A PROGRAM TO MONITOR MOOSE POPULATIONS IN THE DEHCHO REGION, NORTHWEST TERRITORIES, CANADA

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ABSTRACT: Moose (*Alces alces*) are an important traditional and spiritual resource for residents of the Dehcho Region of the Northwest Territories. Maintaining healthy and sustainable populations of moose for future generations is a goal of the Department of Environment and Natural Resources (ENR). Following a regional wildlife workshop with Dehcho First Nations, the need for a program to determine baseline information on moose populations and to foster community-based monitoring of moose in the Dehcho was identified. Such a program needed to be established prior to future proposed developments including the Mackenzie Gas Project. After extensive community consultation between local First Nations and ENR, a baseline aerial survey over a large area of the Dehcho was designed, and was to be followed by an annual monitoring program. Two key components identified for the annual monitoring program were an aerial survey and harvest sampling. The aerial survey would provide information on moose density and calf production, and harvest sampling would provide information on the relative health and physical condition of animals consumed by local residents. In light of increasing developmental pressures in the region, such information collected over time is important to harvesters, First Nations, wildlife managers, and land use planners alike because it should document change in the quantity and quality of a key traditional wildlife resource. Population estimates from the aerial surveys indicated that the estimated population density and calf:cow ratios were reasonable. Harvest data indicated low incidence of diseases and parasites, low levels of cadmium in organ tissue, and that moose were mostly in good or excellent body condition based on observation and fat indices. This study is an example of successfully combining the knowledge and cooperation of First Nation moose harvesters with the technical support of government biologists to secure valuable biological information for baseline data to monitor change associated with development in a region.

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Key words: Aerial surveys, Dehcho First Nations, land development, monitoring, moose, Northwest Territories, physical parameters.

Moose (*Alces alces*) are an important traditional and spiritual resource for residents of the Dehcho Region (Dehcho) in the southwestern Northwest Territories of Canada. Prior to April 2002, the Dehcho had no regional biologist and wildlife research programs were very limited. There had been a few surveys for moose and Dall's sheep (*Ovis dalli*) conducted in the 1980s shortly after the establishment of the all-season Liard Highway (Decker and Mackenzie 1980, Treseder and Graf 1985, Case 1989). An additional moose survey was conducted in the Liard Valley near Nahanni Butte in the late 1990s.

Canada's northern boreal forest is often viewed as one of the last great wilderness in the world. Increasingly, however, northern people are realizing that this wilderness is and will be altered by large-scale factors generated by outside processes beyond their direct control. Mining and oil and gas development are major concerns in communities that rely on native species or "country foods" for sustenance. With increased resource development and access to the boreal forest comes the potential for increased harvest and changes in the relative

health and condition of moose. In September 2002 at a regional wildlife workshop in Fort Simpson hosted by Dehcho First Nations and the then Department of Resources, Wildlife & Economic Development (RWED), First Nations delegates expressed similar concerns and made it clear that there was an immediate need for study of moose in the region. The paucity of information about moose in Dehcho was recognized as an important omission/gap in the biophysical assessment for the proposed Mackenzie Valley Pipeline.

Through many community meetings with local First Nations and government biological staff, a survey area was determined and an extensive baseline population survey for moose was conducted during winter 2003-2004. At the 2nd biannual Dehcho Wildlife Workshop in October 2004 there was high community interest in the results of the baseline survey, the need to continue annual monitoring, and to expand the program to record measures of animal health and condition. After several community meetings with local First Nations, a more extensive moose monitoring program was designed. In this paper I describe the program and provide some preliminary results of the surveys.

STUDY AREA

The study area included the Dehcho administrative region of the southwestern Northwest Territories as defined by the Department of Environment and Natural Resources (ENR), Government of the Northwest Territories (*ca.* 150,000km^2). It included the lower portions of the Mackenzie River Valley to the north and east, the Liard River Valley to the south, and the Mackenzie Mountains to the west. There were 6 communities in the region: Fort Liard, Nahanni Butte, Trout Lake, Jean Marie River, Fort Simpson, and Wrigley. Two of these communities (Nahanni Butte and Trout Lake) were accessible by road only during winter; the others were on an all-weather road system. The study area

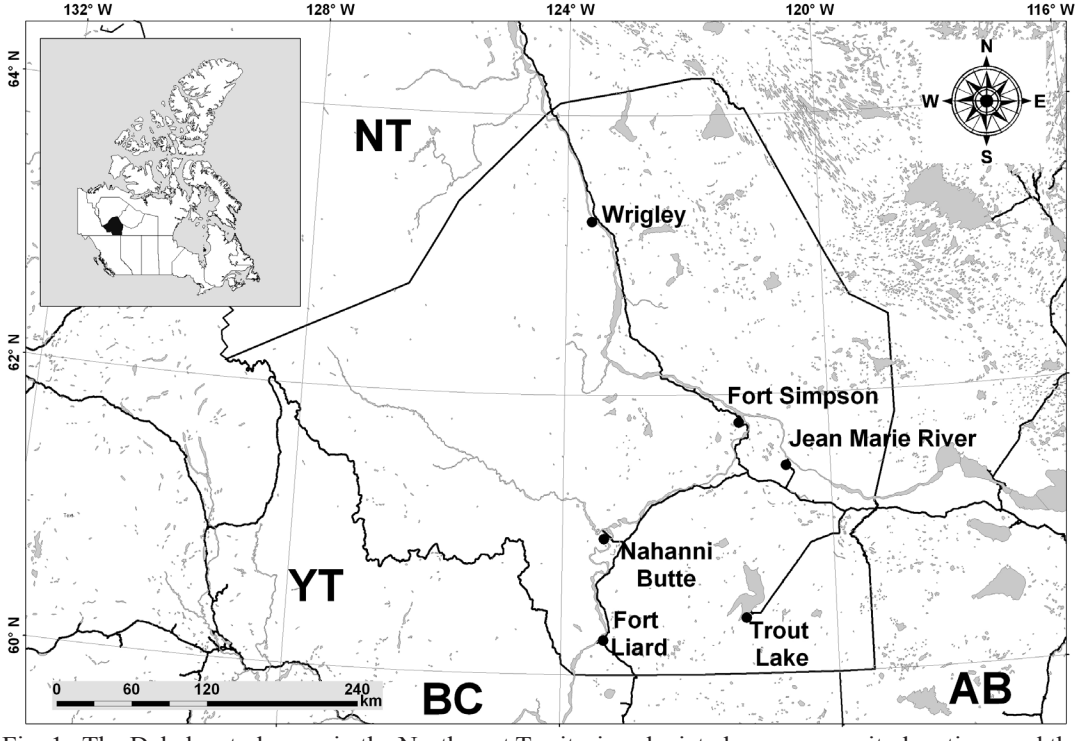

Fig. 1. The Dehcho study area in the Northwest Territories; depicted are community locations and the road system, including winter roads.

also included a portion of northeastern British Columbia because the traditional harvesting area of residents of the Acho Dene Koe Band of Fort Liard extends south into northeastern British Columbia (Fig. 1).

The vast majority of the study area is part of the northern boreal forest and is dominated by the Taiga Plains ecoregion. The Taiga Shield ecoregion is found to the east, and the Mackenzie Mountains that make up the extreme western portion of the study area are part of the Tundra Cordillera ecoregion. Moose and woodland caribou (*Rangifer tarandus caribou*), of both the boreal and northern mountain ecotypes, are the dominant ungulates and wood bison (*Bison bison athabascae*) occur in the Liard Valley from Nahanni Butte south into northeastern British Columbia. Timber wolves (*Canis lupus*), black bear (*Ursus americanus*), grizzly bear (*Ursus arctos*), wolverine (*Gulo gulo*), and lynx (*Lynx canadensis*) are the key predators.

METHODS

Baseline Population Surveys

Logistics and cost precluded the use of the typical Gasaway survey technique (Gasaway et al. 1986) given the huge, relatively uninhabited area to be surveyed. A workshop on moose survey techniques in May 2003 brought together biologists from Yukon, Alaska, and Northwest Territories to discuss new refinements in moose survey methodology. A geospatial technique (ver Hoef 2001, 2002) was in use as the primary survey method in Alaska and the Yukon. After discussions with First Nations, a consensus was reached that this method would be used for baseline surveys of moose in the Dehcho. The geospatial survey method consists of 5 basic elements: 1) defining the survey area, 2) stratifying the area, 3) determining sample sizes, 4) surveying a random sample of sample units within the area, and 5) analyzing the data. The major differences between this approach and the Gasaway technique are that the size of the survey area can be much larger, sample unit boundaries are delineated by latitude (2°) and longitude (5°), correction for sightability is unnecessary, and the analysis utilizes a spatial statistics model. Importantly, data analysis could still follow the basic approach of Gasaway et al. (1986).

We defined 2 survey areas: 1) the Mackenzie River Valley (MRV) extending from Blackwater River in the north to Jean Marie River in the south including the communities of Wrigley, Fort Simpson, and Jean Marie River, and 2) the Liard River Valley (LRV) extending from Poplar River in the north and the British Columbia-Northwest Territories boundary (60° N latitude) in the south including the communities of Nahanni Butte and Fort Liard (Fig. 2). To determine survey areas, we sent maps to each of the communities and requested that they indicate areas they would like included in the survey. The maps were then combined digitally on a GIS system, and a composite map was drafted and circulated. Once the composite map was finalized, a 2° latitude x 5° longitude grid of all the sample units was created (Fig. 2); sample units averaged *ca.* 16 km^2. We evaluated the size of the survey areas, aircraft availability, and length of daylight and decided to survey the MRV (23,281 km^2) in November 2003 and the LRV (9,585 km^2) in February 2004.

The sample units in each survey area were stratified by expected low and high moose density almost exclusively from traditional knowledge of First Nations harvesters after many meetings between communities and Environment and Natural Resources (ENR) biological staff. There was no conflict in stratifying areas that overlapped traditional hunting areas used by neighboring communities. However, there were some isolated parts of the survey areas where harvesters had insufficient knowledge to comfortably stratify the survey blocks. For those areas we relied on previous survey and/or landcover classification information to stratify the survey blocks. A draft of the proposed stratification

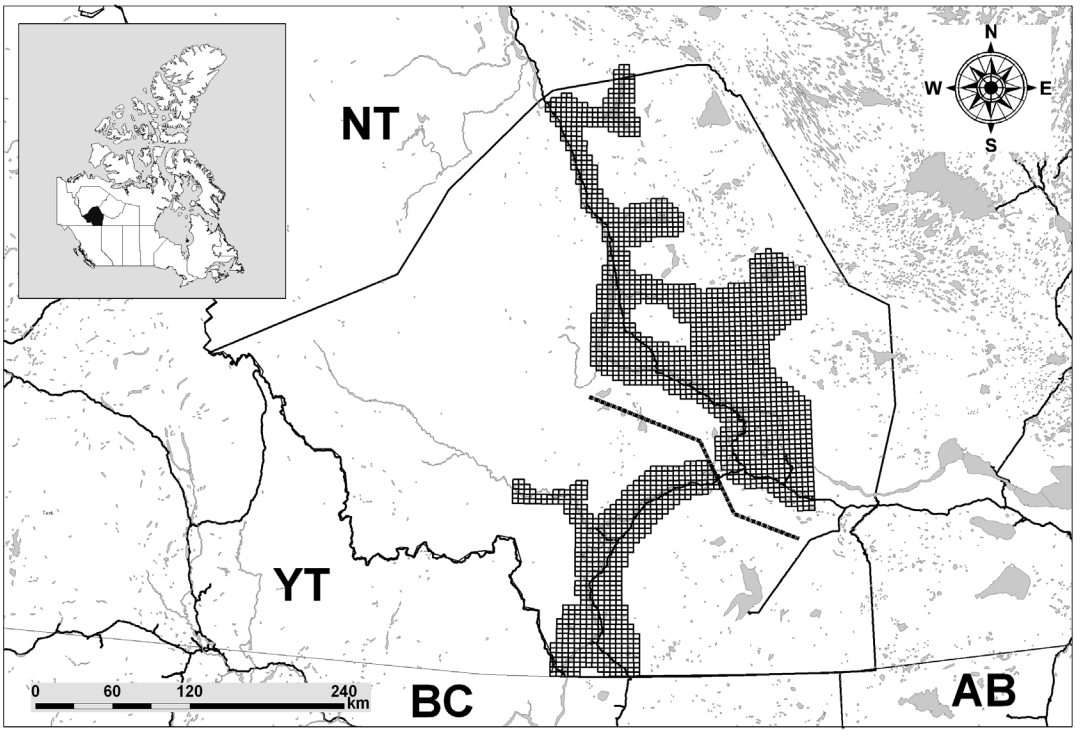

Fig. 2. The two baseline survey areas separated by the hatched line. The Mackenzie River Valley (MRV) contained 1459 sample units covering 23,281 km^2 in the north and the Liard River Valley (LRV) contained 569 sample units covering 9,585 km^2 in the south.

was then circulated to First Nations for ratification. Survey blocks were randomly chosen; 100 blocks totaling 1,595 km^2 for the MRV survey and 78 blocks totaling 1,313 km^2 for the LRV survey. The analysis followed ver Hoef (2001, 2002).

We used 2 Cessna 185 fixed-wing aircraft with pilot and 3 passengers. A survey crew consisted of 1 pilot, 1-2 local harvesters as observers, and 1-2 ENR staff as recorder/observers. We programmed the locations of all sample units into handheld portable and fixed GPS units before each flight, and aircraft flew to the designated sample units. We employed a total count for all sample units, which usually consisted of flying transects of varying distances apart across the sample unit. We attempted to keep airspeed at approximately 160 km/h and elevation at 125-175 m above ground level; altitude was influenced by ground cover. The amount of time required to survey each sample unit varied by topography and ground cover. A waypoint was taken for all observed moose to determine whether or not the animal was located inside the sample unit. Any tracks were followed to determine if the moose was within the unit boundary. A track log of the flight path was recorded on a handheld GPS. We classified moose into 5 different classes: calf, female, and small, medium, and large male based upon antler and body size.

Monitoring Surveys

After completing the initial baseline surveys it was apparent that costs and logistics would be prohibitive to continue annual large-scale surveys. However, there was need to monitor the moose population density, the number of calves:100 adult females, and male:female ratios between periodic large-scale surveys. Following discussions with First Nations and biostatician Jay ver Hoef, a smaller area was designated for annual surveys

to provide an adequate subset of the original sample units used in the baseline surveys. The annual surveys were conducted in November to minimize classification errors of sex/age classes as compared to February when calves are larger and males are antlerless. Accurate sex/age classification to estimate calf:100 adult females and male:female ratios is an important component of this population monitoring program. Five subsets containing 17-66 sample units from the baseline MRV survey area, and 4 subsets containing 18-69 sample units from the baseline LRV survey area were delineated (Fig. 3). We used the same sample unit identification numbers and stratification in these subsets as in the baseline surveys.

In November 2004 we flew 34 of a possible 268 sample units in the MRV, and 20 of a possible 169 sample units in the LRV. Following the 2004 survey, we realized we could fly more sample units cost-effectively and increase coverage to *ca*. 16% of both MRV and LRV. We flew 43, 40, and 43 sample units in the MRV and 27, 28, and 25 sample units in the LRV in 2005, 2006 and 2007, respectively. All sample units surveyed were selected randomly, and survey flights were conducted as in the original baseline surveys except that we used only one Cessna 185.

Health and Condition

Sampling of moose tissue and organs - First Nation harvesters in the Dehcho were requested to provide biological samples and general information from harvested moose starting in the winter of 2004-2005. Posters indicating the required samples were circulated and labeled sampling kits were provided by ENR to local Dene Band and Métis Offices for distribution to local harvesters. Because part of the program was designed to measure the level of various elements in consumed moose,

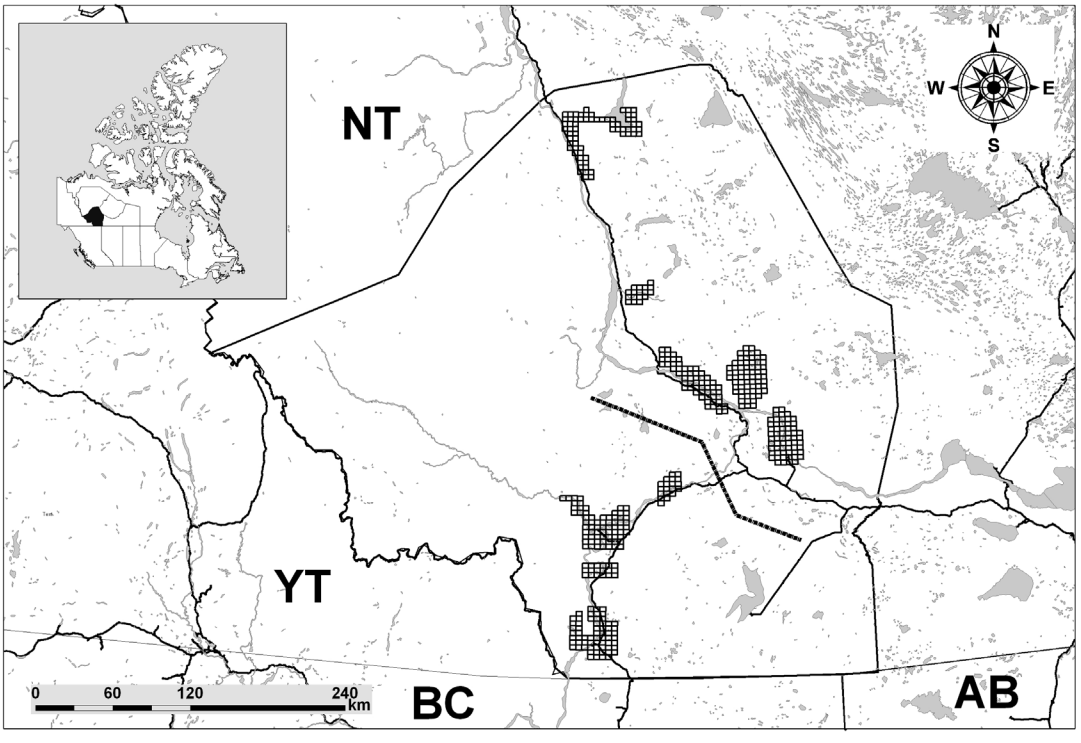

Fig. 3. Location of sample units used in the monitoring surveys; the Mackenzie River Valley (MRV) and Liard River Valley (LRV) survey areas are separated by the hatched line. Monitoring surveys used a subset of the original baseline sample units; 268 sample units covered 4,281 km^2 in the MRV, and 169 sample units covered 2,848 km^2 in the LRV.

we required submission of a complete kidney and a sample of liver. Kidneys are considered a delicacy and harvesters were initially quite unwilling to provide these samples unless there was some form of compensation. Following discussions with First Nations delegates at the Dehcho Regional Wildlife Workshop in 2004, it was agreed that harvesters would be paid $50 (CAD) for submitting a complete suite of samples.

The following information and samples were requested by ENR: name of hunter, date of harvest, location of harvest, sex, estimated age (calf, yearling, adult), general body condition (excellent, good, fair, poor), pregnant (yes, no), lactating (yes, no), an entire kidney including the surrounding attached fat, the lower jaw or incisor bar, a minimum 5 cm x 5 cm piece of liver, a minimum 5 cm x 5 cm piece of muscle, an intact ankle bone with marrow, and a handful of fecal pellets. Each sampling kit contained a pencil and sampling checklist that provided room for additional comments (e.g., presence of abnormalities and parasites).

It was important to compile information about the body condition of harvested moose from the perspective of the harvesters who have a wealth of past experience with moose in the area. Samples were collected until March 2007 to attain a sample size of at least 40 to assess contaminant levels. Sample kits were kept frozen and transferred to the ENR office in Fort Simpson for processing. Since March 2007, ENR has requested a reduced number of biological samples including only the incisor bar or front teeth, an intact ankle bone with marrow, and fecal pellets; sample kits are provided but samples are submitted on a voluntary basis. Harvesters are happy not to have to submit the highly valued kidneys.

To supplement the samples from moose harvested by First Nations residents that were almost exclusively from the main river drainages in the Taiga Plains ecoregion, ENR requested 2 outfitting operations in the Mackenzie Mountains (Tundra Cordillera ecoregion) to provide an entire kidney including surrounding attached fat, the front incisor bar, a minimum 5 cm x 5 cm piece of liver, and a minimum 5 cm x 5 cm piece of muscle from moose harvested by their clients during fall (September-October) hunts, on an opportunistic basis. Samples were collected from fall harvests in 2004-2006 and were processed at the ENR office in Fort Simpson.

Age and bone marrow - A first incisor was extracted from each moose and sent to Matson's Laboratory (Milltown, Montana, USA) where they were aged by counting cementum annuli from the root of the premolar (Matson 1981). Ankle bones were collected only from moose harvested by First Nation hunters. The bone marrow fat was extracted from a 5-10 cm length of bone and placed on a Petri dish. The Petri dish and the wet marrow fat were weighed on an Ohaus electronic balance (±0.005 g) and then placed in a drying oven at 100 ^{o}C for a minimum of 48 h until the weight of the dried marrow fat and Petri dish was constant. I calculated the % fat content in ankle bone marrow with the formula:

% fat content = (dry weight of fat + Petri dish/wet weight of fat + Petri dish) x 100

Kidney and fat analysis - Kidneys and accompanying fat were thawed and weighed on an Ohaus electronic balance (±0.005 g). The fat was trimmed following Riney (1955) and the kidney with remaining fat was weighed. We then peeled the fat and capsule off the kidney and reweighed the organ. The kidney fat index (KFI) was calculated for each kidney with the formula:

KFI = (weight of fat remaining after trimming/weight of kidney) x 100

We also calculated the ratio of the total fat weight (before trimming) to kidney weight for each kidney.

For the elemental analyses the kidney was rinsed in distilled water, and cut in half bilaterally. One half of the kidney was placed in a ziploc bag, labeled, and frozen. Each liver sample was rinsed with distilled water and trimmed to not exceed 300 g wet weight. The rinsed sample was placed in a whirl-pak bag, labeled, and frozen. All frozen samples were shipped for analysis to the Environment Canada Laboratory at the Aquatic Ecosystem Protection Research Division, Burlington, Ontario, Canada.

Organ tissue analysis - All organ samples were thawed, thoroughly homogenized, and subsamples of each tissue (wet) were digested in a closed Teflon vessel using ultrapure nitric acid. The resulting digestate was analyzed for the concentrations of 31 elements including arsenic, cadmium, lead, selenium, and zinc with inductively coupled plasma-mass spectrometry. The digestate was analyzed for mercury by cold vapour Atomic Absorption Spectroscopy. There is little consistency in the reporting of heavy metal levels in moose tissue from Canadian, American, and Scandinavian studies. Some report in wet weight (e.g., Gamberg et al. 2005, Venäläinen et al. 2005, Arnold et al. 2006) and others dry weight (e.g., Paré et al. 1999, Crichton and Paquet 2000); therefore, results are in both wet and dry weights. The moisture content of each tissue sample was determined prior to acid digestion. The results were expressed in mg/kg or ppm wet weight and converted to mg/kg or ppm dry weight with the formula:

ppm dry weight = ppm wet weight/((100 - % moisture content)/100)

Fecal samples - Frozen fecal samples (5-25 g wet weight) were forwarded to the Bow Valley Research lab in Calgary. Subsamples were screened for the presence of *Giardia* and *Cryptosporidium* by the sucrose flotation method. Briefly, fecal material is suspended with phosphate buffered saline solution (PBSS) and filtered, the filtrate is added to a sucrose solution (specific gravity 1.13) with methylene blue added, and then centrifuged. The resulting supernatant and pellet are decanted in PBSS. Immunofluorescent staining is applied to the suspended pellet to assist with the microscopic examination. Presence was reported as the number of oocytes/g of feces. Subsamples were also screened for parasites using the modified Wisconsin fecal floatation technique, based upon a concentrated sugar solution. Briefly, fecal material is centrifuged in water, the resulting homogeneous solution is filtered, and centrifuged again. The supernatant is resuspended in sugar flotation solution (specific gravity1.270) and centrifuged once more before the contents are examined under a microscope. Parasite presence was reported as the number of eggs/g of feces.

RESULTS AND DISCUSSION

Baseline Population Surveys

The MRV and LRV surveys were done after the traditional fall moose harvest in September-October. The MRV survey was flown 11-16 November 2003 (Fig. 2). We surveyed 63 high density and 37 low density sample units, providing approximately 7% coverage of the survey area. An average time of 19 min 45sec (range 9 min 12 sec to 48 min 19 sec) was spent surveying and 140 moose were observed, 74 in sample units. The density estimates were 4.4 moose/100 km^2 and 32.1 calves:100 adult females. The LRV survey was flown 16-19 February 2004 (Fig. 2) and 52 high density and 26 low density sample units were surveyed providing approximately 14% coverage of the survey area. An average time of 17 min 23 sec (range 9 min 3 sec to 30 min 25 sec) was spent surveying and 90 moose were observed, 65 in sample units. The density estimates were 4.9 moose/100 km^2 and 44.6 calves:100 adult females.

In November moose were more active and visible, in larger groups, and easier to classify by sex and age classes than in Febru-

ary. In contrast, ground cover was completely frozen, the weather was generally better for flying, and length of daylight was increasing in February, but moose were in more closed habitats. Based upon the range in number of moose observed in high density areas (0-10) and low density areas (0-2), I feel that the stratification process and decisions were appropriate, and that the geospatial survey technique used for the baseline surveys provided, at worst, a conservative estimate of the minimum population density of moose in the study area following the traditional fall (September-October) moose harvest.

Monitoring Surveys

Coverage of the annual monitoring surveys ranged from 12-16% of the baseline survey areas; 4,281 km^2 for MRV and 2,848 km^2 for LRV (Fig. 3). Annual surveys ranged from 34-43 blocks in the MRV area and 20-28 blocks in the LRV area. The average time spent surveying sample units ranged from about 14 min 14 sec to 20 min 59 sec in the MRV and 15 min 16 sec to 20 min 45 sec in the LRV area; 60-82 moose were observed during these annual surveys. A minimum ratio of 35 calves:100 adult female moose was estimated from the survey data, a value midrange of the those in the baseline surveys.

Health and Condition

Sampling of moose tissue and organs - I was prepared to pay a monetary reimbursement to First Nation harvesters for providing a suite of biological samples that included organs that were highly valued traditional food. I also wanted to ensure that an adequate sample size was collected within a reasonable time frame because voluntary sampling programs often suffer from inadequate sample sizes collected over extended time (years) raising issues of confidence (Thomas et al. 2005). A total of 43 complete suites of tissue samples were

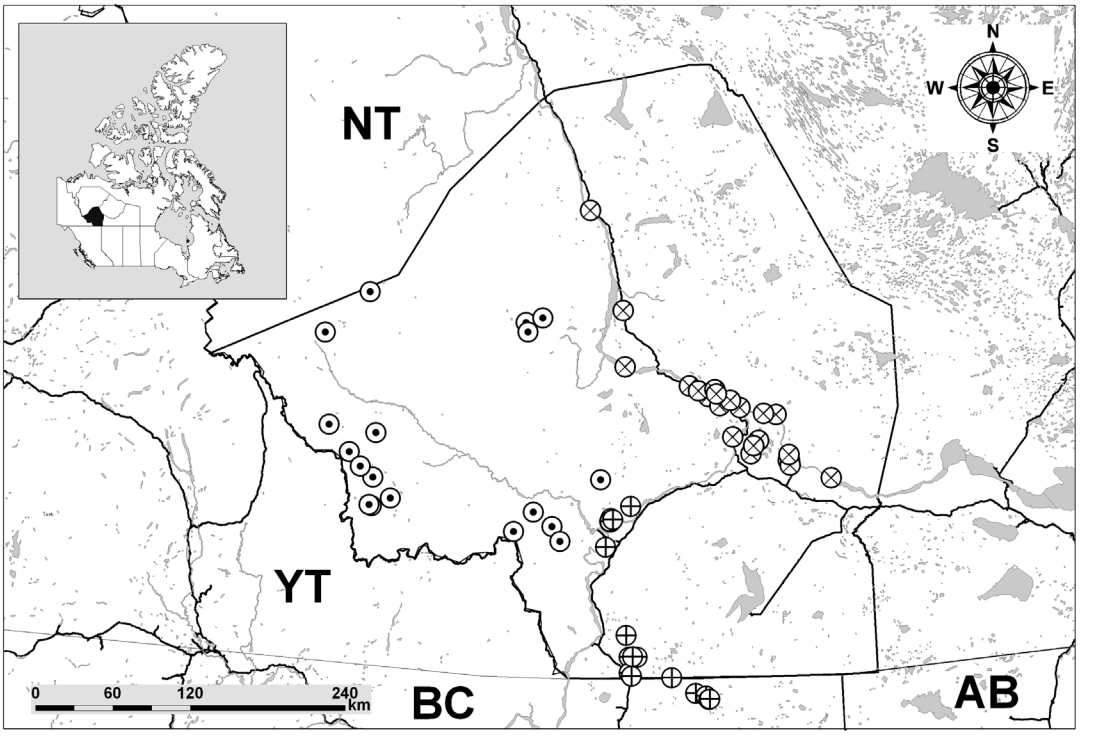

Fig. 4. The locations of 61 harvested moose from which a full suite of biological samples was collected; the origin was designated as ● from the Mackenzie Mountains, x from the Mackenzie River Valley, and + from the Liard River Valley.

collected from moose harvested throughout the study area in January 2005-March 2007. In addition, 18 suites of tissue samples were collected by outfitters in the Mackenzie Mountains where moose were harvested in September and October 2004-2006 (Fig. 4). Harvesters rated most moose as excellent or good condition (Table 1); there were no reports of winter ticks or papillomas on any harvested moose.

Age - As anticipated, the average age of moose harvested by First Nation hunters (x = 4.3 yr, range = 0-12, n = 43) was lower than that of moose harvested by guided hunters in the Mackenzie Mountains (x = 7.4 yr, range = 4-14, n = 17), because the latter harvested exclusively trophy males (Table 1). The average age of females (5.6 years) harvested by First Nation hunters was higher than that of males (3.6 years) even though the age range was the same for both sexes (0-12 yr; Table 1).

Bone Marrow - Ideally I would have preferred to collect femur bones for measuring marrow fat content because it is a commonly reported index for assessing starvation and the capability of habitat to support moose (Franzmann 1998). However, only ankle bones were made available. Few harvested moose had low marrow fat regardless of sex or when they were harvested; just 4 of 39 had marrow fat content <50.0%. The average marrow fat content of males (69.6%) was lower than that of females (78.4%; Table 1). The lowest marrow fat was from a 12 yr old male harvested in January 2007; although the hunter described the moose as skinny, it was ranked as fair not poor condition.

Kidney and fat analysis - Although there is some question about the relationship between total body fat and KFI (McGillis 1972), for First Nation harvesters the amount of fat associated with the kidneys is a visual indicator of overall animal condition. Based upon their reports of body condition, moose rated as excellent body condition had an average KFI of 75.0, those rated as good body condition had an average KFI of 47.6, and those rated as fair body condition had an average KFI of 31.6. No harvested moose was rated as poor body condition. Not surprisingly, males taken by guided hunters in September-October had lower KFI, averaging 29.0; 1 male had no kidney fat. Females harvested by First Nation hunters had a somewhat higher average KFI than males (Table 1).

Organ tissue analysis - The levels of cadmium found in the kidneys of moose harvested by First Nation hunters was similar to those reported in moose harvested elsewhere in North America and Scandinavia (e.g., Paré et al. 1999, Macdonald 2002, Venäläinen et al. 2005). The majority of kidneys from these animals had renal cadmium levels <60µg/g

Table 1. A summary of results from various analyses conducted on biological samples collected from harvested moose in September 2005-March 2007, Dehcho, Northwest Territories, Canada. Data are categorized male and female and are from First Nation (FN) or guided harvesters in the Mackenzie Mountains (MT). Calves were denoted as 0 years of age. The % marrow fat was from ankle bones submitted by First Nation harvesters. Body condition was reported by the harvester and ranked as excellent, good, fair, or poor.

	n	Average	Range
Age	60.0	5.2	0-14
FN male	28.0	3.6	0-12
FN female	15.0	5.6	0-12
MT male	17.0	7.4	34.0
Kidney Fat Index	48.0	47.1	0-155.8
FN male	25.0	50.0	5.2-155.8
FN female	12.0	57.5	15.3-142.2
MT male	11.0	29.0	0-57.8
% marrow fat	39.0	72.7	10.8-96.6
FN male	25.0	69.6	10.8-92
FN female	14.0	78.4	53.3-96.6
Body Condition	61.0	Excellent (21)	Good (34)
FN male	28.0	7.0	17.0
FN female	15.0	6.0	7.0
MT male	18.0	8.0	10.0

dry weight (<20µg/g wet weight). However, the levels of cadmium found in the kidneys of moose harvested by guided hunters in the Mackenzie Mountains was higher than found in moose harvested from the major river drainages; 50% of moose sampled from the Mackenzie Mountains had renal cadmium levels >1000µg/g dry weight (>225µg/g wet weight). Gamberg et al. (2005) found similarly high levels of cadmium in kidneys of moose harvested in Yukon.

As expected, cadmium levels were higher in older than younger moose. Interestingly, there was a relatively strong linear relationship between the level of cadmium in the liver and kidneys of moose. This finding could be important because it could indicate that collecting samples of liver only would be sufficient to measure and monitor the relative cadmium level. Local harvesters are much more willing to provide samples of liver than an entire kidney from their moose.

Fecal samples - Presence of disease and parasites was low; none of the 41 fecal samples tested positive for *Giardia* or *Cryptosporidium*. Although *Nematodirus* eggs were present in 31 of 41 fecal samples (76%), most positive samples had <10 eggs/g. The greatest infestation was 21 eggs/g found in a 2-year old male. Based upon samples from harvested moose, the incidence and prevalence of diseases and parasites is low in Dehcho moose.

SUMMARY

Concern for the impact of increased resource use, access, and development in Dehcho resulted in a cooperative research program to provide baseline information about resident moose. ENR conducted aerial surveys and First Nations harvesters and guided hunters and outfitters provided information from harvested moose. Population density estimates and calf:cow ratios, low incidence and prevalence of diseases and parasites, low levels of cadmium in organ tissue, and fat indices and physical assessments indicated that moose were productive and in good- excellent body condition and provide a highly valued and healthy traditional food resource. This study serves as an example of combining the knowledge and cooperation of First Nation moose harvesters, with the technical support of government biologists to secure baseline data for monitoring change in a moose population.

ACKNOWLEDGEMENTS

This paper is dedicated to the memory of Cam Lancaster of Nahanni Butte Outfitters. Cam provided samples and insight to the moose programs in the Dehcho. Cam passed away in a plane crash in the Mackenzie Mountains shortly after this paper was presented at the 6th International Moose Symposium in Yakutsk, Russia.

I am indebted to all of the many Dehcho traditional harvesters whose input was critical to designing and implementing this program; without their support and input this program would never have materialized – *Mahsi cho*. I thank those harvesters and outfitters that provided biological samples for the program and the many harvesters who have assisted in the aerial surveys conducted as part of the program. Jay ver Hoef is acknowledged for his assistance with the design and statistical analyses of aerial survey data. Deborah Johnson, Dean Cluff, and Lynda Yonge provided discussion and critique of the program and earlier drafts of this manuscript. Comments from Ken Child and another anonymous reviewer improved this manuscript. Erin Bayne completed the statistical analyses of the trace element data. Danny Allaire produced the figures. Funding for this program has come from the Government of the Northwest Territories, Indian and Northern Affairs Canada, Parks Canada, and the Northern Contaminants Program.

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