil (called overburden) is redeposited on the area and graded back to the site's original contour. Reclamation sites are then scarified, furrowed, and aerially seeded and fertilized. See Elliott et al. (1987) for a list of the plants used for reclamation on the Usibelli Coal Mine.

One objective of the study was to evaluate post-mining land use of reclaimed areas by native wildlife. Of particular importance was to determine if reclaimed coal-mined areas provide a source of food for important big game animals, i.e., caribou, moose, and Dall sheep.

Methods

The diet of big game animals was determined by histological examination of fecal material (Hansen and Flinders, 1969). In this procedure, fecal droppings were collected and examined using a microscope. The identity of plants eaten was determined by identifying plant fragments found

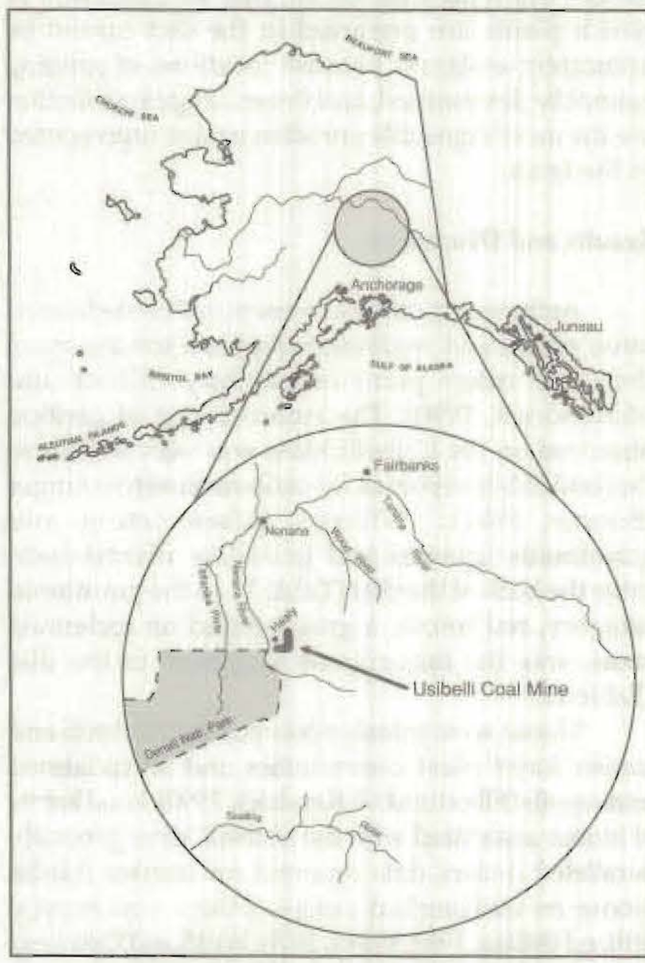


Figure 1. Location of Healy study region.

* **Charles L. Elliott**, Dept. of Biological Sciences, Eastern Kentucky University, Richmond, Kentucky.

** **Jay D. McKendrick**, Professor of Agronomy, School of Agriculture and Land Resources Management, University of Alaska Fairbanks.

Moose are the largest plant-eating mammals in the vicinity of the Usibelli Coal Mine.

in the feçal droppings. Holechek et al. (1982) reviewed the advantages and disadvantages of using fecal analysis for diet determination. Two of the advantages are that it does not interfere with normal habits of the animal and it is a nondestructive technique (no animals need be killed). Major drawbacks with fecal analysis are that an indication of which plants are preferred in the diet cannot be accurately assigned because locations of grazing cannot be determined; and those forage species that are the most digestible are often under-represented in the feces.

Results and Discussion

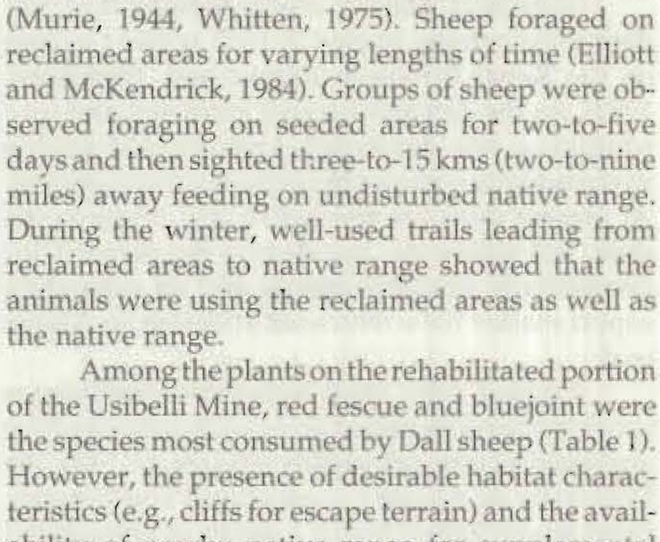
At the mine, caribou were noted on reclaimed mine spoils and undisturbed shrub tundra more than any other plant community (Elliott and McKendrick, 1990). The summer diet of caribou observed on the Usibelli Mine was very similar to the food habits reported for caribou on native ranges (Boertje, 1981). Willows, lichens/moss, and graminoids (grasses and grass-like plants) comprise the bulk of the diet (Table 1). In the graminoid category, red fescue, a grass seeded on reclaimed areas, was the major grass identified in the diet (Table 1).

Moose were mainly observed in tall shrub and conifer forest plant communities and on reclaimed mine spoils (Elliott and McKendrick, 1990). Food habits of moose associated with the Usibelli Mine generally paralleled dietary data reported for interior Alaska moose on undisturbed range—willow was heavily utilized (Milke, 1969; Wolff, 1976; Wolff and Cowling, 1981; Van Ballenberghe et al., 1989; Table 1).

Although known to feed primarily on shrubs, moose also consume grasses (Houston, 1968; Cushwa and Coady, 1976; Cederlund et al., 1980). Of the grasses identified in the diet, Usibelli moose consumed mainly seeded red fescue and native bluejoint (Table l) during the spring and summer months, periods of highest plant protein content and digestibility (Elliott, 1984).

Dall sheep used the Usibelli Mine area mainly as winter range (Elliott and McKendrick, 1984, 1990). Winter and summer diets of sheep on the mine consisted primarily of grasses (Table 1). This consumption of grasses parallels reported winter use of graminoids by sheep on the Kenai Peninsula (Nichols and Heimer, 1972) and in interior Alaska (Murie, 1944, Whitten, 1975). Sheep foraged on reclaimed areas for varying lengths of time (Elliott and McKendrick, 1984). Groups of sheep were observed foraging on seeded areas for two-to-five days and then sighted three-to-15 kms (two-to-nine miles) away feeding on undisturbed native range. During the winter, well-used trails leading from reclaimed areas to native range showed that the animals were using the reclaimed areas as well as the native range.

Among the plants on the rehabilitated portion of the Usibelli Mine, red fescue and bluejoint were the species most consumed by Dall sheep (Table 1). However, the presence of desirable habitat characteristics (e.g., cliffs for escape terrain) and the availability of nearby native range for supplemental feeding may be greater factors governing Dall sheep use of reclaimed mine spoils on the Usibelli Mine than are the plant species seeded for reclamation.



Several groups of Dall Sheep live in and around the mine. They feed on the grasses of both undisturbed sites and areas reclaimed after mining.

Plant Species	Percent of Plant Species in Diet				
	Caribou	Moose		Dall Sheep	
	Summer	Summer/Winter		Summer/Winter	
Willow (*Salix* spp.)	17	64	84	3	3
Red Fescue (*Festuca rubra*)	10	10	0	49	40
Sedge (*Carex* spp.)	2	T	0	0	0
Medicago (*Medicago falcata*)	3	T	0	T	T
Bluejoint (*Calamagrostis canadensis*)	1	3	0	10	15
Unknown moss/lichen	32	1	2	18	8
Unknown graminoids	13	5	0	2	2
Unknown forbs	10	7	2	11	23
Unknown shrubs	0	7	12	0	0

T = Trace —indicates less than 1% present in the diet
Note: Only the major food items are reported, hence the total diet does not equal 100%.

Table 1. *Major food items identified in the diets of big game associated with reclaimed areas on the Usibelli Coal Mine, Healy, Alaska.*

Summary

The impact of strip mine activities and reclamation on big game species in interior Alaska will depend on the magnitude of the areas disturbed. Small scale disturbances, as exemplified by the Usibelli Coal Mine, do not appear to be detrimental to the local big game populations. The ready access to surrounding undisturbed native habitat, and the acceptance of some seeded plants as food, appear to have helped mitigate any negative affects on big game animals caused by mining activities.

Current reclamation and mining procedures should be designed to promote a diverse vegetation and to insure that a sufficient amount of native vegetation will remain intact in a strip-mined area. If such changes are not implemented, large scale coal mining and concomitant reclamation activities within Alaska could detrimentally affect local populations of native wildlife populations.

The Usibelli Mine at present must be considered the premiere Alaska example of how small-scale surface mining, reclamation, and wildlife can

References

Boertje, R.D. 1981. Nutritional ecology of the Denali caribou herd. MS. Thesis, University of Alaska, Fairbanks.

Cederlund, G., H. Ljungqvist, G. Markgren, and F. Stalfelt. 1980. Foods of moose and roe-deer at Grimso in central Sweden. Results of rumen content analyses. *Viltrevy*. 11:169-247.

Cushwa, C.T., and J. Coady. 1976. Food habits of moose, *Alces alces*, in Alaska: a preliminary study using rumen contents analysis. *Canadian Field-Naturalist*. 90:11-16.

Elliott, C.L. 1984. Wildlife food habits and habitat use on revegetated strip mine land in Alaska. PhD. Diss., University of Alaska, Fairbanks.

Elliott, C.L. and J.D. McKendrick. 1984. Food habits of Dall sheep on revegetated coal strip mine spoils in Alaska. In *Proceedings Northern Wild Sheep and Goat Council*. 4:241-251.

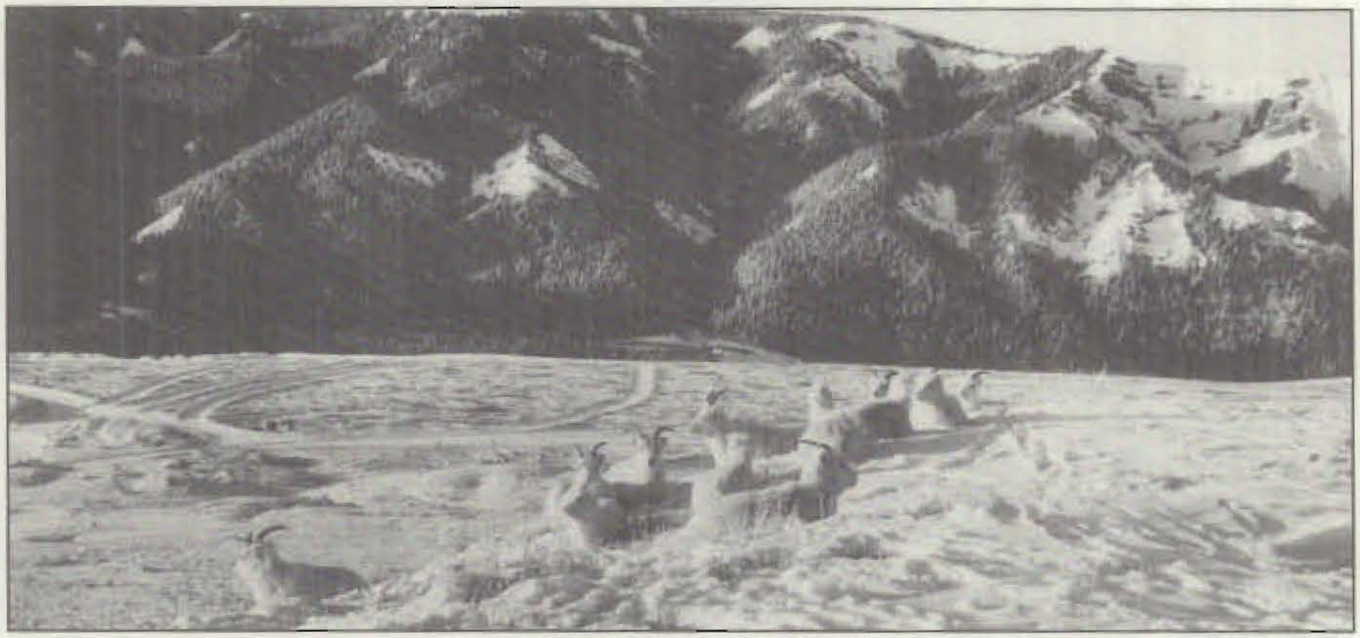
Elliott, C.L., J.D. McKendrick, and D.J. Helm. 1987. Plant biomass, cover, and survival of species used for strip mine reclamation in south-central Alaska, U.S.A. *Arctic and Alpine Research*. 19:572-577.

Elliott, C.L. and J.D. McKendrick. 1990. Big game use of reclaimed strip mine lands in interior Alaska. In *Proceedings National Symposium on Mining*. H. Graves ed. 1-5. University of Kentucky, Publication No. UKY BU153, Lexington. 275 pp.

Hansen, R.M. and J.T. Flinders. 1969. Food habits of North American hares. Colorado State Univ. Range Science Dept. Science Series No. 1.

Holechek, J.L., M. Vavra and R.D. Pieper. 1982. Evaluation of different calculation procedures for microhistological analysis. *Journal of Range Management*. 35:721-723.

Houston, D.B. 1968. The Shiras moose in Jackson Hole, Wyoming. Grand Teton Natural History Association Technical Bulletin No. 1.



Dall Sheep rest on a ridge overlooking the Usibelli Coal Mine's road system.

Milke, G.C. 1969. Some moose-willow relationships in the interior of Alaska. MS. Thesis, University of Alaska, Fairbanks. 60pp.

Murie, A. 1944. The wolves of Mount McKinley. U. S. National Park Series, Fauna Series No. 5.

Naske, C.M. and D. Triplehorn. 1980. The federal government and Alaska's coal. *The Northern Engineer*. 12:11-23.

Nichols, L., Jr. and W. Heimer. 1972. Sheep report. Alaska Department of Fish and Game Federal Aid in Wildlife Restoration Program Report, Project W-17-3 and W-17-4.

Van Ballenberghe, V., D.G. Miquelle, and J.G. MacCracken. 1989. Heavy utilization of woody plants by moose during a summer at Denali National Park, Alaska. *Alces*. 25:31-35.

Whitten, K.R. 1975. Habitat relationships and population dynamics of Dall sheep (*Ovis dalli dalli*) in Mt. McKinley National Park, Alaska. MS. Thesis, University of Alaska, Fairbanks.

Wolff, J. O. 1976. Utilization of hardwood browse by moose on the Tanana flood plain of Interior Alaska. U. S. Forest Service, Pacific Northwest Forest and Range Experiment Station Research Note PNW-267.

Wolff, J.O. and J. Cowling. 1981. Moose browse utilization in Mount McKinley National Park, Alaska. *Canadian Field-Naturalist*. 95:85-88.

Swarming insects drive caribou onto snow patches during the summer to escape the tormenting of the insects.

From Boreal Forest to Reclaimed Site: Revegetation at the Usibelli Coal Mine

Dorothy J. Helm*

Usibelli Coal Mine, Incorporated has been mining coal in the Healy area for three generations. Since 1972, the company has reclaimed sites disturbed by mining activities. Today state and federal regulations require all coal mines in the United States to reclaim lands to meet certain standards after mining is completed. The intent of this paper is to describe revegetation planning and considerations of present-day mines, using Usibelli as an example. Usibelli Coal Mine is involved in all phases of mining from exploration and pre-mining environmental inventories to post-mining reclamation. Vegetation studies are one part of these studies.

This article will attempt to describe some of the vegetation considerations and how Agricultural and Forestry Experiment Station (AFES) researchers are helping with these natural resource management challenges. Some revegetation studies were initiated just over 10 years ago by AFES researchers. Quantitative evaluation of succession on revegetated areas or of native vegetation has been conducted every year for the last six years by an AFES vegetation ecologist. Involvement of AFES personnel with vegetation and soils studies for Usibelli Coal Mine will continue as Usibelli expands into new areas and faces new reclamation challenges. This relationship is providing opportunities for research in natural resource management that would be unavailable otherwise.

Usibelli has completely funded all native vegetation and long-term reclamation evaluation studies on their property since 1984. A small grant from the Alaska State Division of Agriculture has helped with some woody transplant studies in 1990. A U.S. Department of Energy grant to Dr. William W. Mitchell in the early 1980s helped with revegetation and wildlife studies. The studies funded by Usibelli in the last six years have expanded our understanding of the successional processes on natural and man-caused disturbances. This knowledge, in turn, can be applied to other natural resource problems.

Reclaiming lands that have been surface-mined for coal is a process that starts long before the first coal is removed. Surface coal mining in the United States is currently regulated by the Surface Mining Control and Reclamation Act of 1977 (SMCRA) which is enforced in Alaska by the U.S. Office of Surface Mining (OSM, U.S. Department of Interior) and the Alaska Division of Mining within the Department of Natural Resources. All coal mine operators must secure a permit and post a bond guaranteeing proper revegetation before mining is started. Preparation of material for a permit application requires at least one year and usually several

Figure 1. Cover of native vegetation being measured during pre-mining inventory at Usibelli Coal Mine, Healy, Alaska.

* **Dorothy J. Helm**, Research Associate, Palmer Research Center, Agricultural and Forestry Experiment Station, University of Alaska Fairbanks

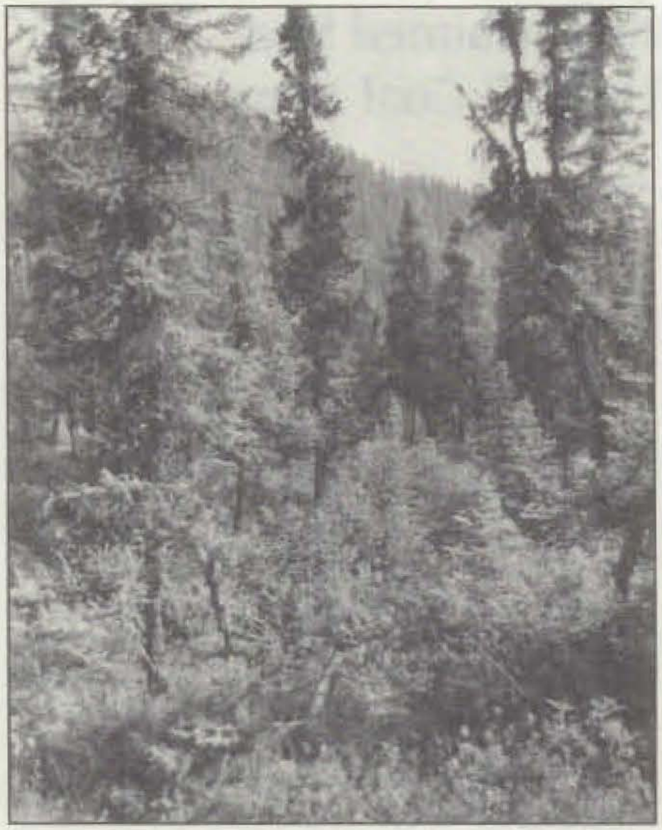


Figure 2. Open white spruce community with ericaceous shrub understory which is typical of some boreal forest communities prior to mining at the Usibelli Coal Mine.

years of environmental data collection, synthesis, and report writing. AFES expertise in quantitative vegetation ecology has been helpful to Usibelli and to other coal mining companies in the design and execution of the vegetation studies.

Planning

After an approximate permit area boundary—based on the identified coal resource—is outlined, environmental studies are begun to survey the vegetation, wildlife, surface and subsurface hydrology, soils, and cultural resources. Additional exploration for coal may result in minor or extensive modifications in the permit area boundary.

Pre-mining Vegetation Inventory

The objectives of the vegetation studies are to determine and describe the existing vegetation communities and the amount of area they cover. These data are used to determine what vegetation types will be disturbed and what plant resources are available for reclamation. The data are also used to help establish vegetation standards for release of the bond after mining is completed.

Data collected in vegetation inventories include percentage of cover by vascular plant species, mosses, lichens, and litter; density of shrubs more than 20 cm (8 in) tall; age, height, and dbh (diameter-at-breast-height) of trees and tall shrubs; and height and basal diameter of dominant woody species less than 3 m (10 ft) tall. In addition to the measured parameters, a list of vascular plant species and moss and lichen genera is generated for the mine area. Current sampling methods include reporting every plant species located every 50 cm (1.5 ft) along a 20m (66 ft) transect (Figure 1). This is converted to percent cover. Stems of woody plants are counted for density estimates in belt transects (rectangles) beside these transects. Enough of these transects must be sampled to ensure that the total living vascular cover is examined to a specified level of precision. In stands where this would be only a small number of transects, additional transects are read to ensure a reasonable description of the species composition. In addition to the detailed measurements, the successional and ecological conditions associated with the various vegetation types are described.

The Usibelli Coal Mine is located in the boreal forest zone of interior Alaska. Its coal leases contain almost 20 different vegetation types ranging from low shrub communities to dwarf tree forest types to needleleaf, broadleaf, and mixed forests (Figure 2). Grasslands dominated by bluejoint (*Calamagrostis canadensis*) occur in some locations. Low shrub types may be dominated by dwarf birch (*Betula glandulosa*), bog blueberry (*Vaccinium uliginosum*), Labrador tea (*Ledum groenlandicum*), and lowbush cranberry (*Vaccinium vitisidaea*). The most important tree species in the boreal forest vegetation types include white spruce (*Picea glauca*), black spruce (*Picea mariana*), and paper birch (*Betula papyrifera*). All three of these may be found over permafrost in the Usibelli area, although it is usually the two spruce species that are associated with this soil condition.

The area's topography consists of flat ridges with adjacent steep slopes (20° to 40°) where streams are actively downcutting (Figure 3). Vegetation community development on many of the ridges is influenced heavily by fire. Along the slopes, vegetation is controlled predominantly by landslides.

Plant species growing under particular ecological conditions, especially of slope and aspect, are identified for potential use in reclamation. This is extremely useful in reclamation planning. Plant species that occur on steep, south-facing, windblown slopes before mining are the ones most likely to succeed on the south-facing slopes after mining. Plant species that occur in early successional sites are the most likely candidates for reclamation. Species that occur later in succession may require conditions, such as shade or deep soil organic layers, that are not present on recently reclaimed areas.

Reclamation Plan

The main objectives of reclamation are to control erosion, stabilize slopes, and establish a diverse, self-reproducing plant community. Successful reclamation is usually a balance among various options. For instance, grass is usually the fastest, most reliable plant type for establishing protective cover on the mine soil. However, heavy grass cover may slow down natural succession on the site or compete with woody plant establishment while moderate grass cover may help conserve subsurface soil moisture.

The reclamation plan is developed during planning before any mining actually starts. Site conditions such as permafrost and steep slopes must be considered in both the engineering and biological aspects of reclamation. The mined area must be backfilled and graded to restore the approximate shape of the landscape. Guidelines for coal mining require that topsoil (A horizon) be replaced over the graded overburden. Technically, overburden is the geologic material above or between the coal seams but beneath the soil horizons. However, some soil profiles in Alaska do not have A horizons or other material suitable for use as a plant growth medium in reclamation. Legal variances can be obtained in these cases when sufficient justification and documentation are supplied to the regulatory agency. University research helps provide the information needed by both the coal mine and the regulatory agencies. Overburden materials on coal mines in Alaska may provide a suitable medium for plant growth. Our low-sulfur coal is not associated with acid mine drainages or heavy metal toxicities common in the coal mining areas of the eastern United States.

Figure 3. Steep slopes dominate much of the terrain at the Usibelli Coal Mine. This makes pre-mining inventories and reclamation challenging.

Grass species are the primary plant species used for initial soil stabilization. Woody species are then planted from local transplants or cuttings or seedlings. This provides diversity and sometimes deeper rooting which also contributes to soil stabilization. Leaf fall from woody plants may help increase the organic matter and nutrients in the soil. This is particularly important where alder (*Alnus*) is used since its leaves contain high levels of nitrogen. Woody species are usually selected for their availability, rapidness of growth, tolerance of various conditions, and usefulness for wildlife or other post-mining land use. Availability refers to whether the plant species can be obtained from local transplants, locally collected or commercial seed, or seedlings or cuttings propagated in a greenhouse. Woody plants must grow rapidly to overcome competition from grasses. Selected plant species must be able to tolerate drought and low nutrient levels. Some plants, such as alder, may add significant quantities of nutrients to the soil but may require moisture to become established. Others, such as balsam poplar (*Populus balsamifera*), are frequently found in nature on well-drained, steep, south facing slopes. The reclamation plan must include plant species, planting techniques, amendments (such as fertilizer or inoculum) and their rates of application, and general location for different plant communities, such as where grass or woody plant species will be planted.

Bond-Release Standards

Post-mining bond-release standards must also be developed in the reclamation plan. Before disturbing any land, the mine operator must post a bond sufficient to cover reclamation at any given point. This ensures that if a mine operator walks away from the operation, then the state has funds to reclaim the existing disturbance. This bond is returned to the operator when mining and reclamation are satisfactorily completed. The reclamation must meet certain standards after 10 years where precipitation is less than 26 inches annually and five years where precipitation is greater than this. In the Usibelli area, the bond-release period is 10 years. In the Beluga area on the west side of Cook Inlet, the period is just five years because of its greater rainfall.

The biological objective of these bond-release standards is to ensure that a diverse self-reproducing plant community capable of supporting the post-mining land use is established. Bond-release standards can be developed in several ways and have three parts. The standards include total living vegetation cover, woody species density, and plant species diversity. The simplest method of creating a standard is to develop a technical standard. With a technical standard, the operator agrees to meet a certain level of the given parameter, such as 70% (level) living plant cover (parameter). Usually this technical standard is justified by data from existing revegetated areas, test plots, existing native vegetation, or a combination of these. The reclamation plan must be designed to meet these standards at the end of the bond-release period. Usibelli has developed its standards based on older revegetated areas.

Another technique is to use a reference area in nearby undisturbed native vegetation. This area must be characterized and marked when the pre-mining vegetation is described. During the year when the operator measures the revegetated areas for bond release, the reference areas are also remeasured. Vegetation cover, density, and diversity on the revegetated area must equal that of the reference area within statistical limits of confidence. With this approach, a reference area must be established for each vegetation type in the area; this could be 10 or more reference areas in many permit areas in Alaska.

All this information from pre-mining inventories and the reclamation planning plus other environmental and engineering studies are combined in a permit application. If all the studies are satisfactory, as determined by Division of Mining reviewers, then a mining permit is issued and the operator may start mining. The review and revision process may take as long as a year and involve several agencies and consultants.

Post-Mining Reclamation

After the permit is approved, the area is mined in a piecewise fashion according to the mine plan. During this time the mine is inspected by state and federal officials. After mining a particular area is completed, the pit is filled and graded to approximately the original contour. The slopes are sometimes furrowed to reduce runoff. The troughs of the furrows also accumulate more moisture and nutrients which improve plant growth (Figure 4). The site is usually aerially seeded during May or early June (Figure 5).

The Usibelli seed mix consists of grasses adapted to the area including Arctared red fescue (*Festuca rubra*), Manchar smooth brome (*Bromus inermis*), common foxtail (*A lopecuris pratense*), Nugget Kentucky bluegrass (*Poa pratensis*), and reed canarygrass (*Phalaris arundinacea*). Two annual species (rapeseed, *Brassica campestris*, and annual ryegrass, *Lolium temulentum*) are also used to help establish ground early cover. Reed canarygrass prefers moist areas, probably near seeps. Meadow foxtail does well on the more moist areas while dry areas are more suitable for brome. Brome, however,

Figure 4. *Furrows are sometimes put across slopes to reduce erosion. Plants grow better in the troughs of these furrows rather than the ridges because moisture and nutrient levels are greater.*

Figure 5. Seed and fertilizer are applied aerially onto these 3:1 slopes.

will not tolerate the low pH soils common in most of Alaska. About half of the species in the mix are considered native to Alaska. Several of the grass cultivars have been developed through breeding programs at the Agricultural and Forestry Experiment Station. One of the biggest limitations to plant species' diversity in reclaimed communities in Alaska is the few plant species that are adapted to the climate and can be obtained commercially.

Mines in the lower 48 states frequently have seed mixes of 20 species with different mixes for different conditions. In contrast, Alaskan conservation projects may have only a dozen species to choose from, and most species may not be suitable to the particular site conditions or be able to survive in the long term without applying fertilizer or other amendments in later years.

Vascular plant cover on revegetated sites at Usibelli may range from 50 percent on poor sites to 99 percent on good sites by the end of the second year under normal conditions. Cover will remain high if fertilized (Figure 6) but will start decreasing two years after the last fertilization. Openings in the cover will allow local species to start colonizing the area. Litter buildup between the third and eighth years protects the soil from erosion but may also slow colonization.

Usibelli Coal Mine personnel are transplanting young woody plants from nearby vegetation into the reclaimed areas to assist natural succession toward boreal forest communities. This ensures that the plants are adapted to the climatic conditions and that the rooting zone contains the microbial communities, especially mycorrhizae, needed for proper plant growth. Mycorrhizae are "fungus roots," which are associations among plant roots and certain fungi in which the fungi assist the plant in obtaining nutrients and moisture from the soil and the plant provides energy (carbon from organic substrates) to the fungi. Mycorrhizae occur on over 90 percent of the plant species worldwide and are essential for growth of conifers and ericaceous shrubs in the field. Microbes can spread from these rooting zones to the surrounding soil and help vegetation establishment.

Local plant species colonize the reclaimed areas over time. Alder (*Alnus sinuata*) has begun colonizing areas with good moisture on four-year old sites (Figure 7). A few white spruce (*Picea glauca*) transplants and their understory species have survived 12 years on one south-facing slope. Older sites where the grass seedings were not successful may have several native plants colonizing the bare soil (Figure 8). The need for good grass cover to stabilize the soils must be balanced against the need for long-term colonization by local woody species.

Usibelli has also been quantitatively evaluating their revegetation most years since 1985. Their seed mix has changed over the years as they have learned which plant species have been successful. New grass varieties adapted to high latitudes have become available and incorporated into the mix. Some of the species now being used successfully were not available when they began reclaiming mined lands in 1972. Understanding the relationship between plant species and site conditions will enable them to vary the seed mix on future locations

Figure 6. Reclaimed areas at Poker Flats, Usibelli Coal Mine, have good grass cover established within the first two years after seeding to stabilize the soil.

with different slopes and aspects. Researchers from AFES work with Usibelli engineers to help identify relationships of plants to soils and environmental factors, thus improving the chances of reclamation success and reducing the time until a boreal forest or similar community is reestablished.

Conclusion

Reclamation at Usibelli Coal Mine has many challenges. Much of the Poker Flats Mine area where they are currently mining contains permafrost with little or no A horizon. Steep slopes (those greater than 3:1) require engineering techniques for stability before the sites can be seeded. Vegetation then helps stabilize the surface soils. Grass cover achieved on initial reclamation is good in most years. Some colonization by native species has begun in reclaimed areas closest to native communities.

Planning has already begun for reclaiming areas that will not be mined for several years, possibly decades in some cases. Usibelli is utilizing data collected on vegetation and soil inventories conducted by AFES researchers on future permit areas to understand species replacement and mechanisms in vegetation succession. This will help them select species and modify techniques, if need be, in future reclamation. ❑

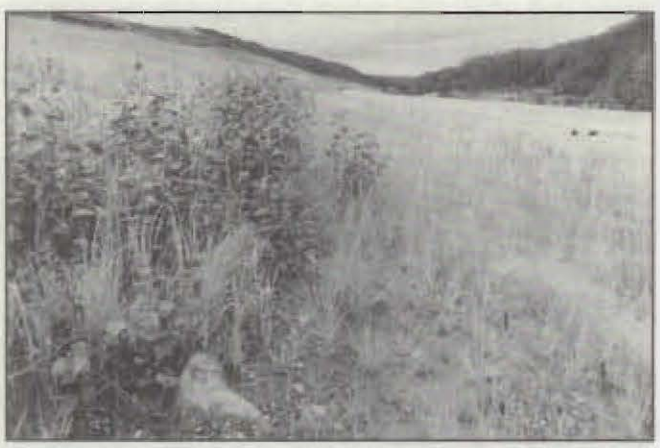


Figure 7. Alder from surrounding vegetation has colonized this 4-year-old site in patches between established plants.

Acknowledgments

I would like to thank Usibelli Coal Mine, Incorporated, for their financial and field support for studies performed over the last six years.

Figure 8. Labrador tea and other local native plant species have colonized many of the older revegetated sites where grass establishment was poor.

Cuisine and Cure on the Dalton Highway

Sheila K. Moore

A feast grows along the Dalton Highway, just waiting for the knowledgeable gatherer to harvest it. The culinary delights of the region's animals—caribou, grayling and musk ox to name a few—are well known. But there's more to life than mooseburger. Native plants offer diversity and nutrition for the harvester. They taste good and some may give relief to common ailments.

The plants in this article are ones that grow along the Dalton Highway. They are easy to find and free for the picking.

Check the land ownership before you start your harvest. If it is private property, you must get the owner's permission before you collect anything. If it is a state park, national reserve, federal reserve or any state land, harvesting is allowed as long as it is for personal use and is not taken in large quantities. If you want to harvest for commercial purposes, you need to contact the managers of the land for their specific regulations. Regulations for gathering in the U.S. National Parks are more restrictive. Before gathering any wild foods in the National Parks, check the rules for the specific park.

In your gathering, please be courteous to the plants and other species that depend on them. Just follow a few simple rules.

- The most basic rule is to use common sense, such as picking healthy looking plants.
- Be sure there's no spraying or garbage dumping in your picking area.
- Along the highway go back a quarter of a mile; the plants along the road absorb chemicals from dust and vehicles. If you are not sure if the plant has been sprayed, boil it in water with a Halozone pill. Halozone contains chlorine and can be bought in most camping stores.
- Remember other animals use the plants and may need them more than you do, so don't take all its edible parts. Be considerate and take only what you need.

Edible plants grow almost everywhere around you, from under the ground to the sky. Cast your attention to the area above your head and see what you can get from trees (Table 1).

Trees

Birch (*Betula papyrifera*) is found all along the highway (below tree line). In the spring the sap, buds, inner bark, and catkins (small flowers without petals) are available. To collect the sap from trees in the interior of Alaska, you can start tapping in mid-April to mid-May, depending on the outside temperature. Drill a hole in the tree on the sunny side 1.5 to 2 inches deep, making the hole 1.5 inches in diameter. You should drill slightly upward, so the sap will flow out due to gravity. Do not make more than two holes in one tree. Use a piece of rubber tubing as a pipe for the sap to flow into a

Yarrow's fern-like leaves offer the wild food gather several traditional medicinal uses as well as seasoning foods.

Sheila K. Moore, Sophomore, School of Agriculture and Land Resources Management, University of Alaska.

Table 1. *Description and Medicinal and Nutritional Uses of Edible Plants.*

Common Name (*Scientific Name*)	Medicinal and Nutritional Uses	Description
Birch (*Betula papyrifera*)	Birch beer or champagne. Twigs and buds in cheesecloth as a spice in stews. In emergencies, cambiumcan be eaten raw or boiled like noodles or, ground into flour. Sap is used to treat mouth sores and external skin problems. The leaf tea relieves headaches, rheumatism, urinary problems, fevers and diarrhea.	White bark, skinny leaves are pear-shaped and have jagged edges.
Spruce (*Picea*)	The reddish buds are good in salads, or ground into a spice. Center of the cones can be roasted and eaten. Inner bark can be used like the birch, and can help alleviate thirst. Leaf and bark teas are often used to relieve colds, congestion and urinary problems. Inhaling the vapor may help bronchitis. Gargling with the tea freshens breath. Sap can be used to heal burns and sores.	An evergreen tree, several different types, but all are edible.
Willow (*Salicaceae*)	Leaf tea can help headaches and urinary problems. Gargle with tea for mouth sores. Foot bath for sweaty feet, and tonic for dandruff. Its steam can be used as a facial for acne. By mixing it with borax and essential oils it can be used as a deodorant. Fluids from the bark are used to repel mosquitos.	Several species, from tree-like to ones that creep along the ground.
Wild Rose (*Rosa acicularis*)	The petals can go in salads, omelets, or spreads. Rose hip tea is used for colds, stomach problems, cramps, a wash for ulcerous skin and wearing clothes soaked in it may prevent headaches. The hips can be made into into a pie or used as a raisin substitute. Oil vapors from the petals can be inhaled for headaches. The petal paste is used on bee stings.	Have pink pedals, the stems have a lot of thin thorns and grow 2-3 feet high.
Fireweed (*Epilobium angustifolium*)	The leaf tea can be used as a laxative, to relieve upset stomach or restlessness. You can eat the marrow plain, with sugar, or in a soup. The flowers can go in salads, or be mixed with its leaves, and soaked in oil and applied to hemorrhoids. For waterproofing, rub the raw plant on the cloth. To draw out puss, try applying raw fireweed on wound.	2-3 feet tall, the flower is either pink or white. Leaves are oblong and skinny.
Yarrow (*Achillea millefolium*)	The dried leaves can be used for seasoning or salads. Tea used to induce perspiration, help colds; traditionally used to help abdominal cancer, hemorrhoids, and stimulates bile. Its vapor is used for sinuses. Stop bloody nose by sticking a leaf up the nostril. Chew on a leaf to temporarily alleviate a toothache. The roots can be boiled and used as an eye wash. Has been used for tuberculosis. It can repel mosquitos.	The leaves are fern-like and grow from the stalk. The flower ranges from white to reddish. They grow at the end of the stalk in bouquets.

Table 1. *Description and Medicinal and Nutritional Uses of Edible Plants (continued).*

Common Name (*Scientific Name*)	Medicinal and Nutritional Uses	Description
Labrador Tea (*Ledum palustre decumbens*)	Its tea can help colds, anemia, stomach problems, heart burn, and hangovers. Chew on leaf and make a paste for burns. Dried leaves make a spice to get rid of the meat's gamey taste. The leaves have been used to help mouth sores and tuberculosis in the past.	A low-bush plant with oblong leaves that are waxy on top and felt-like on bottom. The flower is white.
Bearberry (*Arctostaphylos uva-ursi*)	The leaf can be made into a tea for kidney and bladder infections, and antibacterial wash. The leaves can be used as a tobacco substitute to smoke or chew.	7 inches high, red berries, small evergreen leaf. Flowers are pinkish.

collecting bucket. You can buy the tubing at any hardware store. Cover the bucket to keep the sap free from forest litter. The bucket should be checked two or three times a day to make sure that it doesn't overflow. If there is not a lot of sap in your bucket, check to see if the tubing is clogged. When you are finished drawing the sap, fill in your hole with moss to seal the tree. This makes sure no more damage is done, and within a year the tree will heal itself. Strain the sap through a cheesecloth. Once that has been done you will have a drink by itself, but you can do several different things to spice it up. For instance "Yule Kilcher leaves the sap uncovered until it has fermented, then filters it, adds sugar and yeast, then corks it and he has birch champagne" (Schofield, 1989). It is known that birch bark and leaves contain methyl salicylate, the main ingredient in aspirin, so birch has the potential to relieve headaches. The part of the bark that you want is the inner bark or cambium. When taking the cambium, tearing the bark off horizontally will cause the tree to die, for it cuts off the nutrient and water supply between the roots and the branches. A good technique is to take it from a pruned part of the tree, or in vertical strips of about two inches wide, making sure not to remove more than half of the total bark of the whole tree.

Other trees that have a wide variety of uses, are the several types of spruce (*Picea*). This tree is also found throughout Alaska from muskegs to mountain slopes. Tips, inner bark, and the reddish male buds are best collected in the spring. However you can harvest the limbs, roots, and resins anytime. From this tree you can make such things as spruce tip jelly, and even a foot bath for sore feet.

Many types of willow (*Salicaceae*) live throughout Alaska, and all are edible. In the spring the sap and shoots are at their peak. The bark and leaves can be collected anytime. Willow is a high source of vitamin C. "A good source of calcium according to Justina Mike is to take pussy willow flowers and mix them with chopped backbones from king salmon, let dry, and eat" (Schofield, 1989). For hornet stings, chew a fresh willow leaf and put the paste from the chewed leaf on the sting for about 10 minutes. For an antiseptic, put one cup of willow bark and young, tender leaves into two cups of water, then rinse the wound two or three times a day (Schofield, 1989).

From the sky bring your eyes down to chest level to see what the bushes can provide you.

Bushes

The wild rose (*Rosa acicularis*) has a wide variety of uses. The shoots are best collected in the spring. In late spring to mid-summer you can use the leaves, rosebuds, and petals. In the fall or spring the bark, stems and roots are ready, and after the first frost, use the rose hips. The shoots can be eaten plain or with the petals. Be sure to remove the white tips from the petals, for that part is bitter tasting. Try dipping the petals in whiskey and frying them in oil. Another idea is to mix them with honey, strain and have rose honey (Schofield, 1989). If you have a cut or scrape; place a moist petal on the area while the cut is drying. The petal will form a bandage (Schofield, 1989). Rose hips have been proclaimed for years as being a great source of vitamin C. And it is; one rose hip has about as much vitamin C as three oranges. Not only do they contain vitamin C,

Toxic Plants

In Alaska there are very few poisonous plants—eight to be exact. This does not include fungi; that would require a much more detailed article. The common names for Alaska's toxic plants are baneberry, narcissis floria, water hemlock, wild sweet pea, lupine, locoweed, death camas, and false hellebore.(Table 2)

- **Baneberry** (*Actaea rubra*) usually grows two to three feet high in wooded areas or thickets. Its berries can be either red or white, and each berry grows on its own stalk. If as few as six berries are eaten, it can be deadly (Heller, 1953).
- The **narcissifloria** (*Anemone narcissifloria*) grows in meadows, on hillsides, and tundra. Even though some Native Americans have told of eating the shoots in the early spring, some animals have fed on it and died (Heller, 1953).
- **Water hemlock** (*Cicuta machenziana raup*) looks a lot like wild onions. The easiest way you can tell them apart is by digging up the roots. If it smells like onions, it is the wild onion, and if there is no smell, it is the water hemlock. Common locations for hemlock are wet meadows, streams, and tundra lakes. If eaten, induce vomiting. If not done immediately, death is inevitable (Jones, 1983).
- The **wild sweet pea** (*Hedysarum maxkenzii*) is usually found in sandy, gravelly areas. The flowers are hot pink and have a sweet scent. Its edible cousin, the wild sweet potato, is pale pink or white and has no scent. The wild sweet pea's poisonous characteristics are based on one reported human case. Be safe. Avoid the deep purple-flowered peas (Heller, 1953).
- **Lupine** (*Lupinus moothatensi*) can be fatal to animals. It is not positively known whether Alaskan lupines are also poisonous. They live on hillsides and in open areas such as gravel beds. In an emergency you can use the roots, but only if the woody fiber is completely scraped off. It's safest to avoid these plants altogether (Heller, 1953).
- **Locoweed** (*Astragalus*) grows in meadows, hillsides, tundra, and mountains. Not all varieties are toxic, but it is not easy to decipher between the ones that are toxic and the ones that are edible.
- Another poisonous plant is **death camas** (*Zygadenus elegans pursh*). It can grow in meadows, road sides, and edges of forests. These are usually one of the first plants to appear in the spring, and their leaves are a lot like the iris.
- The last poisonous plant is the **false hellebore** (*Veratrum eschscholtzii*). This plant usually grows in swamps and low-lying boggy areas. It resembles skunk cabbage when it is young. It has been used medically, but it is best to avoid anything resembling it (Graham, 1985).

These are the poisonous plants found in Alaska, however, while others are safe, even an edible plant can have some adverse effects if eaten in excess. Keep this in mind; to plan meals from nature there needs to be variety. Do not use any one plant in excess.

but also vitamins A, B, E, and K, and the minerals calcium, iron, and potassium. The hips by themselves are edible, however, it is recommended that you remove the seeds because the hairs on them have a tendency to irritate people's intestines and stomach (Walker, 1984).

Fireweed (*Epilobium angustifolium*)—so named because it is usually abundant after a fire—also has its uses in the wilderness home. The stalks are good sources of vitamins A and C, and can be harvested in the spring. In late spring use the leaves, and in the summer you can harvest the buds and flowers. The individual stalks vary in taste. They range from sweet and pleasant to unpleasant and bitter. Different sources offer different reasons for this variance. Some say it is due to the soil, others say that it depends on the age of the plant; when the leaves start to turn down they are too old and will taste bitter.

Now tilt your head downward and bend your knees a little and see what grows around your legs.

Low Bushes

Yarrow (*Achillea millefolium*) grows in gardens, meadows, and sandy slopes. It is also called achillea for it is believed that a Greek goddess decided to protect her son, Achilles from death by dipping him in a mixture of Yarrow, however, she dipped him in by holding onto his heels. So his heels were left unprotected. At the Battle of Troy he was killed by an arrow that hit him in the heel (Schofield, 1989).

Table 2. Description and Symptoms of the Toxic Plants.

Common Name (*Scientific Name*)	Description	Symptoms
Baneberry (*Actaea rubra*)	Height: 2-3 feet; Leaves: divided into 3 subgroups at top of branch with jagged edges; Flowers: each small, white and grows on its own stalk.	Dizziness, vomiting, increased pulse, burning in stomach, cardiac arrest.
Narcissifloria (*Anemone narcissiflora*)	Height: 2 feet; Leaves: clustered at top of stem; Flowers: white on top, blue tinted on bottom. The stem has silky hairs 1-5 inches long.	Stomach irritation, inflammation of the stomach and intestines.
Water Hemlock (*Cicuta machenziana raup*)	Height: 3-7 feet; Flowers: white and clustered at top of stalk; Leaves: alternate stems.	Stomach pains, nausea, convulsions, increased pulse, possible death.
Wild Sweet Pea (*Hedysarum maxkenzii*)	Height: 1 foot; Stalks have small, oval leaflets that are smooth on top and have grayish hair on bottom; Flowers: hot pink and have a sweet scent.	Stomach pains.
Lupine (*Lupinus moothatensi*)	Height: 3 feet; Flowers: blue, white, or pink; Leaves: grow on stalk and radiate from a central point.	Inflammation of stomach and intestines.
Locoweed (*Astragalus*)	Height: 6-10 inches; Leaves: grow opposite each other. Some are smooth, others are hairy; Flowers: white, yellow or purple.	Irregular walk, loss of weight and appetite. If untreated, death.
Death Camas (*Zygadenus elegans pursh*)	Height: 1-2 feet; Flowers: clustered at top with greenish petals with 1 or 2 dark spots (glands); Leaves: long, flat and pointed.	Nausea, staggering, Excessive salivation, lowering of body temperature, difficulty breathing, coma.
False Hellebore (*Veratrum eschscholtzii*)	Height: 3-8 feet; Leaves: broad, oval and hairy; Flowers: small, greenish and grow in clusters on drooping branches.	Excessive salivation, spasms, vomiting, abdominal pain, muscle weakness, general paralysis, convulsions, possible death.

Another tasty plant that grows by your legs is Labrador tea (*Ledum palustre decumbens*). It grows in sunny, high areas, bogs, and the best parts are the leaves and flowers. It is a high source of vitamin C. Be careful not to drink too much tea made from the leaves, for it may cause headaches, cramps, paralysis, and intestinal problems, especially when made from freshly picked leaves (Viereck, 1987). Traditionally native people believed that putting this on the door step would repel ghosts and any illness (Schofield, 1989).

Finally, bend your knees to see what the ground will offer you.

Ground-Hugging Plants

The bearberry (*Arctostaphylos uva-ursi*) grows on dry sandy soils, gravel, and river banks. In the summer it has red berries with several small hard seeds inside. You can pick these berries from late summer and into winter, but they are sweeter if picked after the first frost. The berries and leaves are also usable, and have vitamin C and carbohydrates.

One way to prepare bearberries is to fry the berries and leaves in grease, and add sugar for taste (Schofield, 1989). The plant has a high alkalinity, so do not worry if after drinking the tea your urine turns a bright green; it is due to the alkalinity. You can use the berries to make a cool drink. Simmer two cups of fruit in two cups of water with half a cup of honey for 30 minutes, let it sit for an hour, strain, and then chill.

Tea

Several of the plants discussed can be used to make tea, so here's how to prepare them. It is best to collect the leaves when they are not wet. Lay the leaves on a rack, screen or hang in bunches until they have completely dried out. If you live in a very moist area, it may be necessary to dry them in an oven at a setting between 150 and 200 degrees Fahrenheit. Check regularly to make sure that they haven't burned. Put the dry leaves in an air-tight, glass jar for storage after drying. Try to avoid breaking the leaves while putting them in the jar. When you what to use them, break the leaves with your fingers into pieces so the pieces will fit in the bottom of an already heated cup. If you have a fine paper, tea ball or cloth filter then you may want to grind the leaves to get a richer taste. Pour the boiling water into the cup. Cover it for about 10 minutes so that the leaves can soak and none of the flavor or aroma will escape. After that, the tea will be ready for drinking.

Much of what you can see is ready to be harvested from the ground to the skies. These plants are not exclusive to the Dalton Highway, you can find them throughout Alaska. You now have a few ideas about the variety of plants and their uses. Several guide books, such as *Wild Edible and Poisonous Plants of Alaska* (Cooperative Extension Service A-00028) and *First Aid Poisonous Plants and Mushrooms* (Cooperative Extension Service A-00129), offer greater detail and should be used by any inexperienced forager. Other helpful books include *Why Wild Edibles* (Pacific Search Press) and Euell Gibbons's various books.

In trying wild foods take Gibbons's advice. "Don't make the error of thinking of these foods as *substitutes* [for other vegetables]..., or you will fail to appreciate them for their own very real merits. Each species has a flavor, aroma and texture all its own, and is good food in and of itself and doesn't have to pose as a substitute for something else." (Gibbons, 1962).

The only things that will stop you from all of the possibilities of foraging are your own imagination and safety considerations. ❑

References

Gibbons, E. 1962. *Stalking the Wild Asparagus.* David McKay Company, Inc. New York.

Graham, F. K. 1985. *Plant Lore of an Alaskan Island.* Alaska Northwest Publishing Company, Anchorage.

Heller, C. A. 1953. *Edible and Poisonous Plants of Alaska.* Cooperative Extension Service, University of Alaska, Fairbanks.

Jones, A. 1983. *Nauriat Niginaqtuat—Plants We Eat.* Maniilaq Anore Jones and Association, Kotzebue.

Schofield, J. J. 1989. *Discovering Wild Plants.* Alaska Northwest Publishing Company, Anchorage.

Viereck, E. G. 1987. *Alaska's Wilderness Medicine: Healthful Plants of the Far North.* Alaska Northwest Publishing Company. Edmonds, Washington.

Walker, M. 1984. *Harvesting the Northern Wild.* Northern Publishers, Yellowknife, Northwest Territories. Canada.

Fireweed, which grows abundantly along the Dalton Highway, is one of the easiest recognized wild edible plants.

Endangered Aleutian Shield-fern Grows at the University of Alaska Fairbanks

Patricia S. Holloway

Last year, Alaska's rarest fern quadrupled in number. Today three-fourths of the Aleutian shield-fern, *Polystichum aleuticum,* live in the Agricultural and Forestry Experiment Station (AFES) greenhouse—more than 300 of them. It is possibly the rarest fern in North America. In the wild it grows on the Andreanof Islands in Alaska's Central Aleutian Island District.

It was found originally on Atka Island in 1932 (Christensen, 1938), but subsequent attempts by botanists to relocate it on Atka failed (Smith and Davison, 1989). In 1975, seven Aleutian shield-fern plants were discovered on nearby Adak Island. Its rediscovery, prompted an extensive search of Adak and nearby islands, and "Have You Seen This Plant" posters were circulated among local residents. By 1989, two populations had been located on Adak, both on the southeast- to east-facing slopes of Mt. Reed. Approximately 111 shield-ferns found on the mountain constitute the total known population of this fern.

Because of its rarity and possible imminent extinction, the Aleutian shield-fern was designated an endangered species in 1988 and afforded protection under the 1973 Endangered Species Act. This act prohibits collection or destruction of this fern and limits research to studies that do not jeopardize its existence. The Act also requires that the responsible federal agency develop a plan of recovery to ensure its future and prevent extinction. Adak Island is a U.S. Department of Navy Adak Naval Reservation. The federal agency responsible for the shield-fern's recovery is the U.S. Fish and Wildlife Service (F&WS).

In the wild the Aleutian Shield-fern grows to several inches height. Today, just slightly more than 100 known plants still grow in the wild.

An Aleutian Shield-fern begins to spread its leaves in the UAF Greenhouse. The fern is one of more than 300 of the rare species now growing in the greenhouse.

In 1989 the F&WS initiated an attempt to locate additional populations of ferns. Simultaneously they conducted a comprehensive census of existing populations and began an ecological characterization of the existing fern habitat (Tande, 1989). The F&WS signed a contract with the Agricultural and Forestry Experiment Station to attempt spore propagation under controlled laboratory conditions. Resulting plants would be used for future research into basic life history and breeding biology which is necessary for the complete recovery of this species. The Endangered Species Act both protects plants and animals and tries to reintroduce them back into the natural world. The ultimate goal is to bring this species to the point where the protections afforded by the Endangered Species Act are no longer necessary for its survival.

The Environmental Protection Agency granted permits to collect spore-bearing fronds from

Mt. Reed in August, 1989. Pat Wagner of AFES gathered fronds and brought them to Fairbanks. Since this is the first time the Aleutian shield-fern had been grown under growth chamber and greenhouse conditions, researchers used a variety of media including aseptic agar-based nutrient media and a mixture of milled peat and sand. Approximately six weeks after sowing, the spores germinated on nearly all of the media tested. Six months after sowing, the first shield-fern plantlet (sporophyte) appeared, but most plantlet development did not occur until nine months after sowing. One year after the spores were sown, 303 young fern plantlets had developed. This preliminary trial showed that the Aleutian shield-fern produces abundant, viable spores that are easily germinated in controlled conditions. Its rarity is not related to spore viability, but perhaps to environmental factors that prevent germination of these viable spores. Because of the successful germination, the total number of Aleutian shield-ferns in the controlled environment is nearly three times the size of the existing known population in the Aleutians.

How this shield-fern came to the Aleutians and why it is so rare is unknown. Researchers have speculated that it might be a relict species that flourished thousands of years ago and is gradually dying out. Alternatively, reindeer introduced onto Atka in 1914 and caribou introduced onto Adak in 1958 may have destroyed the population by trampling the plant or causing erosion of the fragile habitat.

Not only is this species extremely rare, but its existence in North America is intriguing. Its closest relative is believed to be another shield-fern, *Polystichum lachenense*, that grows in the Himalayan Mountains in western China (Christensen, 1938).

Today more than 300 Aleutian shield-ferns grow in the university's AFES greenhouse. In slightly more than a year the university's experimental effort quadrupled the known world population of this endangered species. University researchers will continue to raise the ferns. In the future, some of the plants may be reintroduced to the wild, thus expanding the population.

If successful, their work will eliminate the need for further protection under the Endangered Species Act. That's in the future. Between now and then, a healthy population will be maintained at the university while researchers work to learn more about this mysterious and almost extinct plant. ❑

References

Christensen, C. 1938. On *Polystichum aleuticum* C. Chr., a new North American species. *American Fern Journal.* 28(3):111-113.

Smith, D.K. and P.G. Davison. 1989. *Polystichum aleuticum* C. Chr. in Hulten. Site Survey of Atka Island, Alaska, 1988. Unpublished field Report. U.S. Fish & Wildlife Service, Anchorage, Alaska.

Tande, G.F. 1989. Aleutian shield-fern (*Polystichum aleuticum* C. Chr.) Field studies for 1989: Establishment of permanent population monitoring plots and habitat characterization. U.S. Fish and Wildlife Service Unpublished field Report. Anchorage, Alaska.

Agricultural Research Cooperation Continues Between Alaska and Siberia

Stephen D. Sparrow

In July of 1990, three University of Alaska Fairbanks agricultural scientists and one USDA-ARS scientist visited several sites in Siberia under the ongoing exchange program between Agricultural and Forestry Experiment Station and the Russian Academy of Agricultural Sciences, Siberian Branch (formerly VASKhNIL SB). The visiting Alaskan scientists were: Dr. Carol Lewis, resource management specialist and team leader; Dr. Donald Carling, horticultural pathologist; and Dr. Stephen Sparrow, soil microbiologist. Weed scientist, Dr. Jeffery Conn, represented the USDA-ARS. We visited experiment stations and production farms near Novosibirsk in southcentral Siberia; near Ulan Ude and Severobaikalsk, both near Lake Baikal, in southeastern Siberia; and near Yakutsk in east-central Siberia (Figure 1).

There were several objectives of the visit:

Figure 1. Map of the U.S.S.R. showing locations visited by Alaskan agricultural scientists in July of 1990.

- to view and discuss cooperative research which was begun in 1989;
- to discuss and plan new cooperative research;
- and to view and discuss agricultural practices in various parts of Siberia and bring back any information that would be useful for Alaskan agriculture.

Originally, we had especially hoped to study this last objective at Yakutsk. We were under the impression that the Yakutsk area was in many ways quite similar to the agricultural areas of Alaska. Yakutsk is fairly far north (about 61°N latitude), has a very continental climate, and is underlain by permafrost. For these reasons, we had assumed that problems associated with crop production there would be similar to those of Alaska, especially interior Alaska. While similarities do exist, such as short growing seasons and risks of mid-summer frosts; there are significant differences. One major difference is that although winters are quite cold, summers are hotter than in Alaska; enough so that crops that are marginal in Alaska's interior are successfully grown there. Also, their climate is much drier than in interior Alaska and much of the area is grassland. Consequently, research at both Yakutsk and Ulan Ude emphasizes crop production under dry conditions.

We were pleased to learn that several of the research projects that we had agreed upon in 1989 were being carried out at Novosibirsk. While it was too early to have any results, Russian scientists were particularly interested in the comparative studies on fertilizer placement, nutrient cycling and weed control based on their initial observations.

Plans for new joint studies and a joint research grant proposal to the U.S. National Science Foundation and the Soviet Academy of Sciences were initiated. Proposed joint research ranged from potato variety testing and Rhizoctonia disease studies to investigation of organic matter depletion in agricultural soils.

We were impressed that some of the Soviet scientists have surprisingly sophisticated research programs considering the lack of modern research equipment and limited contact with scientists outside the U.S.S.R. We were particularly impressed at the ingenuity used by some scientists who build new or modify outdated research equipment. Despite these outstanding examples, much of the research performed is rather mundane, and it is characterized by little imagination or creativity.

Most of it would be considered demonstration in the United States.

Exchange of plant germplasm, especially for horticultural crops, has the potential to be useful for Alaska. However, the Soviet agricultural technology lags far behind ours; thus from a technological standpoint, we are likely to gain little from information exchanges.

In some areas we visited, especially Ulan Ude, Severobaikalsk, and Yakutsk, people expressed a very serious concern over potential harm to the environment from agricultural practices. So much so that unreasonable policies seem to have developed against the use of fertilizers and pesticides. In other areas, on the other hand, the exact opposite seem to be true and herbicides receive undue enthusiasm. Most herbicides have been (many still are) unavailable in the U.S.S.R.; their recent importation has resulted in apparent overuse. We saw evidence of this in some research plots near Novosibirsk.

We were glad to be able to see so much of Siberia. However, our trip was so rushed that we were only able to get a superficial view of much of the research. The group tours typical of the exchange over the past two years have been useful in that they have given Alaskan scientists the chance to view different kinds of Siberian agriculture and to make contact with scientists in different parts of Siberia. However, if the exchange is to continue, it will be much more valuable to focus more on one-to-one exchanges between researchers to work on specific research projects. Perhaps student exchanges can become part of the program. ❑

References

Lewis, C.E. 1990. International Cooperation in Cropping Systems Research between Alaska and Siberia. *Agroborealis* 22:7-8.

Thomas, W.C. 1990. Cooperation in Agricultural Science between Siberia and Alaska. *Agroborealis* 22: 5-6.

Alaska as Seen by Russian Exchange Student

Andrei Streletsky

***Editor's Note:** Andrei Streletsky, is a graduate student in the School of Agriculture and Land Resources Management (SALRM) at the University of Alaska Fairbanks. He is studying this year in Fairbanks under the terms of the exchange agreement between SALRM and the Siberian Branch of the Lenin All-Union Academy of Agricultural Sciences (VASKhNIL SB). The agreement was signed in July of 1989 in both Novosibirsk and Fairbanks during exchange visits between the two units. Other aspects of the agreement cover scientific exchanges and visits by Soviet and Alaskan scientists.*

What things does a foreigner first notice when he comes to America? It is very difficult to answer this question simply, because for me all things here are dissimilar to what I have seen everyday in Russia. Especially as it's my first trip abroad.

A few words about myself. I'm 28 years old, I have a wife and a little daughter. We're all true Siberian Russians. I graduated from the Novosibirsk State University (NSU) and my speciality is economic cybernetics. NSU prepares specialists in the area of industrial economics. I became especially interested in agricultural economics, since in the early 1980s when negative changes were already occurring in the Soviet economy. These changes were acutely apparent in the field of agriculture. Consequently, I wrote my honor's thesis on *The rise of economic efficiency of agriculture: production examples of fruits and vegetables.* To gain a more complete, practical understanding of agriculture, after graduating from the university I worked for four years in the Siberian Scientific Research Institute in Omsk. And only after I completed that experience did I enter the graduate study program of Siberian Branch of the Lenin All-Union Academy of Agricultural Sciences (VASKhNIL SB) in Novosibirsk. The theme of my dissertation was *The mathematical and statistical methods in the forecasting of dairy production*.

I consider myself to be very fortunate to be able to participate in graduate studies in the West , especially in a country such as the United States. Currently my country is undergoing a very critical period of change from a centralized planned economy to that of market economy. Therefore, it is as imperative as air for Soviet economic studies to comprehend what is meant by market mechanism and the price system for allocating resources; strengths and weaknesses of market agricultural economic system and how this system functions in practice in Western economies; how to achieve the main goal for agricultural economic systems such as a reliable supply of abundant, high quality and varied food products for consumers.

Having received a fairly good preparation in the studies of western economies I knew of course, that the American business does not solely consist of giants such as Boeing, IBM, General Electric, or, for that matter, McDonald's.

But, only here I could ascertain that the "outsiders" of American industrial production, especially in the sphere of service, do not occupy by any means, an insignificant or a last place in the economy. I've formed the opinion, that competition of private capital and government industries can really help the renewal of Soviet economy.

Much of what I have seen here does not coincide with what I have observed and seen over many years on television, or what I have read in our newspapers (at least until the recent time). One of the most frequent themes popularized in media has been the depiction of the difficult lives of the American homeless and unemployed. Having seen the special provisions that have been made in many areas for the disabled and the handicapped, I am convinced that the American society cares as much for its people as does the Soviet society.

I would like to note the benevolence and politeness of Americans. I don't want to say at all that Soviet people are not polite. They are polite of course, but in much different ways. The famous American smile is very conspicuous to a Russian especially the first time in America. The expression "keep smiling" is also popular in the Soviet Union, but recently less and less people keep smiling.

I felt a real shock when first going into the supermarket in Fairbanks, where a cornucopia of goods from around the world entices shoppers. Soviet shops, have far fewer goods and the demand on them is much greater. It would be remiss not to acknowledge this difference, and perhaps because of this, Soviet people often do not want to smile.

I was really impressed by the Rasmuson Library at the University of Alaska Fairbanks and the organization of the library system, in general. The computerized system of searching for books is very convenient. The opportunity to enter the library with a bag, or a backpack, or even with books in hand - it's simply perfect! I was very surprised by this, because it is possible to enter a Soviet library with only a small file and a pen in hand - no books and no bags.

As I stay here, I begin to understand the American education system a little bit better. A lot of differences exist between the U.S. education system and the Soviet one. First of all, in the Soviet system, once a student chooses some speciality and enters a department, it is impossible to make a change. A student can't select and take the courses he would like to take. Usually all courses in an academic specialty are defined beforehand and are compulsory for all students in this department. If a student fails an exam, this could be a reason for being kicked out of the university. On the opposite side of the coin, students in the Soviet Union do not think about money for tuition, because the government pays and education is absolutely free.

When I was a kid, my favorite writer was Jack London. I never dreamed that someday I would be only a few hundred miles from the places which I read about in his writings. Here in America I've started to read London's stories in English and I'm glad I'm able to do it.

As I noted before, I was born in Siberia and spent all my life there, so I can understand the severe climate and nature in Alaska. The mountains covered with green trees and the open sky with unfamiliar constellations are really beautiful. And the aurora, of course, which is beyond compare.

I am very thankful to SALRM for giving me the opportunity to carry on my studies during the spring semester. As much as is possible in the next five months, I want to better get to know people, their habits and their national customs. ❑

Publications List for 1990

Journal Articles

Carling, D.E., D.J. Helm, and R.H. Leiner. 1990. In vitro sensitivity of Rhizoctonia solani and other multinucleate or binucleate Rhizoctonia to selected fungicides. *Plant Dis.* 74:860-863.

Carling, D.E., S. Kuninaga. 1990. DNA base sequence homology in Rhizoctonia solani Kuhn: Inter and intragroup relatedness of anastomosis group-9. *Phytopathology* 80:1362-1364.

Carling, D.E. and R.H. Leiner. 1990. Virulence of isolates of Rhizoctonia solani AG-3 collected from potato plant organs and soil. *Plant Dis.* 74:901-903.

Carling, D.E. and R.H. Leiner. 1990. Effect of temperature on virulence of Rhizoctonia solani and other Rhizoctonia on potato. *Phytopathology* 80:930-934.

Cochran, V.L., L.A. Morrow, and R.D. Schirman. 1990. The effect of N placement on grass weeds and winter wheat responses in three tillage systems. *Soil and Tillage Research* 18:347-355.

Conn, J.S. 1990. Seed viability and dormancy of 17 weed species after burial for 4.7 years in Alaska. *Weed Science* 38:134-138.

Conn, J.S. 1990. Herbicide effects on maturity of spring barley in Alaska. *Crop Science* 30:251-254.

Dofing, S.M and C.A. Francis. 1990. Efficiency of one-replicate yield testing. *J. Prod. Agric.* 3:399-402.

Dofing, S.M., M.A. Thomas-Compton, and J.S. Buck. 1990. Genotype *x* popping method interaction for expansion volume in popcorn. *Crop Sci.* 30:62-65.

Greenberg, J., W. C. Thomas, and W. G. Workman. 1990. Economic Evaluation of Reindeer Range in Alaska. *Canadian Journal of Agricultural Economics* 38:89-105.

Holloway, P. and G. Alexander. 1990. Ethnobotany of the Fort Yukon Region, Alaska. *Economic Botany* 44(2):214-225.

Husby, F.M., C.W. Newman, R.M. Beames, R.E. Busch, D.M. Danielson, and D.C. England. 1990. Effects of supplemental protein and fat sources on performance of weanling pigs. *Proceedings Western Section American Society Animal Science* 41:219-222.

Jubenville, A. 1990. Testing the Diary Technique in Measuring Recreation Use Patterns. *Muskox* Spring 1990.

Juday, G.P. 1990. Interview with Jerry Franklin, Bloedel Professor of Forestry, University of Washington, and Chief Plant Ecologist, US Forest Service. *Natural Areas Journal* 10(4): 163-172.

Juday, G.P. 1990. Interview with Dr. Robert E. Jenkins, Vice President for Science Programs, The Nature Conservancy. *Natural Areas Journal* 10(2): 55-60.

Kirts, C.A. 1990. Linking Agricultural and Environmental Education by Integrating Environmental Concepts and Vocational Skills. *National Association of Colleges and Teachers of Agriculture Journal* 34(1): 71-77.

Lewis, C.E. and R.W. Pearson. 1990. Three development models for Alaska's agricultural industry. *Assoc. of Pacific Coast Geographers Yearbook* 52.

Michaelson, G.J. and C.L. Ping. 1990. Mehlich 3 Extractable P in relation to cereal forage production on Alaska soils. *Applied Agricultural Research* 5(4):255-260.

Michaelson, G.J. and C.L. Ping. 1990. Mehlich 3 Extractable P of Alaska soils as affected by P fertilizer application. *Applied Agricultural Resarch* 5(4):261-267.

Packee, E.D. 1990. White spruce regeneration on a blade-scarified Alaskan loess soil. *Northern Journal of Applied Forestry* 7(3):121-123.

Renecker, L.A. and R.J. Hudson. 1990. Digestive kinetics of moose, wapiti, and cattle. *Animal Production* 50: 61.

Sparrow, E.B., V.L. Cochran, and S.D. Sparrow. 1990. Phosphorus mineralization in subarctic agricultural and forest soils. *Biology and Fertility of Soils* 10:107-112.

Sparrow, S.D., J.S. Conn, and C.W. Knight. 1990. Canola seed survival over winter in the field in Alaska. *Canadian Journal of Plant Science* 70: 799-807.

Bulletins

Sharratt, B.S. 1990. Water Retention, Bulk Density, Particle Size and Thermal and Hydraulic Conductivity of Arable Soils in Interior Alaska. Bulletin 83 AFES/SALRM University of Alaska Fairbanks. 12 pp.

Circulars

Carling, D.E. and P.C. Westphale. 1990. Potato Variety Performance 1898. Circular 77. AFES/SALRM University of Alaska Fairbanks.

Clarke, A. and R.A. Dieterich. 1990. Record Keeping for Reindeer Herds. Circular 75. AFES/SALRM University of Alaska Fairbanks.

Dofing, S.M. and S.A. Blake. 1990. Results from the 1989 Alaska Barley Breeding Program. Circular 79. AFES/SALRM University of Alaska Fairbanks.

Gavlak, R.G., D. Carling, M. Comeau, J. Purser, W. Vandre, J. Walworth, and C. Wright. 1990. Vegetable Variety Trials Matanuska Valley, Alaska 1989. Circular 80. AFES/SALRM University of Alaska Fairbanks.

Pearson, R.W., E.M. Rhoades, and C.E. Lewis. 1990. Alaska's Multibooms. Circular 73. AFES/SALRM University of Alaska Fairbanks.

Swanson, R.B., M.P. Penfield, D. Mitchell, M.J. Reimann, and H.D. Loveday. 1990. Quality Assessment of Reindeer Meat. Circular 78. AFES/SALRM University of Alaska Fairbanks.

Thompson, B.N. and R.A. Dieterich. 1990. Construction and Use of a Reindeer Fawn Separator for Injury Prevention. Circular 74. AFES/SALRM University of Alaska Fairbanks.

Windschitl, P.M., K.M. Randall, and D.J. Brainard. 1990. Investigation on the Optimum Level of Salmon Meal for Use in Dairy Cow Diets. Circular 83. AFES/SALRM University of Alaska Fairbanks.

Research Progress Reports

Carling, D.E. and J.S. Conn. 1990. Chemical Control of Weeds in Potatoes in Southcentral and Interior Alaska. Research Progress Report 14. AFES/SALRM University of Alaska Fairbanks.

Carling, D.E. and J.L. Walworth. 1990. The Effect of Hilling on Yield and Quality of Potatoes. Research Progress Report 16. AFES/SALRM University of Alaska Fairbanks.

Dofing, S.M., S.A. Blake, and R.I. Wolfe. 1990. Results of the 1989 Northwestern Canada Barley Trial Grown at Palmer. Research Progress Report 11. AFES/SALRM University of Alaska Fairbanks.

Dofing, S.M., S.A. Blake, and R.I. Wolfe. 1990. Results of the 1990 Northwestern Canada Barley Trial Grown at Palmer. Research Progress Report 19. AFES/SALRM University of Alaska Fairbanks.

Helm, D.J. 1990. Reestablishment of Woody Browse Species for Mined and Reclamation Year 1 (1989) Results. Research Progress Report 12. AFES/SALRM University of Alaska Fairbanks.

Masiak, D. and S.D. Sparrow. 1990. Fall Seeding—Will it Work in Interior Alaska? Research Progress Report 20. AFES/SALRM University of Alaska Fairbanks.

Panciera, M.T., S.D. Sparrow, R.G. Gavlak, and W.E. Larson. 1990. Evaluation of Forage Legume Potential at Fairbanks, Point Mackenzie, and Soldotna. Research Progress Report 13. AFES/SALRM University of Alaska Fairbanks.

Sparrow, S.D., V.L. Cochran, and E.B. Sparrow. 1990. Nitrogen-Fixation by Legumes in Interior Alaska. Report 17. AFES/SALRM University of Alaska Fairbanks.

Walworth, J.L., R.G. Gavlak, and J.E. Muniz. 1990. Effects of Soil Fertility on Potato Plant Development in the Matanuska Valley. Research Progress Report 15. AFES/SALRM University of Alaska Fairbanks.

Walworth, J.L., R.G. Gavlak, and J.E. Muniz. 1990. Effects of Potassium Source and Secondary Nutrients on Potato Yield and Quality in Southcentral Alaska. Research Progress Report 18. AFES/SALRM University of Alaska Fairbanks.

Walworth, J.L., Carling, D.E., Michaelson, G.J., and C.-L. Ping. 1990. Effects of Residual Soil Nitrogen on Yields of Head Lettuce. Research Progress Report 10. AFES/SALRM University of Alaska Fairbanks.

Agroborealis

Gallagher, T.J. 1990. Permit Reform in Alaska's Coastal Zone. *Agroborealis* 22(1): 45-49.

Husby, F.M. 1990. Hulless Barley and Crab Shell in Diets Fed to Steers. *Agroborealis* 22(1): 30-34.

Jubenville, A., W.G. Workman, and A. Smith. 1990. A Profile of Interior Alaska Dog Mushers. *Agroborealis* 22(1): 26-30.

Juday, G.P. and N.R. Foster. 1990. A Preliminary Look at Effects of the *Exxon Valdez* Oil spill on Green Island Research Natural Area. *Agroborealis* 22(1): 10-17.

Kerndt, G.M. 1990. History of the Alaskan Reindeer Industry and Its Problems with Land Use, Ownership, and Marketing. *Agroborealis* 22(1): 22-25.

Kirts, C.A. 1990. A Class Project in Information Transfer: An Effective Application of Learning by Doing. *Agroborealis* 22(1): 35-39.

Klein, D.R. 1990. Musk Oxen Exchange Offers Researchers New Opportunities. *Agroborealis* 22(1): 8.

Lewis, C.E. 1990. International Cooperation in Cropping Systems Research between Alaska and Siberia. *Agroborealis* 22(1): 7-8.

Mitchell, W.W. and S.M. Dofing. 1990. Germplasm Exchange Program. *Agroborealis* 22(1): 9.

Mitchell, W.W. and G.A. Mitchell. 1990. Land Farming of Oil Sludge at Valdez Oil Terminal. *Agroborealis* 22(1): 18-21.

Swanson, R.B., M.A. Stetson, C.E. Lewis, and C.A. Birklid.

1990. Alaskan Food Costs: Do We Really Pay More for a Nutritionally Balanced Diet? *Agroborealis* 22(1): 40-44.

Thomas, W.C. 1990. Cooperation in Agricultural Science between Siberia and Alaska. *Agroborealis* 22(1): 5-7.

Abstracts

Carling, D.E. and R.H. Leiner. 1990. Virulence of Rhizoctonia solani and other Rhizoctonia on potato at three temperatures. *Phytopathology* 80:1008-1009.

Conn, J.S. and R.E. Deck. 1990. Seed viability and dormancy for 4.7 years in Alaska. In *Abstracts 1990 Meeting of Weed Science Society of America*. p. 95.

Dofing, S.M. and C.W. Knight. 1990. Tiller synchrony of barley cultivars as influenced by plant density. In *Agronomy Abstracts*. p. 86 American Society of Agronomy, Madison, WI.

Helm, D.J. 1990. Considerations for vegetation sampling adequacy under Alaskan conditions. Society for Range Management 43rd Annual Meeting. February 11-16. Abstract no. 342. Reno, NV.

Helm, D.J. and D.E. Carling. 1990. Effectiveness of soil-borne inoculum from different successional stages on plant species growth on mine spoils in Alaska. Eighth North American Conference on Mycorrhizae. September 5-8. p. 140. University of Wyoming and San Diego State University. Jackson, WY.

Helm, D.J. and D.E. Carling. 1990. Use of soil-borne mycorrhizal inoculum for abandoned mined land reclamation in Alaska. 41st Arctic Science Conference. October 8-10. p. 33. Anchorage.

Holloway, P. 1990. Aspen wood chips and stone mulches for ornamental plantings in Interior Alaska. *HortScience*. 25(9):1115.

Husby, F.M. 1990. Hull-less barley and snow (tanner) crab shell in beef cattle finishing diets. In: *Canadian Journal of Animal Science* 70(4):1186.

Husby, F.M. and K. Ulz. 1990. Digestibility of high-performance sled dog diets containing hull-less barley and herring meal. In: *Canadian Journal of Animal Science* 70(4):1189.

Husby, F.M., C.W. Newman, R.M. Beames, R.E. Busch, D.M. Danielson, and D.C. England. 1990. Effects of supplemental protein and fat sources on performance of weanling pigs. In: *Proceedings Western Section American Society Animal Science*. 41:219.

Juday, G.P. 1990. Monitoring for Global Change in Alaska Research Natural Areas. In: *International Conference on the Role of the Polar Regions in Global Change*. p. 14. June 11-15. Center for Global Change and Arctic System Research, University of Alaska Fairbanks.

Karlsson, M.G., R.D. Heins, J.R. Dart and H.C.H. McIntyre. 1990. Optimization of flower initiation in Primula vulgaris by environmental factors. Abstracts of contributed papers. XXIII International Horticultural Congress, Firenze (Italy) August 27 - September 1, 1990. Abstract no. 3258.

Karlsson M.G. and J.W. Werner. 1990. Photoperiodic control of developmental growth in Begonia *x* tuberhybrida. *HortScience* 25(9):144.

Karlsson, M.G., J.W. Werner and H.C.H. McIntyre. 1990. Temperature during early development affects plant morphology of Begonia *x* hiemalis. *HortScience* 25(9):86.

Knight, C.W., B.J. Pierson, and F.M. Husby. 1990. Effect of urea and lactobacillus on storage and quality of high moisture barley. In: *1990 Agronomy Abstracts*, p. 189. Annual Meeting American Society of Agronomy.

Matheke, G., P. Wagner, and P. Holloway. 1990. Yield of 'Quinault' everbearing strawberries suing mulches and row covers in Interior Alaska. *HortScience*. 25(9):1116.

Meehan, M.J., F.M. Husby, C. Rosier, and R.L. King. 1990. Historic and potential production and utilization of Alaskan marine by-products. Program for an international conference about fish by-products. Alaska Fisheries Development Foundation and Alaska Sea Grant Program, University of Alaska Fairbanks. April 25-27.

Moore, J.P. and C.-L. Ping. 1990. Temperature regimes and classification of permafrost soils in Alaska. p. 299. In: *Agronomy Abstracts*. American Society of Agronomy, Madison, WI.

Ping, C.L., F. DeConinck, and J.M. Kimble. 1990. Micromorphological interpretation of the Andisol/Spodosol transition in tephra-derived soils. p. 301. In: *Agronomy Abstracts*. ASA, Madison, WI.

Pond, W.G., C.C. Calvert, J. Fadel, J.A. Froseth, R.L. Harrold, F.M. Husby, B.A. Lewis, C.W. Newman, J.W. Lehmann, and R.W. Elmore. 1990. Nutritional Value of grain amaranth germplasm for growing rats. *Journal American Society of Animal Science*. 68(suppl. 1).

Sharrat, B.S., M.J. Schwarzer, G.S. Campbell, and R.I. Papendick. 1990. Modeling the radiation balance of ridge-till in Alaska. p. 22. *Agronomy Abstracts*. American Society of Agronomy. Madison, WI.

Snow, A.P. and S.D. Sparrow. 1990. Feasibility of using salmon bone meal as a fertilizer. p. 259. *Agronomy Abstracts*. American Society of Agronomy. Madison, WI.

Sparrow, E.B. and V.L. Cochran. 1990. Nitrogen, phosphorus, and carbon mineralization in soils from a long-term tillage study. p. 281. *Agronomy Abstracts.* American Society of Agronomy. Madison, WI.

Sparrow, S.D., V.L. Cochran, and E.B. Sparrow. 1990. Nitrogen fixation by seedling-year legumes in Alaska. p. 259. *Agronomy Abstracts.* American Society of Agronomy. Madison, WI.

Windschitl, P.M. and K.M. Randall, 1990. Effect of fishmeal and urea on milk yield, composition, and rumen metabolism in lactating dairy cows. *J. Dairy Sci.* 73(Suppl. 1):217.

Proceedings

Elliott, C.L. and J.D. McKendrick. 1990. Big game use of reclaimed and stripmine lands in interior Alaska. In: *Proceedings National Symposium on Mining,* (May 14-18 National Symposium on Mining). ed. D.H. Graves, 1-15. University of Kentucky Publication UKY BU153. Lexington, KY.

Karlsson, M.G. and P.S. Holloway. 1990. Horticulture research update. In: *Proceedings of the 9th Alaska Greenhouse & Nursery Conference.* 15-19.

Karlsson, M.G., R.D. Heins and M.E. Hackmann. 1990. Temperature controlled leaf unfolding rate in hibiscus. International Society of Horticultural Science Symposium on Bedding and Pot Plant Culture. *Acta Horticulturae* 272:103-107.

Karlsson, M.G. and H.C.H. McIntyre. 1990. Evaluation of low temperature flower formation in chrysanthemum using several microscopy techniques. International Society for Horticultural Science Symposium on Bedding and Pot Plant Culture. *Acta Horticulturae* 272:273-277.

Kirts, C.A. 1990. Student Teaching in Agricultural Education: A National Study Ten Years Later. In: *Proceedings of the Ninth Annual Western Regional Agricultural Education Research Meeting.* (April 1990). 8-22. Fresno, CA.

Kirts, C.A. and M.A. Tumeo. 1989. Teaching Commons Property Management Through Gaming: The Commons Game. In: *Proceedings of the Arctic Science Conference* (September 15) Fairbanks.

Lynch, D.F. and C.E. Lewis. 1990. Some observations on agriculture in Siberia. Subcommission on Highland and High Latitude Zones. International Geographical Union. July 23-27. Ljubljana, Yugoslavia.

Packee, E.D. 1990. Management of Boreal: Past, present, and future if managed. In: *Proceedings Forest Management and Wildlife Conference* (April 26, 1990). p. 19-24. Society of American Foresters, Cook Inlet Chapter and the RDC Education Foundation.

Pearson, R.W. and C.E. Lewis. 1990. Transportation and infrastructure: Keys to successful agricultural development in Alaska. In: *Western Region Cooperative Soil Survey Conference Proceedings.* Fairbanks.

Renecker, L.A. and R. Valdez. 1990. Commercial game production in North America. In: *Proceedings of International Baikal Symposium on Hunting, Game Management, and Conservation of Wildlife.* (Aug. 15 - 22, 1990). Irkutsk, USSR. Published by International Council for Game and Wildlife Conservation. Paris, France.

Renecker, L.A. 1990. Status of moose and its management in Canada. In: *Proceedings of International Baikal Symposium on Hunting, Game Management, and Conservation of Wildlife* (Aug. 15 - 22, 1990). Irkutsk, USSR. Published by International Council for Game and Wildlife Conservation, Paris, France.

Renecker, L.A. 1990. Reindeer production and game farming in North America. In: *The Game Industry - A Holistic Approach: Proceedings of Biennial Conference of National Game Organization,* (October 17-19, 1990). p. 3-31 Kimberly, South Africa.

Renecker, L.A. 1990. Game farming: Agricultural diversity. In: *Proceedings of Fourth Annual National Indian Agricultural Symposium,* (Nov. 27-30, 1990). Spokane, WA.

Sharratt, B.S. and G.S. Campbell. 1990. Soil thaw as influenced by small grain residue color. In: *Proceedings of International Symposium on Frozen Soil Impacts on Agricultural, Range and Forest Lands.* 290-294. CRREL Special Report 90-1.

Sparrow, S.D. 1990. Nitrous oxide emissions from fertilizer management and leguminous crop rotation systems. In: *Proceedings of the Workshop on Greenhouse Gas Emissions from Agricultural Systems-Summary Report of of the Intergovernmental Panel on Climate Change.* VII -3-6 Office of Policy Analysis. USEPA, Washington, DC.

Tumeo, M.A. and C.A. Kirts. 1990. Developing Educational Programs Through the Use of "The Commons Game": A five-hour Workshop. In: *Proceedings of CONSERV 90: The National Conference and Exposition Offering Water Supply Solutions for the 1990s* (August 1990). 1109-1111. Phoenix, AZ.

Theses, Student Professional Papers and Dissertations

Pare, D. 1989. Dynamics of nutrient cycling on post-harvested white spruce sites in Interior Alaska. Ph.D. Dissertation. University of Alaska Fairbanks.

DART, J. J. 1989. A study of the exclusive guide system in Alaska and some important consequences of the October 2, 1988 Alaska Supreme Court Decision. M.S. Professional Paper. University of Alaska Fairbanks.

JACOBSON, W.S. 1989. The effective use of graphics in federial EIS. M.S. Professional Paper. University of Alaska Fairbanks.

KELLY, N. L. 1989. An assignment of environmental change in the Fairbanks North Star Borough during a period of energy development and economic growth. M.S. Thesis. University of Alaska Fairbanks.

KIMMEL, M.E. 1989. Subsistence planning in Alaska: Western and Native perspectives. M.S. Professional Paper. University of Alaska Fairbanks.

MATTHEWS, V. 1990. A Case Study of a Homeland and a Wilderness: Gates of the Arctic National Park and Numamiut Eskimos. M.S. Thesis. University of Alaska Fairbanks.

SMITH, A.E. 1989. Dog mushing in Interior Alaska: an exploratory study of participation, preferences and willingness to pay. M.S. Thesis. University of Alaska Fairbanks.

TAYLOR, S.N. 1989. Alaska's policy for mining hard rock minerals on state lands. M.S. Professional Paper. University of Alaska Fairbanks.

WATSON, S.M. 1990. Economic value of dall sheep hunting in Alaska. M.S. Thesis. University of Alaska Fairbanks.

Popular Press

HELM, D.J. 1990. Considerations in mined land reclamation. *The Alaska Miner* 18(7):7.

HELM, D.J. 1990. Matching plant and soil resources. *The Alaska Miner* 18(8):6-7.

HELM, D.J. 1990. Which are the right grasses for your reclamation site? *The Alaska Miner* 18(10):13,15.

HELM, D.J. 1990. Maximizing benefits from minimal topsoil to improve woody plant establishment. *The Alaska Miner* 18(11):7,18.

HOLLOWAY, P. 1990. Pruning raspberries, *Alaska NAFEX Newsletter*. 5(6):3-4.

HOLLOWAY, P. 1990. Back from Siberia. *Alaska NAFEX Newsletter*. 5(5):2-3.

HOLLOWAY, P. 1990. Russian Expedition. *Alaska NAFEX Newsletter*. 5(6):3.

KARLSSON, M.G. 1990. A major problem. Will colored lily cultivars increase production? Spartan Ornamental Network, Michigan State University, February 20, 1990. Reprinted in: *PPGA* (Professional Plant Growers Association) *News*. 1990. 21(3):6.

KARLSSON, M.G. 1990. Tip of the week. More "miniature" tulip and narcissus cultivars. Spartan Ornamental Network, Michigan State University, February 20, 1990. Reprinted in: *PPGA* (Professional Plant Growers Association) *News*. 1990. 21(3):6.

KARLSSON, M.G. 1990. A major problem. Dutch self-supportive extension service. Spartan Ornamental Network, Michigan State University, April 27, 1990.

KARLSSON, M.G. 1990. Tip of the week. Dutch flower marketing. Spartan Ornamental Network, Michigan State University, April 27, 1990.

KARLSSON, M.G. 1990. A major problem. Nematodes control fungus gnats. Spartan Ornamental Network, Michigan State University, June 21, 1990.

KARLSSON, M.G. 1990. Tip of the week. Dahlia as a potted plant. Spartan Ornamental Network, Michigan State University, June 21, 1990.

KARLSSON, M.G. 1990. A major problem. Artificial plants are a fire hazard. Spartan Ornamental Network, Michigan State University, August 1, 1990.

KARLSSON, M.G. 1990. Tip of the week. Increased greenhouse air circulation. Spartan Ornamental Network, Michigan State University, August 1, 1990.

KARLSSON, M.G. 1990. A major problem. Ficus—hazardous to your health? Spartan Ornamental Network, Michigan State University, September 7, 1990.

KARLSSON, M.G. 1990. Tip of the week. Top-ten potted plants in Denmark and the Netherlands. Spartan Ornamental Network, Michigan State University, September 7, 1990.

KARLSSON, M.G. 1990. A major problem. Greenhouse production in Denmark. Spartan Ornamental Network, Michigan State University, October 12, 1990.

KARLSSON, M.G. 1990. Tip of the week. Gift giving habits. Spartan Ornamental Network, Michigan State University, October 12, 1990.

KARLSSON, M.G. 1990. A major problem. New type of glass for greenhouses. Spartan Ornamental Network, Michigan State University, November 13, 1990.

KARLSSON, M.G. 1990. Tip of the week. Poinsettia is not poisonous. Spartan Ornamental Network, Michigan State University, November 13, 1990.

KARLSSON, M.G. 1990. A major problem. Shipping in cold weather. Spartan Ornamental Network, Michigan State University, November 30, 1990.

KARLSSON, M.G. 1990. Tip of the week. Proper care of Christmas trees. Spartan Ornamental Network, Michigan State University, November 30, 1990.

KARLSSON, M.G. 1990. A major problem. Focus on marketing. Spartan Ornamental Network, Michigan State University, December 18, 1990.

KARLSSON, M.G. 1990. Tip of the week. Change of office for Danish extension. Spartan Ornamental Network, Michigan State University, December 18, 1990.

RENECKER, L.A. 1990. The Reindeer Report. Newsletter for the Reindeer Research Program. May. 3 pp.

RENECKER, L.A. 1990. The Reindeer Report. Newsletter for the Reindeer Research Program. December. 3 pp.

Chapters in Books

WORKMAN, W.G., S.C. MATULICH, and A. JUBENVILLE. 1990. "Recreation Management Theory, Economics, and Resources Allocation: A Unifying Perspective." (Chapter 2) *Economic Valuation of Natural Resources*. ed. R.L. Johnson and G.W. Johnson. Westview Press. Denver.

Research Contract Reports

CARLING, D.E. 1990. Screening accessions of Solanum sp. from the IR-1 collection for resistance to Rhizoctonia solani AG-3. Prepared for IR-1 project leader. 11 pp.

HELM, D.J. and D.E. CARLING. 1990. Use of on-site mycorrhizal inoculum for plant establishment on abandoned mined lands. Final Report. University of Alaska Fairbanks for U.S. Bureau of Mines Contract No. J0289003. Abandoned Mined Land Program. 94 pp.

HELM, D.J. 1990. Hoseanna Creek vegetation succession. Prepared for Usibelli Coal Mine, Incorporated. 77 pp.

JUDAY, G.P. 1990. A Report on Ecological Characteristics of Alternative Research Natural Areas of the Ketchikan Area, Tongass National Forest. 40 pp.

Lewis, C.E., R.B. Swanson, and C. Johnson. 1990. Potential markets for indigenous Alaskan blueberry: basically blue. Report to State of Alaska, Department of Natural Resources, Division of Agriculture, Palmer, AK. 25 pp.

MCKENDRICK, J.D. 1990. *Arctophila* revegetation feasibility study 1988 annual report. Prepared for BP Exploration (Alaska), Inc. Anchorage, AK. 180 pp.

Miscellaneous

DIETERICH, R. and J.K. MORTON. 1990. Reindeer Health Aide Manual. 2nd ed., AFES Misc. Pub. 90-4, CES IOOH-00046, University of Alaska Fairbanks.

JUBENVILLE, A. 1990. ROS—Boon or Boondaggle. *Journal of Forestry*. 87(11):56.

JUBENVILLE, A. 1990. ROS—A Reply to a Reply. *Journal of Forestry*. 88(10):54.

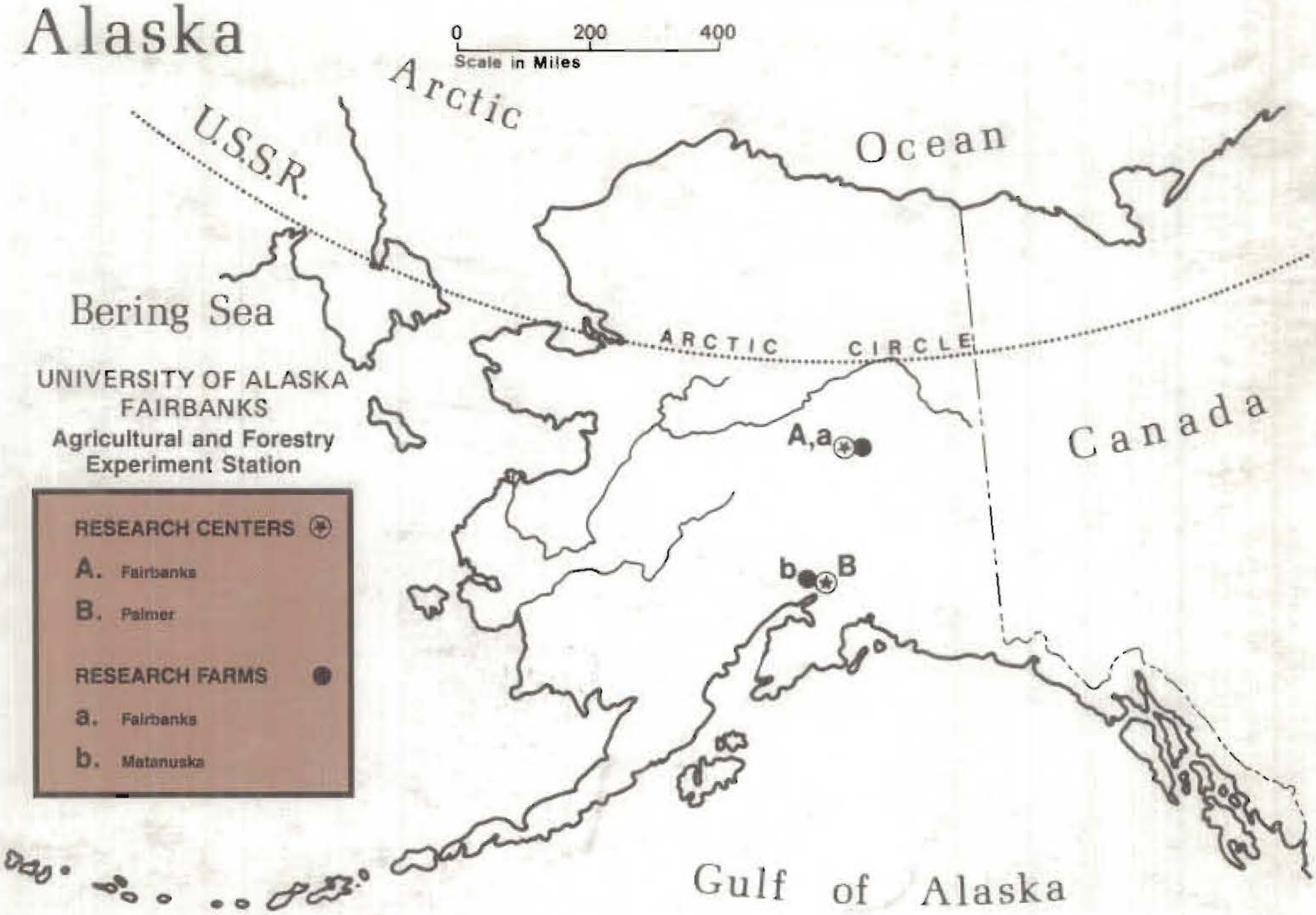
JUDAY, G.P. 1990. Alaska (State Reports Section). Natural Areas Journal. 10(1). pp. 36-37.

JUDAY, G., J. Yarie, K. Van Cleve, P. Adams, L. Viereck, and C.T. Dyrness. 1990. *Bonanza Creek Experimental Forest LITER Field Trip Guide*. International Conference on the Role of the Polar Regions in Global Change, June 15, 1990. University of Alaska Fairbanks and Institute of Northern Forestry, U.S. Forest Service. Fairbanks. 26p.

JUDAY, G., J. ALDEN, and R. DENSMORE. 1990. *Rosie Creek Fire Field Trip Guide*. Alaska Society of American Foresters State Convention, June 3, 1990. Agricultural and Forestry Experiment Station, University of Alaska Fairbanks. 20p.

LAY, J.S. (ed.) 1990. Annual Report 1989. AFES/SALRM, University of Alaska Fairbanks. Misc. Pub. 90-2.

SWANSON, R.B. and C.E. LEWIS. 1990. *Enjoy Alaskan Grown Vegetables and Fruits*. AFES Misc. Pub. 90-3. University of Alaska Fairbanks. ❑



Agricultural and Forestry Experiment Station
UNIVERSITY OF ALASKA FAIRBANKS
Fairbanks, Alaska 99775-0080

Address correction requested
Return postage guaranteed

Non Profit
Organization
U.S. Postage
PAID
Permit No. 2
Fairbanks, Alaska
99701

Bio-Medical Library
University of Alaska Fairbanks
116 AHRB
Fairbanks AK 99775

If you do not desire to continue receiving this publication, please check here ☐; cut off this label and return it to the above address. Your name will be removed from the mailing list.