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Bonita Neiland remembered
Alaska biomass for fuels
muskox husbandry
soil, oil, & fire
wildlife management conflicts
searching for self-sufficiency

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—COURTESY WINDY VALLEY MUSKOX FARM

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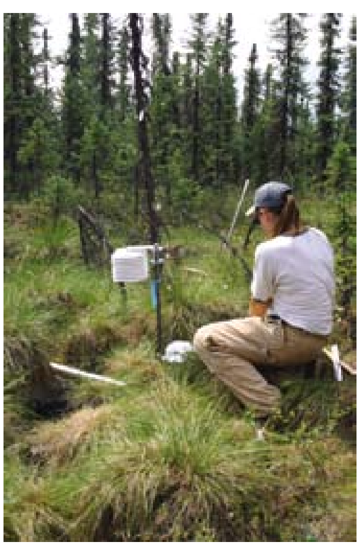

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Bonita J. Neiland Remembered

Dr. Bonita Neiland at the Georgeson Botanical Garden in summer 1995.
—PHOTO BY VALERIE HENDRICKSON

Bonita June Neiland, the woman who was instrumental in the formation of a natural resource program at UAF, died December 25, 2007 in Bend, Oregon. Neiland, 79, became an ecologist when there weren't many woman in the field, and her career was an accomplished one.

Bonita's maiden name was Miller. She was born June 5, 1928, near Eugene, Oregon. Reflecting during an interview on her interest in science she said: "I think it began with a rock collection when I was ten years old. I'd gather all the different types of rocks I could find and bring them into the house. My mom would help me identify and categorize them. As time went on, I collected and cataloged everything I could find outside. I even kept a notebook on all the birds and plants I observed. When you're an only child growing up on a farm, the fields and the forests and the surrounding areas become your playground. Besides, I've always loved plants and cats. At one time I wanted to become a veterinarian."[1]

As an adult, while living in Fairbanks, Bonita had six cats. Professor Patricia Holloway, who was hired by Neiland and considered her a mentor and friend from then on said of Neiland working in the field: "She always brought along three things: her research equipment, a shotgun, and her cats. The shotgun was there to protect the cats from bears."

Bonita's childhood curiosity proved to be the foundation for a fruitful career. After earning an undergraduate degree in biology at the University of Oregon in 1949, she attended Oregon State University at Corvallis, where she finished a master's degree in plant ecology in 1951. She then received a diploma in rural science from the University of Wales, where she studied as a Fulbright Fellow in 1952. In 1954 she was awarded a Ph.D. in botany and agronomy at the University of Wisconsin-Madison.

After returning to Oregon, where she was an assistant professor of botany at the University of Oregon, Bonita married biologist Kenneth Neiland in 1955. When he accepted a job with the Alaska Department of Fish & Game in 1959, they moved to Juneau, where Bonita joined the University of Alaska faculty in 1961 as assistant professor of botany, teaching courses in plant ecology and plant physiology. While in Southeast, she conducted extensive studies on the ecology of forests and bogs in coastal areas. Her research was highly acclaimed, and she is still considered a definitive authority on Alaska's coastal ecosystems.[2]

The Neilands came to Fairbanks in 1965, when Ken accepted a job transfer. They acquired 150 acres on Chena Hot Springs Road, calling their land Cassiar Farms. After their retirement and return to Oregon, Cassiar Farms became Cassiar Heights Subdivision, where flower boxes replaced Bonita's research plots.

Ladies in Science

Speaking of the challenges she faced as a woman in science trying to make her mark in what was traditionally a man's world, Bonita said: "When I first got here, there was no SALRM.[3] It was known as the College of Biological Sciences and Renewable Resources. Back then, women were just beginning to make inroads in a very male-dominated field. If it were not for Dr. Brina Kessel, I might not have been hired. She gave me my first job as a botanist."

Kessel was then dean of the College of Biological Sciences, she is now UAF professor zoology emeritus living in Fairbanks, Alaska. "Those were the days when the men held sway," she said, "and it was men who came down the hall to talk about university involvement in Project Chariot.[4] "They were horrified to see that they'd have to talk to a woman about it. For that project I needed a botanist. I liked the looks of Bonita's resume, so I hired her. When she arrived, she was wearing a cast on her lower leg, the result of jumping down from the tailgate of a pickup truck. They didn't want women, but I sent her right up to Cape Thompson, accompanied by another woman scientist who was pregnant. They accomplished their work."

Former colleague Bob Weeden, resource management professor emeritus, related an incident from those years that didn't directly involve him, but involved his wife, Judy Weeden, and Bonita.

"Dr. Neiland and Judy both joined the biology faculty at UAF in 1959, Bonita as a botanist, Judy as a zoologist. That fall President William Wood had a reception at his big home on campus to welcome new and returning faculty. It ranked among the most formal events at UAF or in town for that matter, Fairbanks' version of high society. Bonita and Judy decided they should go, and, rummaging in closets, decided they could go. However, their reluctance had to be overcome with a little help out of a bottle, which made them a bit late. They hoped to join the party unnoticed, but were discovered immediately by Dr. and Mrs. Wood. Introductions were made as propriety required. As he took them in tow to introduce to other partygoers, President Wood, who clearly had forgotten their names, introduced them as 'The Two New Young Ladies in Biology' which, to him, they remained for over a decade. I wonder if perhaps his mind adjusted to the years' passage, and eventually they became "The Two Old Ladies in Biology."

By 1970, Bonita was a full professor of botany and land resources management, and served as head of the Department of Land Resources and Agricultural Sciences. She developed a successful research program in plant ecology, and supervised numerous graduate studies in plant succession, vegetation analysis, and revegetation of Alaska forest and bog ecosystems.

She is included in the work "Early History and Progress of Women Ecologists: Emphasis Upon Research Contributions," by Jean H. Langenheim (*Annual Review of Ecology and Systematics*, Vol. 27, 1996 (1996). In it the author discusses the "personal and societal obstacles" overcome by these women and insight regarding their research achievements. She describes five time frames for women ecologists, according to the date of their PhD: pre-1900, "protoecologists"; early pioneers (1900-1934), late pioneers (1935-1960), and the first modern wave (1961-1975). She notes that by 1975, their numbers were relatively large.

"I did my masters under Dr. Neiland, a woman who pursued the paths of scientist, researcher, and teacher when it was unusual to find women holding positions in higher education, said Mary Calmes. "In that professional climate, she had to prove herself worthy time and again. She expressed to me on several occasions that she was pleased to watch things change in that regard for women."

Mentor and Friend

Carolyne Wallace, who worked with Neiland as her administrative assistant for sixteen years, recalled that Bonita was dedicated to the students. "They were always her first priority. She held everyone to the highest standards, but she was fair and sensitive to everyone's needs. And she had uncompromising integrity. You always knew where you stood with her."

Calmes recalls her first impression of Bonita. "When I arrived in 1973 to study under Dr. Neiland and first met her, I was dumbstruck. Here was this woman with dyed jet-black hair who smoked cigarettes through a long filter and had a voice and demeanor to go with it. She wore loud colored pants suits and had a presence that could not be ignored. Fresh out of college and the earthy sort, I wondered if this mentor-student combination was going to work. Little did I know that Dr. Neiland was wondering the same thing before she even met me: would it work for her to mentor a female graduate student? She had tried in the past but it had not worked out. For some reason she decided to try one more time with me, and for both of us it paid off handsomely. After I finished my degree, she took on several more female graduate students and found that she enjoyed working with them. Things had changed."

Calmes noted the things she and Bonita held in common that allowed them to "get on famously," despite their outward differences: valuing hard work and common sense, frankness, and honesty. They both held a high standard of excellence and respected each other.

"I worked diligently on my master's program because that came naturally for me," Calmes said. "Dr. Neiland honored my efforts and in return worked hard for me. When there were problems with committee members, she was not afraid to stand up for me and confront the issues. She was encouraging and supportive but always honest. If she complimented you, you knew it was a sincere remark, and I was always grateful for the respect and support she offered. Over the years I watched her change and grow personally. She also understood that we all make mistakes and the only real mistake is not learning from one's mistakes. She also had a sense of humor and a sense of adventure. I remember taking her out to my plots in the refuge area in Farmer's Loop. I, a young twenty-something charging off through the brush, and she laying down the ground rules that I needed to slow down a bit in deference to her not being twenty-something."

Dr. Roseann Densmore, a research ecologist with the U.S. Geological Survey's Alaska Science Center in Anchorage, also had praise for Neiland: "My graduate work and career in plant ecology would not have been possible without Dr. Bonita Neiland. She was a role model and a superb mentor who offered me astute support and guidance for many years."

"She was an important role model for me and a number of women trying to make a career in science," Holloway said. "She gave us the tools to build confidence in ourselves and convinced me I really did have what it took to pursue a PhD degree. She was fiercely loyal to her faculty, staff and students but didn't hesitate to make us see the folly of our ways if we did not meet her high expectations. Many times I would leave her office thanking her for her time but wondering why I felt like I had just been run over by a truck. Her unwavering principles did not always endear her to politicians and administrators, but her career was not driven by popularity contests. She established strong standards for our degree program, but helped all of us reach our potential both personally and professionally. Excellence, integrity, loyalty, honesty—Dr Neiland's middle names—are the ones I've tried to emulate in my own career."

Founding a school

In an effort others have described as determined and relentless, Neiland held on to the dream of creating a school and curriculum that would give students a broad perspective of the field of natural resources management, integrating science, technology, economics, law, and the humanities. In recent years, the emphasis on interdisciplinary research testifies to her foresight. "Bonita was a different kind of ecologist," Kessel said, "more in tune with the modern trend."

In the 1970s, maintaining the curriculum and research programs was a struggle. "The School's emphasis shifted with each university president," Bonita said. "President Patty, for example, wanted the university's focus on liberal arts and social sciences instead of research and applied sciences, and the "wildlifers," as we used to call them, didn't want farming or timber harvesting of the land. It seemed no matter what we did, we encountered opposition."

She recalled an incident from 1971. "A former statewide administrator, who was way at the top, adamantly wanted to abolish the curriculum. Fortunately for us, it was Christmas break and he went on holiday leave. Dr. Kessel and I were able to push it through and get it approved while he was away. And although he wasn't too pleased about it, he later admitted that it was his mistake for going on vacation. There was nothing he could do at that point," she said with a victorious gleam in her eye.

In 1975, when the college of Biological Sciences and Renewable Resources was dissolved and School of Agriculture and Land Resources Management (SALRM) was created, Dr. Neiland became Acting Assistant Dean for Instruction. In 1977 she became SALRM's first Director of Instruction and Public Service.

Dean Carol Lewis, who came to the university in 1973 to work for the then Institute of Agricultureal Sciences, said, "It wasn't until I became active in the teaching program in 1989 that I began to interact with Dr. Neiland and appreciate what she had created. I admired her foresight in her futuristic view of the critical need to unite the physical and biological sciences with the social sciences in an interdisciplinary academic program addressing natural resources management.… It took courage and stamina to make not only the Alaska community, but the University of Alaska, understand the need to combine agricultural and forestry interests with those of ecology and wildlife if we were to manage our resources to benefit communities, individuals, and the economy of Alaska."

Professor Holloway, who arrived in Fairbanks in 1975 as a graduate student in Natural Resources Management recalled that at the time, Dr. Neiland and Carolyne Wallace had just taken up residence in a corner office of O'Neill Building.

"Dr. Neiland fought hard to establish a presence for SALRM at a time when there were a handful of faculty, the halls were nearly empty, and there was so little teaching equipment that most cupboards were bare," she said. "But look at us now. The O'Neill Building is bursting at it seams, faculty are scattered all over campus, and most importantly, our students are leaders in industry and government in Alaska and elsewhere. As a horticulturist, I always say, if you want to have a healthy plant, you have to start with good roots. Dr. Neiland made sure we had good roots."

"I was on the Biology and Wildlife faculty when Bonita began her good fight to establish a new program in Natural Resources Management," said Bob Weeden. "The idea appealed to me, and I helped. Bonita had a lot of people to convince. The agriculture folks weren't too enthusiastic (it wasn't a priority) but they eventually provided the administrative structure for the new program. Research and 'basic science' dominated the thinking of natural scientists; some actively opposed establishment of SALRM while others just stood by. Dr. Neiland, a botanist with a flair for academic politics, did win the day. I kept a foot in SALRM and in the Wildlife Biology department for the next fifteen years or so, but it was Bonita who was most open to my evolving interests in resource decision making and policy, environmental law, and problem-solving, etc. I'm extraordinarily grateful for her tolerant support as I offered a lengthening chain of advanced courses in these unorthodox topics."

"Today, the School of Natural Resources and Agricultural Sciences has a growing academic program, thanks to Dr. Neiland's tenacity in its establishment," Dean Lewis said. "I'm very privileged to play a role in carrying out her dream of graduates from our program having lead roles in establishing sustainable resource management policy in Alaska. To do so, our students must have the multidisciplinary training they get in the academic program Dr. Neiland established in 1975."

After twenty-six years, in 1987, Bonita retired from UAF, and became professor emeritus. The Neilands returned to Oregon, where they lived in the small town of Sisters. In 1995 she commented on retirement. "The pace of my life has really slowed down. I'm finally learning to relax. For so many years I was focused on SALRM at the expense of everything else. Now I spend much of my time reading about things not related to my field, like archaeology and Greek and Roman literature. Lately, I've taken up a new interest—shooting rattlesnakes. There's so many of them down here. I'm becoming a pretty good shot." She also ran a successful campaign for director of the Soil and Water Conservation Board for Deschutes County. "We're having land-use wars down here," she said in 1995. "It's resorts versus farmland. Being on the board keeps me in touch with the issues." The only drawback to retirement she noted was growing older and not being physically able to do the things she used to do.

When asked in 1995 about the highlights of her UAF career, Bonita reflected: "I thoroughly enjoyed teaching, the research, and building the School," she said, "even though there were some long and bitter battles." Looking back on the past achievements, she was modest. "I don't like to toot my own horn. I couldn't have done it without the help of many dedicated and talented people." She noted the many changes that had occurred by 1995 and expressed "no regrets" about her chosen career.

"She was a most remarkable woman," Wallace said, "an excellent boss and one I've been proud to call a dear friend." Their friendship continued in the years after Bonita left Fairbanks.

Bonita was an only child and had no children. At her death, there were no relatives to list as survivors, and at her wish, there was no service. Even so, her influence continues through the curriculum she fought for, the work of the students and faculty she taught and mentored, and in turn, the students they continue to teach.

"She was a wise, intelligent woman," said Calmes. "She taught me a lot about plant ecology, but she also taught me a lot about myself and about life."

By Doreen Fitzgerald, based on personal recollections of others and Neiland's quoted remarks from a 1995 interview (Agroborealis ***Vol. 28 No. 1***).

Notes

1. After her retirement, during a 1995 summer visit to Fairbanks, Neiland was interviewed by Valerie Hendrickson for an article that appeared in the Spring 1996 issue of *Agroborealis*.

Neiland, vacationing in Fairbanks last summer, reflected on her role during the early days of her career, the School, and the events that initially brought her to Alaska.

2. The forest-bog complex of southeast Alaska, Plant Ecology, Volume 22, Numbers 1-3, March, 1971.

3. SALRM, School of Agriculture and Land Resources Management, which is now the SNRAS, School of Natural Resources and Agricultural Sciences.

4. Project Chariot was the extremely controversial proposal to construct an artificial harbor at Cape Thompson by burying and detonating a string of nuclear charges. The history of this project is recounted in the book, *The Firecracker Boys: H-Bombs, Inupiat Eskimos, and the Roots of the Environmental Movement*, by Dan O'Neill, second edition published 2007 by Basic Books.

Dr. Neiland holding up a poster for the school from 1991: "Land of Resources."
—AFES FILE PHOTO

The Dr. Bonita J. Neiland Scholarship

Bonita Neiland is also remembered through the scholarship fund that was created in her honor after her retirement. "Dr. Neiland was my mentor and friend, so when she retired, I had the idea to start a scholarship in her name," Said professor Patricia Holloway. "Tony Gasborro, myself, and John Fox worked on raising funds for it from colleagues and former students. The Bonita J. Neiland Fund for Natural Resource Scholars was initiated at UAF in 1988. The scholarship is awarded each year to a full-time undergraduate student demonstrating academic excellence in the Natural Resources Management degree program.

Memorial donations may be sent to: Dr. Bonita J. Neiland Scholarship, Development Office, University of Alaska Fairbanks, PO Box 757530, Fairbanks AK 99775-7530.

biomass for biofuels: not all trees are created equal

by J. Andres Soria, assistant research professor of wood chemistry SNRAS/AFES

Alaska has millions of acres of trees, but in a state that prides itself for its natural resources, we know very little as to the chemical composition and characteristics of Alaska's woody biomass, particularly in terms of its behavior and potential uses in heat and power applications, liquid fuels, and in producing high value-added specialty chemicals.

Woody biomass is composed of three main chemical building blocks: carbohydrates (sugars), lignin (poly-phenols), and extractives (hydrocarbons, tannins, and others), (Sjostrom, 1993). Lignin is an amorphous polymer related to cellulose that provides rigidity; together with cellulose it forms the woody cell walls of plants and the cementing material between them. Depending on the origin of the woody biomass, from hardwood or softwood for instance, the chemical makeup of the various parts of lignin can be completely different, as can the relative composition of carbohydrates and extractives. The differences, which from a chemical standpoint can be subtle or drastic, will undoubtedly result in different behaviors when these substances are used in specific applications, such as gasification or combustion. In practice, the type of biomass and its chemical quality is significant.

Combustion

Burning biomass was undoubtedly a pivotal moment in human history, eventually allowing us to evolve complex civilizations and develop advanced technologies. Since the early days of human civilization, our knowledge of combustion has increased dramatically as we have developed our understanding of thermodynamics, efficiency, and biomass quality coupled to improvements in stove and boiler design that allows heat to be transferred to a second fluid like water to do work, such as in a turbine.

Combustion continues to be a technically simple endeavor, but the quality of biomass can significantly affect its heating content, as well as the combustion process itself. Technically, heating content is measured as the potential work we can obtain from a closed thermodynamic system; in common language, we understand it as the amount of heat released during a chemical reaction such as burning. When we burn anything, we are modifying the chemical makeup of the original substance, and in the case of biomass, each component breaks down to carbon dioxide and water in the presence of oxygen, releasing heat energy in the process.

Factors such as moisture content can affect the heating value and completeness of the combustion process. Furthermore, the individual building blocks of biomass have different combustion characteristics, with lignin (poly-phenols) and extractives having a higher heating content than carbohydrates. So, a biomass source that has higher proportions of poly-phenols will burn hotter than low poly-phenol biomass. This is the reason why bark is preferred in some industrial applications (bark is mostly a blend of poly-phenol compounds). Also, differences in inorganic matter content and composition can significantly affect the longevity of the combustion device.

If biomass with high silica content is used, pitting of the combustion chamber occurs and over time (sometimes a brief period) can cause deterioration or failure of the device. This can rapidly increase the costs associated with operating a heating unit. Other inorganic chemicals can create a film or slag that coats the walls and combustion chambers, reducing the heat transfer capacity, increasing disposal costs, and reducing equipment life. Metals, including heavy metals, can become airborne during combustion or remain in the ash and released into the environment, affecting air, water, and soil quality.

Current interest in combustion machines and technology has overshadowed the need to address the fundamental characteristics of the biomass itself, which not only includes the chemical makeup, but operation parameters as well, including compressibility (for pellet manufacture), flaming and pyrolytic combustion, and emissions. Furthermore, we will need to address new management regimes for our resources if we are to start using woody biomass in large volumes. Understanding the chemical makeup and behavior of Alaska biomass, coupled to new management practices, should allow the sustainable long-term use of Alaska's forest resource.

Thermochemical conversion processes

The process of converting biomass into different chemical compounds by using heat, pressure, and/or chemicals is collectively known as thermochemical conversion. The advantages of this is that the end products contain a blend of compounds that are useful for displacing petroleum hydrocarbons in a variety of applications, not just as an energy source. The importance of this cannot be underestimated. Petroleum is an incredibly versatile blend of compounds, from which we extract our fuels, lubricants, resins, plastics, and polymers, and produce chemicals, fertilizers, and every other commodity, and at the least, it is used in the manufacturing process of every commodity that we purchase commercially (as a raw material, or as part of the equipment that manufactures, harvests, or processes it). In this complex picture, biomass is the only renewable resource capable of producing hydrocarbons, and unlike burning, thermochemical conversion processes capture these chemicals either as liquids, gases, or solids that can be further refined into useful products.

The process that is favored in pilot-scale applications is pyrolysis, which is an analog to combustion, except that the reactions happen in the absence of oxygen. Under these anoxic conditions, breakdown of the biomass produces a wealth of chemical species, hundreds of individual volatile compounds, and several nonvolatile species, which are collected as a liquid (bio-oil), solid (bio-char), or gas (reformer gas). The proportions of liquids, solids, and gases varies depending on the temperature applied and the biomass composition, but generally, pyrolysis is capable of producing up to 50-60 percent liquids, 1-10 percent gases, and 20-40 percent solids. Our entire use of petroleum resources lies in our ability to distill a liquid (we are a liquid-based economy).

Table 1. Summary of supercritical methanol liquefaction results of Alaska kiln-dried woody species

Woody Species	% liquefied (weight basis)	Number of compounds
Alder	94	170
Red Cedar	89	172
Birch	95	190
White Spruce	93	180
Aspen	96	181
Sitka Spruce	92	131
Hemlock	89	178
Yellow Cedar	91	176

Black spruce.
—US Fish & Wildlife Service

Pyrolysis has the limitation of not capitalizing on the full liquid potential of biomass because the process only converts a portion of it into bio-oil.

Research started at the University of Idaho (Soria et al., 2005) and now continuing at the SNRAS Palmer Research & Extension Center is geared towards optimizing the liquefaction of biomass using novel thermochemical technologies, namely supercritical fluids. For the first time, Alaska biomass is being studied this way.

The process of liquefaction under a supercritical fluid occurs at very high pressures and moderate temperatures, where a solvent, for these experiments methanol, transitions to a state between a gas and a liquid. Under such conditions, fluid densities, polarity, and solubility parameters change, allowing biomass chemicals to dissolve and remain in solution once the reaction is stopped. Unlike pyrolysis, this process can liquefy over 90 percent of the biomass into a bio-oil. For Alaska species I've tested so far, liquefaction has ranged from 89 to 96 percent on a weight basis (Table 1). These experiments were done using kiln-dried wood supplied by the Ketchikan Wood Technology Center.

Although the number of chemical species collected from kiln-dried material is less than from green wood due to losses during the drying process and dissolution in steam, this research should indicate some potential product lines that can be created from Alaska biomass.

Gasification is the last thermo-chemical processes I'll discuss here. It involves the conversion of biomass under very high temperatures into a blend of light hydrocarbons, carbon dioxide, carbon monoxide, and hydrogen. Gasification is capable of generating heat and power, with potential future applications in large power generating schemes. Currently, the technology is in the scale-up, pre-commercial stage of development—not yet in large facilities but beyond the laboratory phase, with several units being used to produce electricity, run vehicle engines, and heat homes (see references). This has potential for Alaska, but as with any other technology, the raw material matters, hence the need for assessing the properties of Alaska biomass.

Hydrolysis

During hydrolysis, biomass carbohydrates are broken down into free sugars, then fermented by bacteria and yeast into alcohols (ethanol). This process has received much attention from politicians, the media, and funding agencies. The hope is to capitalize on the potential for converting 50-60 percent of the biomass chemicals into free sugars. The United States government granted $386 million dollars this year to six private firms and conglomerates to develop the hydrolysis infrastructure. In the short term, what we can do in Alaska (where no such funding exists), is investigate the composition of the biomass. Then, if and when these technologies become commercial, we will have good, solid criteria with which we can assess the feasibility of using locally available biomass in this way.

As far as large industrial-scale biomass utilization projects go, we are at a major disadvantage because we lack a large, established forest products and utilization industry. As a result, harvesting operations, transportation, storage, pretreatment, and processing costs for one of these large-scale facilities may make it uneconomic here. (Southeast Alaska Conservation Council, 2000).

Conclusion

The importance of thinking within the boundaries of our own resources and needs cannot be overstated. In the case of biomass, millions of acres of trees, some live and many killed by insects and fire, provide a substantial resource. However, a major, centrally located processing facility has many associated risks, even without considering the lack of a large forest products industry in the state. Specifically, issues with harvesting, transportation, sustainable resource management, and labor concerns have to be accounted for to ensure the environmental, social, and economic sustainability of using our local resources. Yet we have one advantage in Alaska: our state lends itself to decentralized (and specialized) facilities that can serve the local populations, generate new entrepreneurial ventures, and promote technical and economic growth.

Biomass research performed elsewhere will likely not help Alaska in breaking the dependency on importing its processed hydrocarbon resources (distillates). nor help generate local enterprises, or agricultural and forestry activities at the regional or local village levels. Because not all biomass is created equal, we are championing the study of the local potential that biomass has for addressing the primary needs of the population in both urban and rural areas. The goal for this new research line is to provide a better understanding of the chemical makeup of Alaska biomass, and to provide the foundation for new niche markets in which this resource can be used.

Tools at the UAF Agricultural and Forestry Research Station for conducting biomass energy and characterization work include a gas chromatograph-mass spectrum analyzer capable of separating and identifying volatile chemicals from biomass, a high-performance liquid chromatograph capable of separating and identifying non-volatile compounds, including fermentable sugars, antioxidants and fatty acids. A UV-Vis Spectrophotometer to conduct antioxidant and lignin analysis has recently been housed in the laboratory facility. A state-of-the-art oxygen bomb calorimeter to conduct heating value determinations as well as optical microscopes, extraction devices, and related laboratory equipment is now in place, completing the fundamental tools needed to pursue this research line. The Palmer Research Center welcomes visitors, clients, and partners to contact them for any additional information.

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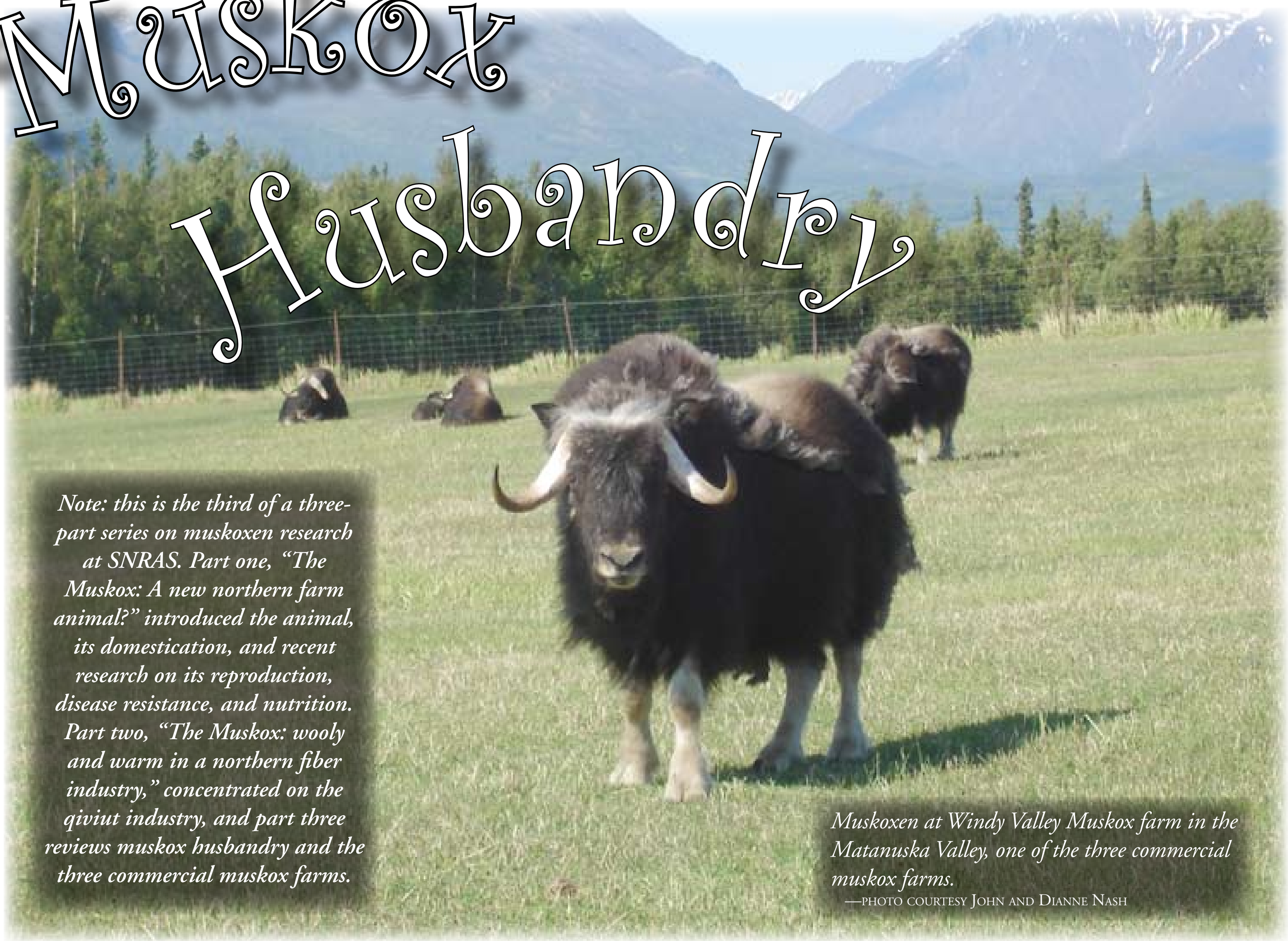
Muskox Husbandry



Note: this is the third of a three-part series on muskoxen research at SNRAS. Part one, "The Muskox: A new northern farm animal?" introduced the animal, its domestication, and recent research on its reproduction, disease resistance, and nutrition. Part two, "The Muskox: wooly and warm in a northern fiber industry," concentrated on the qiviut industry, and part three reviews muskox husbandry and the three commercial muskox farms.

Muskoxen at Windy Valley Muskox farm in the Matanuska Valley, one of the three commercial muskox farms.
—photo courtesy John and Dianne Nash

Animal husbandry, the agricultural practice of breeding and raising livestock, generally implies the science and practice of caring for domesticated animals, but the term is also applied to the care of captive animals such as muskoxen or reindeer. Topics range from veterinary medicine to animal nutrition, genetics, breeding, and reproductive physiology; to specific disciplines relating to a single species or group of species of livestock, or even a particular use of such livestock, such as dairy farming or cattle ranching.

Specialties in animal husbandry include aquaculture for fish or shrimp, beekeeping, camel raising, capriculture (goats), cuniculture (rabbits), horse breeding, pig farming, poultry farming (chickens, ducks, geese, peafowl, pigeons, quail, swans, turkeys, etc.), sheep husbandry, yak herding, and so on. Through husbandry practices, countless breeds for many domesticated species have been developed, from as few as twelve for the yak to as many as 800 for cattle. Many species of livestock have been studied for so long that more is known about their physiology, diseases, and reproduction than is known of humanity! Muskoxen, however, have been studied for so short a time that the field of muskox husbandry is still quite limited, and no breeds have been developed yet. As more researchers and farmers work with them longer, however, the better care these useful and interesting animals can receive.

Muskox farms

The farm with the largest research herd in the world, forty-three animals (six calves are expected spring 2008), is the UAF Robert G. White Large Animal Research Station (LARS), operated by the Institute of Arctic Biology (IAB) north of the campus. Only three farms raise muskoxen commercially. Two of these are in Alaska: the nonprofit Musk Ox Farm (of the Musk Ox Development Corporation, the modern heir to Dr. John Teal's domestication experiment) and Windy Valley Farm, both near the Palmer area in the Matanuska-Susitna Valley. The third is in Canada, Continental Muskox Co., in Mountain View, Alberta.

The Musk Ox Farm

The Musk Ox Farm and LARS are the oldest farms, arising from a cooperative research program begun in 1964. Mike Yankovich, a homesteader and farmer in the Tanana Valley, donated property to the University of Alaska in October 1963 expressly for muskox research. Teal's domestication experiment became established there as the Musk Ox Farm in 1964, working with university researchers. After a contagious virus had spread among the animals at the farm in 1975, all the muskoxen were moved in the following two years to Unalakleet and then to Talkeetna (in part simply to have them near the villages as part of the qiviut cottage industry). LARS was established in 1979 with a grant from the National Science Foundation Office of Polar Programs. Sixteen muskoxen were captured on Nunivak Island in April 1980 and were moved to the Yankovich farmstead after a one-year quarantine.[1] The Musk Ox Farm has been operating on its current grounds in the Matanuska Valley since 1986, offering tours and raising muskoxen for qiviut. Donations are solicited in the form of individual animal "adoptions" or support for the farm's projects or infrastructure. It has a herd of fifty animals, according to farm manager Sandy Belk, and relies on volunteers as well as hired help to care for their animals, conduct tours, maintain and repair buildings and equipment, and do general farm chores.

The farm's mission is to domesticate the muskox, creating a "gentle and nonintrusive form of agriculture" that will provide "subsistence income opportunities for Alaska's first people."[2] According to its website, "the farm relies on foundation grants and private donations to continue its mission. Perhaps the most meaningful support that the farm receives is the many entirely voluntary contributions made by the 'Friends of the Musk Ox,' the public membership arm of the project." According to Belk, Friends of the Musk Ox provides good publicity and gets the public involved with the domestication project. The farm sells its qiviut to Oomingmak, the Musk Ox Producers Cooperative, a knitters' cooperative of approximately 200 Native Alaskan members. The members knit articles of clothing from qiviut, using patterns based on traditional designs indigenous to their area.[3]

The farm's staff is a fairly small group. There are two animal handlers, Mindy Bye and Sandy Belk; the office manager and information contact for the farm, Amanda Kristinat; and in the summertime one or two interns or, sometimes, a part-time grounds and general help person. Belk, who grew up in Illinois and had worked with a veterinarian in California, was in Alaska in 2002, touring the state for a couple of weeks before a job in Seward started, when she and her spouse visited the Musk Ox Farm, which was looking for a new animal handler. Belk, although familiar with large livestock, at the time knew almost nothing about muskoxen, but applied for the job anyway. She has been living and working on the farm ever since. Mindy Bye has been working there with her almost as long, for four years. Both have learned on the job—a necessity in muskox husbandry, since agricultural colleges teaching this branch of animal care are scarce. Pamela Groves, now on the farm's board of directors, was then the animal director and was able to provide assistance. Groves, who is employed at IAB, received her doctorate at the University of Alaska Fairbanks in wildlife biology in 1995, studying the evolution of muskoxen and takin (a Himalayan goat-antelope related to bighorn sheep).

As of this writing the farm has twenty-one cows, twelve bulls, twelve steers, and five calves, from which the farm produces 100 pounds of qiviut a year, sold exclusively to the Musk Ox Producers Cooperative. The farm doesn't sell animals, nor does it use them for meat. It does sometimes acquire animals from zoos. Some of the herd's stock came from Joel and Nancy Bender's farm, but those muskoxen are now deceased (from old age and other natural causes). (The Benders had run one of the earliest commercial muskox operations, a farm in Montana known as the Musk Ox Company. It operated in the 1990s to 2000 and produced qiviut yarn for sale.) The farm at Palmer is working to maintain and even increase the herd size, controlling the population through restricting or allowing breeding, with careful attention to pasture and good land management. The farm encompasses sixty-six acres; "the best animal density for the acreage," says Belk, is something the staff has not yet determined.

Windy Valley Muskox

Windy Valley farm, also in the Matanuska Valley, raises muskoxen and sells qiviut and other fibers such as alpaca, cashmere, guanaco, and pima cotton. The owners, John and Dianne Nash, keep a muskox herd of about nineteen animals (as of this writing, nine of their cows are pregnant). Their original animals, two cows and a bull, came from the Musk Ox Company in 2000. When the Benders decided to get out of muskox husbandry, they sold off their animals to various buyers, including the Nashes.

"We got started with a crazy idea," wrote John Nash. "I have always been interested in a game animal and we liked the fiber aspect of the muskox. Our goal was toward qiviut production and herd increase and with the profits off the qiviut it has worked out well."

Windy Valley is a family-run farm. The farm grows its own hay, which is used to feed the muskoxen along with a muskox ration that Windy Valley obtains from Alaska Mill & Feed, which, John Nash said, he's modified a little. The cost to feed each muskox is about $300 per year, he estimates, including fertilizer for the pastures.

Continental Muskox Company

Continental Muskox, run by James Meservy and his family (including five young children), has a herd of fifteen animals, including eleven adults: six cows and five bulls ranging from two to seven years old, with four new calves born in spring 2007. Their 1,120-acre ranch is a working cattle ranch, with 160 head of cattle, some chickens and turkeys, dairy goats, and Berkshire swine, along with the muskoxen. Unlike proprietors of other muskox farms, the Meservys plan to raise muskoxen for sale primarily to other ranchers rather than for qiviut or meat production (although they are keenly interested in their qiviut). Meservy describes how he and his wife decided on raising muskoxen:

> In 1998 I was enrolled in a PhD program in molecular

genetics at Baylor College of Medicine in Houston, Texas. We made the decision to leave the program and return to southern Alberta to join my in-laws on their ranch. However, I knew that I wanted to diversify away from traditional livestock in order to stabilize and expand the ranch income. I wanted to avoid getting into any alternative industry that would require convincing someone to eat something in order to justify the animal (elk, bison, llama, wild boar, etc.). I…came across muskoxen and qiviut with the help of Nancy Bender and became hooked. There was only one place to buy animals in the world (Nancy had just sold her last animals to John and Dianne Nash of Palmer, Alaska) and that was the Yukon Game Farm outside of Whitehorse. We spoke for all calves born in 2000 and the first right of refusal for all calves born 2001 and 2002.

The Yukon Game and Wildlife Preserve (now the Yukon Wildlife Preserve) was at the time run by Danny and Uli Nowlan, and has now been taken on by the Yukon territorial government.

Meservy sees an industry with potential: "I anticipate that within five years, that muskoxen and qiviut will become a major player in the income of the ranch perhaps even to exceed that of the cattle."

Raising alternative livestock

Ranchers working with exotic and undomesticated species face unique challenges. According to an article at Deerfarmer.com[4] there are several practical problems that are obstacles to success in the specialty livestock industry. Aside from the lack of adequate information on the needs of various exotic livestock species in comparison with that available for traditional livestock, these include: inadequate training in promotion and food preparation; the need to build greater convenience into a product; insufficient volume for export outside of the local area; capital-intensive startup and maintenance; lack of industry infrastructure; lack of production standards, weights, or conformations; production units too small; production not yet specialized within a species (each producer must do everything required themselves); farm-gate selling rather than distribution or industry lot; poor product marketing; lack of food security rules specific to the species; lack of value-added products; lack of or weak industry associations.

Muskoxen's most valuable product, qiviut, is often only available to the public in value-added form, i.e., spun into yarn or made into finished garments. Careful marketing by Oomingmak and various clothiers has heightened the public perception of products made with qiviut as luxury items of great desirability and exclusivity. Its very rarity has become a selling point. In this respect, muskoxen have overcome the marketing challenge; muskox meat and other products have yet to be produced or marketed sufficiently to be more than a novelty.

Care & breeding of muskoxen

Animals kept for their meat, wool, or other products need to be kept healthy, of course, and that requires knowledge of their nutrition, reproduction, physiology, anatomy, immunology, and other aspects of their biology need to be studied. Because muskoxen are still wild animals and they behave as such: somewhat unpredictable and at times intractable. Compared to their relatives the sheep (*Ovis aries*) and goats (*Capra aegagrus hircus*), which are among the earliest-domesticated herbivores, not much is known about muskoxen biology or husbandry. In 1992, Pamela Groves published *Muskox Husbandry*, which remains one of the only practical guides to muskoxen care, yet husbandry research has made significant strides in the last sixteen years.

Muskoxen live about ten to twelve years (males) and fifteen to twenty years (females). Cows are sexually mature between one and four years of age, and will calve annually if they have enough food and sufficiently good nutrition, but usually calve every other year. Cows give birth to one calf after a gestation period of eight months, giving birth April-May. Twins are rare. Calves weigh between nine and eleven kilograms (twenty to twenty-four pounds) at birth, and although they start eating adult food within a few weeks, they may continue to nurse for up to a year. Bulls become sexually mature at two to four years old, and, although known for their spectacular head-butting during the rut, "are docile in comparison to dairy bulls."[5]

Taming muskoxen must begin when they are very young (less than five months old, according to Groves), and they must be handled frequently, gently, and consistently. It is important that muskox handlers establish dominance over their charges, for, as Grove points out,

> Muskoxen that are tamed when young, but never learn to be submissive to humans, can be troublesome and dangerous when mature. These animals are not afraid of humans and frequently try to assert dominance over their handlers.[6]

When the animal in question is four to seven times its handler's weight, the need to keep it submissive and under its handler's control is obvious.

Handling muskoxen

The Musk Ox Farm receives a tremendous number of information requests on obtaining muskoxen or raising them, says Sandy Belk; however, she tends to steer people away from muskox. They are "still very much wild animals," she cautions, requiring a specific diet and handling. They are also difficult and expensive to obtain: a single live, healthy muskox can cost $5,000. They can't be treated like cattle or sheep; they have more goatlike tendencies and unique behavioral characteristics of their own. Some of these behaviors are well known, such as head-butting (calves only days old will start head-butting, and will punt toys and each other in play), and the formation of a protective circle when a herd is threatened by predators.

A primary predator of muskoxen in the wild is the wolf. Muskoxen have developed an evolutionary quirk to handle threats from wolf packs: sometimes they may react with violence toward creatures that are at about wolf height, charging them or attempting to toss or gore them with their horns, or trample them. This means, from the point of view of human beings trying to work with them on a farm, that if one is at the rough height of a wolf or bear, i.e., shorter than the muskox's eye level, one can be mistaken for a predator and run over by a fearful animal. This is an instinctive and somewhat unpredictable reaction on the part of muskoxen which has not yet been thoroughly documented or studied, but, wrote Groves in a recent e-mail, "It does seem that sometimes muskoxen are more likely to charge at children than adults, possibly because children appear more wolf-sized than adults standing upright. However, the same could be true of an adult crawling on hands and knees. A lot depends on the individual muskox and what they have been exposed to." Muskoxen are still wild animals, and certain biologically determined behaviors such as this can only be mitigated by domestication and many generations of breeding for tractability, something not yet achieved with the muskox.

Tim Smith and Jim Dau of the Alaska Department of Fish & Game used dogs with wild muskoxen in the 1980s. Dau explained in a recent e-mail that he and Smith were fitting muskoxen on the Seward Peninsula with radio collars. This work involved sedating the animals with a dart gun, so the dogs kept the herd occupied while the two men approached closely enough to dart the muskoxen they wished to collar. Smith used a blue heeler and Dau had a border collie:

> I had two border collies when I worked for the Reindeer Research Project in Nome. The project bought them to see if it was possible to use dogs for intensive herding as practiced by Scandinavian and Chukotsk herders, and as taught in Alaska when reindeer were initially introduced here. One of the dogs had been trained to herd sheep and was of field trial caliber. The other collie hadn't been trained at all.

Dau said that the heeler "instinctively tried to herd" the muskoxen, which "of course, bunched up in a defensive cluster as we approached." He took the trained collie out with him once:

> The border collie worked the first group of [muskoxen] as if they were sheep. The situation was similar to working sheep in that the [muskoxen] were close to me and the dog so she could easily hear my voice commands (not so with the reindeer). The second group of [muskoxen] had an aggressive bull which immediately charged the collie (and me—repeatedly). This frightened her and, after that, she was too intimidated to get far from my side and provided no help whatsoever.

Dau explained that their intent was simply to get close enough to the muskoxen to dart them, and they never tried to move the animals using dogs to herd them. Bill Hauer said, "I don't see why dogs couldn't be used for farmed animals, but I've never heard of it done." Belk confirmed that the Musk Ox Farm does not use dogs with their animals. Dogs trained to herd sheep or cattle would be used to herding animals with a different set of behaviors, but given proper training appropriate to

John Nash hand feeding his muskox bull Maximus.
—PHOTO COURTESY WINDY VALLEY MUSKOX

muskox behavior, a dog may be able to assist a muskox keeper. This is, like many aspects of muskox husbandry, as yet unexplored.

Muskoxen acclimated to a human presence are fairly easygoing. Bulls are generally more difficult to work with than cows, as is true with many other livestock animals. Says John Nash, "My muskoxen aren't very gentle, but they don't try to kill me. My oldest bull, Lefty, will eat out of my hand." During the rut, bulls can be extremely dangerous—but again, this is also true of other livestock, such as cattle. To help reduce the possibility of harm to farmhands, muskox horns may be trimmed short to remove the sharp tips. The horns grow from the base throughout the animal's life, and so must be trimmed periodically. At Windy Valley, the Nashes have found that trimming isn't usually necessary, and at LARS, it is done only to a few castrated males that are used for specific research purposes. At the Musk Ox Farm they will trim the animal's horns, the first time when the animals reach two years of age and then again at four or five years old. Trimming, or "tipping," is done every four years after that.

As at LARS, the Musk Ox Farm uses a modified bison scale (also known as a squeeze or crush) to restrain an animal gently for combing, hoof trimming, or veterinary checkups (as necessary). The crush's sides are hung with dark burlap curtains; to help keep the animal calm, the curtains are closed when it is brought into the scale, and usually only one person combs the animal. This keeps distractions down and makes it a bit easier on the muskox. Sometimes up to four people may be in the room with the muskox (if it and the people are acclimated to each other). Each side of the bison crush has two short panels, and from the middle up are bars. The bottom side panel can be lifted away and is about five and a half feet long. Belk has ideas for its improvement: she would like to make it sliding or hinged at the bottom, so the heavy panel is more easily moved into and out of place.

According to Belk, muskoxen are very communicative: "the body language of these guys is just amazing." To keep all its animals used to being handled, the Musk Ox Farm moves them at least three times a week. Muskoxen are more active in the winter, she says, as they "don't have to deal with the heat." For animals adapted to a climate north of the treeline, with long, thick, well-insulated coats, summer in the Matanuska Valley is a bit warm. In fact, it is far more likely that a muskox will suffer from heat stress than from hypothermia. However, muskoxen do not do well if they get wet, particularly calves. As Groves writes in her husbandry guide, "Muskoxen depend upon clean, dry qiviut and guard hairs for warmth during winter. Guard hair and qiviut that remain wet and dirty for a long time have a tendency to fall out, leaving the animal with bald patches that are exposed to the cold." She cautions that young muskoxen or calves are particularly susceptible to ill effects from wet and matted hair.

Breeding muskoxen

Breeding animals for selected traits is an integral part of domestication. Research on reproduction management of muskoxen at SNRAS and LARS includes studies of estrous synchronization (Jan Rowell, Milan Shipka, and Marsha Sousa); nutritional effects on breeding success, nursing behavior, and lactation (Bill Hauer, Robert White, and others); and mounting behavior (Rowell, Shipka, and Sousa). One desirable trait is friendliness or tractability. But, says Belk, "We have never had the luxury to breed only our tamest, gentlest animals;" muskoxen are simply not common enough nor well enough understood yet to breed for specific behavioral characteristics. Instead, breeding at the few farms in existence concentrates on physical health and diversity in the genetic line, a special problem with muskoxen since they were reduced to such few numbers in the early twentieth century that their genetic diversity is very narrow. Shipka and Rowell are with SNRAS; Hauer and White are with LARS; and Sousa was with LARS and SNRAS both and now is with the Allied Health department of UAF).

Bottle feeding a muskox calf at the Musk Ox Farm.
—photo © John Gomes / Anchorage, Alaska: www.akjohn.com

Artificial insemination is an important means of improving a breed. It is much easier and cheaper to ship frozen semen than to ship an animal, and enables one animal with desirable characteristics to impregnate females across the world. It is used for virtually every domestic livestock species. However, it is not yet used with muskoxen, although the technique could help tremendously in increasing the availability of muskoxen to farmers.

Muskoxen are seasonal breeders, going into rut in late summer. Pregnancy lasts eight months, and calves are born in April and May. Cows experience very fast birthing. The cow is kept in a birthing pen, at the Musk Ox Farm an enclosure of about three acres which opens up on to a larger, ten- to twelve-acre pasture. Signs of labor include pacing or twirling, but usually takes only about an hour, according to Belk.

Raising babies

Calves are usually standing and nursing within an hour of birth. At LARS, all calves are handled within twelve hours of birth, so that sex and birth weight can be measured and any prescribed treatments administered. Calf health is closely monitored throughout the summer.

Taming them begins at weaning. Calves are kept with their mothers for two to three months at the Musk Ox Farm, six to seven months at LARS. At the Musk Ox Farm, weaning starts with introducing the calves to a bottle, using commercial milk formulas. (Pam Groves stated that, along with information about medications, "the milk formulations for bottle feeding" would be among the main things she would update in *Muskox Husbandry* were she able to do a revised edition; muskox handlers should look to the most recent information available from LARS or other sources.) At the Musk Ox Farm handlers use a combination of FoalLac, a product for horses, mixed with MultiMilk, a multiple-use animal milk substitute. LARS has a general bottle feeding protocol and evaluates the formulas used each year, advising consistency: "choose a brand that works and stay with it. Keep a record of the formula recipe and be alert to factory changes. Avoid switching brands."[7]

Muskox milk is sometimes available if a cow has lost her calf. Writes Groves,

> If the bereaved cow is a reasonably calm animal, she should be milked for a few days, particularly if she is still producing colostrum. This milk can be saved to be fed to sick calves that need supplementing.
>
> With effort, a muskox cow can be trained to stand quietly while being milked on a daily basis. Clipping some hair and qiviut from around the udder will facilitate milking and yield cleaner milk. I have trained three muskox cows to be milked. Their milk production remained constant at 1 pint (0.5 l) per day, collected in two milkings [per day] from September until the following May. If not needed to feed calves, the milk is good in coffee and makes excellent yogurt and ice cream.[8]

The taming process takes a few weeks. Calves are generally shy—unlike fully domesticated animals, where the young are often fearless—but gradually become less afraid, and will begin to approach people and look for the bottle. Hand feeding is used for training and taming, and the calves, once acclimated, are friendly. "I have three babies on bottles right now [December 2007]," wrote James Meservy. His three-year-old daughter Hannah helps him with the calves: "She really likes to feed them with me."

At the Musk Ox Farm the weanlings are kept together, except for three daily sessions with a handler in a stall or small pen. The confined area helps gets them used to people. The calves are housed in the barn for the first week, depending

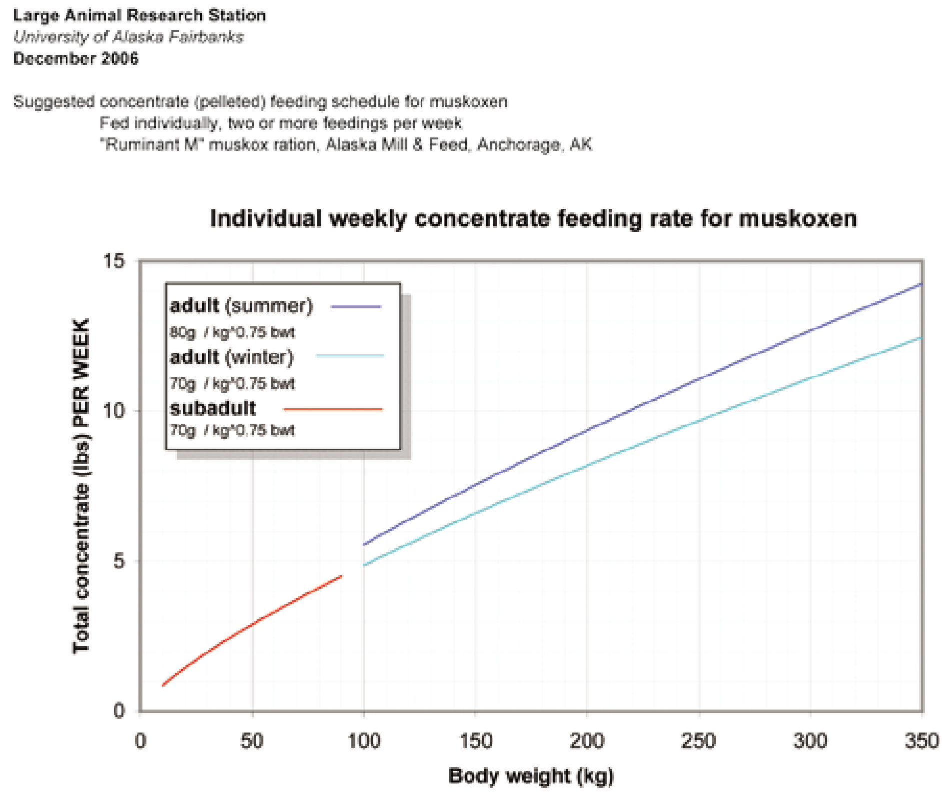


Figure 1. Recommended weekly rates (in pounds per kilogram) for feeding winter and summer supplements to yearling and adult muskoxen. Graph from LARS.

on the group size and temperament, and then are let into a larger pen. The calf group will bond, and form a youthful herd. The animals are weighed at least once a week, and herded every day. "A lot depends on individual temperament," said Belk, and explained that the calves are very sensitive to change, reacting not only to a new person, but even to the same person wearing different clothes. Acclimatizing the babies to differences starts out slowly, and the handlers will make sure to wear the same clothes each day—which after a while can get a bit pungent. Gradually the calves are introduced to new clothes, new people, and so on, the farm switching handlers for each taming session during weaning. Bottle feeding continues for at least six months, tapering off starting in January or February by diluting the formula with water until the calves are drinking just warm water.

Feeding and keeping muskoxen healthy

Calf mortality has been a significant problem in raising muskoxen, but over the years, with more experience to draw on and improved nutritional understanding, farmers have been able to improve the chances that their calves will grow to adulthood. Belk explains that calf mortality varies according to the weather (a damp year increases their chances of dying), and, she added, "luck." One year, she said, nine out of ten babies born survived, another year, three out of four were lost. Many are lost during weaning, and they are very vulnerable during their first fall and winter.

Calves are vulnerable to problems associated with high stocking density—too many animals in too small a space—and thus become susceptible to parasites (strongyles, hematodiris), weather conditions (wet, cold), and nutritional upset, especially scouring—chronic diarrhea—which breaks down the intestinal lining, causing scars and ulcerations and leads the calf to starve to death even while eating because it can't absorb nutrients. Much of the muskox research at LARS has concentrated on proper nutrition of calves and cows. Certain nutrients, such as copper, are important in the muskox diet, particularly for calves,[9] and the University of Alaska has developed special muskox feeds, which were released in 2001 and licensed to Alaska Pet and Garden (Alaska Mill and Feed) for production and sale.

> The licensing agreement comes as a result of the research of Perry Barboza and John Blake, from the UAF Institute of Arctic Biology and Biology and Wildlife Department. Barboza and Blake conducted experiments on muskox, caribou, and reindeer at UAF's Biological Reserve and Large Animal Research Station. These projects focused on seasonal changes in animal tissue and requirements from protein and trace minerals for reproduction and development. One application of the research is to provide cost-effective, reliable feeds and feeding standards for developing herds of muskox to produce qiviut, a super-fine underwool.[10]

This grain ration, Ruminant M, is a vitamin- and mineral-supplemented pelleted food. "We have two formulations," said Barboza, "a complete diet for calves to transition from milk to adult foods and a mineral supplement for adults maintained on grass hay. I have formulated several other products for experimental work and routinely revise our maintenance rations as ingredients change." Muskoxen are fed pelleted food three times a week at the Musk Ox Farm as a supplement to hay or forage, with the poundage estimated according to the given animal's weight (see Figure 1). A large male muskox requires only a couple of pounds of the pellets per feeding, according to Belk, and their animals require no other supplements or salt licks. Muskoxen have extremely efficient digestive systems, eating about one-eighth the amount of hay that an equivalent-weight domestic animal eats. The hay they are fed at the Musk Ox Farm is local high-fiber brome hay harvested on adjoining land. They love dandelions, willow, and fireweed, and eat fescue and ryegrass in the pasture as well as bromegrass.

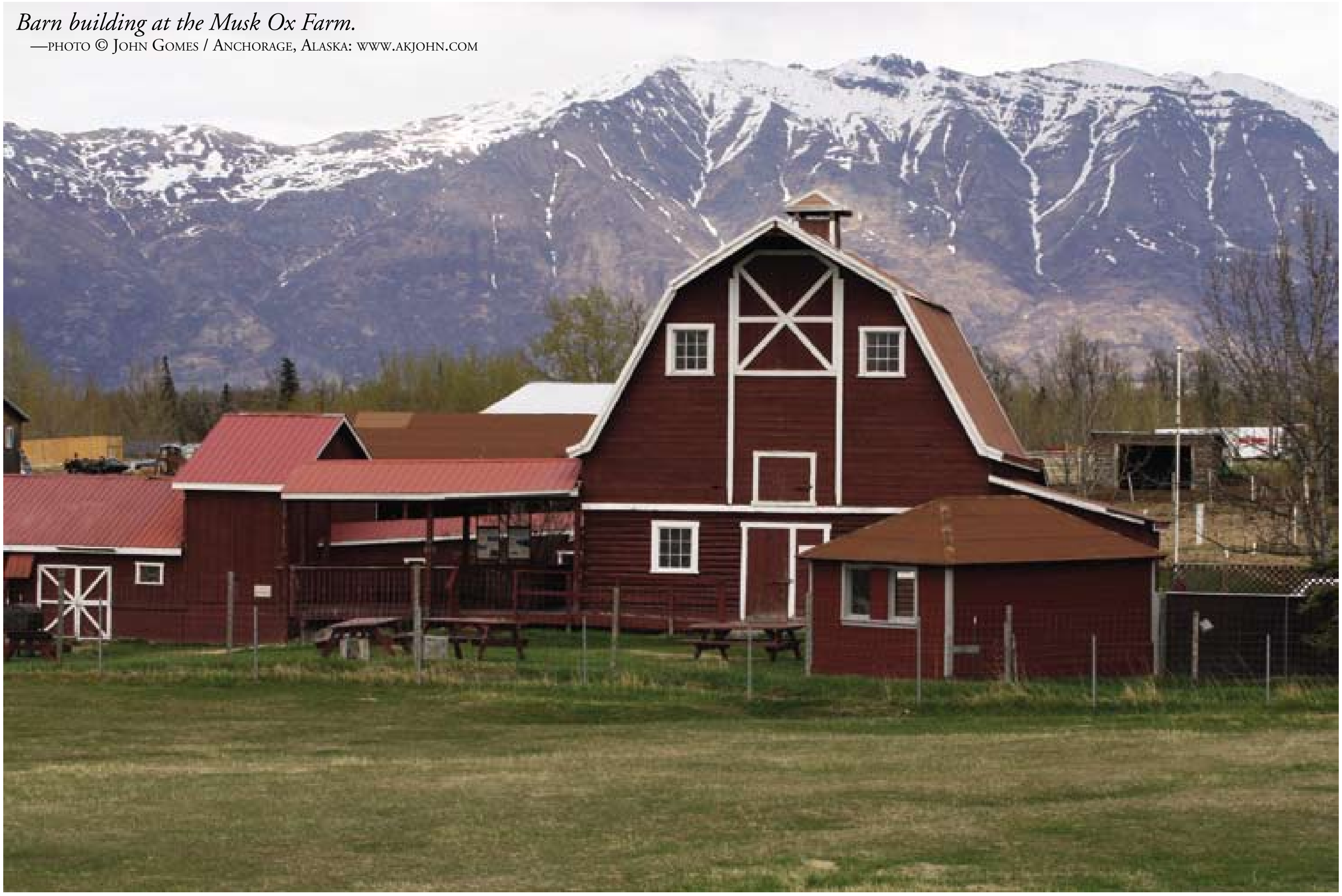
Barboza explained that a significant aspect of keeping muskoxen in captivity is that they change food intake with the seasons ("cheaper in winter because unlike steers they reduce feed intake"), and "they can tolerate low protein and high fiber hays, especially in winter." In fact, too-high protein feeds can cause digestive problems, "but," he added, "they do need to chow down in the fall to gain fat." With regard to calves, Barboza said that "copper seems to depleted rapidly when they are exposed to infections so the supplements need to address those trace minerals. Keep them cold, clean, and adequately supplied with copper (but not overdosed)."

Barboza and Robert J. Forster (of Agriculture Canada in Lethbridge, Alberta) are continuing research on the conditions in muskox stomachs, examining their internal temperatures and conditions in relation to the number and activity of the microbes present. Muskoxen are ruminants, which use symbiotic microorganisms to produce cellulase, which breaks down the cellulose in plant matter—something that other herbivores cannot do—and releases fatty acids that are absorbed in the stomach. (Animals with single-chambered stomachs absorb nutrients in the intestine only.) After chewing, predigesting in the rumen, and rechewing, the food passes into the intestine, where more nutrients are absorbed. Because of their ability to extract nutrition from cellulose and their two-stage digestion, ruminants are able to survive on comparatively poor forage. Muskoxen are even more efficient than most other ruminants at this. Barboza explained:

> Muskoxen eat snow and drink cold water that drop the rumen temperatures by up to 13°C for several hours. However, the cold rumen temperatures are not responsible for the winter reductions in microbial numbers. It seems that the microbes are actually cold tolerant. Winter reductions in microbial activity are due to low intakes of the muskox as well as the animal spending less [energy] on maintaining the conditions for microbes. The animals spends less on the microbes in winter because food is usually low in quality and they can rely on fat stores. Our preliminary data from the genetics indicate that the diversity of the microbial community changes with season even when the animals consume the same foods. One suggestion is that the variable intakes of muskoxen fosters a diverse community that is more efficient when food intakes are high and drops to lower cost forms in winter. This sort of complex community may have been lost in domestic ruminants by selecting for continuously high food intakes. The muskoxen and their microbes may give us some new organisms and enzymes for animal production and perhaps even bio-fuel production.

While food and digestion is of course extremely important in muskox care, other aspects of disease prevention are also quite necessary. At the Musk Ox Farm, each animal is given annual vaccinations: an eight-way cattle vaccine with doses adjusted for muskox weights. Pregnant muskoxen at LARS are vaccinated with Calf-Guard, a Rota-coronavirus vaccine, and an E. coli bacterin.

The genetics of disease resistance in muskoxen is being studied at SNRAS: Milan Shipka, George Happ, and senior thesis student Erik Wood examined DNA samples of six muskoxen and compared them with goat DNA to look at possible susceptibility to scrapie, or transmissible spongiform encephalopathy. Specifically, the muskox prion protein gene was compared to that of goats. Muskoxen, it turns out, may have a lack of resistance, as indicated by a similar genetic structure: "all muskox sequenced possessed the wildtype alleles


Barn building at the Musk Ox Farm.
—photo © John Gomes / Anchorage, Alaska: www.akjohn.com

most closely associated to vulnerability to prion disease in goats."[11] The lack of genetic diversity in muskox means that although this sampling of DNA was small, it may have wide application to the species.

The future of muskox husbandry

Research funding for Alaska agriculture is comparatively slim, despite the promising new directions it is taking; even states such as Florida are cutting back on agriculture research. Yet, a diversified and sustainable economy requires appropriate technology, industry, and development, and that takes knowledge. Muskoxen yield an immensely valuable fiber, and are uniquely suited to the extremes of the far north; research into questions on muskox physiology, nutritional needs, genetics, reproduction, embryology, lactation, growth, behavior, and other areas is needed to help the new Alaska textile industry develop. As interest in muskox husbandry grows, research into their care will continue, whether informally on the small farms now raising them, or formally in a university setting.

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Resources on muskox husbandry:

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Sandy Belk with a muskox calf in a pen used to acclimatize the babies to humans.
—PHOTO © JOHN GOMES / ANCHORAGE, ALASKA: WWW.AKJOHN.COM

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Matanuska muskox herd in a Windy Valley farm pasture.
—PHOTO COURTESY WINDY VALLEY MUSKOX

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Dianne Nash of Windy Valley Muskox spinning qiviut. The Nashes raise muskoxen and harvest qiviut for products they make and sell.
—PHOTO BY JOHN NASH, WINDY VALLEY MUSKOX

boreal forest soils:

Nutrient cycling, microbes, and the fate of oil

by Doreen Fitzgerald, based on the master's thesis of Jessica Garron

For Jessica Garron, a high-school interest in DNA persisted while she earned a bachelor's degree at the University of Maine, and it eventually led to her master's degree thesis, "Oil and Wildfire Effects on Nutrient Cycling and Microbial Diversity in Subarctic Mineral Soils." Garron worked with soil samples from a unique experimental oil spill site using both molecular and ecological methods.

"I was at a national meeting presenting some other molecular data, and Joan Braddock, who has done a number of studies on the UAF oil spill site, asked me if I would be interested doing some molecular work," Garron said. Braddock, a microbiologist and her thesis advisor, is dean of the UAF College of Natural Science and Mathematics. SNRAS professor David Valentine, a soil scientist, served on her thesis committee.

In 1976, scientists with the Cold Regions Research and Engineering Laboratory created an experimental crude oil spill on a plot near Fairbanks, Alaska, to mimic an oil pipeline spill. For nearly thirty years, this research site was available for scientists to examine the long-term effects of the spill, which initially killed more than forty black spruce trees

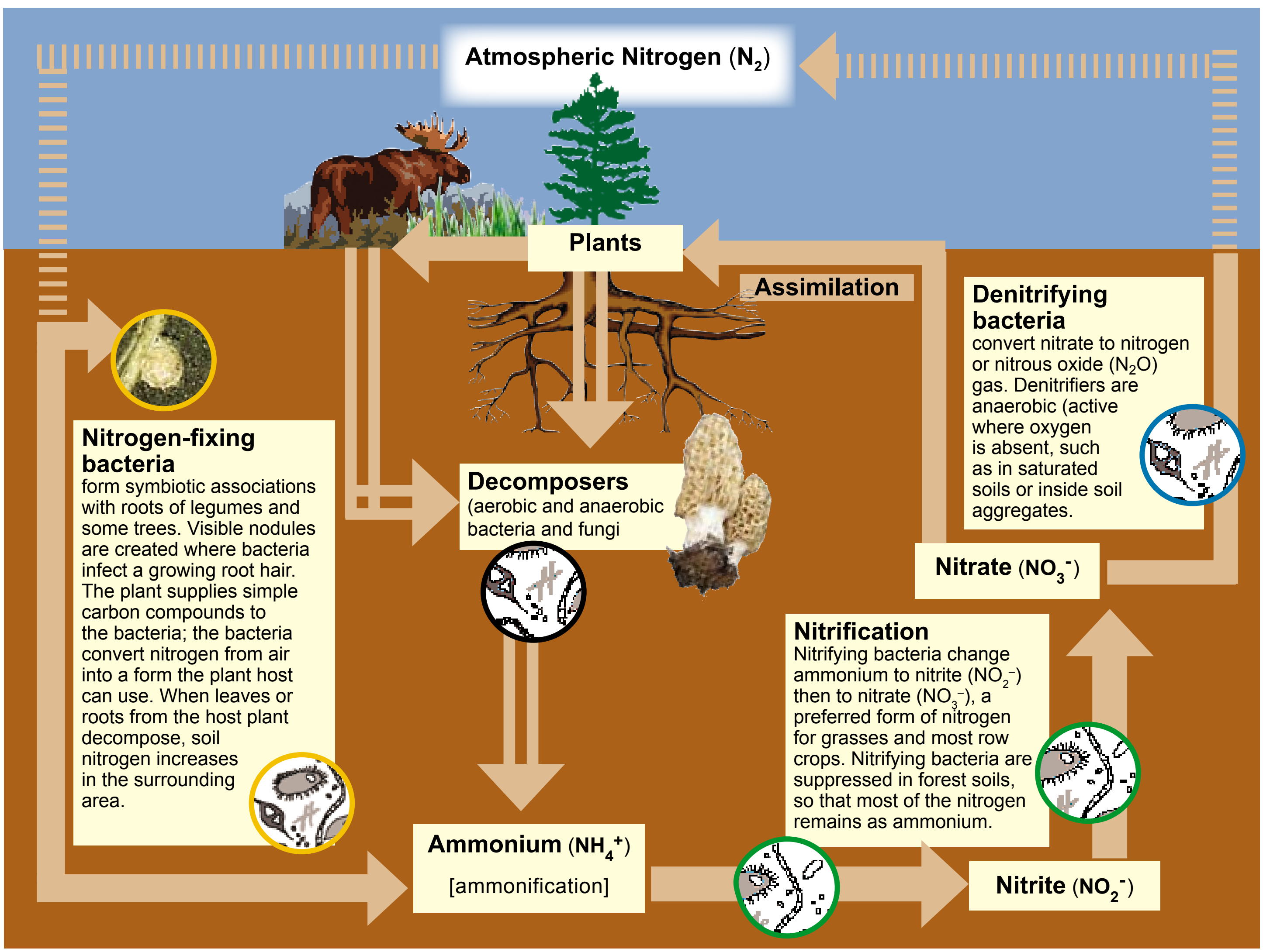

figure 1: the nitrogen cycle

and most surrounding vegetation. No experimental treatments were applied to the site, and oil was still abundant at the soil surface many years later (Braddock et al., 2003).

"After about 25 years, only ten percent of the oil in the mineral soil was degraded," Garron said, "and in the organic layer about 60 percent of the oil remained. In the tropics, change due to degradation would be obvious after a month."

Since 1976, the spill areas have been periodically monitored for hydrocarbon transformations and microbial activity, and to a lesser extent, nutrient cycling. A description of the black spruce forest research site starts on page 25.

In soil systems, microbes are ultimately responsible for nutrient cycling, and disruption of microbial communities will affect nutrient cycling into and out of any given ecosystem. "Until now, oil persistence has been hypothesized to be due to a suite of factors, including a lack of microbially available nitrogen required for metabolism, reproduction, and diversification of the hydrocarbon-degrading microbial community," Garron said. (See Sparrow & Sparrow, 1988; Lindstrom et al., 1999).

In 2004, shortly after Garron placed instrumentation at the spill site, she experienced one of the hazards of fieldwork, a major disruption of site conditions. "The plot and surrounding area were burned by wildfire, so I had to revise my research design and start over," she said. "Instead of studying oiled and unoiled soils, my soil samples now included oiled/burned soil, unoiled burned soil, and control plots." The samples were used to evaluate the effects of disturbance on nutrient cycling and soil bacterial communities.

"After fire in the surrounding boreal forest had burned itself out, the experimental oil spills continued to smolder for an additional two weeks. Once the smoking ceased, large amounts of oil were still visible at the sites. A later hydrocarbon analysis confirmed that large amounts of oil persisted after the fire," Garron said.

February 26, 1976: experimental crude oil spill in the Caribou-Poker Creeks Research Watershed. Two thousand gallons of hot Prudhoe Bay crude oil were applied through a 30-foot long perforated pipe, shown above.
—PHOTO BY TERRY MCFADDEN

Fire is a common disturbance in the boreal forest. For interior Alaska, large fires burn across the landscape at varying intensities, creating a mosaic pattern. In some places organic matter is entirely consumed, which exposes the mineral soil; elsewhere the fire may only singe the vegetation, and islands of green can be found after the fire has extinguished.

How fire affects nutrient cycling can also vary with these uneven burn patterns, ranging from drastic reductions in nutrient-cycling processes to almost no observable change. Concern that fire frequency may be increasing in the pan-subarctic boreal forest warrants a better understanding of ecosystem responses to such large-scale disturbance.

"The influence of disturbance on boreal forest mineral soils in general has been under-characterized, because most soil disturbance studies have focused on the organic layers, the apparent zone of greatest activity," said Garron. "But intensity of disturbances can render these carbon-rich organic layers functionally inoperable, so the ability of the mineral soil to process nutrients and provide substrate for soil system recovery is essential." A substrate is the base on which an organism lives.

Soil samples were collected August 3, 2004, approximately two weeks after the spill-site fire burned itself out. For each soil type, soil cores from the top ten centimeters of mineral soil were collected, pooled, and analyzed. Control soil samples (unburned and unoiled) were collected on the unburned side of the fire line, within the research watershed. Oiled/burned soil samples were collected from the winter oil spill plot, which had no organic layer remaining. Unoiled/burned soils were sampled from beneath the burned, intact, moss layer areas adjacent to the unburned control plot. Besides the scorched vegetation and organic matter, burn and control sites visually appeared to be similar to each other, except for differences in albedo following the fire.

Because the oiled soil continued to smolder for approximately two weeks after the fire in the surrounding unoiled area had burned itself out, Garron expected to find evidence of different fire effects in these samples than in the unoiled samples. The three soil types (oiled/burned, burned, and control) were subjected to a number of analyses to ascertain their specific responses to the oil and burning.

Total carbon and nitrogen content was measured, along with the carbon mineralization rate, and the net nitrogen mineralization rate following the fire. Nitrogen fixation was evaluated to determine if the oiled and burned site was still cycling nitrogen released during vegetation die-off immediately following the oil spill, and whether new nitrogen was entering the system.

"Assaying the response of the soil to these processes in burned but unoiled soils gave me an opportunity to distinguish those disturbance effects attributable to fire from those attributable to residual oil compounds," Garron said.

The nitrogen cycle

In air, soil, water, and living organisms, nitrogen appears in different forms, and the nitrogen cycle describes how these forms are interconnected. The nitrogen is never completely lost, rather it changes form and is held in different places (see figure 1). This cycle involves five major processes:

Through **ammonification**, organic nitrogen (nitrogen in proteins of dead plants and soil animals) is converted to ammonium (NH_4^+). Many different types of soil organisms (bacteria and fungi) carry out this process. From the breakdown of organic matter the organisms get carbon and energy, and nitrogen is released.

Through **nitrification**, the ammonium is converted to nitrite (NO_2^-) and then to nitrate (NO_3^-). A relatively small number of species in soil are involved in nitrification. They are autotrophic, getting energy from the chemical transformation of NH_4^+ to NO_2^-, while any needed carbon is obtained from CO_2. One group of organisms converts ammonium to nitrite; another group converts nitrite to nitrate.

Through **denitrification**, is the process where oxides of nitrogen (nitrate and nitrite) are converted into gaseous nitrogen and are removed from the soil system. Examples are the gas nitrous oxide (NO_2), and nitrogen gas (N_2), the most common form of nitrogen in the atmosphere. Many microorganism species are denitrifiers. This process mainly occurs when there is little or no oxygen in the soil, in waterlogged soil, for example. In this case, if the soil dries denitrification will stop.

Through **nitrogen fixation** nitrogen gas (N_2) is converted to ammonium (NH_4^+) by either free living bacteria in soil or water, or by bacteria in symbiotic association with plants (e.g., legume symbiosis).

Through **nitrogen immobilization** nitrogen is incorporated into microbial cells and is 'tied-up' in the microbial nitrogen pool; it occurs in parallel with ammonification.

Although there have been a few studies that incorporate the top few centimeters of mineral soil into their disturbance analysis, Garron found no published studies examining the role of diazotrophic nitrogen fixation in mineral soils of interior Alaska following disturbance. Diazotrophs are bacteria that fix atmospheric nitrogen gas into a more usable form such as ammonia; a diazotroph is able to grow without external sources of fixed nitrogen. She decided to examine the mineral soils at her chosen sites in part because they have received less research attention than have organic soils, but also because the organic layer in the oiled plot was nearly completely removed during the fire. The mineral soils contain carbon and nitrogen substrates that allow the persistence of specialized microbial communities that are less affected by the wide temperature and chemical fluctuations that occur in interior Alaska.

Garron explained that in interior Alaska the effects of wildland fire on carbon and nitrogen cycling of the mineral soil have been preliminarily established by scientific pioneers during the last century without the benefit of the applied environmental isotopic tracers and the molecular biological methods that are available to researchers today. Her research incorporated both modern experimental techniques and traditional ecological methods.

"Applying these newer techniques to fire-affected systems provides a unique scientific opportunity to study the nutrient-cycling activity of residual oil in the mineral soil matrix at our site and to document responses in unoiled soils," she said.

The experiment

Garron initially hypothesized that oil persists at the experimental spill site because nitrogen supply rates constrain oil degradation by microbes. She proposed to examine the nitrogen fixation potential of these soils to determine whether nitrogen inputs to the system are limiting nitrogen availability for oil degradation, or if nitrogen availability is more specifically tied to rates of nitrogen cycling within the system. "With this approach I hoped to reveal any nitrogen cycling bottlenecks in these soil systems," she said.

Garron found that available nitrate and ammonium levels were low in all soil types. In the control and burned soils there was net nitrogen mineralization, but in the oiled/burned soils there was significant nitrogen immobilization by the microbial community under laboratory incubation conditions.

The amount of nitrogen fixed in a five-day incubation was significantly different among the three soil types, and the greatest amount was fixed in the oiled/burned soil. Nitrogen fixation values in the control and burned soils were less than half of those observed in the oiled/burned soil, with a small but significantly greater amount of nitrogen fixation taking place in the control soil over the five-day incubation period. Total nitrogen concentrations in oiled/burned soils were over twofold higher than the concentrations of total nitrogen in control and burn soils; control and burn soil total nitrogen values were not significantly different from each other.

Garron also hypothesized that carbon mineralization rates are greater in oiled/burned and in burned soils than in control soils because available carbon is released with fire. Since total carbon was greater in oiled/burned soils due to the presence of residual oil, and because fire itself introduced new forms of carbon to the system, she examined if disturbance is reflected in carbon mineralization rates *in vitro*.

She found that carbon mineralization rates reflected total carbon values: oiled/burned samples respired approximately tenfold more carbon than either the control or burned soils. The control and burned soils' carbon mineralization rates were not significantly different from each other. However, the variability in the control samples throughout the incubation period was much higher than in the burn soils. "This may have masked any existing difference between these two soils," Garron said.

She also found that the ratio of carbon to nitrogen did not differ between the burn and control soils (19:1 in both cases), but was much greater in the burned/oiled samples (64:1).

Nutrient cycling conclusions

Garron's varied soil samples responded to the incubation conditions in different ways, and she suggests that these differences were due to different microbial responses to the three soil types.

"Total carbon, although apparently unaffected by fire in burned and control soils, was a good indicator of microbial mineralization potential," she said. "Mineral soils of oiled/burned samples had ten times more carbon than both control or burned soils and respired ten times more CO_2. Burned and control soils, with indistinguishable total carbon values, mineralized similar amounts of carbon, though we suspect that the form of organic matter used may have been altered by some of the fire effects."

Total nitrogen was also a good indicator of potential activity. The oiled/burned soil had the greatest total nitrogen and the greatest nitrogen-processing activity (high nitrogen-fixation rates and high immobilization), in contrast to the burned and control soils with the same relatively low total nitrogen and lower nitrogen-processing activities.

Oil, Flame, & Soil

One of Garron's research goals was to better understand the effects of nitrogen cycling in this oil- and fire-disturbed system. She analyzed soil samples for total available nitrogen, soil carbon and nitrogen mineralization potentials, nitrogen fixation potential (using 15N2), total bacterial diversity (16S rDNA), and functional genetic diversity (nifH). Her experiments showed that soil processes and microbial populations in black spruce soils did respond to perturbations (the crude oil spill and wildland fire). Her overall finding was that type of disturbance and length of time since disturbance affected both microbial function and diversity:

- **Inorganic nitrogen was low in all soil types.**
- **In control and burned soils there was net nitrogen mineralization.**
- **In oiled/burned soils there was significant nitrogen immobilization.**
- **Carbon mineralization was much higher in oiled/burned soils than control or burned soils.**
- **While the highest nitrogen fixation potential was measured in oiled/burned soils, the diversity of the nitrogen-fixing bacterial community in those soils was about the same as that of the control.**
- **For 16S rDNA, diversity was higher in control and burned soils than in oiled/burned soils.**

"Because the dominant carbon signature did not significantly shift with fire, and because mineralization rates were highest in oiled/burned soils, it is unlikely that carbon is limiting nitrogen fixation, oil degradation, or microbial metabolism in these oiled soils," Garron said. "The large amount of nitrogen fixed in oiled/burned soils indicates that the micro- and macro-nutrients required to support nitrogen fixation apparatuses are available in these soils. It also indicates that the microbial nitrogen demand is not being met by rates of nitrogen re-cycling within the system; in other words, N-limitation occurs in these soils. However, the large amount of nitrogen present in the oiled/burned soil matrix indicates there are additional limitations to oil degradation beyond nitrogen availability. We speculate oil degradation *in situ* may be directly limited by nitrogen supply, but also indirectly limited by either oxygen availability or perhaps oil residue recalcitrance."

The data collected in this study have begun to shed light upon the complex nutrient-cycling processes that occur in disturbed mineral soils of interior Alaska. Future landscape-level studies of these processes and their supportive microbial communities in mineral soil are important because disturbance due to fire and oil pollution are likely to increase in Alaska.

The community of nitrogen-fixing microbes

Fire is an important component in interior Alaska black spruce forest systems, which burn on average every eighty years. After fire these forests tend to return to black spruce, unless the fire was severe enough to remove all organic matter from the soil surface. Black spruce forests and their supporting soils are thus in a state of quasi-equilibrium either recovering from fire, or building up fuels for the next one.

Garron wanted to know whether, in highly disturbed soil systems, a few key genera are responsible for the functional response or are many taxa responsible? She hypothesized that oiling and burning of soils create environments that support lower microbial diversity. To address this hypothesis, she asked three questions:

What is the total bacterial diversity of the three soil types: oiled/burned, un-oiled burned, and control?

In these soil types, **what is the relative diversity of bacteria** that are able to fix nitrogen?

How is disturbance reflected in diversity of genes? Specifically, in highly disturbed soil systems are a few key genera responsible for the functional response, or are many taxa involved?

To examine the effect of crude oil and wildfire on the microbial diversity, Garron examined microbial population dynamics in her three types of soil samples. She performed phylogenetic analyses using the nifH (nitrogen-fixing) and 16S rDNA genes as well as Restriction Fragment Length Polymorphism (RFLP) analysis and Amplified Ribosomal DNA Restriction Analysis (ARDRA). The same assays were also performed on soil samples of the burned forest that had not been oiled and on control soil samples.

"We found that for 16S rDNA, control and burned soils had greater diversity than did oiled/burned soils. But for nifH genes, the greatest diversity was seen in the burned-only soils," Garron said. "Thus, the type of disturbance as well as the length of time since disturbance both appear to affect microbial diversity."

Some previous studies examined the microbial population using traditional culture-dependent techniques, wherein they found reduced microbial biomass in oiled soils ten years after the oiling event (Sparrow & Sparrow, 1988), which persisted twenty years after the oiling event (Lindstrom et al., 1999). Although a study twenty years after oiling examined substrate utilization patterns to estimate how oiling affected diversity of heterotrophs in the soils, detailed microbial community structure analysis was methodologically limited. A heterotroph is an organism that requires for metabolic synthesis complex organic coumpounds of nitrogen and carbon, as obtained from plant or animal matter.

The results from these previous studies indicated that oil may have persisted in the soils due to nitrogen limitation of hydrocarbon degradation (Sparrow & Sparrow, 1988), but there was limited information on how nitrogen cycling has been affected by the oil spill, or how the primary nitrogen-cycling microbial guilds themselves have been affected by the oil.

A microbial guild is a group of metabolically related organisms within a microbial community. The importance of microbial community composition in the soil matrix continues to be poorly understood. Schimel (1995) proposed that microbial community structure is of little consequence at the landscape level, but that specific microbes, and likely their supporting microbial community members, are crucial to processes carried out by physiologically or chemically restricted groups of microbes. How these specialist communities are parsed by disturbance is unclear.

Microbial biomass

In both oiled and unoiled samples, total fungal biomass was greatest in burned soils; oiled/burned soils had the greatest active fungal biomass. In contrast, total and active bacterial biomass was greatest in both of the unoiled soils (control soils and burned-only soils). Thus, the two different types of disturbance (oiling and fire) appear to have different effects on fungal and bacterial biomass. Total fungal biomass was stimulated by fire and perhaps also by oiling. In contrast, fire appeared to have little effect on bacterial biomass, while oiling greatly inhibited it.

"These microbial biomass values were unexpected, because previous studies of organic soils at these sites have shown fungal biomass to be greater than bacterial biomass," Garron said. "These discrepancies can be partially attributed to our study's use of mineral, rather than organic soils, but also to methodological limitations for determining biomass. In nutrient cycling assays also performed on these soils, the oiled/burned soil samples showed the greatest nitrogen fixation, which is a process known to be carried out only by specific bacterial guilds."

Garron found that the major ecological characteristics of the site's system (acidic soils, spruce forest) and disturbance (oil, fire) led to the presence of microbial community members found at other similarly defined sites from around the world.

"Our analyses revealed an acid-tolerant microbial community that shares attributes with organisms from other ecosystems similar to those in our study, including other spruce soils, post-fire soils and oiled soils," she said.

"The hypothesis that disturbance would reduce microbial community diversity relative to control soils, was somewhat supported by our data, and for the oiled/burned soils, was confirmed by ARDRA and RFLP data for both 16S rDNA and nifH. For bacterial clones from the burned soil samples, the apparent increased diversity in the functional gene signatures may suggest that in these systems there was a species expansion functional response strategy to natural disturbance that was repressed in oiled soils."

"Total bacterial community diversity is likely related to carbon substrate diversity and the bacterial community's ability to access that carbon," Garron said. "However, the nitrogen-fixing community may not only be a function of carbon availability; it may also be a function of the site's nitrogen limitations, increasing or decreasing functional demands on the nitrogen-fixing microbial community. Our data suggest that within these black spruce overlain mineral soils the microbial community employs specialized niche procurement as the key to both species and community survival."

System stability

An aspect of stability of an ecological system, sometimes called resiliency, can be described as its capacity to recover from disturbance. Long-term system stability is affected by short- and long-term nutrient cycling processes and the ecosystem response to those processes, which are largely controlled by the microbial consortia responsible for the cycling of nutrients through a given system.

System stability can be affected by ecological disturbances if they are severe enough to fundamentally alter the system's character. Disturbance causes a suite of changes that affect carbon availability, nutrient availability, temperature, albedo, and moisture. Microbial ability to access energy and mineral compounds immediately after disturbance will dictate the initial responses of the soil complex to that disturbance. These environmental changes can release bacteria from dormancy, increasing microbe-microbe competition for niche space, or enhance populations that have survived the disturbance, supporting a particular pattern of microbial dominance. Depending on the temporal and spatial distribution of microbes, different life strategies may be employed by the overall microbial community. Whether the post-disturbance nutrient pulse advances the populations of quick- or slow-growing microbes depends not only on the pulse itself, but on feedback loops initiated by the immediate post-disturbance environment.

"Sequencing of selected clones from oiled, oiled/burned, burned, and control soils indicated that many of our clones grouped with organisms from environments similar to ours," Garron said. "Since our soils were acidic, many of our clones grouped with known acidophiles, as one might expect. Many of our clones, particularly from control soils, grouped with organisms isolated from other coniferous forest soils. Also, several clones from our perturbed samples grouped with organisms from other perturbed sites. For example, clones from the oiled plot grouped with organisms from other hydrocarbon-contaminated sites (but not necessarily from forest soils), and clones from the burned plot grouped with organisms from other forest fire-affected soils."

Garron's research showed that at this interior Alaska site long-term oiled mineral soils were more affected by residual oil than by fire. This is supported by several findings: there was no evidence of pyrogenic compounds in the oiled samples; genetic patterns were consistent with established hydrocarbon degrading communities; and high rates of nutrient cycling. "I think these oiled soils will likely remain more affected by oil residues than by fire and other natural occurrences," she said.

"The genetic signatures of anaerobic microbes isolated from field samples and the high rates of respiration observed in our aerobic incubations indicate that oil may persist at this site in part due to nitrogen limitations; however, oxygen limitation to hydrocarbon degradation may also be significant and warrants further study."

Certainly, the persistence of oil from the experimental spills indicates the vulnerability of the widespread black spruce-permafrost environment to disturbances.

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For more on genetic tools and techniques, visit: www.microbeworld.org/microbes/tools_genetic.aspx

End of an era for experimental oil spill sites

by Jessica Garron

Risks associated with oil transport are well recognized, including those associated with the Trans-Alaska Pipeline, which carries crude oil about 800 miles overland from Alaska's North Slope to the Port of Valdez. During pipeline's construction in the 1970s, a number of studies examined how crude oil spills would affect Alaska ecosystems. One of these took place in the Caribou-Poker Creeks Research Watershed, about 32 miles northeast of Fairbanks. There, in 1976, researchers with the Cold Regions Research and Engineering Laboratory created two experimental oil spills to mimic a rupture in the Trans-Alaska Pipeline. Oil at pipeline temperature was applied in winter (February) and one summer (July). To date, no amendments or cleanup efforts have been applied to the site.

The oil was released on low-sloping hillside plots of open black-spruce forest underlain by permafrost. Common to interior Alaska, the understory was dominated by lichen and feather moss (*Peltigera* spp, *Cladonia* spp, and *Nephroma* spp). Other forest understory vegetation included resin birch (*Betula glandulosa* Michx.), low bush blueberry (*Vaccinium uliginosum*, L.), two forms of Labrador tea (*Ledum groenlandicum* (Oeder) Hult. and *Ledum decumbens* (Ait.) Hult.), and healthy tussocks dominated by cotton grass (*Eriophorum vaginatum* L.).

The undisturbed portion of the study area is underlain with discontinuous permafrost that ranges in annual thaw depth from 8–24 centimeters. The soils are typical of the Saulich Series. They were previously described as Histic Pergelic Cryaquept and reclassified in 2003 as Ruptic-Histic Aquiturbels The overlaying organic mat varied in thickness from 1.2–6.3 inches. Though these forests receive less than 16 inches of precipitation annually the mineral soils in this portion of the forest are very poorly drained and tend to be at or close to soil water saturation.

For each experimental spill, about 2,000 gallons of Prudhoe Bay crude oil, heated to the temperature at which it travels through the pipeline (~57°C), were released on a plot 11 by 55 yards in size. The effects of these spills on vegetation, microbial populations, ecosystem functional processes, permafrost deterioration, and hydrocarbon degradation have been examined in a number of studies, beginning immediately after the spill.

In the winter experimental spill, the crude oil was evenly released across the top 33 feet of a low-sloping (7–8 percent), west-facing portion of the forest. The spilled oil traveled vertically through the snow profile, then laterally, primarily flowing along the interface of snow and the frozen soil profile; in some areas the top few centimeters of mineral soil were also thawed. Horizontal movement of the oil reached 59 feet down slope during the first 24 hours, where it mostly remained until spring thaw, when it migrated down slope another 56 feet. Subsequent studies revealed increased seasonal thaw depths and the eventual melting of the underlying permafrost down to bedrock beneath these oiled soils, with oil thoroughly integrated into the mineral soil matrix.

Initial studies

During the years since the experimental spills, many scientists have visited and revisited these sites to answer research questions pertaining to the spills and their long-term ecosystem effects. The site has been periodically monitored for hydrocarbon transformations and microbial activity, and, to a lesser extent, nutrient cycling. From these studies it appears the soils may be nitrogen-limited, but there is little information on how nitrogen cycling has been affected by the oil spill, or how it will be altered over longer periods of time and by global climate change.

The first sets of post-spill studies included physical measurements of the oil spill extent, effects on black spruce forests and measurements of microbial populations in oiled and control plots. The microbial populations were counted using traditional enumeration methods (most probable number (MPN) and dilution plate count) on a variety of diagnostic substrates. In these microbial experiments, for samples from the oiled plots taken immediately after the spill and throughout the first growing season, bacterial counts showed a significant increase in the heterotrophic bacterial population; an opposite trend was observed in fungal propagules.

Soil respiration was measured *in situ* and *in vitro* (at 4°C and 20°C). Respiration rates were high in oiled soils compared to unoiled control soils during all seasons of the year, apparently a result of increased carbon from the oil itself, or from recently killed plants in the plot. The effect of oil stress on soil respiration rates in situ in this study was more variable than in laboratory incubations. The authors speculated that the observed rates were influenced at least partially by methodology, the freshly killed plant biomass introduced with the spill, and the spilled oil itself, the latter two providing a flush of labile carbon to the microbial population. It is noteworthy that this study was conducted immediately following the oil spill and throughout the following sampling year when the system was still in a state of flux in response to the spill.

The spill site after ten years

In 1986, Steve and Elena Sparrow of the School of Natural Resources and Agricultural Sciences observed no significant difference between the respiration rates of oiled and unoiled control soils when soil profiles were considered on a per-area basis in vitro (10°C, 7 d incubations, reported in g m-2 d-1). However, when separated into organic (O) horizons and mineral (C) horizons, there was two- to three-fold more CO_2 respired from the oiled mineral soils than from the control mineral soils, but no significant difference in samples from O layers. At that time the site was also surveyed for microbial biomass, ammonium-N, soluble nitrite-N and nitrate-N. Microbial biomass, determined with ATP (adenosine triphosphate) analysis, was lower in the oiled plots and attributed to a reduction in fungal biomass.

In subarctic soils, fungi are considered to be primarily responsible for organic matter decomposition; thus, a decrease in fungal biomass would have a significant effect on nutrient cycling processes. To quantify decomposition, both birch tongue depressors and enmeshed filter paper were placed in three different locations in the soil profile to measure annual rates of decomposition of lignin and cellulose, respectively. This experiment revealed healthy populations of decomposers in all levels of the control soil profile, but little cellulose and lignin decomposition in the oiled soils at all levels. Coupled with the greater rates of respiration of oiled mineral soils, it was evident that the microbial population was utilizing as a primary energy source the more-labile portion of hydrocarbon C.

The Sparrows found that nitrite and nitrate levels were extremely low in both spill plots and that most inorganic nitrogen, which was significantly higher in the oiled plot, was in field samples available as ammonium. They suggested that increased levels of ammonium in oiled soils were possibly due to freshly fixed dinitrogen (N_2 gas fixed from the atmosphere into a usable form—a very specific and limited process) or decomposition of wind-deposited black spruce forest litter, but were primarily attributable to the lack of an nitrogen-loss mechanism in the oiled system.

The spill site after twenty years

In 1994 and 1995 the spill sites were again examined for a number of ecological and microbial parameters. No significant differences in carbon mineralization rates were observed between oiled and unoiled control plots in vitro. Interestingly, rates varied throughout the active growing season in the unoiled control plot, whereas rates were relatively constant across the active growing season in the oiled plot. This indicates that the oil-plot microbes were using a more consistent C substrate, the residual oil, and that the unoiled control microbes were accessing more heterogeneous C substrates that varied with seasonal inputs, such as leaf litter and root exudates. This hypothesis was supported by the general substrate utilization patterns that were determined using Biolog GN microplates (Biolog Inc., Hayward, CA), and by the MPN 'Sheen Screen' technique for enumerating hydrocarbon degraders.

This study also reported no detectable net nitrification in the oil plot in 1994 and 1995, as compared with the unoiled control plot, where both nitrification and net ammonification were observed for incubations of one month at 15°C. The authors suggested that either the nitrifying community was either inhibited or nonexistent in the oiled soils, but most importantly, after twenty years, the differences between nitrogen cycling in the oiled soils compared to unoiled control soils persisted.

The spill site since 1995

The site was left untreated and twetny-five years after the spill there was only minimal recovery of the vegetation at the site, which included *Eriophorum vaginatum* and mosses, primarily located on the tussocks above the general soil surface. Before my research, the most recent study at the site was the Braddock study, which was conducted approximately twenty-five years after oiling, in 2001.

Jessica Garron taking a soil sample at the oil spill experiment site, July 2004.
—PHOTO BY JOAN BRADDOCK

Braddock's work focused on the relative condition of the oil compounds in the soil matrix and the various hydrocarbon degrading and heterotrophic microbial communities therein. Though significant photooxidation and biodegradation were observed in the upper soil profiles, deeper mineral soils harbored hydrocarbons with signatures not substantially different from the initial oil spilled, suggesting that degradation limitations are different in deeper soil profiles where oxygen and other essential nutrients may be limited and temperatures may be lower.

Culturable populations of crude oil emulsifying bacteria and total heterotrophic bacteria (requiring complex organic compounds of nitrogen and carbon for metabolic synthesis) remained elevated in oiled soils compared to unoiled control soils, indicating that under persistently oiled conditions a microbial population in oiled soils still acclimated for survival. All of the soil samples collected in the Braddock study had a portion of their photooxidizable or biodegradable hydrocarbons remaining, leading to the conclusion that the degradative processes active at the site would likely continue at these relatively slow rates for some years to come. This probably would have been the case had the oiled site not burned during the 2004 wildfire season.

Wildland fire and spilled oil: the site after 28 years

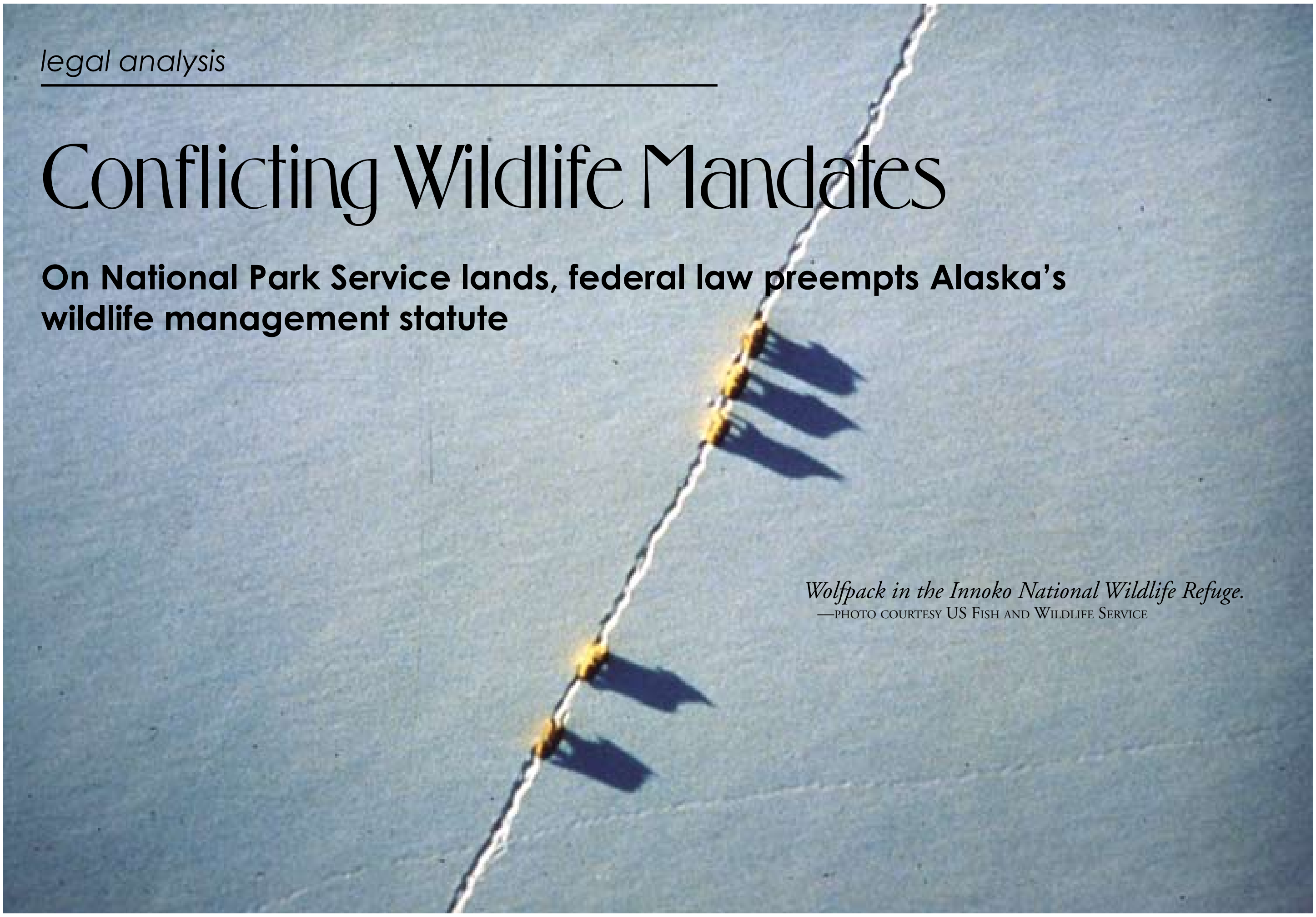
During the summer of 2004, as I prepared to conduct my master's thesis research at the spill sites, wildland fires consumed more than 2.5 million hectares of forests and wetlands in interior Alaska (Alaska Interagency Coordination Center [http://fire.ak.blm.gov/]). At the research watershed, to protect long-term experiments and neighboring communities, a prescribed burn (backing fire or backburn) was conducted to reduce fuel load available to the fire.

The fire-affected portion of the research watershed included the oil spill sites, effectively ending their status as undisturbed since the spill. The fire burned in a mosaic pattern, similar to other black spruce forest fires in interior Alaska. Across the landscape, varied fire intensity caused the forest floor to be completely consumed to mineral soil in some locations, while at others the forest floor was only scorched enough to kill the active moss layer in adjacent locations.

References available upon request.

Conflicting Wildlife Mandates

On National Park Service lands, federal law preempts Alaska's wildlife management statute



Wolfpack in the Innoko National Wildlife Refuge.
—PHOTO COURTESY US FISH AND WILDLIFE SERVICE

A new legal analysis finds that Alaska's wildlife management statute directly conflicts with the management mandates laid out by Congress in the National Park Service Organic Act and the Alaska National Interest Lands Conservation Act (ANILCA). It also explains why this type of conflict means that on federal lands, state law must give way to federal mandates.

"This conflict prevents the National Park Service from achieving the goals set out by Congress," said authors Julie Lurman* and Sanford Rabinowitch in a paper published in the December 2007 issue of the *Alaska Law Review*, "Preemption of State Wildlife Law in Alaska: where, when, and why." Lurman is an attorney and assistant professor of natural resources law and policy at SNRAS; Rabinowitch is a subsistence manager with the National Park Service in Alaska.

Since 1994, Alaska has managed wildlife in accordance with the intensive management principles laid out in Alaska Statute 16.05.255, which calls for maintaining artificially high levels of prey animals to meet the needs of all hunters in the state. The authors conclude that this goal is "incongruous to the goals of the Organic Act and the ANILCA," which are to maintain natural and healthy populations and processes.

"Our analysis shows that regulations enacted by the state to meet or further the goals of intensive management are, when they directly affect National Park Service lands, likely to discourage, complicate, or thwart the agency's ability to meet the goals Congress set forth when establishing the parks," Lurman said. "The stark differences in the animating legislation of the state and the National Park Service have led to misunderstandings on the part of both the hunting and conservation communities, as well as the management agencies themselves."

Because it is physically impossible to meet simultaneously the goals of the federal and state statutes, the authors argue that Alaska's statute, as well as other intensive management activities, is preempted on Park Service lands.

In *Hines v. Davidowitz,* the Supreme Court ruled that where the state's law stands as "an obstacle to the accomplishment and execution of the full purposes and objectives of Congress," it must be preempted.

"This is exactly the case before us in Alaska," Lurman said.

Although wildlife management is an area of law typically left to state control, the property clause of the U.S. Constitution gives the federal government the right to legislate concerning its land and the wildlife on it. Given their full effect, the property clause and the supremacy clause mean that federal laws must trump state law, even in the area of wildlife management, the authors argue.

"Our analysis does not imply that intensive management practices are philosophically bad or wrong," Lurman said. "The state has every right to manage wildlife for abundance of key species, and this practice does meet the needs and desires of many residents. But such management techniques and goals, while perfectly legitimate on state and private lands, are neither appropriate nor legal on Park Service lands, which are required to be managed for purposes other than maximized human consumptive uses. Reconciling these two disparate systems is not a matter of determining who is right and who is wrong; it is a matter of determining on which lands these practices are allowed by law and on which they are not."

The Lurman-Rabinowitch paper outlines federal mandates for wildlife management on Park Service lands in Alaska and describes Alaska's intensive management statute and related regulations. The authors also discuss the theory of preemption as a result of direct conflict, and describe how the criteria for preemption of state law based on a theory of direct conflict are met by the facts in the current situation in Alaska.

Wildlife Management and the National Park Service

For wildlife management on Park Service lands, guidance is provided by the legislation that created each park unit, which often carries detailed instructions regarding Congress' intentions for the specific land areas; overall guidance is provided to the agency by its enabling statute, the 1916 National Park Service Organic Act, as well as by the agency's interpretation of this statute, which was most recently stated in the 2006 Management Policies. The Organic Act tells the agency to: "conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations" (16 U.S.C. §1 (1916)). Over the years the courts have interpreted this somewhat vague statement to mean that the agency has broad discretion to make resource use decisions and to determine the proper balance between preservation and enjoyment.

"Particularly where wildlife is concerned, the agency initially applied this statutory language inconsistently, sometimes emphasizing preservation, sometimes emphasizing use and enjoyment," said Lurman. In the Park Service's early years, animals were exterminated to maintain peaceful scenes: "…Predators such as cougars, wolves, coyotes, lynx, bobcats, foxes, badgers, mink, weasels, fishers, otters, and martens were unnatural impairments to the natural grandeur that the Service sought to 'leave unimpaired.'"[1] In the late 1960s the Park Service implemented less intrusive techniques that allowed wildlife populations to fluctuate naturally. The 1978 Redwood National Park Expansion Act amended Park Service responsibilities and reaffirmed Congress' intention that agency actions be consistent with the conservation purpose of the parks. By the 1980s, Park Service policy had "evolved to emphasize maintenance of natural ecological processes as a means of managing native wildlife. The tradition of nonintervention in wildlife dynamics in U.S. national parks is an outgrowth of this policy."[2] This approach was formalized in a series of Management Policies, the latest being Management Policies 2006.[3]

The Management Policies direct managers to "adopt park resource preservation, development, and use management strategies that are intended to maintain the natural population fluctuations and processes that influence the dynamics of individual plant and animal populations, groups of plants and animal populations, and migratory animal populations." Only under unusual circumstances is this rule set aside for more active management.

Lurman and Rabinowitch report that the Park Service has a long history of court-supported preemption of state wildlife laws where those laws conflict with agency mission or regulations. "From its beginning, the NPS has maintained exclusive jurisdiction over the management of wildlife in parks. And, although legally contested by individual state game departments, court decisions have uniformly supported the right of the NPS to own and manage wildlife on its lands."[4]

The authors conclude that the Park Service clearly has the authority to regulate activities in park areas even where the regulations conflict with state regulations. Because wildlife management within the parks depends on Congress' statements at the time the land was set aside, the authors also discuss the relevant establishment legislation.

In 1980, ANILCA created or expanded nearly every park in Alaska and continues to be Congress' most detailed statement as to their proper management. It makes it lawful to take wildlife for subsistence purposes from most parks and all preserves in Alaska, and allows sport hunting in preserves. It also provides guidelines for responding to a decline of wildlife population numbers, requiring that subsistence hunting be given priority over sport hunting; if this measure is inadequate, the Federal Subsistence Board is then authorized to decrease even subsistence use of animal resources.

"The management mandate, as found in several sections of the statute, clearly can be summarized as requiring conservation of natural and healthy wildlife populations," Lurman said. "Intensive management techniques are inconsistent with the common understanding of the conservation of natural and healthy populations."

Although both the Organic Act and the ANILCA encourage Park Service cooperation with state and local agencies, there is no authorization of variance from statutory directives.

"Congress did not authorize cooperation with state law to the point of sacrificing the mandates expressed in ANILCA itself," Lurman said.

State Intensive Management of Wildlife

When the Alaska state legislature in 1994 amended the statute that directs

Bull moose in Chugach State Park: Alaska game management policy works toward maintaining artificially high levels of prey animals to meet the needs of all hunters in the state.
—Photo by Donna Dewhurst, courtesy US Fish and Wildlife Service

the State Board of Game on wildlife management, the amended law called for the "intensive management" of wildlife populations; the resulting statute directs the board to maintain, restore, or increase the abundance of big game prey populations for human consumptive use.

Lurman said that when prey population levels are not considered high enough to meet human consumptive needs, the law allows the state to respond by curbing harvest levels or taking other conservative measures only if managers simultaneously implement intensive management practices.

The statutory definition of intensive management is management of an identified big game prey population consistent with sustained yield through active management measures to enhance, extend, and develop the population to maintain high levels or provide for higher levels of human harvest, including control of predation and prescribed or planned use of fire and other habitat improvement techniques.

This definition, and the general statutory goals, promote high levels of human intervention in natural systems so that a high level of consistent human consumptive use can be achieved. The goal of intensive management is sustained yield, which the statute defines as "the achievement and maintenance in perpetuity of the ability to support a high level of human harvest of game, subject to preferences among beneficial uses, on an annual or periodic basis."

Under the regulations implementing this statute, the state uses the level of hunter demand for big game prey as one of four criteria for "identifying big game prey populations that are important for providing high levels of human consumptive use" (5 Alaska Admin. Code 92.106 (1) (D). State regulations require the Board of Game to "utilize active management of habitat and predation as the major tools to reverse any significant reduction in the allowable human harvest of the population" (5 Alaska Admin. Code 92.106 (1) and (6). The implementing regulations continue to underscore the human-centered, utilitarian goals of the statute and the high degree of manipulation of wildlife systems that is required in order to achieve those wildlife management goals. If a hunting quota cannot be met in a game management area, then intensive management methods must be put into place (Alaska Stat. § 16.05.255 (e)).

Along with predator control, which is generally not permitted on Park Service or U.S. Fish and Wildlife Service lands, intensive management includes such actions as increasing bag limits and liberalizing hunting seasons for predators to increase their harvest; eliminating the need for hunters to obtain or purchase hunting tags or permits for predators (thereby permitting the "incidental" taking of these animals); same-day airborne hunting and trapping which allow taking an animal on the same day one flies in an aircraft; allowing easier and greater use of motor vehicles while hunting to increase the hunter's advantage; expanding the allowable means and methods of hunting for predators, like baiting or feeding, thereby creating additional opportunities for taking; allowing the sale of raw hides and skulls thereby creating economic incentives for taking; and many others.

Such yearly changes to hunting regulations apply to all hunters within the game management unit (or sometimes statewide) on all lands, whether state or private, and most federal land, unless a specific exception is written into the regulations. These regulatory changes are not considered predator control activities (which may only be executed by those specifically permitted to do predator control).

"The intensive management statute not only affects Alaska Board of Game decisions once populations are in decline," Lurman said. "It is the state's wildlife management mandate in the same way that sections 802 and 815 of ANILCA and section 1 of the Organic Act form the management mandate for the National Park Service in Alaska. This means that all state wildlife management activities carried out by the Board of Game must be driven by the goals and directives of the statute or the board risks violating its legislatively prescribed responsibilities."

Intensive management actions also are carried out in areas other than those officially designated as Intensive

Management Areas, as are actions intended to promote prey species that are not officially recognized by the Intensive Management Statute.[5] "While these management practices don't directly result from the Intensive Management Statute, they still represent an intensive type of wildlife management designed to increase selected prey populations for the benefit of human hunters and to the detriment of natural ecosystem dynamics," Lurman said.

Preemption

After a substantial analysis, the authors conclude that, based on the Property Clause and the Supremacy Clause of the U.S. Constitution and various Supreme Court rulings, federal laws must trump state law even in the area of wildlife management.

A state statute may be preempted either because congressional legislation completely occupies a given field so that there is no room for state action, or because, although Congress left room for the state to legislate, the state's legislation directly conflicts with the federal statute. In the case of wildlife management on federal lands, Congress has not expressly preempted state law.

"These statutes are explicit that, in the absence of conflict, state law regarding wildlife management is to remain in effect or is at least to be given serious consideration, so it cannot be said that Congress intended the statutes to completely occupy the field of wildlife management," Lurman said. "But when state law and related regulations directly conflict with federal legislation and agency regulations, the state must give way when the federal statute is based on a legitimate constitutional authority like the property clause."

Laws such as the Organic Act and ANILCA are passed by Congress under the granted constitutional power of the Property Clause (U.S. Const. art. IV, § 3, cl. 2): "Congress shall have Power to dispose of and make all needful Rules and Regulations respecting the Territory or other Property belonging to the United States."

The landmark Supreme Court case describing the federal government's powers under the Property Clause, specifically as they relate to wildlife, is *Kleppe v. New Mexico* (426 U.S. 529 (1976)). The Kleppe Supreme Court stated: "In our view, the 'complete power' that Congress has over public lands necessarily includes the power to regulate and protect wildlife living there." (426 U.S. at 540-541). Therefore, according to the Court, Congress retains the power to enact legislation respecting federal lands pursuant to the Property Clause, and when Congress does enact such legislation, under the Supremacy Clause it "necessarily overrides conflicting state law" (426 U.S. at 543).

"When Congress exercises a granted power, concurrent conflicting state legislation may be challenged via the Preemption Doctrine."[6] In other words, state law must yield where it conflicts with federal law. The concept of preemption is derived from the Supremacy Clause of the Constitution (U.S. Const. art. VI, cl. 2), which requires that state laws that "interfere with, or are contrary to" federal law be invalidated: "This Constitution, and the Laws of the United States which shall be made in Pursuance thereof; and all Treaties made, or which shall be made, under the Authority of the United States, shall be the supreme Law of the Land; and the Judges in every state shall be bound thereby, any Thing in the Constitution or Laws of any State to the Contrary notwithstanding."

Lurman said that the conflict under consideration can be a subtle one, such as when a state law manifestly discourages the very acts or conduct that the federal law was meant to foster and encourage, or if the state law encourages conduct that, when absent, would aid in the implementation of the federal laws.

The Lurman-Rabinowitch analysis concludes that where Alaska wildlife management on Park Service lands is concerned, it is physically impossible to meet the goals of the federal and state statutes simultaneously, and they therefore conclude that Alaska's intensive management statute, as well as other intensive management activities not specifically carried out under the statute, are preempted.

"The idea that National Park Service mandates and regulations, under the Organic Act, may preempt conflicting state wildlife management laws is not a new one," Lurman said. "What our analysis clarifies is that Alaska's Intensive Management statute and the derivative regulations and policies meet the criteria for direct conflict with federal law and must be preempted in favor of wildlife management goals and techniques that are in line with congressional mandates for these federal lands. It is important to keep in mind that this conclusion is necessarily a very fact-specific one. A different state wildlife management regime might yield very different results."

Lurman also said that their conclusions do not support a shift in responsibility among federal and state managers or alter the balance of power, since Congress has never suggested that it would tolerate the co-existence of state laws that thwarted its own legislative intent.

During 2007, Lurman authored two other articles that have been accepted for publication: "Agencies in Limbo: Migratory Birds and Incidental Take by Federal Agencies," which will appear in the December 2007 issue of the *Journal of Land Use and Environmental Law*, and, with coauthor Martin Robards, "Interpretation of 'Wasteful Manner' within the Marine Mammal Protection Act and its Role in Management of the Pacific Walrus," which will appear in the spring 2008 issue of the *Ocean and Coastal Law Journal.*

—Adapted by Doreen Fitzgerald from the article that appeared in Alaska Law Review

Endnotes

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Note: for the complete citations for this analysis, see Julie Lurman and Sanford Rabinowitch, "Preemption of State Wildlife

Brown bear cubs playing at Kodiak National Wildlife Refuge.
—photo by Steve Hillebrand, courtesty US Fish and Wildlife Service

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Agriculture 100 Years Ago: the Search for Self-Sufficiency

excerpts from *Like A Tree to the Soil: a history of farming in Alaska's Tanana Valley, 1903 to 1940*, by Josephine E. Papp and Josie A. Phillips

The Flouring Mill

The Tanana Valley Agriculture Association was being watched. A group of curious dealers from California and Pacific Coast Grain and Feed visited Fairbanks the summer of 1917 for a look at Interior agriculture. That October, the TVAA sent a display to Seattle to be exhibited for ten days at the Northwest Land Products Exposition. The display created so much interest at that location that it was moved to the Second Avenue window of the Bon Marché.

Various local businesses continued to import farm equipment. The N.C. Company had sold a record number of breaking plows in 1916 and far more in 1917. E.R. Peoples advertised wing plows and "northern" potato diggers. Samson Hardware Company provided agricultural equipment and parts. These suppliers provided estimates for customers interested in certain pieces of equipment or parts. The experiment station purchased a new threshing machine with a 21-inch cylinder. Included in the 1917 order was an 8-horsepower 8-16 Mogul tractor, which ran on kerosene, gasoline, or a distillate, and in turn ran the thresher. The thresher had a capacity and horsepower to handle forty to sixty bushels of oats or fifteen to thirty bushels of wheat an hour. There were four self binders in the valley in 1917. Potato crates cost the grower twenty-five cents each, a whole grain sack cost seven cents and a patched grain sack cost five cents.

In 1919 TVAA talked of purchasing a 45-horsepower tractor for members to use when clearing land. There is no record that a tractor was acquired. Do-it-yourself clearing land ready for the breaking plow was heavy, tiring labor. Timber cut and hauled away as cordwood put a few coins in the trouser pockets, yet roots remained to be pulled loose, moved, piled and burned—a long and costly job. Horses were used to drag timber and stumps off the new field. It would be another forty years before crawlers or bulldozers would routinely be used to clear land.

A notice in the *[Fairbanks Daily] News-Miner* September 22, 1917 surely quickened the heart when farmers read it. "Farmers Attention—Steamer Jacob due September 23 will get potatoes contracted from TVAA. The following bring potatoes—Henry Riddle, Charles Miller, J.W. Wiest, T.H. White, W.P. Borden, Charles Des Jardin [sic: Desjardins], J.E. Williams, P.J. Rickert and P.A. Nelson." The potatoes were subsequently delivered to Fort Gibbon, located at the confluence of the Tanana and Yukon rivers. For the first time the association brought money home and into the pockets of the growers. They earned $100 per ton.

Prices in 1917 were said to be "exceedingly high" according to an Alaska Engineering Commission publication cited in the *News-Miner.* Farmers were getting $80 to $200 per ton for potatoes depending on demand. Hay cost $80 to $150 per ton. The report noted that there was a stable and ready market for farmers in the Interior, adding that farming in the Tanana Valley was ahead of other areas in the Territory and that the climate allowed both grain and vegetables to mature.

…The Fairbanks station acquired a flouring mill after [Fairbanks Agricultural Experiment Station Superintendent] Snodgrass arrived. It was capable of grinding 400 pounds of grain an hour. Due to the coarseness of the grind, Snodgrass was not satisfied with the mill. TVAA began discussion of acquiring its own flouring mill. The organization entrusted Superintendent Snodgrass to be their spokesperson. He was given authority to purchase and make arrangements pertaining to the purchase, shipping, and installation of a flouring mill. TVAA was taking a big agricultural step that would benefit the people of the Interior.

As the First World War approached, most of the stampeders-turned-farmers were too old to serve in the military. Many men left Alaska when the United States entered the war on February 28, 1917, but few of them were farmers.

Months before the declaration of war, Fairbanksans were being advised by the Federal Administration of the Interior about food restrictions. For example, Tuesday was to be a meatless day. One meal each day was to be meatless as well. Two days were to be porkless and one day a week was to be wheatless. Recipes for oatmeal bread were offered in the newspapers as part of the nationwide effort to provide food for the war effort. Cornmeal recipes were printed to encourage the saving of wheat by housewives under a Wheat Conservation Program.

Spring was late coming in 1918. The second week of May there were still two feet of snow on the ground. The previous year, potatoes and grain had been planted by that date. Breakup came fast and the Chena River rose rapidly. High water cut the bank shouldering the old Anderson greenhouse on Garden Island in Fairbanks and washed it away.

Mid-June 1918 the farmers were making plans for a flouring mill and a sugar beet factory. Each TVAA farmer was to plant 100 pounds of wheat seed. They were also to plant sugar beets, a crop Wickersham encouraged. The Matanuska and Susitna Valley farmers had also planted grain as well as potatoes, although the year before potatoes had been their only crop.

Grain in general, and wheat in particular, had the attention of TVAA members. A flouring mill in Fairbanks was pertinent and progressive. Magnus Nelson grew grain on his forty acres of homesteaded land on the Fox Road. He bought a small mill to make his own flour from the wheat he grew—the first in the Interior. TVAA member James Wiest bought a small twelve-horsepower motor mill which arrived on one of the last boats before freeze-up. Wiest set it up in H.C. Davis' sash and door factory on Garden Island. That November, William Borden's wheat was the first grain to be ground in the mill. The mill at the experiment station was larger than James Weist's mill. The station's mill, which Superintendent Snodgrass found too coarse, ground graham or whole grain flour. The average yield of wheat at the station was 18 bushels to the acre and it sold for $1.20 per bushel. The local market was said to have sold 186 tons of soft white flour in 1918. The end of summer brought the realization to TVAA members that there had been two successful seasons, 1917 and 1918. It had been profitable. The Alaska Engineering Commission alone had paid TVAA $8,000 for vegetables delivered to them.

…*News-Miner* editor Thompson continued to write of the need for local businesses to support farming, arguing that the 1918 import of $700,000 of food from Outside could have instead been raised in the Tanana Valley. The farmers agreed that they could grow the amount imported, but they were in a bind for cleared land and the money necessary to clear the land. These unresolved problems would continue to haunt the aging farmers.

As an act of appreciation to the businessmen who had faithfully and strongly supported the TVAA, a January dinner was planned for them. Everything on the menu would be Alaska grown except the sugar and cigars. Serious discussion followed the dinner. The Farmers Bank had closed in the fall of 1919. Judge Bunnell talked about the Farmers Loan Bank. W.F. Thompson hashed over the merits of a dehydrating plant—an idea he promoted. He offered to write letters in order to find a structure suitable to house both a flouring mill and a dehydrating plant. The dehydrating plant was an interesting and novel idea in 1919. All the locally grown vegetables could be processed; there would be no loss for the producer due to overproduction or a poor market. Dried vegetables could be available through the winter locally or along the many trails of woodcutters, trappers, roadhouse operators, or snowbound cabin dwellers.

Through the years Thompson's input was one of TVAA's best assets. He gave the farmers courage to dream of what could be. His hope of families on the homestead, the idea of a sugar beet factory, flouring mill, or dehydrating plant all came from his clear objective—a thriving agricultural industry in the Tanana Valley.

The first president of the Tanana Valley Agriculture Association, P.J. Rickert, was another dynamic and tenacious man, as well as an excellent grower. Leaving his wife Stacia to run the farm, Rickert spent the winter of 1917–1918 Outside. Before leaving he gave the newspaper an outline of four goals, the accomplishment of which would benefit the TVAA. Farm loans for Alaska farmers were of utmost importance. Rickert saw so much potential; he knew the men wished to make the effort, but they had few financial resources with which to accomplish their plans. The purchase of modern farm equipment for TVAA was on his list, as was finding better seed suitable for the northern climate. Last, he wanted information and assistance on growing crops. When he returned, he said the one thing he did find was the "talk of war everywhere Outside."

After Rickert returned to Fairbanks, he became a very vocal and strong force for the College of Agriculture and Mining. He spent a year as a delegate to the legislature working toward a land-grant college. A September 4, 1922 *News-Miner* article mentions Rickert as a member of the board of regents of Alaska Agricultural College.

…The demand for seed was tremendous the spring of 1920. Superintendent Snodgrass reported that all the grain raised in 1919 could be used for seed in 1920, such was the demand for wheat seed.

…It was a good summer for hay. Wagonloads of hay were brought to town to be weighed on the N.C. Company scales; from there they then went into the TVAA warehouse for storage. Some farmers drove their loads out to mining claims where they easily sold the hay. The association was disappointed when farmers from the Hot Springs made better offers on the sale price of some produce going to the Alaska Engineering Commission and to Fort Gibbon. The year ended with sixty farmers attending their members-only meeting; the TVAA stated up front that there was "no room for back yard farmers" at the gathering. The TVAA estimate of grain harvested in 1920 was 3,000 bushels. The Engineering Commission had bought cabbage, potatoes, and other vegetables. One hundred tons of potatoes had been sent to Nenana on the railroad from the Garden Island warehouse.

Bottle cap from Bentley's Dairy: "Pure Sanitary Milk From Contented Cows."
—PERSONAL COLLECTION OF JO PAPP

Below is a representative biographical entry for one of the many people who contributed to agriculture in the Tanana Valley. The authors of *Like A Tree to the Soil* included more than 300 farmers, greenhouse operators, drovers, and other agriculture-related professionals in their book.

Badger, Harry Markley

Born: November 19, 1869
Died: October 14, 1965 (age 96);
buried at Alaska Pioneer Cemetery, Sitka

Harry Badger was born just two years after the United States purchased Alaska from Russia, on November 19, 1869, in Wyoming, Montana (then named Sunrise), near the spot where General A. Custer and his 276 soldiers were killed in 1876. He remembered the Indian massacre because at the time many of the women and children in the area moved to St. Paul, Minnesota, until the uprising cooled off. He was raised on a farm and attended public school until his sixteenth birthday. For the following three years he worked in the pine woods of his native state, farming and clerking in a store.

Badger went to California in 1889 and to Washington the following year. There, he purchased a tract of land in the fertile Skagit Valley and planted an orchard. He remained there for ten years. In 1900, the call of the North took him to Skagway and over the White Pass to Dawson in the Yukon Territory. It took him forty days to make the trip from Skagway, dragging his sled by hand and living in a tent even as the temperature dropped to 60° below zero.

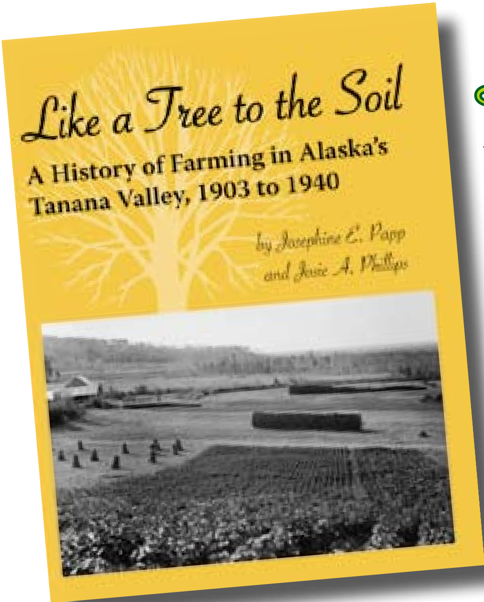
The next three years were spent mining on Bonanza Creek. When Jujiro Wada, a Japanese adventurerer, prospector, and then-cook in the employ of E.T. Barnette, brought the news of a rich gold strike in the Tanana Valley, Badger hit the trail again. He reached what is now Fairbanks in March of 1903. At that time, the place was mostly wilderness interrupted by a few log shacks. When he arrived, Badger was disappointed to hear the latest rumors circulating in the growing camp—namely that the strike had been a fake. Some of the stampeders organized a meeting—the first miner's meeting ever held in the Tanana Valley—and Badger was selected to preside over the gathering. Serious plans were considered to punish Wada for having spread false rumors and thereby exacerbating the hardships endured by the miners. However, an agreement was reached with storeowner E.T. Barnette that allowed the stampeders to purchase much-needed supplies at greatly reduce prices until serious prospecting could yield real results.

Soon after arriving in Fairbanks, Badger walked to Cleary Creek, twenty-six miles north of the settlement. He asked a miner there if he had found any gold and was told that it was none of his business—which, of course, told Badger that the possibilities of a person finding rich ground must be pretty good.

By 1904 gold was discovered in paying quantities on several creeks in the area. Seeing an opportunity, Badger opened up the first real estate office in the Tanana Valley. That same year he was elected town recorder for Fairbanks, and found himself parceling out lots for $2.50 each.

In 1916 Badger began homesteading on what is now Badger Road, eleven miles from Fairbanks. His buildings were located on the banks of Pile Driver Slough. He believed strongly in the agricultural potential of the Fairbanks district and served for a time as president of the Tanana Valley Association.

Badger considered soils consisting mostly of clay silt to be especially favorable to strawberry plants; in other soils they seemed to be more likely to get frozen out during the winter. He excelled in growing strawberries and three or more distinct types of fruit



Like a Tree to the Soil

A History of Farming in Alaska's Tanana Valley, 1906 to 1940

by Josephine E. Papp and Josie A. Phillips. Published by SNRAS. Book available from the Georgeson Botanical Garden, www.uaf.edu/gbg/, 907.474.5651

The men and women who came north to Alaska's great wilderness for gold, furs, and adventure had one thing in common, no matter their origin or their purpose: they all had to eat. Along with the miners and trappers came farmers and dairymen, people whose dream was a homestead and the joys of growing good food. Getting enough to eat could be a struggle in the heart of winter, but early Fairbanks farmers, gardeners, and greenhouse operators rose to the challenge, making the Tanana Valley almost self-sufficient in crop production. Their work a century ago can provide insight to today's movement toward creating sustainable agriculture in the circumpolar north. This book, written by two Fairbanks-area farm women, records the names and lives of the many unrecognized agricultural pioneers of the Tanana Valley. Family photos, photographs from Alaska library archives collections, interviews with pioneer farmers, and excerpts from their writings complement information gleaned from the newspapers of the day and reports from the United States Department of Agriculture.

bear the name Badger Berry. Badger was known as the Strawberry King of Alaska and his farm became known as the Farthest North Strawberry Ranch.

The Pioneers of Alaska Igloo #4 had their one of their annual strawberry feasts on August 4, 1936. Members from many farms and camps gathered for the occasion. Badger enthusiastically demonstrated to the crowd that the finest of all berries and fruits could be cultivated in the north. There were Pioneers present who claimed that at one time, famished on the trail, they would have traded a pan of gold for a dish of strawberries.

By 1938 Harry Badger planned to step up production by doubling his acreage from two to four acres of John Scharle strawberries. That August ten percent of his crop was ruined by heavy rains that battered his plants. The previous year he had had an excellent crop—300 crates, each consisting of twenty-four boxes.

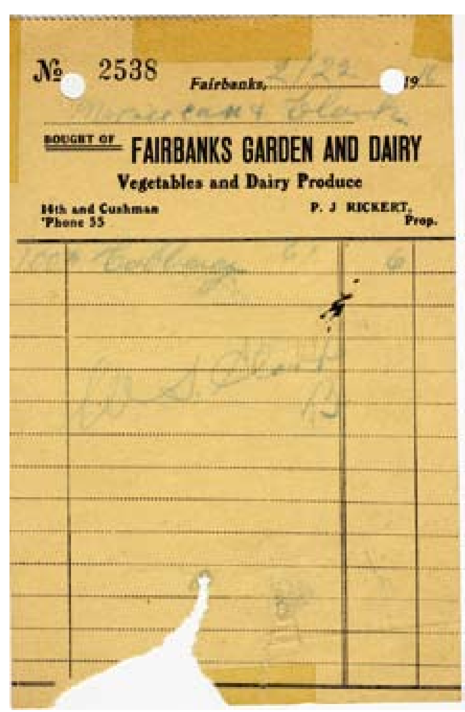
Besides strawberries, Badger also grew Potlatch peas, beets, carrots, and turnips. He raised raspberries for sale as well. Also, a large part of his farm was devoted to raising brome grass for hay.

On his 160-acre homestead, Badger grew fully matured wheat twenty-six out of the twenty-eight years he farmed. The two failures (1922 and 1933) he attributed to "sun spot" years. Another observation he made was that one could not expect warm weather until the sandhill cranes appeared, and one could start looking for frost soon after they left. In the spring, ducks on their northward migration would land on his strawberry fields, and Badger liked to feed them. One year when the water in the river was extremely high, he reported that the ducks would swim into his barn and help themselves to his grain sacks.

Badger served a term in the Territorial legislature in 1945. He said there were thousands of acres of land in the Tanana Valley well suited to diverse feed farming. With twenty-four hours of sunlight for almost sixty days of the year and an average of 90 to 100 frost-free days during the growing season, interior Alaska had a huge potential for agricultural production.

Badger continued to live on his homestead until the 1960s, when he entered the Pioneer Home in Sitka. When he died in 1965, funeral services were held in Sitka.

Bottle cap from Creamer's Dairy.
—PERSONAL COLLECTION OF JO PAPP



Sales ticket from P.J. Rickert's Fairbanks Garden and Dairy, dated February 22, 1910, for 100 pounds of cabbage.
—PERSONAL COLLECTION OF JO PAPP

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A new legal analysis concludes that it is physically impossible to meet the management goals of both the federal government and those of the state of Alaska on Park Service lands. See story on p. 28.
—photo courtesy US Fish & Wildlife Service