The Muskox

a new northern farm animal

research on muskoxen at the University of Alaska is providing insight into their domestication and care, and aiding the development of a textile industry

Deirdre Helfferich

Muskoxen at Windy Valley Muskox in the Matanuska Valley, one of the three commercial muskox farms.
—PHOTO COURTESY JOHN AND DIANNE NASH

Muskoxen, large shaggy ruminants of the Arctic, are best known for their soft underwool, or qiviut. But the muskox has economic potential for a variety of products: meat, wool, horn, pelts. Muskox meat, for example, is described by the Nunavut Development Corporation as "a gourmet delicacy that offers a natural alternative to beef.… Muskox is an excellent source of protein, iron and vitamin B. The well marbled meat is much leaner than pork or beef (1-2% verses 12-20%) and subsequently has fewer calories. It also has 5% more moisture than beef making it very tender and flavourful."

In Canada and Alaska, controlled hunts limit the number of wild animals that may taken, so the meat is rarely offered in restaurants and tends to be very expensive. Qiviut is highly prized, rare,

Muskox calf at the Robert G. White Large Animal Research Station, about three weeks old.
—PHOTO BY CHRIS TERZI

and expensive. Yet domestication and commercial production of muskoxen may make the currently rare products of this northern beast better known and more accessible. According to the Robert G. White Large Animal Research Station (LARS) website,

> Given the strong demand for muskox products and the limited supply of animals, there is potential for the muskox industry in Alaska. Business success will depend on calf survival (>70-80%), herd management (e.g. herd size and harvest), and the reliable supply of forages (grass hay and/or pasture) and formulated feeds. This is no different than the parameters for succeeding in other diversified animal enterprises.

Wild muskoxen on Banks Island.
—PHOTO COURTESY MIKE DNEGA, WWW.OILONICE.ORG

Alaska is one of the few places in the world that produce commercial quantities of qiviut. Canada also produces qiviut, but, unlike that from Alaska, where the animals are farmed, most of it comes from animals taken in controlled hunts overseen by the government, which produce horn, meat, pelts, and qiviut. Qiviut is among the softest, finest, and longest of animal fibers, does not shrink, and is about eight times as warm as sheep wool. The underwool, or down, can keep a muskox warm at temperatures down to -100°F.

Muskoxen are related to the goats and sheep, but are in their own tribe, *Ovibovini* (sheep and goats are in *Caprini*). Their common name is a misnomer, as they are not oxen. Although they do have facial scent glands near the eyes, they do not produce musk. Male muskoxen can be pungent (mostly from their urine, and particularly during the rut), but not as much as, say, male goats. Muskoxen are found in the Arctic in Alaska, Canada, Greenland, where they are native, and in Norway and Siberia. They are herd animals, gathering in groups of thirty or so in the winter, thinning out to smaller groups of around five to ten in the summer. They are also quite large: adults stand about 1.4 m (4.6 ft) high at the shoulder and

Calf following its mother at the Robert G. White Large Animal Research Station (LARS).
—PHOTO BY C. TERZY

weigh about 280 kg (~620 lbs) for adult bulls, 180 kg (~400 lbs) for adult cows in the wild, with captive animals sometimes getting as large as 400 kg (~880 lbs) or more.

"The largest bull I've seen was actually over 1,000 pounds!" said Milan Shipka, associate professor of animal science at the School of Natural Resources and Agricultural Sciences and large animal specialist for the Alaska Cooperative Extension Service. Muskoxen are known for their distinctive defensive behavior, in which they form a line or ring, adults outermost to face the danger. Unfortunately, this stand-and-face-the-music defense is no protection from human hunters armed with projectile weapons, and makes them easy targets. Hunted to extinction in most of their range, Canadian and Greenlandic muskoxen were exported in the mid-twentieth century to repopulate the species in other areas in what was a successful reintroduction to their original range. Muskoxen are now considered to be at low risk of endangerment from extinction.

An adult musk ox can produce four to seven pounds of qiviut a year. The average sheep produces about eight pounds of wool per year, but some breeds produce as much as thirty pounds annually per animal. Although muskoxen are larger than domestic sheep, they are not domesticated and hence not bred for wool production. The muskox is still a wild animal; domestication, which takes many generations, was only undertaken in the latter half of the twentieth century. (Most agricultural animals have been domesticated for thousands of years; for example, sheep were among the first animals to be domesticated, about 10,000 years ago in Mesopotamia.) At LARS, however, there is a program of domestication of muskoxen that has been underway for fifty years. John Teal, Jr., an anthropologist, founded a small herd in Alaska, where they had been hunted to extinction, from animals captured in Canada. He began the domestication project in 1954 and established the muskox farm with the University of Alaska in 1964.

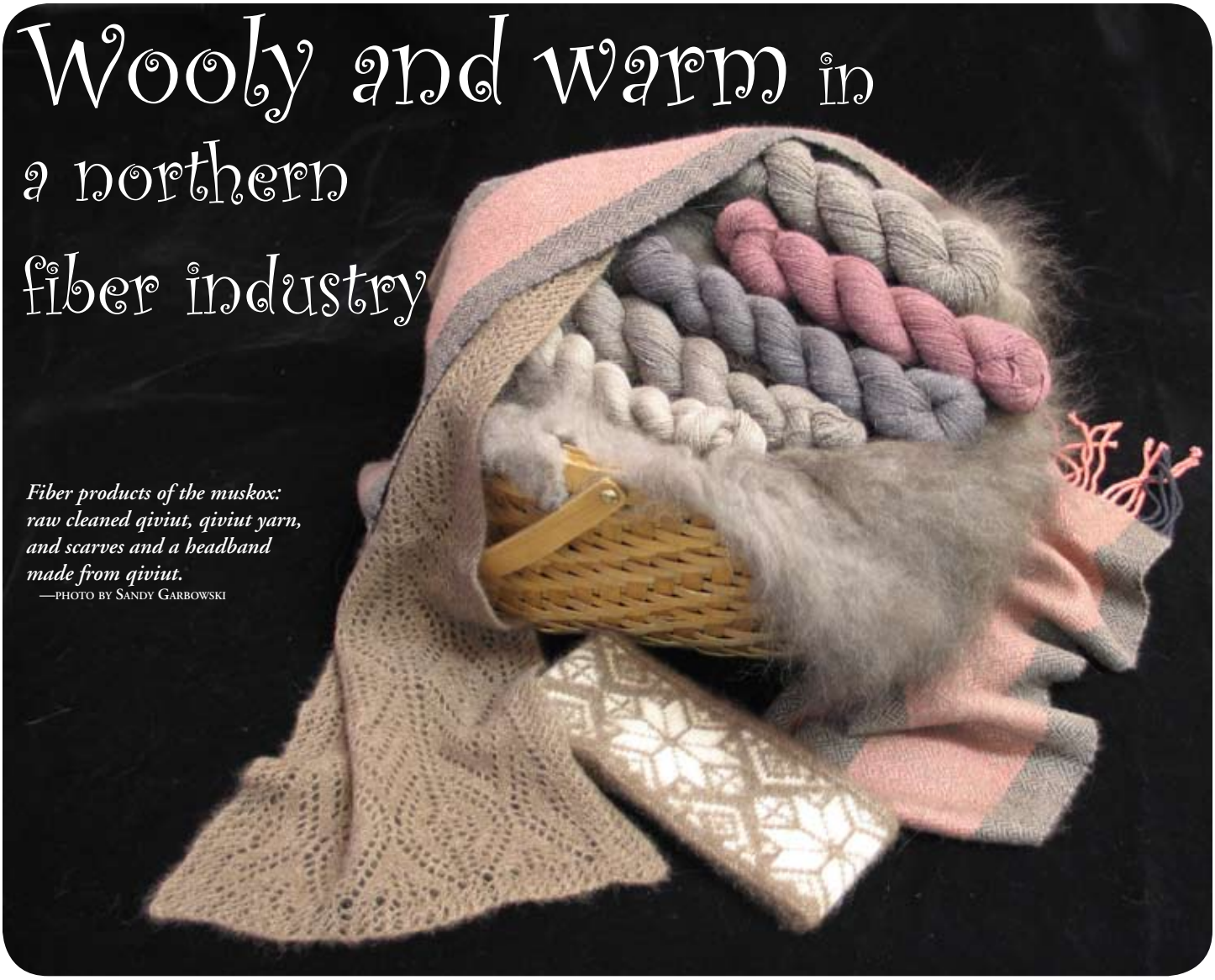
> Teal's philosophy in domesticating the muskox was that the domesticated animals and plants of each of the world's major biogeographical zones should be selected from among the indigenous species of those areas, rather than continuing the often unsuccessful attempts of preceding millennia to transplant a few traditional domesticates to every corner of the globe.[1]

Starting with thirty-three animals (ten males and twenty-three females) captured from Nunivak Island in 1964 and 1965, the herd had grown to 100 by 1976. Differences in vision between the university and Teal over the herd's purpose and the conduct of the project had developed during this time, and led to a parting of ways for Teal and university researchers. Teal's original domestication project is now independent of the university, having formed a nonprofit private organization in 1986, the Musk Ox Development Corporation, and relocated to the Matanuska Valley near Palmer. Qiviut from this farm and from LARS is provided to knitters in the Oomingmak Musk Ox Producers' Co-Operative, and to other spinners and weavers around the state. (The word "oomingmak" is derived from an Inuit word for muskox that translates roughly as "the bearded one.") The Musk Ox Development Corporation "is dedicated to the development and domestication" of the muskox, focusing on the creation of "a gentle, non-intrusive form of agriculture to the Arctic," with the specific purpose of developing a qiviut industry for Alaska Natives. Scientific study of muskoxen continues at the Institute of Arctic Biology (IAB) and LARS, with emphasis on muskox husbandry and genetics.

Reproduction management, disease management, nutrition, and calf survival are areas that need further study in muskoxen. For example, muskox calves have a high mortality rate, but researchers are still striving to understand the reasons why. Progress is being made, however: in 2001, University of Alaska Fairbanks researchers Perry Barboza (IAB) and John Blake (Biology and Wildlife Department), developed and licensed a muskox food for captive herds in Alaska, which has addressed some of their nutritional needs when in captivity.

Such studies in nutrition, genetics, reproduction, and other areas improve the chances that muskoxen will eventually become a viable domestic animal, and that the valuable products of the Bearded One will become a regular part of Alaska's economy.

Wooly and warm in a northern fiber industry



Fiber products of the muskox: raw cleaned qiviut, qiviut yarn, and scarves and a headband made from qiviut.
—PHOTO BY SANDY GARBOWSKI

When I was a child, my parents would, in summertime, frequently take me to visit what I knew as the Muskox Farm on Yankovich Road, north of the University of Alaska Fairbanks campus. This farm became the Robert G. White Large Animal Research Station. I loved to watch these big, longhaired relatives of sheep and goats—from a safe distance, that is—and would importune my parents to drive by the farm on the way home in the hope that I might get a glimpse of the animals. Forty years later, small children still delight in the great hairy beasts that roam the fields of the station, and now visitors can go on guided tours of the animal enclosures there from June to September to learn more about the natural history of the caribou, muskoxen, and reindeer kept on the grounds. Researchers at the Institute of Arctic Biology and the School of Natural Resources and Agricultural Sciences have delved into the biology and behavior of muskoxen, discovering many things about the reproduction, nutrition, and husbandry of these animals.

Sustainable agriculture and muskox

Muskoxen, although undomesticated, are at the forefront of the movement toward sustainable northern agriculture. Human beings have long used animals and plants originally native to equatorial and Mediterranean climes, adapting them to more extreme environments as they moved outward from these areas into Asia, the Americas, and the polar regions. For many animals that evolved in tropical and temperate zones (sheep, cattle, goats, horses), the move to subarctic and arctic climes has been difficult, and has required special housing and other accommodations, adding to the expense of their husbandry. Alaska has depended on subsistence and transport of food from lower latitudes to maintain its population, and has never been agriculturally self-sufficient. In modern times, it has simply been easier and less expensive to ship food and other agricultural goods from lower latitudes than to support the development of local agriculture that is independent of the industry elsewhere. However, the hidden costs of expending the energy to raise food and agricultural goods in one place and ship them thousands of miles to where they are consumed are becoming untenable socially, environmentally, and politically, and have given rise to concerns for the long-term sustainability of our

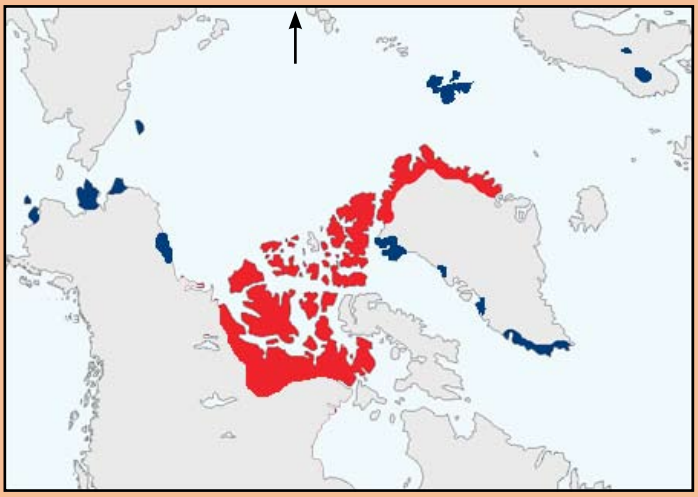
Sustainable agriculture policy in North America

In 1988 Congress established the Sustainable Agriculture Research and Education program, or SARE, part of the Cooperative State Research, Education, and Extension Service, to promote and research ecologically sound agricultural practices. One program goal is to help farmers and ranchers increase their profits while lessening the environmental impact of their agriculture, and to strengthen communities. The program provides information to researchers, educators, farmers, and consumers, and offers competitive grants for sustainable agriculture research and education.

Congress defines sustainable agriculture as "an integrated system of plant and animal production practices having a site-specific application that will, over the long term:

1. satisfy human food and fiber needs;
2. enhance environmental quality and the natural resource base upon which the agricultural economy depends;
3. make the most efficient use of nonrenewable resources and on-farm resources and integrate, where appropriate, natural biological cycles and controls;
4. sustain the economic viability of farm operations; and enhance the quality of life for farmers and society as a whole."[1]

Mother and baby at LARS.
—PHOTO BY JAN E. ROWELL



The map shows the distribution of wild muskoxen. The red shows the "original" distribution of muskoxen (at the beginning of the nineteenth century, after their decimation by hunting and other factors). The blue shows the areas where muskoxen have been reintroduced with success in the twentieth century. A small population has also been introduced successfully on the Taimyr Peninsula in Siberia (arrow, landmass not shown on map).

— MAP COURTESY WIKIMEDIA USER MASAE, 2007; MODIFIED BY D. HELFFERICH

The Canadian government also is supporting sustainable development, which "integrates environmental, economic, and social interests in a way that allows today's needs to be met without compromising the ability of future generations to meet theirs." Similar to the description above, in Canada the government has outlined four key points defining sustainable agriculture:

- [It] protects the natural resource base; prevents the degradation of soil, water, and air quality; and conserves biodiversity
- contributes to the economic and social well-being of all Canadians
- ensures a safe and high-quality supply of agricultural products
- safeguards the livelihood and well-being of agricultural and agri-food businesses, workers and their families."[2]

Thus, a sustainable agriculture would depend on native plants and animals where feasible, locally developed and grown food and other agricultural products, and locally manufactured value-added goods.

1. "What is Sustainable Agriculture?" from the SARE program website, accessed 5/10/07 at www.uaf.edu/coop-ext/SARE/sustainable.html.

2. Agriculture and Agri-Food Canada, "Sustainable Development Strategy. Sustainable Agriculture: Our Path Forward." From the introduction, accessed 6/6/07 at www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1175533355176&lang=e

agricultural practices. The groundswell of the sus-tainability movement in this country and worldwide has resulted in changes over the last two decades in the national and state policies of the United States and Canada (see sidebar, opposite).

The sustainable agriculture concept fits with John J. Teal, Jr.'s guiding philosophy that indigenous animals and plants for each major biogeographical zone should be selected for domestication, rather than attempting to adapt creatures from one area (such as the Mediterranean ancestor of the sheep) to the rest of the world. Teal worked to put his philosophy into action, raising muskoxen for their qiviut. Others soon followed his example, some successfully and some not. Today there are at least three commercial farms in North America that raise muskoxen, concentrating on the production of qiviut. Qiviut is a valuable fiber, and has been marketed and popularized as a luxury fiber in part by the work of the Oomingmak Musk Ox Producers' Cooperative, centered in Anchorage, Alaska, which uses qiviut in a cottage fiber industry.

Attempts to domesticate the muskox began as early as 1899 (primarily with an eye toward its meat), although the possibility was discussed in scholarly journals before this.[2] Muskoxen disappeared from Siberia and Alaska by the mid-1800s, reduced to only a few hundred animals in Canada and Greenland by 1917, at which point an international agreement to protect them was reached.[3] In the early 1930s an attempt to reintroduce them to their old range was made, and Greenlandic muskoxen were brought to Nunivak Island. They thrived, and further reintroductions elsewhere helped to speed their spread in Alaska, Siberia, northern Quebec in Canada, and Norway. However, it was not until Teal's efforts in 1954 that a rigorous domestication process began.

Muskoxen, being already elegantly adapted to extreme northern temperatures, forage, and other conditions, are site-specific to Alaska and other parts of the polar north. They produce extremely valuable fiber and meat, and are already part of a small, but important, northern fiber industry—making them a potentially suitable livestock animal for a sustainable world.

In 1969, muskoxen were recognized for their agricultural value in Alaska by Secretary of the Interior Walter J. Hickel, when he banned hunting of muskoxen on Nunivak Island National Wildlife Refuge, saying, "The muskox is not a game animal and should continue to be developed for domestic purposes…. To permit such a hunt would be contrary to the intentions of the conservation-minded people who worked so hard in the 1930s to import the first of these gentle animals to this country from Greenland. The muskox is a rare animal and one which, through careful breeding and domestication, offers an excellent means of developing new industry in the Arctic." As governor, Hickel had vetoed a bill the year before, approved by the Alaska State Legislature, that would have allowed big game hunts of the animal.[4]

Renee in the LARS fields with muskoxen, bringing in a cow for combing.
—PHOTO BY JAN E. ROWELL

Qiviut and muskox skirts

The shaggy muskox is perhaps best known for its long pelt, and in particular for its fine underwool, or qiviut. The fibers of this insulating underlayer are long (about 8 to 13 cm depending on where on the animal they grow) and fine, averaging around 17-18 microns for wild muskoxen, with females and young animals having slightly finer hairs. Qiviut is thus classed as a superfine fiber. In comparison, sheep's wool usually ranges from 17 microns for the finest merino wool to 40 microns for coarse wool. Qiviut does not shrink in hot water, and is smooth in comparison to sheep's wool. This means that it does not felt. Articles of clothing made with qiviut may be cleaned by handwashing gently in warm water.

Fleece combed from a muskox, clearly showing the distinct layers of qiviut (light gray) and intermediate hairs (gray-brown). The qiviut stands about 4 inches high, with intermediate hairs another 3–4 inches above that (the ruler is 6 inches).
—PHOTO BY JAN E. ROWELL

Muskox skin includes primary and secondary hair follicles. Primary follicles are associated with sweat and sebaceous glands, and produce the long, coarse guard hairs; secondary follicles produce the qiviut, which are not associated with sweat glands. Because of this, unlike wool, which has about twenty percent lanolin and oils, raw qiviut is a much dryer fiber, at about seven percent grease. Qiviut is shed, or molted, in the spring, from May to June. The secondary hair follicles from which this underwool grows are dormant in the winter, becoming active again in spring. The onset of the spring molt marks the beginning of the growth cycle. Muskoxen grow new qiviut throughout the summer and fall, with peak growth occurring during August and petering out by the end of November.[5] In research done by Morgan A. Robertson for her master's thesis with the Institute of Arctic Biology, earliest-season qiviut growth was shown by cows who had given birth and the latest-season growth was shown by yearling calves.

The primary follicles are interspersed with secondary ones, in a pattern similar to those of domestic sheep, goats, bighorn sheep, wildebeests, impalas, and other such animals. However, according to a paper by University of Saskatchewan researchers Peter Flood, Margaret Stalker, and Jan Rowell (Rowell is now with SNRAS as a research associate in animal sciences):

> The feature that clearly distinguishes the muskox from other wild ruminants examined to date is the extraordinarily high [secondary to primary follicle] ratio, averaging 37:1. In other wild species this ratio ranges from as low as 0.26:1 in Grant's gazelle (Gazella granti) to 7-8:1 in the kongoni…. Among domestic ruminants, it is only in the improved breeds of sheep that the [secondary to primary] ratio approaches that in the muskox, being 20:1 in the Merino. The more primitive mountain breeds have ratios between 3:1 and 5:1. However, domestic wool-producing sheep have an important characteristic not possessed by the muskox: their primary follicles produce fine fibres that are similar to wool.[6]

This means that all the follicles on a sheep produce the fine wooly fibers needed for the textile industry, and do not need to be separated from the coarse guard hairs as they do on a muskox. Thus, a sheep can simply be sheared of all its pelt, while a muskox must shed the undercoat, which then must be cleaned of rougher fibers to be useable.

The density of hair follicles on muskoxen is also very high, approximately 42 per square millimeter, which makes sense given the extreme temperatures that the animals must survive. Muskox hairs are of three main types: the downy qiviut, the long guard or skirt hairs, and the intermediate hairs (finer than skirt hairs and of variable diameter). The guard hairs are shed irregularly throughout the year, while the qiviut and intermediate hair comes out in great clumps and sheets during a concentrated period in the spring. The qiviut can be plucked or combed from the muskoxen in spring or gathered from shrubbery in the field.

Nutrition and hair growth

Adult muskoxen only produce about five to eight pounds of qiviut a year, about the same amount of fiber as an adult Merino sheep per shearing, even though they are significantly larger than sheep. Sheep have been bred for thousands of years

to produce prodigious amounts of wool; a Peppin Merino ram can produce up to forty pounds of wool per year.

Factors controlling production of qiviut include secondary hair follicle density, which is very high in muskoxen, as stated above, and the effect of nutrition on the growth rates of the hairs themselves. Adjustments made to muskox feed to improve overall nutrition and qiviut production can have an effect. Wild muskoxen have slightly thicker hairs than farmed ones, and there is some indication that this may be due to better nutrition: in a good year animals in the wild have their natural diet available to them, whereas, because of the lack of knowledge about their needs, kept muskoxen may not necessarily get a fully nutritious or appropriate diet.

Muskoxen have extremely efficient digestion for ruminants, and cannot thrive on the high-protein diets that domestic horses and cattle require, for example. Early attempts to domesticate muskoxen were sometimes complicated by feed that was suitable for horses, such as clover and grain, but caused muskoxen intestinal distress and even led to death from malnutrition. Wild muskoxen eat a varied diet, changing according to season, of shrubs, grasses, and leafy plants, such as daisies, Labrador tea, crowberry, blueberry, horsetail, fireweed, sedges, mosses, young or dwarf birches, alders, or willows. Researchers at LARS have been improving the quality of their muskoxen fodder, with an eye toward maintaining the health of the animals and increasing qiviut production.

Morgan Robertson studied the effects of commercial rumen-protected methionine (an essential amino acid) supplements on qiviut production for her master's thesis. She conducted her experiments using the commercial methionine Smartamine M, discovering that it promoted qiviut growth, increasing yield and improving fiber length and strength. The study showed significant gains in raw qiviut harvested, about 11 percent for steers, 15 percent for lactating cows, and around 17 percent for calves. This translates to approximately a half pound to a pound more per year per adult muskox. In a 1999 interview with Doug Schneider for Arctic Science Journeys, Robertson explained:

> "What we're specifically interested in with these animals…is the role methionine plays in wool production. So they absorb methionine from their gut. It's transferred to cystine in their body and cystine plays a major role in hair growth and skin growth…. We found that we did get improvements in wool yields, and we also found that we had differences in fiber properties. We got stronger fibers and we also got somewhat larger fibers, somewhat coarser fibers."[7]

Robertson went into more detail in her thesis:

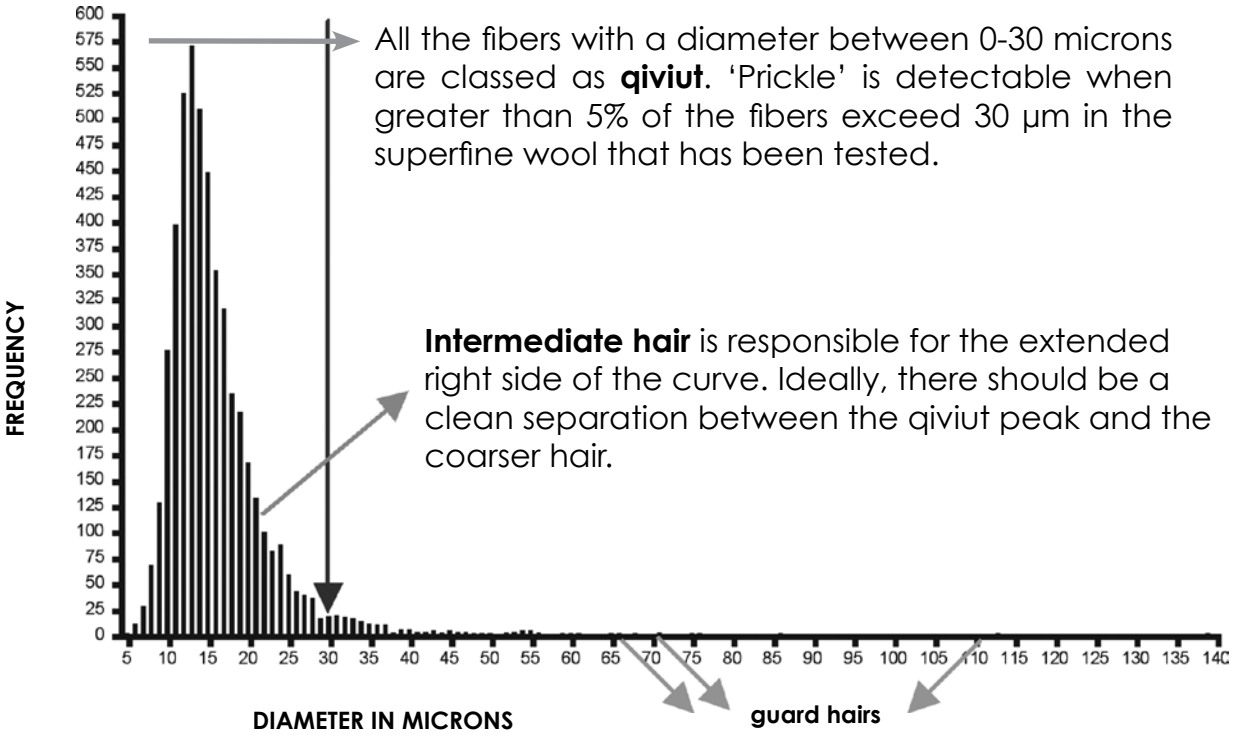
> Methionine is considered the preferred dietary precursor for wool protein synthesis, increasing both fiber length and fiber diameter in sheep…Following absorption in the small intestine, methionine is converted to cystine in the body by transulfuration. Cystine is critical to wool synthesis because it provides disulfide bonds, or cross-linkages, that are required for fiber formation. Keratin, the primary component of wool and hair, is known to have a high concentration of cystine when compared to most other body proteins…Ruminal microorganisms can degrade dietary methionine, which constitutes a major limitation to the supply of methionine, and cystine, for wool growth. Protection of dietary methionine from microbial degradation can be achieved by a chemical protectant, and some cystine and methionine containing proteins are naturally resistant to ruminal degradation (e.g., fish and blood meal). Commercially available rumen-protected methionine and fishmeal can positively influence protein deposition in members of the family Bovidae (e.g., cattle, sheep, goats) when the post-ruminal supply is limiting…. The ability of methionine supplements to improve wool production and body protein turnover in domestic ruminants suggests that such positive gains could be made in farmed muskoxen.[8]

Although the hairs of muskox fed methionine were slightly thicker (making them stronger), the fiber AFD was still finer than the 17-18 microns found on wild-harvested muskoxen

Muskox cow at LARS, her entire fleece on the floor before her after combing. This is about four pounds of raw qiviut.
—PHOTO BY JAN E. ROWELL

the Optical Fiber Diameter Analyser and Average Fiber Diameter

Average Fiber Diameter (AFD) is the single most important characteristic for determining commercial value and end product use of wool. The optical fiber diameter analyser generates a frequency histogram for each sample measured. The graph below characterizes combed raw qiviut from a captive adult cow at LARS.



FROM "QIVIUT: DEFINING QUALITY," POSTER BY J.E. ROWELL

and the qiviut was still soft and fine. So methionine supplementation may be a useful tactic for the muskox farmer.

Qiviut production

Most commercially available qiviut is removed from hides of wild muskoxen harvested for food. Qiviut combed from captive animals during shedding is still relatively rare. The down is "shed in a tightly synchronized moult each spring."[9] Shedding is first evident in yearlings and two-year-olds, who start to shed in late April (in the Fairbanks area, at the 65th parallel). Then comes the rest of the herd, with the newly-calved cows the last to start (mid-May to early June). Once they begin shedding, muskoxen will rub themselves against fences or other handy objects, leaving tufts of qiviut behind. This qiviut, however, is not likely to match the quality of combed qiviut.

Because muskoxen have a completely synchronized shedding period, Rowell said, it makes it "very easy to time and concentrate the combing" of the qiviut, which is convenient and economically advantageous for the farmer. Rowell has been studying muskoxen and their potential as an agricultural animal for much of her professional career, researching fiber characteristics, reproduction, behavior, population dynamics, as well as other aspects of muskox health and growth. She has worked to establish quality standards for muskox fiber and good management practices to improve the yield and quality of qiviut.

The characteristics of the raw fiber determine the quality and textile performance of the end product. Qiviut is valued for its softness, light weight, and warmth, and, as in any animal textile industry, the fiber must be harvested for both quality and yield. Many fiber characteristics can be measured mechanically, providing a consistent, accurate measurement that is helpful in maintaining good farm management practices. These are known as objective measures, and are valuable for consistently producing high-quality qiviut.

The average fiber diameter, or AFD, is "the single most important characteristic for determining commercial value and end product use" of an animal fiber.[10] Generally speaking, the finer and longer the fiber, the more valuable (although, of course, fiber strength also plays a part in its utility and commercial value). Fiber diameter is measured using an optical fiber diameter analyser, which generates a frequency histogram for each sample measured. The histogram (see illustration above) is a graph providing a visual indicator of the quality of the sample, based on the diameters of the hairs. Qiviut from farmed muskoxen has an AFD between 14-16.5 microns, according to research by Robertson, 2-3 microns lower than that measured from wild muskoxen. "This," writes Rowell, "is commercially significant," making qiviut one of the finest fibers harvested in the world. Fiber diameter varies not only with the type of hair, but also by the region of the muskox's body, as does the amount of intermediate fiber and the cleanliness of the qiviut. This means that with farmed muskoxen, the prime, clean qiviut can be selectively harvested—and associated processing costs to the farmer reduced.

Morgan Robertson, above, combing a cow confined in the modified buffalo crush. Note the characteristic "spectacles" around the cow's eyes and the evident thickness of the qiviut remaining in the animal's coat along the spine.

—PHOTO ABOVE BY JAN E. ROWELL, PHOTO BELOW COURTESY LARS

Alastair Newton, below, a former LARS intern, combing an exceptionally fine fleece, demonstrating how the qiviut can be removed from the animal in a single sheet.

Also, with captive animals, the farmer can potentially breed for fine AFD, supplement the diet for improved yield, and comb the qiviut for high quality. Qiviut coarsens with age, going from an average of 16.7 microns in yearlings to 17.9 in adults. "While this could be commercially significant," says Rowell, "it is not as dramatic as the fiber coarsening that occurs in cashmere goats, where a 1.3 micron difference exists between the first and second fleece with a continued coarsening rate of about 0.5 microns a year." In most animals producing superfine fibers, like cashmere goats, fiber coarsens with age until individuals cease to be commercially useful for the production of superfine fiber. In many species males produce coarser fibers than the females, to the point that only a portion of the herd, in some cases only the babies and the younger females, produce good quality fiber. "With muskoxen," said Rowell, "you get equivalent quality between

male and female, young and old." The entire herd provides good qiviut, and the increase in coarseness with the age of the animal is minimal, making each member of the farmer's herd a valuable fiber producer.

Because farmed qiviut is combed and not shaved, it contains very little guard hair. A muskox fleece, rather than being the entire pelt, is a single large sheet of qiviut that is carefully combed from the animal rather than being plucked in tufts. In the shedding process, the qiviut loosens from the skin and begins to lift away from it, eventually falling away from the skirt, rubbed off by the animals or snagged by twigs and pulled out. At a certain stage in the molt, the undercoat will be a short but relatively uniform distance from the skin, and the comber can use a long-toothed hair pick to pull it gently away in a single sheet. The loosening process starts at the head and moves backward along the body, so they can be combed in a few sessions over a period of a week or two. Muskoxen will develop what look like large spectacles of underwool around their eyes when their fleeces are ready for combing. If the fleece is combed out too early, the hairs will tweak the skin as they pull out, irritating the muskox and coming out in small tufts.

Muskoxen have to be acclimated to combing. At LARS, an adapted buffalo crush is used to gently but firmly hold the animal in place while being combed. Generally speaking, females, calves, and castrated males are amenable, but bulls tend to be more irritable or even dangerous, and at LARS, are sometimes sedated and given their annual hoof-trimming and veterinary checkup in one go with their spring fleecing, to make the process easier and less traumatic for both the bull and the farmhands.

Combed qiviut contains intermediate hairs and a small amount of guard hair. Depending on the process used to clean it, farmed qiviut can give a dehaired yield of 80-88 percent, which is very good, especially in comparison to the shaven pelt, where 50 percent or more by weight is removed during dehairing. (Dehairing is the process of removing the skirt and other coarse hairs from the fleece.) The fleece can be graded and cleaned as it is combed. Cleaning at this stage is the removal of foreign matter. Matted, dirty qiviut and qiviut contaminated with vegetation can be easily pulled from the fleece. After the fleece or raw qiviut is combed and dehaired, it may be further cleaned.

Another view of the muskox cow and her fleece, showing the buffalo crush with adjustable side panels. Standing to the left of the cow is Jennifer Miller Hack, former student assistant at LARS.
—PHOTO BY JAN E. ROWELL

The raw, cleaned qiviut is spun and then the yarn is washed. Natural qiviut is a soft grayish brown in color, but it takes dye well and can be found for sale in myriad colors. Bleaching weakens the fiber, however, so many spinners and knitters recommend using only the overdyed natural qiviut, which has darker, more subdued colors. Because the fibers are very smooth, qiviut yarn is slippery and hence better suited for knitting than weaving. It is usually spun into a fine, lace-weight yarn because it is so warm, and sometimes used in blends with silk or other fine fibers.

The potential for a qiviut industry

A search on the Internet reveals many fiber artists who have explored qiviut's qualities, among them Donna Druchunas, author of *Arctic Lace*, a recent book that explores knitting with

Above and upper right: Tundra, a bull at LARS, shown in frontal and side views during the spring molt, illustrating the classic shaggy muskox look. This animal was not combed soon enough, so some of its qiviut was lost as a result, and that recovered harder to clean.
—PHOTOS COURTESY LARS

qiviut, and the knitters of Qiviut-Knit-Along, a community blog of knitters, spinners, and crocheters.

Qiviut yarn can be found in many specialty yarn shops now, but it is still expensive, ranging from $60 to $100 an ounce for 100 percent qiviut: a luxury fiber indeed! Raw qiviut, according to Robertson, can cost as much as $330 to $385 per kilogram ($147 to $171 per pound).[11] The expense, fiber length, and insulative value of qiviut yarn lends itself to use as a lace-weight yarn, and most patterns and clothing made from it are fine and lacy. Companies such as the Oomingmak knitters' collective, the Jacques Cartier Clothier Qiviuk Boutique, and others sell finished clothing made with these yarns and market them using such adjectives as "luxurious," "rare," an "indulgence," "exotic," and the like.

The engaging appearance of the animal, its symbolism as an animal of the high Arctic and of the last Ice Age, and qiviut's cachet as an exclusive and desirable fiber is important to the public

Karen Hills carrying an armful of qiviut.
—PHOT BY JAN E. ROWELL

Dianne Nash spinning qiviut at her home in the Matanuska Valley.
—PHOTO COURTESY WINDY VALLEY MUSKOX

demand for muskox products and to their monetary worth. The high value of qiviut means that there is economic incentive to raise muskoxen commercially, despite the challenges inherent in farming alternative, undomesticated livestock about which little is known.

Yarn and articles of clothing made from qiviut, sold at the store at Windy Valley Farm.
—PHOTO COURTESY WINDY VALLEY FARM

Spinning & knitting with qiviut:

Alaskan Pastures. Linda N. Cortwright. *Wild Fibers Magazine*, Winter 2004. www.wildfibersmagazine.com

Arctic Lace: Knitting Projects and Stories Inspired by Alaska's Native Knitters. Donna Druchunas. Nomad Press, Ft. Collins, Colorado. 2006.

Domesticating the musk ox. Bobbie Irwin. *Spin-Off Magazine*, Summer 1993. www.interweave.com/spin/

Dorothy Reade: A woman ahead of her time. Kathy Sparks. *Spin-Off Magazine*, Summer 1993.

Guard hair to garment. Helen von Ammon. *Spin-Off Magazine*, Summer 1993.

Handspun Gallery of Throws for your inspiration. *Spin-Off Magazine*, Fall 2005.

Knitting Under the Arctic Sun: Women of Wool. Linda Cortwright. *Wild Fibers Magazine*, Summer 2005.

Knitting Under the Arctic Sun, Part 2: Oomingmak, The Musk Ox Producers Cooperative. Linda Cortwright. *Wild Fibers Magazine*, Fall 2005.

Knitting with Arctic Gold. Linda Cortwright. *Interweave Knits*. Vol. 11, Number 4, Winter 2006.

The Miracle of the Muskox. Linda Cortwright. *Wild Fibers Magazine*, Vol. 3, Issue 3, Summer 2006.

Montana qiviut. Bobbie Irwin. *Spin-Off Magazine*, Summer 1993.

Musk ox madness. Joanna Wons. *Spin-Off Magazine*, Summer 1993.

Qiviuq. Wendy Chambers. *Spin-Off Magazine,* Summer 1993.

Qiviut Knit-Along. This is a blog with twenty-four participants devoted to "the experience of knitting with qiviut," with patterns and listing several qiviut sources. On line at http://qkal.blogspot.com/.

Some Hints on Spinning Musk Ox Wool. E. Marguerite Cornwall. *Spin-Off Magazine*, March 1983.

Spinning musk ox hair. Diane Olthuis. *Spin-Off Magazine*, Summer 1993.

That curious "Q" word. Bobbie Irwin. *Spin-Off Magazine*, Summer 1993.

Hand spinning with qiviut

Carding raw muskox wool requires different techniques than those used for wool or cashmere; qiviut can be damaged if carded or spun as though it came from a sheep or goat. E. Marguerite Cornwall provides instructions on cleaning, carding, and spinning qiviut in her 1983 article, "Some Hints on Spinning Musk Ox Wool," recommending cotton carders "to align the musk ox wool and render a more uniform mass without too much mixing. It is the mixing which causes the fiber to wrap around the hooks and work into pills." Cornwall writes that qiviut "blends beautifully with fine wools, especially with high-count Merino, and with cashmere, silk, angora, camel down, etc.," but she recommends carding the qiviut separately first.[1]

The LARS website includes these instructions for fiber preparation for spinning:

> To de-hair the fiber before spinning, grasp a handful of fiber and pull out the long, coarse guard hairs.
>
> Next, remove the intermediate fibers, those that are fine, but straighter than the underlying qiviut. The more intermediate fibers removed, the softer your spun yarn will be. The intermediate fibers can be saved and blended with other fibers or spun alone for a somewhat heavier, fuzzier yarn.
>
> Any dandruff on the base of the fiber can be carefully snipped off with small, curved scissors. Carding is not required, however, if you choose to card the fiber, cotton cards are recommended. Care should be taken or the fiber will pill.[2]

1. Some Hints on Spinning Musk Ox Wool. E. Marguerite Cornwall. *Spin-Off Magazine*, March 1983.

2. Robert G. White Large Animal Research Station website, page on Qiviut. Accessed 5/31/07 on line at www.uaf.edu/lars/qiviut.html#Preparation.

Muskox husbandry

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

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.[12] 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."[13] 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.[14]

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).

Sign welcoming visitors to the Musk Ox Farm.
—PHOTO © JOHN GOMES, ANCHORAGE, ALASKA: WWW.AKJOHN.COM

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 Farm

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

John Nash and his old bull Maximus in June 2000.
—PHOTO COURTESY WINDY VALLEY FARM

Windy Valley muskox, showing the distinctive "helmet" created by the horns.
—PHOTO COURTESY WINDY VALLEY FARM

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

Matanuska muskox herd in a Windy Valley Farm pasture.
—PHOTO COURTESY WINDY VALLEY FARM

Part of the Continental Muskox Company's herd, in Alberta, Canada, summer 2007.
—PHOTO COURTESY JAMES MESERVY

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.

Two calves and adults in a pasture at Windy Valley Farm in the Matanuska Valley, June 2007.
—PHOTO COURTESY WINDY VALLEY FARM

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[15] 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."[16]

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.[17]

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

John Nash hand-feeding Maximus.
—PHOTO COURTESY WINDY VALLEY FARM

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

Three calves at the Large Animal Research Station. These calves were the result of research into synchronization of breeding.
—photo by Sandy Gurbowski, from Reproductive Management of Alaska Livestock, AFES Circular No. 134, February 2007

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 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

Babe, a cow at the Continental Muskox Company, and her calf.
—PHOTO COURTESY JAMES MESERVY

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).

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.

Milan Shipka and Jan Rowell have been studying muskox reproduction. Animal husbandry requires a good understanding of the physiology, reproduction, behavior, and nutritional needs of the species in question, and comparatively little is known of muskoxen. (The first international muskox symposium was held in December 1984, compared to the thousands of years of study and breeding of sheep, goats, donkeys, horses, cattle, and other domestic animals.)

Shipka and Rowell have been studying estrous synchronization of cow muskoxen; being able to time estrus, mating and fertilization, and hence the birth of calves is very important in maintaining healthy herds and improving their productivity. Controlling reproduction is an essential part of animal husbandry. At its most basic, this is "so you know who breeds who when," explained Shipka, but it also has many other repercussions, such as health of calves.

If calving can be timed so that the herd's young are born around the same time, then the muskox keeper can adjust management routines for the entire herd, rather than individual schedules for each animal. A good example of the advantage of this is in vaccination: muskox calves have to be at least two months old before being vaccinated, because their immune systems aren't functional enough to react to the vaccine before this age. Left to their own devices, cows in a herd will bear young over a period of about two months. This means that the muskox keeper would have to administer vaccines to individual calves over a period of two months, or wait until the youngest calf is two months old but risk the oldest calves being unprotected for two months longer than need be. If the calves are all born within a few days of each other, then their keeper can have them all vaccinated at the same time, which is much more convenient and safer. Likewise, many other aspects of herd health and management are improved by managing reproduction.

Muskoxen go into rut in August, in large part affected by day length. Bulls in rut will roar like lions, engage in high-impact head-butting with other bulls, and gather "harems" of cows. A rutting bull muskox can be dangerous, not only to handlers and other bulls, but to the cows in its harem. If a cow is injured or becomes sick, the bull in rut will not let

Bottle feeding a calf at the Musk Ox Farm.
—PHOTO © JOHN GOMES / ANCHORAGE, ALASKA: WWW.AKJOHN.COM

people near her and will charge them if they try. Rut can last six to eight weeks, and the bulls are aggressive and hard to handle throughout. Cows have an estrous cycle of about three weeks, but are fertile for only 1-24 hours; mounting occurs during this brief period.

Shipka and Rowell have discovered that by keeping the sexes apart before the start of rut and then introducing the bulls abruptly to the cows, estrus and mating will occur within a week. This results in the bulls mellowing out faster and calves being born during a one-week span rather than over four to eight weeks. In further studies, they experimented with inducing estrus and fertility by using a commercial progesterone-releasing device used for cattle, which were modified for their experiments. Removal of progesterone triggers estrus. At the beginning, progesterone levels rise, and then fall, triggering a rise in estrogen, and then release of the ova. The researchers implanted a device in a muskox cow's vagina to release progesterone over a period of a week; after the device's removal, the muskox cow's estrogen levels went up and she became fertile. The cows treated this way were then introduced as above to the bulls, and mating took place over only a one- to two-day period, further reducing the time span over which births later took place.

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

Hannah Meservy bottle feeding Rascal at the Continental Muskox Company.
—PHOTO COURTESY JAMES MESERVY

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."[18]

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.[19]

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 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.

Sandy Belk and calf at the Musk Ox Farm in a pen used to acclimatize the babies to humans.
—photo © John Gomes / Anchorage, Alaska: www.akjohn.com

Muskox calves at the Large Animal Research Station February 2004. Research by Milan Shipka and Jan E. Rowell studying synchoronization of breeding produced these calves over a five-day calving period.
—PHOTO BY SANDY GURBOWSKII, FROM REPRODUCTIVE MANAGEMENT OF ALASKA LIVESTOCK, AFES CIRCULAR NO. 134, FEBRUARY 2007

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,[20] 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.[21]

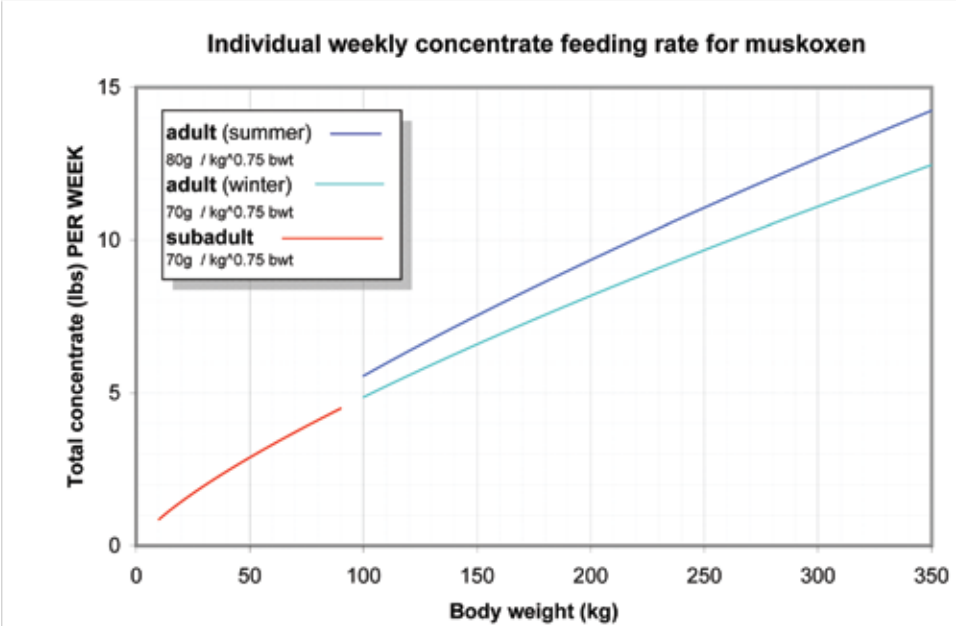
This grain ration, Ruminant M, is a vitamin- and mineral-supplemented pelleted food. "We have two formulations," said Barboza, "a complete diet for calves to transition from milk to adult foods and a mineral supplement for adults maintained on grass hay. I have formulated several other products for experimental 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)."

In more recent work, Barboza has been studying the influence of microbes in muskox digestion, and potential commercial applications for

Large Animal Research Station
University of Alaska Fairbanks
December 2006

Suggested concentrate (pelleted) feeding schedule for muskoxen
Fed individually, two or more feedings per week
"Ruminant M" muskox ration, Alaska Mill & Feed, Anchorage, AK



muskox digestive tract microbes and their enzymes: according to the UAF Biosciences Facilities website, "improved use of fibrous crop residues; improved use of pastures and public lands for production of meat, milk and wool in domestic ruminants; and the production of biofuels from acids and alcohols produced by fiber degradation."

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

Wild muskoxen on the Seward Peninsula, September 2007.
—PHOTO BY ELIZABETH LABUNSKI, U.S. FISH & WILDLIFE SERVICE

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, a geneticist at IAB, and senior thesis student Erik Wood examined the homology of DNA samples of six muskoxen and compared them with goat DNA to look the genetic potential for transmissible spongiform encephalopathy (TSE) in muskoxen. This disease, known as scrapie in goats and sheep, is more infamously known as "mad cow disease" in the strain that affects cattle. It has not yet been seen in muskoxen, but the species has not been studied nearly as intensively as have cattle, goats, and sheep, so it is uncertain whether muskoxen do not contract the disease or if it has occurred in wild populations but simply remained undetected by researchers. Specifically, the muskox prion protein gene was compared to that of goats. Goats are genetically very similar to muskoxen, so the same genetic region is useful in predicting TSE susceptibility in muskoxen. Some goats are more susceptible to scrapies than others, and markers in goat DNA have been identified that correspond to resistance or susceptibility to TSE. Blood samples were taken from muskoxen, the DNA analyzed, and compared to the goat DNA. Muskoxen, it turns out, may have a lack of resistance, as indicated by a similar genetic structure: "all muskox sequenced possessed the wildtype alleles most closely associated to vulnerability to prion disease in goats."[22] 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 this 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 or government setting.

Endnotes

1. The Muskox Domestication Project: An Overview and Evaluation," Wilkinson, Paul F. and Pamela Nunavik Teal. Proceedings of the First International Muskox Symposium, 1984. University of Alaska, p. 4.

2. Charles Gordon Hewitt, in his 1921 book, *The Conservation of the Wild Life of Canada*, reviewed the previous discussions of this possibility, citing Vilhjalmur Stefansson (1916) and S.F. Baird (1854), pp. 312–318. Stefansson 1921: Charles Scribners Sons. Google digitized book.

3. DNA Studies of Musk Oxen and River Otters in Alaska. Michael D. O'Neill, 1/1/1999. *BioBeat Online Magazine*, Applied Biosystems, Inc. Accessed 6/7/07 at www.appliedbiosystems.com/biobeat/index.jsp?articleId=40d6a9cb-37f1-f3d8-c2a268758ed2f9ec&type=0

4. Press release, March 10, 1969, Office of the Secretary, United States Department of the Interior, available on line at www.fws.gov/news/historic/1969/19690310.pdf, accessed 7/18/07.

Dr. Milan Shipka with a muskox cow at the Large Animal Research Station.
—photo courtesy Milan Shipka

5. Fiber characteristics of qiviut and guard hair from wild muskoxen (Ovibos moschatus). J.E. Rowell, C.J. Lupton, M.A. Robertson, F.A. Pfeiffer, J.A. Nagy, and R.G. White. *Journal of Animal Science*, 2001. 79:1670–1674.

6. The hair follicle density and seasonal shedding cycle of the muskox (*Ovibos moschatus*). Peter F. Flood, Margaret J. Stalker, and Janice E. Rowell. *Canadian Journal of Zoology*, 1989. 67:1143–1147.

7. Research Boosts Qiviut Production. Doug Schneider, radio script, 1999. *Arctic Science Journeys*, Alaska Sea Grant, University of Alaska Fairbanks.

8. Maximizing Qiviut Growth in Muskoxen. Morgan A. Robertson. Master of science thesis, May 2000. University of Alaska Fairbanks Institute of Arctic Biology (Biology & Wildlife). p. 3.

9. Rowell, et al., p. 1670.

10. Qiviut: Defining Quality. J.E. Rowell. abstract/informational poster, 200X. Robert G. White Large Animal Research Station, Institute of Arctic Biology, University of Alaska Fairbanks.

11. Robertson, p. 20.

12. "Robert G. White Large Animal Research Station," InfoSpot by Lesa Hollen, University of Alaska Stories. Available on line at www.alaska.edu/opa/eInfo/index.xml?StoryID=161.

13. Musk Ox Farm website, www.muskoxfarm.org

14. Oomingmak website, www.qiviut.com

15. Challenges facing the alternative livestock industry. Published July 24, 2003, at www.deer-library.com/artman/publish/article_34.shtml. Based on a report by Kaji Kado for the Canada-Saskatchewan Agri-Food Innovation Fund, entitled Saskatchewan Specialty Livestock Marketing Study.

16. Groves, Pamela. *Muskox Husbandry: A Guide to the Care, Feeding and Breeding of Captive Muskoxen*. p. 56.

17. Groves, p. 10.

18. "Basic Bottle Feeding Protocol For Muskox, Reindeer And Caribou Calves," UAF Veterinary Services, June 1999. Available on line at www.uaf.edu/lars/document_links/Bottle%20feeding%20protocol.htm

19. Groves, pp. 95-96.

20. "Trace mineral status," From ASTF Final Report, April 2003 -- Feeds for qiviut production: trace mineral nutrition of muskoxen. Available on line at www.uaf.edu/lars/mox_husbandry.html#Trace%20mineral%20status.

21. "New musk ox and reindeer feed now available in Alaska," press release, UAF Institute of Arctic Biology. Available on line at www.uaf.edu/univrel/media/FY02/005.html.

22. "Genes Encoding Muskox Prion Protein as Compared to a Caprine Model," unpublished senior thesis by Erik Wood, May 2007, SNRAS. Senior Thesis Committee members: M.P. Shipka, G.M. Happ, T.M. O'Hara.

Sources & Further Reading

Beasts of No Burden. Melissa DeVaughan. November 2003, *Alaska* magazine.

A brave return from the brink for an Ice Age relic. Charles Bergman. *Smithsonian*, vol. 16, number 11, February 1986.

Muskox Husbandry: A guide for the care, feeding and breeding of captive muskoxen. Pamela Groves. Institute of Arctic Biology. Biological Papers of the University of Alaska Special Report No. 5, January 1992. 148 pp.

Groves, P. 1997. Muskox. *Alaska Geographic* 23(4):56-94.Proceedings of the First International Muskox Symposium. David R. Klein, Robert G. White, and Sue Keller, eds. Biological Papers fo the University of Alaska, Special Report No. 4. December 1984.

International Studbook for Muskox, Ovibos moschatus. Bengt Holst, editor. 1st ed., 1990. Copenhagen Zoo.

Proceedings of the 2nd International Muskox Symposium. P.F. Flood, ed. 1989. Ottawa, National Research Council of Canada.

Muskox underwool—qiviut: A study of best methods of fibre utilization for reasons of time and cost economy and end product wearability. Edna Marilyn Baker. Ontario Handweavers and Spinners Master Spinners Program, September 1984. Port Perry, Ontario, Canada. 98 pp.

Ontario Handweavers and Spinners, www.ohs.on.ca. 2097 Gary Crescent, Burlington ON L7R 1T1 Canada. 888-OHS-1232 or 905-634-3234. The guild offers classes and certification, and publishes a quarterly magazine,

Windblown muskoxen in a pasture at Windy Valley Farm in Alaska.
—PHOTO COURTESY WINDY VALLEY FARM

Fibre Focus. In-depth studies, or certification theses, are available for loan to members by contacting Beth Whitney, OHS Librarian, at 100 Victoria Street, London, ON N6A 2B5 Canada

Sustainable Agriculture Program, Cooperative Extension Service, University of Alaska Fairbanks. Copies of the program's newsletter, *Sustainable Agriculture for Alaska*, are on line at www.uaf.edu/coop-ext/SARE/news letter.html.

Websites:

Alaska Department of Fish & Game Wildlife Notebook page on musk oxen: www.adfg.state.ak.us/pubs/notebook/biggame/muskoxen.php

Animal Diversity Web, University of Michigan Museum of Zoology, entry on muskox: http://animaldiversity.ummz.umich.edu/site/accounts/information/Ovibos_moschatus.html

"DNA Studies of Musk Oxen and River Otters in Alaska", Michael D. O'Neill. January 1, 1999, *BioBeat Online Magazine*. Accessed 11/3/06 at www.appliedbiosystems.com/biobeat/

Large Animal Research Station, muskox husbandry and research: www.uaf.edu/lars/mox_husbandry.html and www.uaf.edu/lars/abstracts_links.html

"Muskox microbes may be boost to beef," November 2006. Biosciences Facility. Accessed 1/11/07 at www.uaf.edu/bios/research/muskox.html

Nunavut Development Corporation, muskox website: www.nunavutmuskox.ca. Provides information on muskoxen, with links to Canadian retailers of muskox products (leather, qiviut, meat).

Oomingmak Musk Ox Producers' Co-Operative. www.qiviut.com

Taiga.net fact sheet on musk oxen: www.taiga.net/wmac/species/muskox/factsheet7_resource.html

"New musk ox and reindeer feed now available in Alaska", press release. July 2001. Available on line at www.scienceblog.com/community/older/2001/D/200114661.html

Contact information for muskox farms:

Continental Muskox Company
P.O. Box 123, Mountain View, AB T0K 1N0, Canada
Ph: 403.653.2331, jmeservy@gmail.com

Musk Ox Farm
P.O. Box 587, Palmer, AK 99645
Ph: 907.745.4151, Fax: 907.746.4831
www.muskoxfarm.org, moxfarm@alaska.net

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www.uaf.edu/lars/ • fylars@uaf.edu

Windy Valley Farm
9523 N. Wolverine Road, Palmer, AK 99645
Ph: 907.745.1005, Fax: 907.745.8838
nashfarm@mtaonline.net, www.windyvalleymuskox.net

Resources on muskox husbandry:

Alaska Mill & Feed
www.alaskamillandfeed.com

Alaska Diversified Livestock Association
c/o John Nash
9523 N. Wolverine Road, Palmer AK 99645
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www.uaf.edu/snras/faculty/shipka.html

Papers and reference works:

Note: several abstracts and reports are available on line from LARS at www.uaf.edu/lars/pub_index.html. The ASTF Final Report (2003), which contains information on feeding and maturation studies to 2003, is available in part on the LARS website. This report summarizes the basis for the original work, but several journal articles have been published by these researchers since then on digestion, growth, and mineral balances (see below). A PDF of the final report may be obtained from Perry Barboza.

Rowell, J.E., M.C. Sousa, and M.P. Shipka. 2007. Estrous synchronization in captive muskoxen. *Can. J. Anim. Sci.* 87:535-538.

Basic Bottle Feeding Protocol For Muskox, Reindeer And Caribou Calves. UAF Veterinary Services, June 1999. Available on line at www.uaf.edu/lars/document_links/Bottle%20feeding%20protocol.htm.

Muskox calving protocols, rev. April 2007. UAF Veterinary Services—Guidance for Development and Annual Evaluation of a Facility Calving Management Plan, January 2005. Available on line at www.uaf.edu/lars/mox_husbandry.html#Muskox_calving_protocols.

Lawler, James P. and Robert G. White. 2003. Temporal responses in energy expenditure and respiratory quotient following feeding in the muskox: influence of season on energy costs of eating and standing and an endogenous heat increment. *Can. J. Zool.* 81(9): 1524-1238.

Barboza, P.S., Rombach, E.P., Blake, J.E., Nagy, J.A. 2003. Copper status of muskoxen: A comparison of wild and captive populations. *Journal of Wildlife Diseases* 39. Available on line at www.uaf.edu/lars/document_links/jwdi_39_315_610_619.pdf

The male effect, mounting behavior, and the onset of estrus in farmed muskoxen. J.E. Rowell, M.C. Sousa, and M.P. Shipka. 2003. *J. Anim. Sci.* 2003. 81:2669-2674. Available on line at www.animal-science.org/cgi/content/full/81/11/2669

Shipka, M.P., and J.E. Rowell. 2007. Reproductive Management of Alaska Livestock. AFES Circular 134. University of Alaska Fairbanks.

Shipka, M.P., M.C. Sousa, and J.E. Rowell. 2002. Characterization of estrous behavior in muskox cows. Proceedings of the Western Section of the American Society of Animal Science 53: 387-389.

Exploring Pasive Transfer in Muskoxen (*Ovibos moschatus*). Cheryl Rosa, D.V.M., Ph.D., Debra Miller, D.V.M., Ph.D., Matthew J. Gray, Ph.D., Anita Merrill, Tammie Vann, and John Blake, D.V.M., M.Vet. *Sc. Journal of Zoo and Wildlife Medicine* 38:1 (March 2007):

Qiviut and dandelions in a pasture of the Continental Muskox Company.
—PHOTO COURTESY JAMES MESERVY

pp. 55–61. Available on line at www.bioone.org/perlserv/?request=get-abstract&doi=10.1638%2F05-048.1&ct=1

Wilkinson, Paul F. Wool shedding in musk oxen. 1974. *Biological Journal of the Linnean Society* 6 (2), 127–141. Available on line at www.blackwell-synergy.com/doi/abs/10.1111/j.1095-8312.1974.tb00718.x.

White, R.G. and K.L. Parker. 1988. Nutritional effects of lactation, nursing behavior and breeding success of muskoxen (*Ovibos moschatus*). 1987 Annual Report to the Center for Field Research and Earthwatch (36 p.).

White, R.G., D.F. Holleman, K.L. Parker, B.A. Tiplady and W.E. Hauer. 1988. Nutritional effects on nursing, milk yield and reproductive success in muskoxen. Final Report to the University of Alaska Foundation and Standard Alaska Production Company.

White, R.G. and W.E. Hauer. 1988. Nutritional effects of lactation, nursing behavior and breeding success in muskoxen and caribou. 1987 Annual Report to the Center for Field Research and Earthwatch.

White, R.G. 1998. Comparison of lactation, nursing behavior and breeding success of muskoxen. 1995 Annual Project Report. Submitted to the Center for Field Research and Earthwatch. Available on line at www.uaf.edu/lars/document_links/1995_Report.pdf.

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