REVIEW OF MUSKOX TRANSPLANTS

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INTRODUCTION

The capture, handling and care of muskoxen is sufficiently prevalent that quite a body of knowledge has accrued. Unfortunately that knowledge is widely scattered in unpublished reports. This review draws together information from these sources for two reasons: 1) to provide, under one cover, technical details and considerations from the successful and unsuccessful experiences of others (Tables 1 and 2) which may be helpful if the N.W.T. Wildlife Service became involved in the capture and transplant of muskoxen, and 2) to describe the fate of transplants and to draw attention to their long-term implications in terms of management requirements and public expectations.

Quebec

The transplant to Quebec was a provincial government venture to establish a captive herd for future releases of small herds as a basis for a cottage industry using the qiviut.

Northwest Territories

The rationale for potential transplants has shown a shift between the late 1960's and 1980's reflecting the awareness of increased muskox populations and increased demands for country foods. Early interests pertained to the production of wool (Birt 1871), however, the current emphasis is on transplanting muskoxen to re-establish populations in historic ranges (Simpson Peninsula, Keewatin), or creating range extensions (Baffin Island, Southampton Island). The motivation is to use the transplanted muskox for their meat, as well as reducing muskox populations in high density areas.

CAPTURE METHODS

Ideally, a capture technique should minimize stress from chasing and handling an individual and have minimal impact on other members of the herd. The size and strength of even yearling muskoxen require that manual restraint or drug immobilization is necessary, but all handling has to be consistent with the minimization of distress (Schmidt and Bruner 1981).

The grouping together of muskoxen into a defense formation when faced with danger is useful for would-be captors, as the muskoxen will stand their ground and individuals can be selected. That same formation is a disadvantage as it can be difficult to isolate an individual away from the group. The difficulty of isolating an individual resulted in mortality during early capture efforts; muskoxen were held in a circle by dogs, and the animals shot until the calves were left and could be caught (see illustration in Alendal 1980a). This method was standard between the 1890's to 1930's, but by 1964 other techniques had been developed that did not require indiscriminate killings.

Capture of Entire Herds

Small muskox groups can be approached on foot and a Cap-Chur gun can be used to safely drug all the individuals in the groups (E. Broughton pers. comm.). The drugging of an entire group was succesfully tried in eastern Greenland in August 1982 (K. Jingfors pers. comm.). Eskimo dogs, trained to circle a muskox group were used to hold groups of less than 10 muskoxen together until the animals had been drugged with M99. The team darted, drugged and marked 103 between 21 July and 1 August, 1982 with only two fatalities; a bull rolled down a slope and was asphyxiated when he became jammed up against a boulder, and a cow had to be shot when she charged the capture team (K. Jingfors pers. comm.).

Snowmachine-net Method for Individual Muskoxen

The Alaskans have developed a successful procedure to catch yearling, subadult and most recently, adult muskoxen without using drugs or aircraft (see Hout 1969 for photographs, Jennings and Burris 1971). Yearlings were split from the herd by a 6-man crew with snowmachines and chased until they stopped. They were then approached on foot and then bulldogged to the ground. The animals were hobbled and tied onto sleds for hauling to a holding area. Manila rope (1.3 cm diameter) was used for hobbles but 5 cm nylon straps and slip buckles might be an improvement (Reardon 1981). Lariets were not used because in 1969 a muskox was strangled by a rope.

The 2-year olds were similarly segregated from the herd by snowmachines and either driven into a net or the net was thrown over the animal. The net had a 24 cm mesh and was made from 5 mm nylon parachute cord. Three and 4-year old cows have been captured in a similar fashion.

The technique is relatively efficient; e.g., two, 6-man crews captured 54 muskoxen in 7 days (Hout 1969). It is also relatively cheap, with the major proportion of the cost going to a native settlement in the form of wages for local hunters. The incidence of mortality and injuries is low; e.g., in 1970, out of the 72 muskoxen captured, one muskox was shot after breaking a limb, one drowned, one died from a ruptured aorta and one fell from a cliff.

Capture of Calves in Water

The basic technique was developed by J. Teal in 1954 (Lønø 1960). A fixed-wing aircraft or helicopter is used to drive a herd into water and the calves can then be maneuvered ashore and manually restrained. The technique was successful three out of four times in the Thelon Game Sanctuary. In 1954 and 1955, seven calves were captured and taken to a game farm in Vermont, USA. In August, 1967, only one calf was caught but it escaped from the corral (H. Monaghan pers. comm.). Two years later the Calgary Zoo was more successful and caught four calves (Karsten 1974). A helicopter and 3-4 men on the ground drove the herd into the water. A man on the helicopter float held the calf by its neck as the helicopter slowly flew along the surface of the water to the shore. A ground crew grabbed the calf before it could get its footing and it was carried to land, dried and wrapped in a blanket. The calves were estimated to be 12-14 weeks of age and weighed 55-65 kg (Karsten 1974).

This technique involves driving the muskoxen in summer and will cause heat stress. A second disadvantage is that the choice of location is restricted to herds of muskoxen within a few kilometers of a lake. Although the technique allows capture of calves without using drugs in the snow-free season, it is logistically inflexible, causes possible heat stress of herds and cannot be used to capture age classes other than calves.

Calf Capture During Organized Hunts

Large increases in the muskox quota for Banks Island in 1981 led to a change in hunting methods. The muskox groups were herded by snowmobiles to a central location and all group members were shot. This technique could be used to capture live muskoxen. Calves are usually left behind during the drive and can be easliy picked up. Yearlings could be netted at the kill site or older animals could be immobilized with drugs. Alternatively, the required muskoxen could be separated during the drive, similar to the Alaskan approach.

The capture and raising of newborn calves is only suitable if a captive herd is being established. During the 1982 spring hunt 13 newborn calves were separated from their herds by hunters on snowmachines. They were captured and put in burlap sacks to be carried back to Sachs Harbour by sled (J. Rowell pers. comm.). They were later flown to the Western College of Veterinary Medicine in Saskatoon to form an experimental herd.

Drug Immobilization

The compilation of data on immobilizing large game with drugs by Hebert and McFetridge (1979) is a useful and current introduction to the use of drugs, however, it does not include specific references to muskoxen. Although details of various drugs are given here, the preferred drug now is M99, with the addition of Rompun (E. Broughton pers. comm., R.G. White pers. comm.), Sernylan (Phencylidine hydrochloride)

Sernylan is a central nervous system depressant leading to loss of consciousness of the animal. It is often used with a sedative as convulsions may develop during the recovery phase. The disadvantage in using it with muskoxen is the need to make accurate estimates of weight and condition as overdoses can result in immobilization for a day or longer. The muskox's thick coat can give a misleading impression of the animal's size, making it difficult to accurately estimate the weight.

Hout (1969) describes poor success with use of Sernylan (from a helicopter) as 5 of 8 muskoxen immobilized with Sernylan died. Hout (1969) speculates that improper use, poor physical condition and bloat caused by the long recovery time (12+ hours) may have contributed to the deaths.

By contrast, Jennings and Burris (1971) reported greater success using Sernylan and working from the ground. Mixed with glycol to prevent freezing, Sernylan did not result in deaths of the eight muskoxen drugged. They and Hout (1969) injected Tranvet (propiopromazine hydrochloride) to minimize convulsions. The Tranvet dosages were 44 mg/100 kg of body weight though the dosage apparently were not critical (Jennings and Burris 1971).

Hout (1969) used higher dosages of Sernylan for males than females, but Jennings and Burris (1971) reported that females needed twice the dosage given to males to reach a similar level of immobilization. Precise dosages are difficult to compare as Hout (1969) only gives the weights of the muskoxen that died. The dosages were, however, similar to the range used by Jennings and

Burris (1971) i.e., 0.73-1.1 mg/kg and 0.73-1.23 mg/kg, respectively.

Hubert (1974) suggested that Sernylan was not a suitable drug if the muskox was to be slung after immobilization. Too small a dose would allow the muskox to struggle. Too large a dose could cause respiratory problems that would not be obvious when the muskox was in the sling.

F.L. Miller (pers. comm.) used Sernylan alone and with the tranquilizer Sparine (promazine) or Wydase (hyaluronidase) while successfully immobilizing muskoxen on Melville Island in July and August, 1973. Dosage rates were 100-300 mg Sernylan, 100-250 mg Sparine and 350-450 mg Wydase for adult bulls and cows.

Succinylcholine Chloride

Succinylcholine chloride (Sucostrin Anectine) is a so-called paralyzing drug (the animal remains conscious). It is rapid acting and causes paralysis for a relatively brief duration. Hebert and McFetridge (1979) recommend against the use of such paralyzing drugs in preference to central nervous system drugs because of 1) the narrow range between effective and toxic dosage, 2) the influence of the physical state of the animal, and 3) more importantly, because the animal is conscious, and therefore the effect of handling is more traumatic.

Succinylcholine has a rapid rate of induction, which can be a disadvantage if the muskox collapses in a place not rapidly accessible. Delays in reaching the animal can result in death from respiratory failure, which is also a common result of overdosage.

Succinylcholine chloride was used in March and April 1969 to immobilize 23 muskoxen: two adult males and three pregnant females died of respiratory failure. Dosages were 60-100 mg but precise dosage is only available for four of the animals that died; 1.1 mg/kg body weight (Hout 1969).

Jonkel et al. (1975) used succinylcholine chloride to immobilize muskoxen on Bathurst, Devon and Ellesmere Islands in the Canadian Arctic. The succinylcholine chloride was combined with Sparine to minimize excitement during the recovery. Dosages were based on the Alaskan transplant experiences. They immobilized 26 adults; one bull and cow died apparently because artificial respiration was applied too late. There was considerable variation in reaction to the drug and recovery times were also variable which may have been influenced by the distances that muskoxen had been chased by the helicopter.

F.L. Miller (pers. comm.) also commented on the problem of individual responses and respiratory difficulties which caused the death of an adult bull (260 kg) which had been dosed with 100 mg succinylcholine chloride (Anectine). An adult cow (190 kg) also died from respiratory failure after being dosed with 80 mg Anectine and 250 mg Sparine.

Etorphine (M99) and Rompun

Etorphine (M99) is a central nervous system depressant causing loss of consciousness. M99 has become widely used although induction in some species may be accompanied by intense excitement (which can be overcome by using Rompun, xylazine hydrochloride). Although the intense excitement has not been observed in muskoxen, Rompun is useful to maintain a sedated state after the antidote has taken effect (E. Broughton pers. comm.). Alaskans used 3-5 mg M99 for yearlings and adult cows. The dosage for bulls was 4-6 mg if the animals were calm and had not been chased. Rompun was used in low dosages of 20-30 mg (R. Dieterich pers. comm.). P. Reynolds (pers. comm.) used higher doses (7.3 mg) to drug muskoxen on the Alaskan North Slope in April 1982, and also in April 1983 when 8 of 12 muskoxen had to be given additional doses of 3.0-5.0 mg.

R.G. White (pers. comm.) used M99 and Rompun to drug muskoxen that were grouped in response to snowmachines. The muskoxen were approached to within 30 m before an animal was darted. As it took about 30 min for the drug to immobilize the animal, a net was placed over it to assist in handling. When the antidote (M50-50) was injected, the muskox could stand within 2 min and forage within 30 min.

M99 was also used to successfully immobilize 10 muskoxen on Banks Island in August 1975 (E. Broughton pers. comm.). A dosage of 3 mg M99 and 60 mg Atravet was the drug combination for yearlings. The induction time was 6-15 min and all animals went down on their briskets. E. Broughton used M50-50 to reverse the M99, and when used intramuscularly, the recovery time was about 15 min (10-17 min).

Rompun alone was used but 2 of 3 yearlings died because of complications during arousal (Hubert 1974). E. Broughton (pers. comm.) commented that the animals drugged with Rompun had difficulty in resting upright on their briskets. One of the female yearlings died without regaining her feet; the other was found dead about 45 min after it had been able to move normally. The recovery time was prolonged which would be a disadvantage if the objective was to release the muskoxen following capture. With penned muskoxen, monitoring would be required to prevent bloat or ruminal regurgitation. Jones (1971) reported the successful use of Rompun to immobilize a captive 12-year-old muskox bull. Jones commented that it was possible to maintain a level of sedation such that the bull remained standing thus preventing ruminal regurgitation.

Henaff (1976) also reported success with using M99 on 11 muskoxen at the Fort Chimo muskox farm. Dosage was 2.2-3 mg/100 kg and 1 mg/kg of chloropromazine. The muskoxen were immobilized, then crated and slung by helicopter 135 km to a release site. No antidote was used and the muskoxen were left overnight in a pen to recover.

Drug Administration

The immobilizing drugs are injected using barbed darts and powder charged dart guns. Jonkel et al. (1975) recommended 8 or 10 cc darts with 5 or 6 cm needles so the dart could be seen in the long hair. Either helicopters or snowmachines have been used to reach a herd, position the shooter and transport the immobilized muskox.

A helicopter was used in summer operations on Banks and Melville Islands, in late winter on Nunivak Island in April on the North Slope, and in the Canadian Arctic. Hout (1969), F.L. Miller (pers. comm.), E. Broughton (pers. comm.) and P. Reynolds (pers. comm.) darted animals from a helicopter while hovering by the herd. Jonkel et al. (1975) flew behind a herd until a muskox dropped back and could be cut off. When about 0.5 km away from a herd, the animal was darted from the helicopter. As Jonkel et al. (1975) noted, this approach is selective for old, injured or pregnant muskoxen and possibly herd bulls although they do not mention them. F.L. Miller described landing several hundred meters from the darted muskox to wait until the drug took effect. He and a helper then walked up and hobbled the animal by tieing a front leg to a horn. Hout (1969) used hobbles to restrain the muskoxen after drugging.

E. Broughton described driving the herd up a slope or through a snow drift to slow the animals down to help selection of a particular individual. They darted the individual and then withdrew and watched the group from a vantage point. Jonkel et al. (1975), E. Broughton and F.L. Miller rolled immobilized muskoxen upright to reduce respiratory problems and ruminal regurgitation.

Hout (1969) had to use the helicopter to isolate the selected muskox from the herd by driving the others away. F.L. Miller (pers. comm.) reported no problems with the herd staying with an immobilized muskox. He and E. Broughton (pers. comm.) observed that the unusual movements of the animal as it succumbed to the drug caused the other muskoxen to move away. He commented, however, on the inadvisability of drugging bull-only groups as a bull would aggressively defend against efforts to approach his downed companion. F.L. Miller was working in July and August

(1973) and he suggested that the level of aggression associated with the rut made darting potentially hazardous to the capture crew.

The chief disadvantage of a helicopter is the extremely high cost of operating especially in the Canadian Arctic where long ferry and fuel caching flights are usually necessary. A second potential disadvantage is that the success of the operation largely depends on the skill and motivation of the pilot.

Snowmachines on Nunivak Island were used to hold a herd in a defense group while the herd was approached on foot. The selected muskox was darted and the snowmachines were used to drive the other muskoxen away. The technique is relatively cheap and particularly suitable to operations within reach of a settlement. Again local hunters are involved and much of the cost is returned in the form of wages to the settlement.

Jonkel et al. (1975) discuss cautionary procedures to minimize stress to muskoxen during mark and capture studies. Their suggestions include avoidance of operations during the calving season (March to May), staying with a drugged animal until fully recovered to prevent predation, tagging only one animal from each herd, and not concentrating on one area.

Timing of Capture

The Alaskans have captured their muskoxen in late winter when cold temperatures alleviate heat stress. Cows however, are near-term and abortions or stillbirths can result from harassment (R. Dieterich pers. comm.) P. Reynolds (pers. comm.) thought a stillborn calf, and a cow dying 4 weeks after the capture may have been related to the capture but also six cows gave birth to calves, one within 6 days of being immobilized. Also, most animals are at the nadir of the annual cycle of condition which could increase vulnerability to stress and make responses to drugs less predictable. Seidel (1979) discusses different responses to stress and drugging of muskoxen in zoos.

Probably the best time to catch muskoxen is in October and November when stress will be minimized due to cold temperatures, the good condition of the animals and early stage of pregnancy in cows. The disadvantages of those months are decreasing daylight length and a greater probability of storms and poor weather. Possibly, induction times of drugs may be slightly prolonged as fat animals absorb drugs relatively more slowly (Hebert and McFetridge 1979) if the drugs are injected into the fat tissue (E. Broughton pers. comm.).

HANDLING

The careful and considerate handling of the animals immediately after capture is necessary to avoid of further stress. It is advantageous to use holding structures that allow easy surveillance of the captives but the exciting effect of curious by-standers has to be guarded against. If individual health problems are noted, the muskox will have to be restrained and treated without indirectly exciting it or other captives.

Precautions should also be taken to protect the handlers. Education, especially for inexperienced handlers, is necessary to explain the potential dangers of frightened and thus dangerous adults muskoxen. Two people were critically injured when they entered an enclosure and excited an adult bull muskox on the Fort Chimo farm in 1981 (I. Juniper pers. comm.).

Care of Newborn Calves

Newborn calves, especially if they are only days old, require special treatment in handling as the physical susceptibility of newborn animals must be considered. Considerable recent details on handling and rearing newborn calves have been acquired during the establishment of a captive muskox herd by the Western College of Veterinary Medicine, University of Saskatchewan in 1982 (Flood et al. in press).

Precautions, however, may be necessary to prevent the young calves from becoming too attached (imprinted) to humans. Imprinting could eventually interfere with handling of adults and successful breeding. I. Juniper (pers. comm.) observed that the muskoxen released near Leaf Bay from the Fort Chimo farm in Quebec were familiar with humans. One adult bull moved into the village and by his boldness caused fear among the inhabitants who demanded his removal. Imprinting could be minimized by reducing exposure to humans. On the other hand, if the captive herd is intended for scientific studies, muskoxen imprinted on humans may be easier to work with.

Restraint Following Capture

The Alaskans, after capturing yearlings on Nunivak Island, tied them onto sleds pulled by snowmachines to a temporary base camp or to Mekoryuk. In 1971, the muskoxen were taken directly to Mekoryuk (56 km), and after being given numbered metal ear tags, were released into permanent 2-m-high chain link enclosures (Jennings and Burris 1971). The enclosures are part of a complex with capacity for at least 40 muskoxen in the pens which are 6x12 to 12x12 m. All the adults and subadults (22+ months of age) were hobbled in the pens and in 1975 yearlings were penned separately from 2-year-olds. Conventional hobbles caused lameness and were replaced with single 6 m ropes. The rope was used to tie the muskoxen to fence posts and to guide them into shipping crates. Most of these aspects of early handling and restraint are illustrated by photographs in Hout (1969, 1975), and Jennings and Burris (1971). The temporary pens used at a base camp in 1975 were simply pits dug into the snow about 2 m deep and measuring 3x5 m (Hout 1975). In 1971, 2-year-olds were held in snow holes and hobbled (Jennings and Burris 1971).

On Banks Island in 1975, after drugging with M99, the muskoxen were positioned in a cargo sling to keep them upright in sternal recumbancy. Ophthalmic ointment was applied to the eyes to prevent drying of the cornea during the flight. The helicopter slung the net to the camp at 40-60 km/h and 300 m agl. At the camp, the muskoxen were carried in the net to a holding pen where long-acting penicillin and streptomycin were injected intramuscularly. At that time M50-50 was also injected, and when the animal recovered, it was placed in one of the other pens with similarly sized muskoxen. Seal netting covered with burlap was used to create holding pens but as the yearlings caught their horns in it, plywood sheets were used to cover the netting (E. Broughton pers. comm.). Although muskoxen are agile climbers, they do not apparently jump, and are usually relatively calm in pens. A large enclosure - 3.6 x 6.4 m with 2.4 m walls - was divided into three pens 3.6 x 2.1 m. The doors were 1.5 cm thick plywood and opened inwards. The pen uprights were dug into the ground for about 0.6 m until permafrost was reached and guy ropes were used for extra rigidity.

Tranquilizers such as Tranvet or Atravet or low doses of M99 have been successfully used (E. Broughton pers. comm. 1981) when the muskoxen have had to be handled into shipping crates etc. Topical antibiotic ointment was applied to the dart wound after the muskoxen had been immobilized with darts (E. Broughton pers. comm.). Hibler (1981) reported an outbreak of malignant edema in captured mule deer (Odocoileus hemionus) which was traced to improperly sterilized darts used with a Cap-Chur gun. Karsten (1974) gave his muskox calves antibiotics as well as vaccinations for black leg and malignant edema.

The use of temporary holding facilities allows monitoring of recoveries from immobilization and the stress of capture. Any injuries or resulting illnesses can then be treated. During release into the holding pens, the age class, sex and ear tag numbers should be checked as mistakes can occur when speed is necessary during capture. If radio-collars are used, a receiver should be used to check that all magnets have been removed to activate the signal transmission.

The Alaskans have not used holding facilities at the release site. However, Nelson (1981) recommended that if the muskoxen must be driven to a release site, they should be held in an enclosure for at least 2 days to recover from stress. The Russian and Quebec biologists used holding pens at release sites for months, and less than 24 hours, respectively.

A point emphasized in Alaskan reports was the care needed to protect the fragile horns of yearlings. The horn sheath is easily dislodged exposing the bony core. Padding from hay-stuffed sacks or folded reindeer hides were necessary to prevent the damage (Jennings and Burris 1971). Treatments for other health problems including traumatic injuries have been developed in Alaska from experience with transplanting and captive muskoxen (Dieterich in press).

Capture Myopathy

Capture myopathy (CM) is a recently recognized disease of captured wildlife. As capturing and handling of large mammals became prevalent in the 1960's and 1970's, more accounts and descriptions of the disease have been reported.

The symptoms are easily recognized as muscular stiffness, uncoordination, coffee-coloured urine, and paralysis which is evident by weak hind-legs where an animal may walk on its "knees". Collapse and coma usually precede death, but sudden death can occur in the absence of warning symptoms (hyperacute form). In the acute and subacute forms, death occurs within 12 hours, or weeks, respectively. In the chronic form, death is sudden following renewed stress weeks or months after the original stress (Harthoorn in Chalmers and Barrett 1979). Plans for post-capture and post-release monitoring should consider the possibility of delayed mortality.

The gross pathological signs of CM are lesions in limb, cardiac, pectoral, and intercostal muscles. The lesions may be pale or white striations often with associated hemorrhages. The muscle may have light and dark bands or white streaks parallel with the plane of the muscle mass. The liver and kidneys may be swollen and pale; the urine may be brown. Froth and or blood congestion may be present in the trachea and bronchia.

CM has been described in most ungulates that have been captured (Chalmers and Barrett 1979), but the first recognition of CM in muskoxen was not until 1979 during a transplant from Nunivak Island (Dieterich 1981). Three adults developed the symptoms; one died on Nunivak Island and one died at the University of Alaska farm. Additionally, one yearling from a subsequent transplant developed the symptoms and was taken to the University farm, but by December 1981 had only partially recovered (R. Dieterich pers. comm.).

No treatment was used in Alaska (R. Dieterich pers. comm.), though other workers have reported varied success using solutions (intravenous or intraperitoneal) of sodium bicarbonate (Chalmers and Barrett 1979).

The condition is basically caused by a build-up of lactic acid in the muscles but nutritional deficiencies such as Vitamin E or selenium may contribute. If CM is suspected from the severity of the capture, blood samples to test the levels of enzymes such as SGOT (serum glutamic oxaloacetic transaminase) can be taken to indicate the onset of CM as symptoms may not be evident for several days or weeks (R. Dieterich pers. comm.).

In drive trapping of pronghorns (Antilocapra americana) in Alberta from October to December, the animals were driven for 15-50 min and some animals that were chased but not caught developed CM (E. Broughton pers. comm.). Although, the disease is usually subsequent to violent exertion such as chase or struggles during restraint, CM can also be caused by drug immobilization without a chase. Therefore, to reduce the likelihood of CM mortality during transplants, the operation should: 1) minimize the duration of chase, handling, restraint and exposure to humans (Chalmers and Barrett 1979); 2) avoid use of immobilizing drugs (which can cause thermoregulatory problems); 3) avoid prolonged restraint, and 4) use blindfolds (R. Dieterich pers. comm.).

Marking

The marking of muskoxen before release is especially useful in tracing the fate of the transplant. This marking ensures that wanderers from the transplant will be identifiable. Additionally, marking the muskoxen whose age is known at the time of release will provide valuable known-age tooth material -- if, of course, the carcass is found.

The Alaskans have used eartags, with and without streamers, and the eartags have lasted up to 14 years on one recovery (B. Dinneford pers. comm.). The eartags are difficult to see at any distance because of hair and wool especially in summer. Gray (1979) used plastic streamers attached to the horns with metal hose clamps but they worked loose on some bulls. The Alaskans are experimenting with heat-shrink tape to overcome that problem (P. Reynolds pers. comm.). Gray (1979) commented that the visual collars (red vinyl) were relatively visible after 2 years despite shedding wool. The most recent (spring 1981) transplant of muskoxen from Nunivak Island to Seward Peninsula included five muskoxen fitted with radio-collars (B. Dinneford pers. comm.). Quebec biologists used eartags and some radio collars in 1975 to monitor their transplanted muskoxen. If radiocollars are used, addition of a mortality mode (the frequency changes if the collar does not move after a certain time period) is an advantage. Prompt location of carcasses helps to determine cause of death, which might prompt modifications of capture techniques if deaths from handling such as capture myopathy, were indicated.

Feeding

Calves

Calves not yet weaned can be raised on a milk formula for lambs (R.G. White pers. comm., Flood et al. in press). The

Alaskans have successfully used lamb starter (Land-O-Lakes medicated powder, "Lamb Milk Replacer" or "Lama" from Carnation Company). The milk powder was mixed in the ratio of 300 ml milk powder to 1200 ml water with 1 teaspoon cod liver oil to 1500 ml milk mixture. The calf was given 5-6 meals/day for the first month increasing the amount from 0.9 to 2.0 liters/day (K. Frisby pers. comm.).

Calves are possibly weaned in the fall, though observations have been made of suckling by yearlings (Tener 1965, Jingfors 1980). Projects intent on capturing calves of the year in late summer, early and late winter should include preparations to provide supplemental rations for the calves.

Karsten (1974) provided willow and elder browse to his 2-month-old calves, supplemented by a large bowl of warmed (35^{o} to 36^{o}C) calf milk replacers (4 cups Swift's Nursing Formula to 4 litres water) three times a day. Karsten (1974) also fed orphan calves in Calgary Zoo's Rescue Nursery canned evaporated milk diluted by volume 1:1 with water. Four feedings of 28-45 g each were offered daily. After the calves were 6 weeks old, grass pasture and hay were offered as well as herbivore pellets (Calgary Zoo formulae) and dried beet pulp. The calves were weaned by 4-5 months (Karsten 1974).

R.G. White (pers. comm.) noted the advantage of continuing to offer a bottle once a week to hand-raised calves even at 9 months of age. The bottle acts as a bribe to foster the relationship with the handlers of the experimental herd at University of Alaska (K. Frisby, J. Rowell, pers. comm.).

Glover and Haigh (in press) have described the helath care of the calves in the University of Saskatchewan and have made recommendations on hygiene and quarantine procedures.

Subadult and Adult Muskoxen

The Alaskans reported no difficulty in using alfalfa or timothy hay to feed captive muskoxen (Hout 1969, Jennings and Burris 1971). In 1979, brome hay and cow concentrate pellets were used to feed the captive muskoxen in Fairbanks, and R.G. White (pers. comm.) reports that the diet was satisfactory and was essentially unchanged in 1981. In a summer operation on Banks Island, E. Broughton (pers. comm.) buried a water pail to ground level in a corner of each pen and fed hay at the rate of one bale (25 kg) per day to five animals. He occasionally tranquilized aggressive males when they attempted to monopolize the hay. Careful consideration should be given to the source and species composition of the hay (Beckley and Dieterich 1970) as foxtail (*Alopecurus* spp.) awns caused irritation, infection and death to two muskoxen in Alaska. The hay should not come from ranges used by domestic stock, especially sheep due to possible inadvertent transmission of diseases such as contageous ecthyma (R. Dieterich pers. comm. 1981) and parasites (Samuel and Gray 1974).

Transportation

Aircraft figure largely in the transport of captive muskoxen. Therefore, consideration has to be given to moving muskoxen from holding facilities to a suitable aircraft strip, loading and unloading the aircraft, and the location of the release site relative to an aircraft strip. The availability of landing sites largely determines the types of aircraft that could be used, though the practicalities of loading the crates should not be forgotten. E. Broughton (pers. comm.) noted that the crates built on site to ship the muskox yearlings from Banks Island in 1975 were designed to be loaded into a Twin Otter. The airplane's doors were 124.5 cm high and the crates were 122 cm high. The overall width was 61 cm and two crates would fit abreast in the plane. Despite the narrowness of the crates, one muskox yearling managed to turn around. The lengths were 183 cm except for one crate of 193 cm accommodating the largest male; the animals weighed between 115 and 135 kg. There are relatively few data on body weights (Table 3) and measurements especially from Canada. The costs of large capacity aircraft combined with helicopter support can offset the costs of using an aircraft that can land at the release site but can only carry a small load.

For safety reasons and to minimize stress the muskoxen are usually individually crated. During the most recent transplant from Nunivak Island in 1981, some of the yearlings were loaded two to a crate with no apparent problems (B. Dinneford pers. comm.). Newborn calves probably should be crated in pairs allowing them to press up against each other to reduce stress (K. Frisby pers. comm.). The crates used in 1971 were 2 cm plywood with outside bracing and 2-3 steel bands (Jennings and Burris 1971). The crates used in the transfer of muskoxen from Banks Island to Russia could be opened at either end, which allowed for effective ventilation of the crated individuals especially during the long aircraft journey (E. Broughton pers. comm.).

Table 3. Body weights (kg) by age class and sex of muskoxen.

Location and sex	11 months	23 months	35 months	Adult
Nunivak Island (Lent 1978)[1]				
Bull	74 (29)	116 (5)	269 (3)	
Cow	69 (43)	107 (10)	172 (6)	
Banks Island (P. Latour pers. comm.)[1]				
Bull	93 (5)	145 (6)	173 (5)	
Cow	87.5 (4)	133 (5)	182 (2)	
Mainland Canada[4] (Tener 1965)				
Bull				340 (4)
Arctic Island (F.L. Miller pers. comm.)[3]				
Bull				260 (1)
Cow				190 (1)
Captive in Vermont (Tener 1965)[4]				
Bull				587 (2)
Cow				290 (2)

1 April.

2 Sample size in parentheses.

3 Summer.

4 Unknown season.

RELEASE

The method, timing and location of release are key points in the successful growth of a transplant to an expanding population. There is a natural tendency to emphasize the capture phase as the more dramatic and exciting aspect of planning for the transplant project but the release requires as much, if not more, preparation and planning.

Site Location

Winter range is a key point in choosing a release site because of the importance of snow depth affecting forage availability. Muskoxen rarely forage in areas with snow deeper than 0.3 m and prefer areas with shallow or no snow cover (Tener 1965, Lent 1978). Muskoxen in winter are usually found on gently rolling hills, plateaus and slopes where the wind blows the snow away. The effect of wind and terrain makes extrapolation of average snow depths from settlement weather stations difficult, hence the release site should be examined in winter before the muskoxen are released. Low productivity, low survival and even die-offs occur during winters of deep snow, delayed melt and icing conditions (Vibe 1967, Miller et al. 1977). Muskoxen browse on willow (*Salix* spp.), dwarf birch (*Betula glandulosa*), and other low shrubs which stand up through the snow, and graze on sedges and grasses exposed by pawing away the snow.

Most studies of muskox habitats relate to the Arctic Islands (Wilkinson and Shank 1974, Parker et al. 1975, Parker and Ross 1976, Parker 1978, Russell et al. 1978). Tener (1965) describes range use and forage selection in the Thelon Game Sanctuary. Robus (1981) describes habitat use patterns of muskoxen of the Barter Island release in northeastern Alaska, and Bos (1967) describes habitat use by muskoxen on Nunivak Island.

Within the considerations of suitable range types and snow conditions, the release site should preferably have some natural topographic boundaries which limit initial dispersion but that will not prevent eventual population expansion. Water-bodies will act as barriers (including large rivers) and are also often associated with sedge meadows (and can be used for ice landing strips). I have not seen any references to the need for "escape" terrain like that required for wild goats and sheep, but muskoxen when harassed are impressively agile climbers and will retreat up steep rough slopes.

There is merit in avoiding releases along the coast, especially if there are cliffs with bird colonies. There are documented cases of death, including falls from cliffs, by muskoxen foraging on enriched vegetation near seabird colonies, and muskoxen venturing out on sea-ice and breaking through or not being able to return.

The release site should be distant from a settlement and not on a regular travel route or frequently used hunting area. Problems arose in Alaska from snowmachine harassment during caribou hunting, when the muskox groups scattered (Lent 1971b). In northeastern Alaska, the temptation for local people on snowmachines to approach and circle newly introduced muskoxen for a "closer look" sometimes led to unintentional harassment (K. Jingfors pers. comm.). A publicity campaign, directed toward people living in the area to describe muskox appearance and behaviour might prevent the harassment and shooting of muskoxen that has occurred in Alaska and Yukon. Also, areas likely to be used for industrial activities or tourism should be avoided to minimize potential disturbance.

Competition between muskoxen and caribou has been suggested to occur but has not been demonstrated (Vincent and Gunn 1981). Competition is empirically unlikely under normal conditions as the two species have evolved together on the arctic tundra. Under conditions of abnormally high densities or severe weather, habitat and forage selection patterns may change and result in competition.

Site Reconnaissance

The Alaskan transplants were preceded by reconnaissance of varying degrees of thoroughness; but emphasis was on availability and suitability of forage and on winter snow conditions. In some cases, data were unavailable from other studies in the immediate area (R. Bishop pers. comm.).

In the N.W.T. little is known about range conditions especially along the arctic coast and in the eastern Arctic. The studies along the proposed Polar Gas line in the eastern Arctic from the Boothia Peninsula through the Keewatin (Russell et al. 1978), the ALUR land classification system and some studies more limited in extent (Fleck and Gunn 1982) are all relevant sources for published information on range types as a background to site selection. D.R. Klein (pers. comm.) suggested that if releases were in known historic range, the records of distribution should be sought, and known or suspected changes in habitat or inter-specific relations should be considered. A range study is necessary to reconnoiter ground vegetation, to estimate the proportion of vegetated areas with shallow snow cover, and the likelihood of icing conditions detrimental to foraging.

Holding at Release Site

Temporarily penning the muskoxen at the release site allows the animals to rest and reorient after the excitement and stress of the handling, crating and transport. Injuries or illness brought on by the journey can be monitored and treated if necessary. The provision of hay and native forage species together, will avoid an abrupt transition in diet which could cause gastric problems.

The holding pens should be at the actual release site. If the aircraft cannot land there, snowmachines or a helicopter can be used to move the crated muskoxen to the site. The holding pens will allow synchronous release. Individual releases from crates, especially if at intervals with snowmachine or helicopter disturbance, may increase scattering of released animals.

Scattering of muskoxen during the 1969 release on Barter Island may have been partly due to the method of release. The muskoxen were released, then driven by snowmachines for several kilometers to suitable range (Hout 1969) . This also occurred during the release in 1981 on Seward Peninsula, and in 1976 and

1977 in Quebec, but should be avoided as it is another source of stress.

Monitoring of Released Muskoxen

Numbers and distribution of transplanted muskoxen should be monitored annually to detect changes in distribution, and health, productivity and recruitment of the population as well as possible problems such as poaching. Monitoring would be the feedback on the success of the transplant and indicate the need for, and timing of, management options including harvest.

The most useful monitoring would be aerial location of groups and singles followed by a count from the ground using snowmachines. Muskoxen are most easily spotted against a snow background, and surveillance from a distance of 200-300 m would allow a count of group size, by age class (calves, yearlings and cows). Such monitoring could be carried out by a wildlife officer and local hunters. The timing should be as early in March (to avoid possible disturbance to parturient cows) or early in October or November as snow conditions allow. Aerial counting of newborn calves and even yearlings is difficult, even if the animals do not group. Surveillance of the numbers of cows by age class allows for a more detailed description of productivity.

Composition and Size of Release

The age and sex composition of the transplanted muskoxen bears on its immediate success, in terms of grouping and wandering as well as on subsequent population growth. The normal muskox population consists mainly of groups of all ages and both sexes, usually led by a prime bull. Bulls also occur as solitary animals or in small groups of 2-10. Most of those bulls are not senile, but potential breeding bulls that try, and sometimes succeed, in becoming herd bulls of mixed groups during the rut (Gray 1979). The solitary bulls appear to wander more widely than the mixed groups which could be a dispersal mechanism if the solitary bull becomes a herd bull, and leads the herd to new ranges. In the absence of a herd bull, a mature cow will assume the role, which includes leadership when faced with obstacles such as rivers and travel to new ranges. The lead animal also is the last animal to enter a group defence formation and, in fact, often remains on the periphery of it (Miller and Gunn 1980).

The Alaskan transplants were almost all young muskoxen. Of the 160 muskoxen transplanted between 1967 and 1970 (Lent 1971b) 65.0% were yearlings, 22.7% were 2-year-olds, 9.3% were 3-year-olds, and only 2.0% were 4-year-olds. In each of the six Alaskan transplants, the sex ratio was almost equal. Lent (1971b) speculated that the scattering of the muskoxen released on Barter Island was partly due to the high proportion of yearlings. The yearlings formed groups and may have wandered while seeking the company of older muskoxen. However, the Nelson Island transplant was also mainly yearlings, but dispersal was limited.

There are practical reasons for a preponderance of yearlings such as ease of capture and handling and lighter body weights to ship (Table 3). I suggest, however, that a proportion of older muskoxen (2+year-olds) be captured and released. A sex ratio of one male to three females will probably be adequate because of the role of the herd bull in breeding the cows in a group. A tendency to release transplants in groups more similar to natural groups might increase herd stability and reduce the extent of dispersion. Transplanting only young males is not a problem as they can breed as yearlings (Lent 1971b), and an older cow will assume the lead role in the absence of a mature bull. The most recent release in Alaska was modified from earlier releases as only adult and subadult cows (5) were released with 32 yearlings.

Muskox groups are smaller in summer when single or bull-only groups are common. During and after the rut, however, many single and bull-only groups join the mixed groups (Table 4). The high proportion of single bulls (and bull-only groups) on Nunivak Island probably reflects the fact that bulls 4 years or older were the largest sex-age class in the population in April 1968. Lent (1971b) notes that small groups wandered more than large groups of transplanted muskoxen; he implies that unbalanced age composition was a factor leading to small groups. Lent (1971b) describes apparently "stable" groups that formed within months of the release as adults or subadults with yearlings. Logistics will, however, likely determine numbers released. If possible releases should be in groups of 20-40, each with four to eight 2 and 3-year old cows, and the remainder as yearlings roughly in the proportion of one male to three females. Releases at the beginning of winter should be of larger groups.

Table 4. Statistics on seasonal group sizes of muskoxen on Banks Island, Melville and Nunivak Islands.

Location	No. groups	Mean size	Range	No. single bulls
<u>Banks Island</u>[1]				
August 1974	88	8.1	1 - 25	26
October 1974	45	13.9	1 - 60	2
<u>Melville Island</u>[2]				
March-April 1972	161	12.8	2 - 77	6
August 1972	61	9.2	2 - 24	17
March-April 1973	146	17.8	2 - 110	0
July-August 1973	230	10.0	2 - 38	80
July-August 1974	211	7.2	2 - 25	36
<u>Nunivak Island</u>[3]				
April 1968	36	14.5	2 - 35	12
July 1967	50	11.1	2 - 30	67
August 1968	73	7.8	2 - 20	50

1 Beak Consultants (1976)

2 Miller et al. (1977) - August 1972 was 13-24 August

3 Spencer and Lensink (1970)

FATES OF TRANSPLANTS

Post-release Movements

In areas where summer and winter ranges are contiguous, wild muskox groups are relatively sedentary and appear to have home ranges. This was evident for the muskox groups on the North Slope of Alaska and northeast Prince of Wales Island (Jingfors 1980, Miller and Gunn 1980). In other areas, winter and summer ranges are separated; in the Thelon Game Sanctuary, 3-40 km separated the seasonal ranges (Tener 1965). Gray (1973, 1979) and Hubert (1974) described movements of muskoxen on Bathurst and Devon islands, respectively. Movements on Bathurst Island were similar to the pattern seen on other arctic islands with a tendency for a summer movement from the coasts to the interior along drainage courses (Miller et al. 1977). Gray's (1979) observations of marked muskoxen suggested that there were no regular seasonal movements through Polar Bear Pass but there were movements between areas up to 50 km away.

Lent's (1971b) descriptions of transplanted muskoxen in Alaska suggest that some stable groups formed within months of the release and remained in an area within 20-60 km of the release site. Seasonal movements were short and also elevational (ADF and G 1979). The group that moved 60 km from Barter Island between early and late April 1969 included an adult female, subadult female and three yearlings. That group of five muskoxen formed a nucleus and muskoxen have since remained in that area (Jingfors and Klein 1982). In 1972 and 1973, of the 20 observations of the Sadlerochit group, all except four were in an area 15x10 km

(Roseneau and Warbelow 1974). On Nelson Island, stable groups formed within 1 month and remained within 30 km of the release site (1967-1970) (Lent 1971b). On the Seward Peninsula a stable group did not form until 2 months after release. Four adults and 16 yearlings then grouped together within 20 km of the release site for a month. They moved 60 km, and a further 80 km, by March 1971 (Lent 1971b). Significantly, the group has stayed for 9 years within 40 km of the area where they were seen in March 1971, but has split into two main groups -- Black Mountain and Nuluk groups (ADF and G 1979).

Some of the released muskoxen moved long distances before they were lost track of or shot. From Barter Island, a subadult male travelled 240 km before being shot. An adult male and female yearling moved 130 km, and an adult or subadult bull was 160 km from its release point before being shot in August 1969 (Lent 1971b). Similarly, three yearlings from the Seward Peninsula release site had travelled 120 km when located 6 months after release (Lent 1971b). Two yearlings located 6 months after release were 260 km from the Cape Thompson release site (Lent 1971b).

The wandering of solitary adult bulls especially in summer is normal behaviour, though not particularly desirable in initially transplanted herds. Widely scattered sightings of bull muskoxen are reported - e.g., from the transplants to the Alaskan North Slope. A bull muskox was seen on Gary Island in the Mackenzie Delta in the summer of 1980 (A. Martell pers. comm.). The tendency of adult bulls to leave herds and wander, as well as the difficulties of handling adult bulls, suggest that adult bulls should not be transplanted.

Increase of Transplanted Muskox Herds

High rates of population growth, at least initially, are characteristic of introduced populations of mammals. Muskoxen introductions, once established, have been no exception. The best documented introduction is that on Nunivak Island with annual surveys since 1947 (Spencer and Lensink 1970).

Tener (1965) summarized observations on productivity and he suggested, 1) that twinning was exceptional; 2) that cows usually calved in alternate years depending on their nutritional status; and 3) that in the wild cows did not calve until 4 years old, but in captivity, yearlings and 2-year olds were bred. The second and third of Tener's (1965) points have been regularly refuted by observations of transplanted populations (Lent 1971b, Alendal 1979, Jingfors and Klein 1982) as cows have calved in successive years and were bred as yearlings or 2-year-olds). Survival of twins has not been documented though twin fetuses are occasionally found in Alaska: 4 of 107 pregnant cows from Nunivak and Nelson Islands had twin fetuses (Dinneford in press) and a captive cow in the Alaskan domestic herd delivered stillborn twins (R. Bishop pers. comm.).

There is no way of predicting whether transplants in Canada's eastern arctic regions, such as Pelly Bay (where transplants have been requested) will have the same reproductive characteristics of the other introduced populations. Although some of the Alaskan transplanted populations doubled their size in 3 or 4 years, the rate will likely slow down as range becomes limiting (Nunivak and Nelson islands) and the sex and age structure becomes more similar to wild populations.

Nunivak Island

The growth of the muskox population on Nunivak Island since the release of 31 animals in 1935 and 1936 has been documented by annual aerial surveys since 1947. The initial rapid growth in the population changed to a decline between 1941 and 1947 (50 in 1938; 76 in 1941; 49 in 1947) possibly because groups wandered out on to the pack ice and perished (Spencer and Lensink 1970). Between 1947 and 1968 the population increased at an annual rate of 16.2%, with an average annual calf production of 19% determined from aerial surveys (Spencer and Lensink 1970). In the late 1960's and 1970's the population structure was altered by selective removals for transplant, and after 1976 by regulated hunting. About 350 animals were removed for transplants (sex ratio slightly favoured females) and about 100 were killed during hunts (sex ratio strongly favoured bulls).

The sex ratio favoured males before 1968 but then shifted toward a more even ratio. The shift in the sex ratio impedes comparison of calf or yearling to total population size. For example, ADF & G (1980) notes that calf production averaged 15% from 1968-1977 but increased to 20% in 1978 and 1979, which is more similar to the rate of 19% reported by Spencer and Lensink (1970). The proportion of cows increased since 1968; for example, calf production appeared low in 1971, as calves were 13% of the total population. However, cows were only 30% of the population. Calf production measured as a percentage of cows 3-years and older was good - 65 calves to 100 cows. In 1980, calf production as a percentage of total population was 20.4%, but the ratio of calves to 3-year and older cow was only 50:100.

Spencer and Lensink (1970) and Lent (n.d.) described muskox mortality on Nunivak Island. Mortality averaged 7% of the total population between 1947 and 1968. The mortality varies between years. In severe winters when less than half of the preferred winter range was available, malnutrition from forage unavailability led to high mortality, e.g., 22% in 1968-69. The low incidence of picked up skulls and carcass findings suggested that part of the mortality resulted from falls from sea-cliffs and walking out onto the pack-ice, and breaking through. In March-April 1982, at least 9 muskoxen moved out onto the ice and drowned leading to the suggestion that the increased movements may have been the result of high densities (ADF & G 1982). Fatal falls from cliffs where lush vegetation fertilized by bird colonies attracted the muskoxen are described by Spencer and Lensink (1970), Lent (1971b), Freeman (1971), and Lønø (1960). There are no natural predators on Nunivak Island.

Calf survival averaged 85% (64-97%) for 5 years for which there were data (Lent n.d.). Calves showed the lowest survival - only 32 of the 50 calves born in a severe spring (1970) survived the following relatively mild winter, suggesting those calves may have been weak at birth or poorly nursed. Productivity and survival of calves has remained high since 1975 (Tables 5 and 6).

Nunivak Island has a high annual snowfall of 130 cm which exceeds the 20-75 cm prevalent on the Canadian arctic mainland (Spencer and Lensink 1970). The key to the survival of muskoxen on Nunivak Island is the marine escarpments, dunes and mountain slopes where the wind sweeps the snow away. The dune and cliff habitats are, however, vulnerable to trampling damage. The number

Table 5. Productivity (measured by proportion of calves to total number segregated) of muskoxen in Alaska.

Location	Year	Month	No. segregated	No. calves	% Calves
Nunivak Island[1]					
	1975	August	569	60	10.5
	1976	August	683	132	14.0
	1977	August	542	87	16.0
	1978	September	394	88	22.3
	1979	August	495	101	20.4
	1980	August	406	79	19.4
	1982	September	310	64	20.6
Sadlerochit River[2]					
	1972	Summer	14	3	21.4
	1973	Summer	12	3	25.0
	1974	Summer	27	3	11.1
	1976	Summer	35	8	22.9
	1977	Summer	35	8	22.9
	1978	Summer	46	13	28.3
	1979	Summer	58	17	29.3
Black Mountain[1] (Seward Peninsula)	1979	June	32	12	37.5
	1980	June	43	11	25.6

1 ADF & G reports
2 Jingfors 1980

Table 6. Recruitment (proportion of short yearlings to total population excluding solitary bulls) of muskoxen in Alaska.

Location	Year	Month	No. segregated	No. yearlings	% yearlings
Nunivak Island[1]	1976	February	554	71	12.8
	1977	February	651	111	17.1
	1978	February	491	92	18.7
	1979	February	529	114	21.6
	1980	February	601	121	20.1
	1981	February	702	134	19.1
	1982	February	538	91	16.9
Sadlerochit River (North Slope)[2]	1977	Summer	35	7	20.0
	1978	Spring	33	7	21.2
	1979	June	58	12	20.6
	1980	May	64	17	26.6
	1981	May	74	12	16.2
Black Mountain[2] (Seward Peninsula)	1979	June	32	5	15.6
	1980	June	43	12	27.9
Nelson Island[1]	1975	May	66	9	13.6
	1980	Feb.	167	29	17.4
	1981	Feb.	265	45	17.0
	1982	Feb.	217	33	15.2

1 ADF & G Reports
2 Jingfors 1980

of muskoxen that the island can support was considered to be 500 (Spencer and Lensink 1970). Wind and tide action prevent formation of continuous ice, so migration to the mainland is not possible. Manipulation of the population to hold it below the carrying capacity, and thereby prevent damage of the range continues to be necessary. Removal of muskoxen in the 1970's for transplants and by hunting has prevented the determination of such factors as, 1) whether the population would have stabilized itself, 2) whether boom or bust cycles would have occurred or, 3) whether competition would have occurred with reindeer on the island. The emphasis on hunting of bulls has changed; in spring 1981, 65 cow and only 10 bull permits were issued. The high proportion of cows taken was to reduce the breeding potential of the population and reduce the sex ratio to equality (ADF & G 1981b).

North Slope

Fifty-one muskoxen from Nunivak Island were released on Barter Island in April 1969 and 13 were released at the mouth of the Kavik River in June 1970. As Barter Island is only 130 km east of the mouth of Kavik River, the two transplants probably became mixed. Lent (1971b) described the dispersal of muskoxen from Barter Island and noted that no successful reproduction had occurred from 1969 to 1971. Lent (1971b) believed that no more than 22 of the 51 muskoxen were alive in March 1971: at least 8-10 had died shortly after the release.

Roseneau and Warbelow (1974) believed that, in 1972, 28 adults occurred in three groups between the Kavik and Aichilik Rivers, and seven other adults may have been present in Alaska and Yukon. Seven calves seen in 1972 were the first observations of calves, but presence of one yearling indicates some reproduction 2 years after the release. The three groups were still identifiable in 1980, and were using essentially the same areas as in 1972. Subsequently, the large groups have fragmented and increasing dispersal has occurred (ADF & G 1983).

A group of 11 adults and 3 calves in the Sadlerochit drainage (Area II, Roseneau and Warbelow 1974) in 1972 was probably the nucleus of the muskox group whose behaviour was studied by Jingfors (1980), and range use by Robus (1981), between 1978 and 1980. The 11 muskoxen (in 1972), with some possible immigrants, had increased to 58 in June 1979, and 64 in May 1980 (before the end of calving) in the Sadlerochit drainage (Jingfors and Klein 1982). After a slow start, the transplanted muskoxen showed high productivity between 1978 and 1982, even compared to Nunivak Island (Table 5). Observations of 2-year-old cows in 1979 documented two of them nursing calves. Also, there were only 15 cows aged 3 years and older but 17 calves, further suggesting that some cows were bred as yearlings and produced calves as 2-year-olds. Yearling and calf survival were also high (Jingfors and Klein 1982). The population numbered 219 in February 1982, and the Alaskan Board of Game created a hunter season for 5 bulls in 1982 (ADF & G 1983).

Seward Peninsula

A similar story of initial low productivity and scattered dispersal from the transplant site, followed by high productivity in the established herds, occurred on the Seward Peninsula. In 1970, 36 muskoxen were released and four calves were born from cows pregnant before the transplant. Carcass remains found in 1971 suggest that one muskox had fallen through the sea-ice and drowned and another was possibly killed or scavenged by a bear (ADF & G 1979). Two of the four calves born in 1970 were seen as yearlings in 1971, but apparently calves were not born until 1971. Since late 1971, the muskoxen were found in two areas about 160 km from the original release site, namely, the Nuluk River and Black Mountain areas (ADF & G 1980). Eight adults, two yearlings and three calf muskoxen were observed in 1974 in the Black Mountain area. In 1978, the group numbered 22 adults and 6 calves. The following year, in June 1979, there were two solitary bulls and a group of two adult bulls, 13 adult cows, five yearlings and 12 calves (ADF & G 1980). Thus, both productivity and calf survival were high (Tables 5 and 6). A group of five muskoxen in 1978 had likely moved from the Nulak area to Black Mountain area. Counts in 1979 showed 12 calves, all of which survived to 1980; but the counts did not classify the cows to year class, so the cow:calf ratio was 92-100:100. In late June 1980, the Black Mountain herd had 14 cows, 12 yearlings and 11 calves (Jingfors and Klein 1982). The calf:cow ratio in 1980 was 79:100 (compared to 89:100 for the Sadlerochit River herd).

The muskoxen in the Nuluk area are less well known but numbered 45 to 55 muskoxen in 1979 and at least 61 in May 1980. Unlike the Black Mountain population, the Nuluk population occurs as several groups. The Seward Peninsula population has not increased as rapidly as the North Slope population despite recent high productivity and survival. Dispersion of adult bulls and grizzly attacks may be part of the explanation (ADF & G 1981a). The initial slow growth may be partly due to dispersal caused by harassment from snowmachines (Lent 1971b).

Nelson Island

The release of muskoxen on Nelson Island in 1967 and 1968 resulted in limited dispersal and fast initial population growth even though the introduction was of young muskoxen (22 yearlings and 1, 2-year-old). Initial survival and production were exceptional, as in 1969, four calves were observed, so at least two 2-year-old females had calved (Lent 1971b). In 1970, 28 muskoxen were observed including five calves (Lent 1971b). The population continued to increase and the minimum population estimate was 265 in February 1981, which assumes an average annual rate of increase of 23% for the population (B.Dinneford pers. comm.). The estimated size of the adult population exceeds the possible carrying capacity of the range (ADF & G 1982), and a management plan is being developed. The first hunt was for 20 cows in 1981 and in 1982 the quota was raised to 30 cows (ADF & G 1982).

Cape Thompson

The release of 36 muskoxen in March 1970 was followed by extensive movements of some yearlings up to 90 km away by July. Only small groups formed in 1970, possibly because of disturbance by snowmobiles (Lent 1971b). One animal died in 1970 and two drowned after falling through the sea ice in 1971. Groups were still small, transitory and spread over a large area in 1971. A group of 11 muskoxen settled near Cape Dyer in 1972 and in 1973 had two calves. Only three other muskoxen were seen in 1973 (ADF & G 1974). In 1974, a group of 16 muskoxen and 3 calves were seen in the Cape Dyer area, and four other muskoxen were seen elsewhere (ADf & G 1976). In 1977, a further 36 muskoxen were released near Cape Thompson but the muskoxen were not closely monitored. In June 1981, the population was estimated to number at least 76 (ADF & G 1982).

European Transplants

Only 2 of the 10 transplants from East Greenland to Norway, Sweden, Iceland and Svalbard have been successful (Lønó 1960; Alendal 1976, 1979, 1980b). Lønó (1960) describes the failures of the early transplants, which tended to be small and were released in climatically unsuitable areas where contact with livestock was possible and poaching was not prevented (Table 7). The only successful releases were in the Dovre area of south Norway (1947-53) and the release on Svalbard in 1929.

The muskoxen in the Dovre Mountain area have shown high productivity, but accidents have limited the increase of the

Table 7. The fates and causes of mortality of muskoxen released in Europe (compiled from Lønø 1960).

Location	Dates		Number	Calves	Number of Deaths						
					Disease			Accident		Illegal	Unknown
	Release	Ended	released	produced	Stock	Transport	Other	Cliff	Other	kill	
Sweden	1900	1903?	4	No	2[1]	1[2]					1
	1901	1903	2	No							2
Norway	1924	1927	13	Yes			7[3]	1		7?	
	1932	1945	10	Yes				1	5[4]	11?	
	1947-53		27	Yes			5	3	1	1+?	5
	1948	1959?	10	No			2[3]		1		1
Iceland	1929	1931	7	No	7[1]						
	1930	1932	7	No			5[5]				2
Svalbard	1929	1980?	17	Yes		1[2]	9	11		20	18

1 Disease transmitted from domestic stock.

2 Disease resulted from transportation effects.

3 Pasture too rich.

4 Avalanche

5 Malnutrition

population. Five muskoxen moved from Dovre to Sweden in 1971 and had increased to 20 in 1980 (E. Alendal pers. comm.) and 25 in 1982 (Lundh in press). Evidence for exceptionally high productivity comes from the observations of Alendal (1979), who described 2-year-old cows calving and an incidence of apparent twinning. In July 1978, Alendal (1979) observed two calves suckling a 3-year-old cow, which could indicate twins or thief suckling by one calf. The two calves were observed with the cow on several occasions. This observation is the first documented incident of possible twinning. Confirmation of twinning, e.g., the presence of two corpora lutea - was not obtained. Accidents that limited the increase of the population included casualties from railway accidents and most recently, the herd of 39 was reduced to 27 by a bolt of lightning in July 1978 (Alendal 1979). Subsequently, numbers have increased slightly to 33 in 1982 (Alendal in press).

In 1929, 17 calves and one yearling muskoxen (seven females) were released on Svalbard. The first 3 or 4 calves were apparently born in 1932. Productivity has never been high as the number of calves has always ranged between 1 and 5 (Alendal 1976). The population grew slowly, reaching an estimated maximum of 50 (from 36 counted) in the summer of 1959. The causes of death are recorded for 40 of the 58 known deaths from 1933-1975 (Table 7). Eleven muskoxen fell from cliffs (including one in a river bed), 20 were shot and the others died from miscellaneous causes (Alendal 1976). In 1974 the population numbered only 30, including one calf. The decline continued until 1981 when only one cow was left (E. Alendal pers. comm.). The slow increase and subsequent decline may partly reflect the relatively mild winters, as temperatures above 0°C can occur in any month, causing icing. At least three yearlings are believed to have died from starvation in April 1963. Alendal (1976), through acknowledging his lack of evidence, ascribed the population decline to competition. The rapid growth of the reindeer (Rangifer tarandus platyrhynchus) population, from low numbers during World War II to a population of several thousand in 1974, parallels the decline of the muskoxen. Alendal (1976) noted that in the summer both species foraged on the same grass and sedge ranges, but this is not necessarily evidence for competition.

Greenland

The introduction of a total of 27 muskoxen in 1962 and 1965 to Sondre Stromfjord, West Greenland has been, to date, successful. The transplanted population was initially stable for 5 years (K. Jingfors pers. comm.), but now has high productivity and low mortality. Roby (1978) reports that the 1978 population was 205 but in 1982, the population had increased to between 400 and 500 (Thing et al. in press). The ratio of calves to cows 2-years and older was 67:100 in 1977 and 69:100 in 1978. The available area in Sondre Stromfjord is relatively limited and Roby (1978) suggests that the population growth will slow down unless emigration takes place. The ranges to the south are blocked by an ice cap, so emigration will have to be to the north where a few bulls have already been seen. The increase of the muskox population is concurrent with a decline in the reindeer population, as in the winter of 1977-78, above normal snowfall resulted in starvation of most caribou calves and 20% of the adults.

Quebec

The 15 muskoxen transplanted from Ellesmere Island in 1967 to a farm at Fort Chimo, Quebec were to be the basis of a cottage industry. However, the project has apparently run into administrative difficulties. The calves caught in 1967 (12 females, 3 males) produced only three surviving calves in 1971, which were unhealthy due to parasites. The next year, 10 calves were born and all died from parasites. By 1973 however, the parasite problems were solved. At least 43 muskoxen were released from the farm by 1975 to form wild herds for a knitting-weaving industry, which has not developed (I. Juniper pers. comm.). The native corporation wanted to aquire the project, but the necessary funding was not forthcoming and the muskoxen are now the responsibility of the Department of Agriculture (I. Juniper pers. comm.). Lack of recent monitoring prevented evaluation of success of the releases in 1975, 1976, 1977 and 1978. In 1980, there were about 20 muskoxen at the farm.

Productivity and Survival in N.W.T.

Data on muskox productivity in N.W.T. (Table 8) are difficult to compare with the Alaskan data for several reasons. In the N.W.T., productivity data are largely from aerial surveys and are expressed as the ratio of calves to total numbers classified

Table 8. Productivity (measured by proportion of calves to total number segregated) of muskoxen in Canada.

Location, year	and month	Type of survey[1]	No. segregated	No. calves	Percentage	Source
Bathurst Island						
1961	July	AT	97	10	10.3	Tener 1963
1968	Summer			0	0.0	Gray 1973
1969	Summer			0	0.0	Gray 1973
1970	Summer			0	0.0	Gray 1973
1971	Summer			0	0.0	Gray in Parker et al. 1975
1973	August	GS	103	27		
1974	August	AS	135	1	0.7	Fischer and Duncan 1976
1974	August	AT				Miller et al. 1977
1975	June	AT	69	7	10	Fischer and Duncan 1976
1981	August	AT	222	36	16.2	M. Ferguson pers. comm.
Eastern Melville Island						
1972	August	AT	190	16	8.4	Miller et al. 1977
1973	July	AT	397	80	20.2	Miller et al. 1977
1974	August	AT	147	1	0.7	Miller et al. 1977
1974	August	AT	53	0	0.0	Fischer and Duncan 1976
1975	July	AT	29	2	6.9	Fischer and Duncan 1976
1977	August	AT	260		24.6	McLaren et al. 1977
1981	August	GS	104	18	17.3	McLaren 1981
1982	late May	GS	127	1		McLaren and Green 1982
Devon Island						
1970	August	GS	287[2]	57	19.9	Hubert 1977
1971	May	GS	251[2]	48	19.1	Hubert 1977
1970	May	GS	156[2]	27	17.3	Hubert 1977
1970	August	GS	95[2]	15	15.8	Hubert 1977

Table 8. continued

Location, year	and month	Type of survey[1]	No. segregated	No. calves	Percentage	Source
Northeast Prince of Wales Island						
1974	July	AT	306	43	14.0	Fischer and Duncan 1976
1975	June	AT	95	14	15.0	Fischer and Duncan 1976
1976	July-August	GS	154	33	21.4	A. Gunn field notes
1977	July-August	GS	126	39	30.9	A. Gunn field notes
1979	August	GS	259	39	14.7	A. Gunn field notes
1980	August	AT	408	50	12.3	A. Gunn field notes
Banks Island						
1970	June	AT	491	74	15.1	Kevan 1974
1971	September	AT	426	103	24.2	Urquhart 1973
1972	Summer	GS			18.1	Wilkinson et al. 1976
1973	July	GS	223	40	17.9	Wilkinson et al. 1976
1974	August	AT	293	25	8.5	Beak Consultants Ltd. 1976
Thelon Game Sanctuary						
1951			254[2]	30	11.8	Tener 1965
1952			145[2]	19	13.1	Tener 1965
1954			266[2]	38	14.3	Tener 1965
1955			172[2]	18	10.5	Tener 1965
1957			63[2]	0	0.0	Tener 1965
1961			110[2]	12	10.9	Tener 1965
1962			177[2]	15	8.5	Tener 1965
Northeast of Thelon Game Sanctuary						
1980	June	AS	247	29	11.3	A. Gunn field notes

Table 8. continued

Location, year and month		Type of survey[1]	No. segregated	No. calves	Percentage	Source
Queen Maud Gulf						
1976	July	AT	660	126	16.03	Spencer 1976
1979	August	AS	3968	448	11.3	
1982	August	AT	692	82		Gunn et al. in press
North of Great Bear Lake						
1975	July	AT	675	103	15.3	V. Hawley pers. comm.
Bathurst Inlet						
1976	July	AS	91	19	17.2	Spencer 1976

1 Type of survey: AT aerial transect, AS aerial survey (unsystematic) and GS ground survey.

2 Solitary bulls and bull pairs excluded.

(usually mixed groups), often with no specification of whether single bulls or bull-only groups are included. The Alaskans also rely on aerial surveys but do include periodic ground counts. Muskoxen can be classified into sex and age classes by horn development, body size and coat characteristics only from the ground. If the muskoxen group together during an aerial overflight calf counts and even total counts are difficult to obtain and calf counts are likely minimal. McLaren et al. (1977) compared calf counts in the same area during aerial transect surveys at 90 m agl, and from the ground and found 17.9% and 24.6% calves to total muskoxen segregated, respectively.

A second difficulty in comparing productivity is the difference in range potential in Alaska and N.W.T. Alaskan muskoxen were introduced into areas where predator populations were low (R. Bishop pers. comm.) and range conditions especially good, as the range had not been subject to muskox foraging pressure for centuries. An indication of the effect of range (and presumably winter conditions) on productivity is the breeding of yearlings, and successful production of calves by 2-year-old cows (Nelson Island, Sadlerochit and Black Mountain herds). Lent (1971b) suggested that the presence of older cows might inhibit the breeding of subadult cows, and that the absence of adult cows allowed the breeding of yearlings in 1968 on Nelson Island. The description of 2-year-olds calving in the Black Mountain and Sadlerochit herds when 4+-year-old females were present suggests that range condition is more important than social dominance in determining the age of calving. Under poor range conditions, however, social dominance could be a mechanism for reducing the breeding of younger cows (Gunn in press). Alendal (1979) attributed the calving of 2-year-old muskoxen and high productivity to good range conditions and a long growing season. The muskoxen, by moving down to birch forests in mid-May to the end of June, can forage on vegetation growing a month earlier than vegetation higher up in the mountain areas.

A third difficulty with comparing data from the N.W.T. to data on transplanted muskoxen in Alaska and elsewhere is the annual variability in productivity (Table 8) and survival (Table 9), especially on the Arctic Islands. Whereas in some years no cows are bred (Gray 1973), in other years most cows, including 3-year-olds have calves (Hubert 1977) and cows calve in successive years (Jingfors 1980, Miller and Gunn 1980).

Finally, some N.W.T. muskox populations can be considered as natural reintroductions. Along the Canadian mainland coast (Gunn et al. in press) and on Banks Island (Vincent and Gunn 1981) the muskoxen were almost extirpated by hunting in the early 1860's. Subsequently, those muskox populations have rapidly increased. Once those populations have reached equilibrium with their habitat, those high reproductive rates will likely decrease. The comparison of productivity between data from N.W.T. and elsewhere is further complicated by the abnormal age and sex structure of the Alaskan transplanted herds, which had a disproportionately greater number of yearlings at the time of release. Equally, in the Nunivak Island population hunting pressure and removals for transplants have altered the age, and especially, the sex ratio.

In Canada, calf production (as measured by calf:cow ratio and proportion of calves to total muskoxen) and calf survival may be

Table 9. Recruitment (proportion of short yearlings to total populations excluding solitary bulls) of muskoxen in N.W.T.

Location	Year	Month	No. segregated	No. yearlings	% yearlings
Thelon Game Sanctuary[1]	1952		145	12	8.3
	1956		191	12	6.3
	1962		177	13	7.3
Fosheim Peninsula[2] (Ellesmere Island)	1951		87	3	3.4
	1954		150	3	2.0
Devon Island[3]	1971	May	156	5	3.2
	1972	May	251	21	8.4
	1973	May	268	31	11.6
Prince of Wales Island[4]	1976	July	154	6	3.9
	1977	July	126	6	4.8
Banks Island[5]	1972	March	?[5]	?[5]	11.7
	1973	July	233	22	9.4
Eastern Melville Island[6]	1982	May	127	6	4.0
	1981	August	129	9	7.0

1 Tener 1965
2 Hubert 1977
3 A. Gunn field notes
4 Wilkinson et al. 1976
5 no data
6 McLaren 1981, Mclaren and Green 1982

higher than has been previously recorded. Tener (1965) speculated that calf survival was greater than 50% on the Canadian mainland, and less than 50% on Arctic Islands, but most of his data were from relatively stable populations.

On Nunivak Island, calf survival has averaged 85% between 1966 and 1971 (Lent 1978). Calf survival in the transplanted herds has been higher -- 100% in 1980 and 1981 in the Sadlerochit River herd on the North Slope (Jingfors and Klein 1982). In some years, calf production and survival in Canada may be as high as that recorded in Alaska, but data from ground composition counts is scarce.

The increase in some Canadian muskox populations such as Banks Island (Vincent and Gunn 1981) and mainland areas such as the Queen Maud Gulf area suggests that rates of increase are similar to those described for transplanted muskox herds in Alaska. The high survival is assumed from the high proportions of yearlings on southeast Victoria, in March 1983 the proportion of yearlings was 20.3% in a sample of 301 muskoxen of an increasing population (K. Jingfors pers. comm.) and also in March 1983, north of Great Bear Lake, K. Poole (pers. comm.) classified 30.6% yearlings among 258 muskoxen from an increasing population.

DISCUSSION

Several rationales for the capture and transplantation of muskoxen in the N.W.T. have been advanced. On the N.W.T. mainland, muskox populations are naturally expanding into areas where they had been extirpated by hunting in the late 19th and early 20th centuries. To speed up this process, transplants have been requested by settlements.

Interest (eg., January 1980 and February 1982 sessions of N.W.T. Legislative Assembly) in transplanting muskoxen to establish wild populations has centred on the eastern Arctic, Baffin and Southampton Islands. Although Baffin and Southampton are not historic muskox range, the area south of Pelly Bay to Wager Bay, Chesterfield Inlet and south toward Henik Lakes is historically muskox range. Muskoxen were likely exterminated (Burch 1977) in that area by the time protection was enacted in 1917, and relatively few sightings have been made since then. Reasons for the slow recovery in this area, compared to the western Arctic, are admittedly, speculation, but discussion of them may be useful in predicting the success of transplants to the area.

Mean annual total snowfall is less than 100 cm over most of the current muskox range in Canada. North of the treeline the lightest snowfall (<50 cm) is in the area of Queen Maud Gulf. Toward the east the snowfall increases: Melville Peninsula, Southampton Island and Baffin Island (southeast of Pond Inlet) all receive more than 100 cm snowfall a year (Maxwell 1980). The absolute amount of snowfall is not restrictive however, if wind action and topography result in areas of shallow snowcover. Instead, there is a complex relationship between snow depth and duration, length of growing season and plant productivity. Snow lies longer in the eastern Arctic (Maxwell 1980) and that prolongation of deep snow cover into spring may be a limiting factor for muskoxen.

In other areas where muskoxen have been successfully transplanted, such as Nunivak Island and Fort Chimo (Quebec), annual snowfalls are higher than in the Northwest Territories but the snow melts sooner. The growing season is longer and descriptions of vegetation suggest the ranges are more productive than in the eastern Arctic. The northeastern Arctic mainland has a combination of deeper snow cover of longer duration, a shorter growing season, and cooler temperatures in the summer (Maxwell 1980, 1981). Descriptions of range types in the northeast District of Keewatin suggest some impoverishment of diversity and probably plant productivity compared to the western Arctic.

There are relatively few descriptions of the vegetation in the eastern Arctic mainland. One of the few existing studies described the range types of the Boothia Peninsula and northern Keewatin to Back River (Russell et al. 1978). There was almost no suitable muskox range on Boothia Peninsula, but large expanses of wet sedge-moss meadows were found west of Pelly Bay, which are likely suitable summer ranges for caribou and muskoxen. Russell et al. (1978) noted that deep snow could be the reason for the absence of muskoxen. In the area between Hayes and Meadowbank Rivers, the extensive sedge-moss meadows would have a deep snow cover and dwarf shrub range types (muskox winter range) were infrequent and patchy. Adequate winter range to compensate for the deep and long-lying snow may not be present in the northeastern District of Keewatin. Older hunters of Pelly Bay, Spence Bay and Gjoa Haven, however, recall that 30-40 years ago muskoxen were found in the Hayes and Murchison river valleys (A. Helmer pers. comm.) which suggests muskoxen could at least seasonally use the area.

Muskox numbers have never been high in northeastern Keewatin (Tener 1965) and it is worth recalling Tener's (1965) comment about the Hudson Bay muskox (once considered a separate subspecies but now classified with O. m. moschatus). Although his sample size was small (six adult bulls), skull measurements for animals from Wager Bay, Chesterfield Inlet and west Hudson Bay were smaller than for other mainland muskoxen, possibly reflecting poor range conditions.

The evidence for Southampton and Baffin Island as historic muskox range is reviewed by Harington (1961). He concluded that muskoxen rarely, if ever, occurred on those islands. He ascribed their absence on Baffin to deep snow cover and on Southampton to the hunting by early man.

The consideration of historic muskox range, climate and weather and range conditions suggests that muskoxen transplanted to the eastern mainland Arctic would increase slowly due to deeper and longer snow cover and a shorter growing season. Transplants to Baffin and Southampton islands would have the likelihood of high mortality at periodic intervals due to deep snow with icing conditions (Vibe 1967).

Introductions into areas where endemic muskoxen may spread should be the same subspecies. Introducing muskoxen from Banks Island (*O. m. wardi*) into ranges of the mainland muskoxen (*O. m. moschatus*), (which has been suggested as one way to reduce the muskox population on Banks Island) should not be attempted. The local people on Banks Island have expressed fears that the muskox population is competing with the caribou (Vincent and Gunn 1981). For a situation such as Banks Island, where efforts are being considered to reduce the population, removal of muskoxen is not a practical answer. Not only would the island's relative isolation make logistic costs high (even in conjunction with organized kills), but in addition, the removal of transplants would have to number hundreds of muskoxen to have any impact on reducing the population. It is currently recognized in Alaska that muskox transplants are not an appropriate technique to reduce or stabilize an increasing population (Coady and Hinman in press). Instead, selective hunts should be used (ADF & G 1981) as on Nunivak Island.

The transplants of muskoxen in Alaska were not specifically intended to provide a future source of game meat. The decline of caribou populations and growth of human populations in the N.W.T. has, however, prompted suggestions that muskoxen could be transplanted to start new, or reinforce established, populations for harvesting. This approach is long term and is not an instant panacea to current problems.

Even if a population increased at rates consistent with those of the successful transplants in Alaska, harvesting would be minimal for 10-20 years. Premature harvesting or poaching would drastically reduce growth of a recently established population. On Nelson Island, harvesting did not begin until 13 years after the successful establishment of the population and the kill was restricted to 20 cows. On the Alaskan North Slope, the quota is five bulls from the muskoxen population that was transplanted there 14 years ago. Harvest of a limited number of bulls could perhaps have begun earlier. The estimated 20% population increase is also possibly optimistic over a longer term for the Canadian mainland. Even one severe winter could slow down the increase of the transplanted population. Finally, a degree of certainty of the acceptance of muskox meat as a replacement for caribou is necessary.

The key to any muskox transplant in the N.W.T. is community consultation and education. The local people must be aware of the limitations of transplants in terms of population increase and its potential use. Their awareness of the consequences of poaching and inadvertant harassment is vital to the success of the transplant. The exploration of population dynamics and potential of muskoxen use must be realistic to avoid false expectations. The public consultation should explain the capture method, the problems of stress and how stress can be increased by well-meaning and curious onlookers.

The rapid changes in the N.W.T., as industrial development gains momentum, will foster efforts to stabilize the boom and bust cycle characteristics of much northern development. Those efforts will be partly channelled into establishing local industries relying on local resources, and will almost inevitably include more emphasis on domestication (or more accurately, farming) of muskoxen. Administratively, wildlife management should be separate from game ranching and farming as the basic philosophies, techniques, and objectives of the two are different, if not mutually exclusive. Avoidance of an ad hoc, piecemeal approach to those issues is necessary to insure that standards for human safety, and animal health and welfare will be met.

Interest in the domestication of muskoxen for qiviut (or even meat production) is a topic that has resurfaced at intervals since the 1700's. To date, the few efforts have been with captive herds and progress toward domestication have been marginally successful. A cottage industry could not be supported by collecting wool shed by wild muskoxen. The practicalities of collecting enough wool as the fine wisps and clumps are scattered by the wind, and cleaning the wool from the leaves and debris, are daunting. Within a month of being shed, the wind, sun, and moisture bleach the wool and the fibres become harsh and brittle.

To treat the wild muskoxen like domesticated reindeer and round them up at shedding time (June-July) is equally impractical. The potential stress resulting from rounding up and corralling the muskoxen, must be considered, moreover, the animals would have to be held, as shedding is not an overnight process. In the wild, the different age-sex classes shed at different rates. In short, if a qiviut-supported cottage industry is to be established, only a muskox ranch is practical.

The N.W.T. Wildlife Service investigated the potential of a captive muskox program in the 1960's. Birt (1971) reported on the economics of establishing a muskox farm at Fort Providence, Eskimo Point and Belcher Island. Birt (1971) noted that it was a "high-risk" project and an optimistic forecast for profitability was at least 6-8 years. Birt's (1971) report was followed up with a study of the range conditions at Fort Providence, N.W.T. (Penner at al. 1972). To reduce costs, Penner at al. (1972) recommended a ranch-style management, rather than the more confined conditions of the muskoxen farm. However, expense and logistics ruled against the venture (H. Monaghan pers. comm.).

Only one of the three previous attempts to establish a captive herd to support a local "cottage" industry for knitting qiviut (muskox wool) actually produces commercial quantities of quivit. The Muskox Producers Corporation's project in Alaska required 10 years of subsidy and is still not self-sufficient. Range damage, and disease (contagious ecthyma) within the herd, are problems still to be solved. A similar project in Quebec failed partly through administrative problems and partly because the program never achieved acceptance by the native people. The project at Bardu in Norway failed because of disease problems caused by the domestic stock.

If a domestication project fails and disposal of the muskoxen is required, under no circumstances should they be simply released. Their handling would have changed their behaviour toward humans, and their consequent lack of fear and sense of curiosity could cause a situation which could be dangerous to humans or the muskoxen. Additionally, there exists the danger of the released or even escaped animals spreading diseases such as lungworm or contagious ecthyma, to endemic muskox or other ungulate populations. Captive muskox herds are economically a long-term project and their planning should take that into account.

Muskox transplants are not a short-term management tool. Their subsequent effects, such as potential problems of range damage and competition with other range users (primarily caribou), and their potential utilization, require long-term consideration and planning. When considering transplants, wildlife managers should also evaluate the advantages of managing the existing muskox populations to foster the continued colonization of historic ranges.

RECOMMENDATIONS

1. Full and detailed community consultation shoul be part of the planning for a transplant, especially to gain acceptance for transplants as a long-term project.

2. No transplant should be considered without planning and a committment to the long-term monitoring and management of that transplant.

3. Prior to a transplant, summer field work should be done to evaluate winter and summer range, including estimation of range extent and ground sampling. Winter range snow conditions should be evaluated including areas of shallow snow and snow conditions.

4. The release area should be chosen in consultation with the Habitat Management Section to avoid; 1) sea coasts with cliffs, 2) areas of potential industrial activities, and 3) the possiblity of competition with other ungulates.

5. The snowmachine-net capture method should be used in the fall using local hunters, a veterinarian, and advisers from Nunivak Island. Radio-collars should be fitted to some animals and all animals should have eartags before being released.

6. Chases during capture should be limited to minimize the possibility of causing capture myopathy to either the animals being caught or others in the herd.

7. The transplant should number 20-40 yearling muskoxen with 4-8, 3 and 4-year-old-cows.

8. The released population should be monitored by aerial and ground surveys on an annual basis. The first release should be treated as a pilot experiment and evaluated before other transplants are considered.

9. The health status of the source herd should be determined. Capture and transplant to virgin areas present an excellent opportunity to establish a disease-free group (R. Dieterich pers. comm.).

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