REINDEER NUTRITION AND PASTURE ANALYSIS IN THE MONGOLIAN TAIGA

Honors Thesis
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by
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ABSTRACT:

The research for this thesis has taken place over the last two years (2005-2006) in the northern-most pinnacle of Mongolia only miles from the Russian border. It is aimed at assessing nutritional availability, range quality and utilization by domesticated reindeer (*Rangifer tarandus tarandus*) in a small sliver of taiga ecosystem inhabited by a nomad reindeer-herding people called the Tsaatan. Indigenous reindeer herding practices and cultural strategies link the survivability of the people with the survivability of their reindeer.

The period of Soviet occupation in Mongolia from 1921 to 1991 caused massive damage to the social fabric of Tsaatan culture and also herd health. Since 1991, the Tsaatan have been attempting to revive their culture in post-soviet, Mongolian democracy. Through dairy, packing, riding, meat and other by-products, reindeer provide the raw materials and power the Tsaatan need to survive in this cold mountainous region of Mongolia.

Though a multitude of health problems effect the herd today including inbreeding and zoonotic diseases such as *Brucellosis*, I believe the herd's recovery is predicated on first establishing better herd nutrition. Herd demographic data collected by myself and other researchers in 2006 showed a correlation between herd body condition and management strategies/forage quality [Appendix 1]. With the underlying assumption that heard health is influenced by nutrition, this study set out to collect the first set of data on forage availability/quality in Tsaatan pastures. My hypothesis was that both availability and diet composition vary from other reindeer groups and warrant a dynamic set of considerations in terms of best-management policies for the herd.

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Thanks to **The Itgel Foundation** for logistical support and for allowing me to be of service to the Tsaatan community. In giving voice to the community, the organization has improved lives and widened perspectives around the world.

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PREFACE:

The Tsaatan, an indigenous population in Mongolia's northernmost province, maintain their unique culture through nomadic reindeer husbandry. They rely on reindeer for milk, meat, transportation, packing and income generation. Unfortunately, recent socio-political transitions including former Soviet occupation, have resulted in a massive interruption of sustainable reindeer husbandry practices. Government-sponsored culling programs, forced relocation, suppression of traditional knowledge, and changes in land-use policy have left the Tsaatan community struggling to maintain their subsistence lifestyle.

From 1921 to 1951, when the border between Mongolia and Russia was open, the Tsaatan migrated freely between the two countries as part of their traditional nomadic herding strategy. In 1952 when the border between Mongolia and Russia closed, the Tsaatan were adopted as Mongolian citizens and integrated as the country's smallest ethnic group. Today there are approximately 250 people and 450 reindeer.

Soon after the border closed the Soviet government, motivated by profit and under the slogan of communal labor, implemented an assimilation program for the Tsaatan. The people were moved out of the taiga, down to the steppe where they were trained as fisherman; a more profitable enterprise. Non-Tsaatan armed guards were hired to keep the reindeer in pens in the steppe where they were fed harvested forage from the mountains. The warmer weather of the steppe, contact with other livestock, and poor nutrition contributed to declining heard health. In 1984, again motivated by profit and cost, the government reduced herd numbers from approximately 2,000 to current levels near 450 . They also administered a vaccine for *Brucellosis* which the herd had contracted from local livestock. The culling program has resulted in inbreeding in the herd, while the vaccine program, for the wrong strain of *Brucellosis*, has made new vaccine production difficult today.

In 1991 the USSR collapsed and the Soviets withdrew from Mongolia. The country adopted it's first constitution in 1992 establishing democracy as the new government model and the principles of self-determination and free-market have been promoted in the country ever since. This change has allowed the Tsaatan to reclaim their reindeer and return to the taiga. But the negative effects of Soviet-occupation and even democracy continue to be felt by the community and herd. *Brucellosis*, inbreeding and malnutrition are still evident in the herd today. The loss of free government health care and veterinary treatment has produced new problems with ecto-parasites and basic health management.[1]

While the Tsaatan are now free to practice a subsistence lifestyle, the new capitalist market still requires that they generate income for medical care, schooling, and staples such as clothing and rice/flour. It is important to note that reindeer herding was and is not profitable. Reindeer-products such as meat and milk are produced at subsistence-level and so are not available for trade or income at markets. Even if previous numbers of reindeer could be reestablished and an excess of milk, skins, or meat could be produced, no infrastructure exists to transport materials to market where they would remain uncompetitive given the high production rates of cattle and sheep industries in Mongolia.

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[1] Baskin of the Russian Academy of Sciences confirms the negative impacts of Soviet policy on wild and domesticated reindeer populations throughout the USSR. He offers a more complete, scientific, analysis of pre and post Soviet populations managed by the relatives of the Tsaatan; the Dukha people of Tuva. [5]

A number of NGO's and non-profit organizations have been created in the last five years that are attempting to address the many concerns of the community including representation in government, generating new markets, and addressing heard health. In 2001, the Itgel Foundation, an American non-profit organization, began seeking answers to some of the health problems in the herd; immediate solutions such as annual treatment of ecto-parasites and veterinary care, have already improved herd condition. But before issues such as inbreeding and *Brucellosis* can be addressed, basic nutrition in the herd needs to be stabilized since vaccines and artificial insemination are less effective without good herd health [35].

The goal of this research is to gather data which can be used to inform reindeer management strategies among the Tsaatan so that overall herd nutrition might be increased from present levels. In an attempt to re-acquire traditional knowledge lost during the 70 years of Soviet occupation, this research utilizes methods from animal sciences as well as ecology and microbiology to assess pasture for forage; quality, quantity, seasonality, and availability.

Herd demographic data in 2006 confirmed nutritional inequality within the heard. This is motivation for a more in depth study of nutrition. By measuring body condition of several individuals, the study found that certain groups in the east taiga, "were in better body condition, had higher milk yields and may have experienced better long term nutrition than reindeer from other camps. Although stocking density and the quality for grazing areas may be responsible for these differences, animal use patterns such as intensive use of males for transportation, intensive and prolonged milking practices and early weaning of calves may have influenced the energy balance of reindeer under the different management strategies" [Appendix 1]. The conclusions confirmed that nutritional levels in the population vary and a combination of pasture and management differences is probably responsible for the variation. Furthermore, nutrition in the herd is not optimal and more data is needed to inform new/updated herd management strategies. Herd management strategies would be formulaic if reindeer around the world had access to the same forage and exhibited the same dietary needs [21] but this is not the case. The underlying hypothesis of this study is that dietary requirements and forage availability/quality are unique to this herd. Existing knowledge about reindeer nutrition is not sufficient to inform updated management strategies for the Tsaatan. This research is a general survey of the range of Tsaatan grazing grounds because information on what is available, when, where, it's quality and variation, and what the reindeer might be getting from it, is all new and vital data. By designing a forage survey which focuses on the availability and quality of forage, this research creates a body of knowledge from which the practical solutions to poor nutrition might be derived.

REVIEW OF THE LITERATURE:

Reindeer are ruminants with a highly selective forage strategy. Unlike cattle and many other domesticated livestock which are bulk-roughage feeders, reindeer are concentrate selectors, preferring to eat smaller quantities of higher quality forage [37]. This adaptive strategy is necessary for their survival in the taiga; a biome characterized by cold weather, short growing seasons, and smaller plants (low biomass). In the summer, during the growing season from May-August, forbs and new grass shoots provide essential nutrients to the reindeer while short brush such as willow and birch provide the bulk of ingested material. Summer forage is usually of higher nutritional value particularly protein and minerals [28]. Recent research by Collins reiterates the importance of the short growing season in May/June in sub-arctic systems when nitrogen-rich shoots provide body reserves for the rest of the year [9, 32] often aided by protein availability [49]. During the winter, and at reduced levels in the summer, lichen are the primary source of food for reindeer.

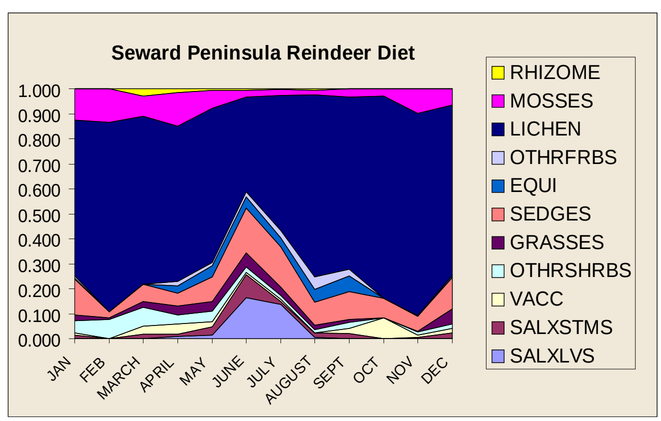

Fig 1. **Above**: a reindeer forages among the short forbs and graminoids that dominate the growing season. Behind the reindeer is *Betula nana* (darker green in background) and *Salix pyrolifolia* (lighter-silver brush in middle-ground).
Graph 1. **Below:** Graph of typical Seward Peninsula reindeer diet showing high lichen concentrations (dark blue) with a seasonal spike in vascular plants corresponding to the growing season.

Research out of the Reindeer Research Program in Fairbanks, Alaska has produced a graph of typical reindeer diet on the Seward Peninsula (Fig 1). It emphasizes a high reliance on lichen with a seasonal spike in vascular plants during the growing season typical of reindeer diet [7]. The consequences of forage quality and availability in the summer and winter have shown to be strong influences over body condition, survivability, and viability in the next breeding season [31]. Under conditions of stress or compromised immunity, as in the case of the Tsaatan's reindeer, nutritional condition can be a strong indicator of survivability. Recognizing the importance of the growing season for reindeer nutrition, the research takes place from July-August each year.

Carbohydrate-rich and nitrogen-low lichen, consumed at an average rate of 3.7-6.9 kg dry weight every day, provide the necessary energy for reindeer in the winter [6, 28, 46, 47]. A reindeer's rumen is capable of harvesting nitrogen from traditionally indigestible sources, and their circulatory and nutritive pathways have adapted to recycle nitrogen rather than loosing it to the environment as urea [1]. But lichen are typically small, primary community plants with slow regeneration times. This forces the reindeer to move and graze almost constantly, using up much of their reserves. When energy lost by cellulose-degrading bacteria in the rumen is added to these considerations, it is evident that spatially, nutritionally and energetically, reindeer are at a disadvantage. Furthermore, hobbling and herding techniques used to keep the reindeer at a manageable distance place the reindeer of northern Mongolia at an even greater disadvantage compared to their wild (Caribou; *Rangifer tarandus caribou*) or free-range counterparts who are able to exploit sparsely populated and extensive tracts of land.

The barriers to proper nutrition are formidable. Evolution on the part of some lichens has produced acidic compounds designed to reduce palatability [50] and/or effect the cellulose-degrading bacteria in the rumen. Lichen can also accumulate heavy metals which are then ingested and transferred to the reindeer and animals further down the food chain including humans [12]. Research in Finland has shown that lichen regeneration, which can take between 5-20 years, is not linear and requires dynamic reindeer husbandry practices modified year after year in order to remain sustainable[29]. New social and ecological climates are also threatening nutrition in the herd. Research suggests that recent increases in pedestrian traffic into and out of taiga ecosystems [14], the possible effects of global warming [17], pollution [22], and further industrial development [13] present formidable challenges to vegetative viability and sustainable reindeer husbandry. These may indeed be factors that further compound nutritional struggles for reindeer in the Tsaatan system. Given these constraints, management practices become increasingly important.

Several management systems for reindeer around the world rely on free-range approaches where reindeer graze freely in open pastures except for a couple times a year when they are processed in large corrals. On Alaska's Seward Peninsula where ~40,000 reindeer inhabit +6 million ha (~14.8 million acres) herds are managed and moved by helicopter and snowmobile only twice a year [43]. On the other side of the world, the Sami are the most famous, indigenous, reindeer herders today. Residing in Norway, they traditionally had more contact with their reindeer, using them for milking and transport like the Tsaatan. But modern technology, capitalism, and the pressures of production have increased herd numbers similar to Alaska and decreased dependence on reindeer for products beyond meat [13]. Management strategies with high densities, even free range, often produce overgrazing, especially lichen depletion which is necessary for winter survival [43, 13]. These management systems also put pressure on summer foliage when heavy grazing prevents new growth in brush, germination of forbs, and encourages the spread of grasses which respond positively to grazing [11] but make poor-quality reindeer forage. The results of such overgrazing have been reported in other reindeer populations around the world where vegetative loss resulted in increased mortality, the effects of which were not immediately relived by supplemental feeding [3]. Though the populations of Tsaatan reindeer are much smaller, their range is also greatly restricted by the daily cycles of capture and release. It is highly likely that reindeer have had important effects on the balance and composition of forage in the Mongolian taiga especially within a short radius (~2 km) around camps.

While significant research has been conducted on related topics, no published literature exists on Mongolian reindeer, nutritive content of Mongolian vegetation, or the relationship between the two. In recent years, there has been data on general floral surveys of the taiga but they often encompass all of Mongolia [19, 33]. Though many new species have been identified, their depth is limited and much remains to be discovered in the taiga near Russia. These studies also lack information such as nutritive content of the plants, seasonality, even distribution. Other studies have looked at livestock's effect on pastures but this research has not been conducted in areas with taiga ecology let alone the small strip of land utilized by the Tsaatan [10, 15]. Studies conducted around the world in reindeer pastures can be useful for a baseline of nutritional data [26]; confirming high carbohydrate levels in lichens, some micro nutrients in forbs, etc. But these studies do not take into account unique Mongolian forage or nutritional variation in that forage caused by variations in soil quality which can effect nutritional composition of plants on the same hill let alone different countries [20]. Therefore, an analysis of reindeer forage in Mongolia is necessary for understanding the underlying causes of sub-optimal nutrition in the Tsaatan's herd.

METHODS:

This study has utilized a wide variety of methods over the last two and a half years including field methods from ecology and the animal sciences as well as laboratory techniques inside and outside of Mongolia. In 2005 the research began with a general survey of available forage throughout the Tsaatan's pastures. The first year I concentrated on identifying lichens, forbs, and brush from the Salix family. Species taxonomy, especially lichens which can be difficult to classify, was completed by Nansaalma Batszaya at the University of Ulaanbattar, Mongolia to ensure that local variations could be correctly identified.

Only those species that were suspected or confirmed reindeer forage were collected. Palatability tests, information from herders, and international experts/previous scientific knowledge, and behavioral observations of the reindeer foraging guided the plant selection. For a full description of in-field methodology for 2005, see Appendix 3. The results of the first field season included the identification of key summer (growing season) and winter forage. A manual/guide to these key forage species is available in modified form in Appendix 7.

The Tsaatan are geographically segregated into two populations (Fig 2) between which little gene transfer occurs via people or reindeer. Though the two locations are only 10-20 km apart, their climate and culture can vary significantly influencing herd management strategies and forage. The two locations are referred to as the east and west taiga based on their location relative to each other. The east taiga is the more northerly of the two ranges with less precipitation and less intense terrain. The west taiga lies more to

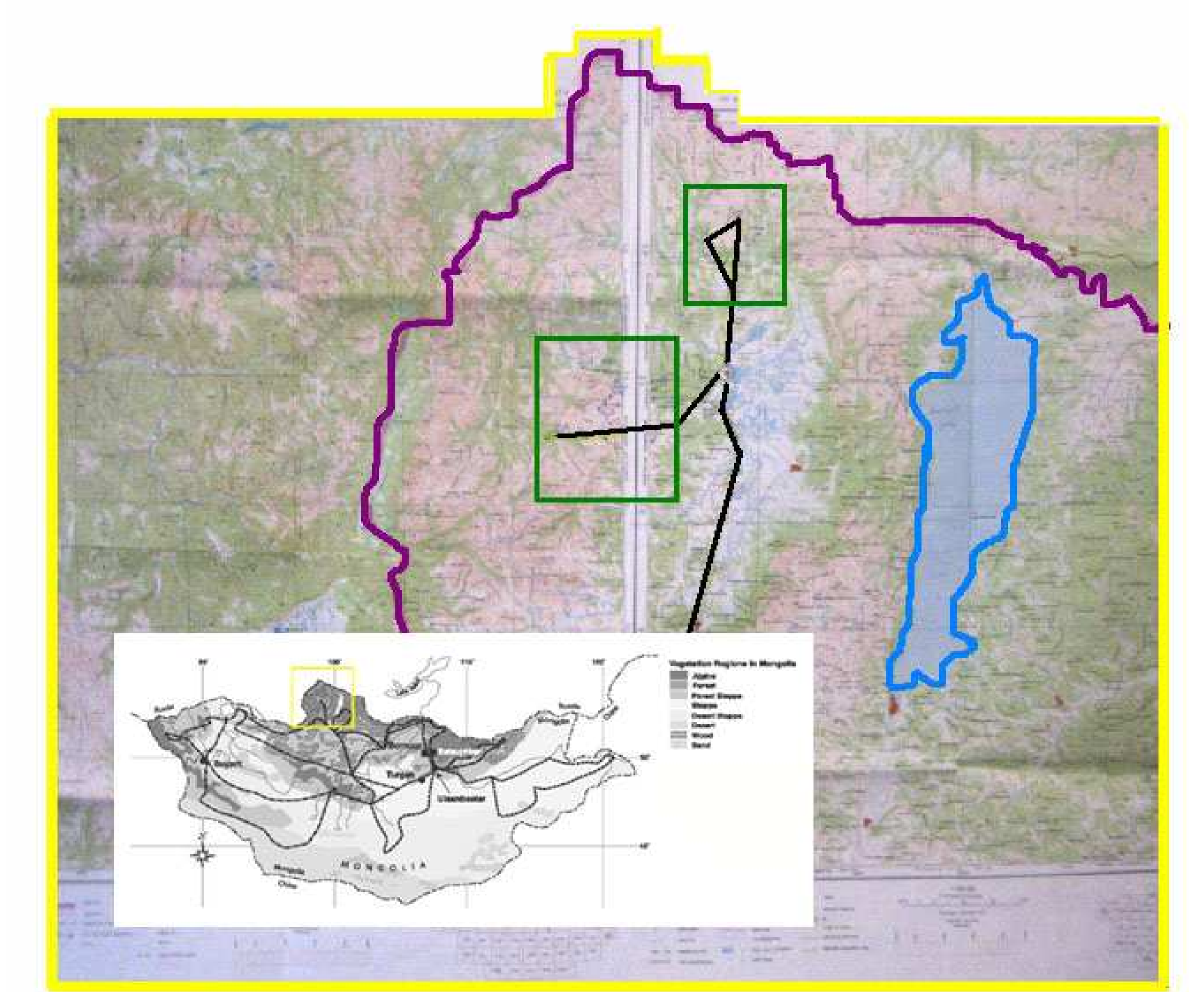

Fig 2. Topographic map of northern Mongolia with map of ecological zones of Mongolia inset. Green boxes denote east and west taiga herding grounds. The purple line is the political border between Russia and Mongolia. Blue indicates major bodies of water. Black lines are the routes into and out of the two taigas which have no access between each other except by coming down to the steppe first. Three way split in “road” is the town of Tsaagan Nuur where supplies can be purchased and roads end.

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the south but has steeper elevation grades and more extreme weather. Because of a suspected difference between the two, all data were kept separate. This difference was confirmed in the 2006 study on body condition of individuals in the herd [Appendix 1]. Most data, especially after the first year, were separated by camp since there are several camps (pastures) in each area which constitute the whole range of the Tsaatan’s nomadic cycle.

In-field methods for 2006 built on the knowledge from 2005 and adaptations from a similar forage study done by the University of Alaska, Fairbanks [16]. Though the use of similar methods, the Alaska study evaluated and mapped the entire grazing range of reindeer on the Svalbard Peninsula. This information, together with a government sponsored curriculum on reindeer management was distributed to herders who benefited from increased knowledge about their pastures. The Alaska study used several methods beyond the resources and scope of this study such as remote sensing [45], and time and man-power. Because of the sensitivity of the environment and culture, only small groups up to 9 people go into the taiga during the 4-5 months between the ice melting and freezing. However, the basis and idea behind the Alaska study was still beneficial in guiding field methods used in Mongolia.

Ecology field methods utilized large transect areas in order to determine forage composition and species richness. Species composition is of particular importance for Tsaatan reindeer since the capture-release management system restricts reindeer grazing and movement. The consequence is that reindeer are restricted to the local forage composition of particular camps which can effect digestion and absorption. For instance, previous research has shown that forage composition, especially hemicellose levels positively affect the size of the distal fermentation chamber, while a diet of pure lichen increases populations of lactic acid-producing bacteria in the small intestine, and high levels of protein and carbohydrates increase the rate of cellulose digestion in the rumen [38].

When possible, data for species composition, richness, and samples for laboratory work were collected at the same pasture to yield a detailed picture of the area instead of scattered data for several areas. This also ensured that annual variation in soil condition and growth was controlled. For this reason and because the methods for 2006 were time consuming and the time available was short, two pasture areas were selected for analysis; one in the east and one in the west taiga. The east taiga pasture (Fig. 3) was a camp that has been used for the last two years called "Pushtug." It is situated at the top of a long, ascending valley that narrows and eventually terminates at the base of a large steep mountain pass at the north end of the pasture which acts as a barrier for humans and reindeer alike. From the northern barrier, the valley works its way south for several kilometers allowing ample, if steep, grazing for reindeer.

Fig 3. **Left:** Picture of east taiga camp surveyed for richness and samples for nutritional analysis. View is from the top of the hill looking down the valley which extends for several kilometers. **Right:** Picture of west taiga valley with transect lines superimposed. Bisecting line runs North-South approximately following the river/stream while perpendicular transects run East-West.

The west taiga pasture (Fig. 3) was a camp that had not been used in several years, (best herder estimates were anywhere from eight years to somewhere during Soviet occupation). It is located in a deep wide valley with a shallow water table in the center encouraging grass and wetland ecosystems. In the process of collecting data along transects, several old camps sites were found from previous stays in the valley; old spoons and ortz (teepee) poles were found in various places along the valley. Old horse tracks and pathways between camps and river systems were still visible with diverse but shallow plant growth. Because of the slow growth rate in this climate, especially for lichen, and potentially heavy historical use (as evidence by the many camps and growth over pathways), there was the potential that this site had not fully recovered prior to its occupation in 2006.

Because of the labor and time requirements, forage composition was only conducted at the camp in the west taiga. One researcher (myself) collected data over a period of a week in late August as the growing season ended but brush and forbs were still foliated.

Though reindeer can travel several kilometers in a day, the capture-release management system employed by the Tsaatan keeps most deer within a 2 km radius. The total pasture area was estimated based on this assumption as well as observations of reindeer location the previous day. The pasture was bisected using an initial GPS coordinate [Appendix 2] and randomly generated numbers were used to establish distances from the start point where the GPS had been taken so that perpendicular transect lines could be marked out. For instance, if a valley naturally ran North-South, then the natural line of the valley would guide the bisecting line. Since both areas were valleys, it was convenient to set the line following the natural progression of the valley. This also gave equal representation to transitioning biomes which typically moved from water-rich to rocky and barren and reflected the natural barriers to reindeer movement. The transects established based on GPS coordinates and randomly generated numbers would then run East-West, perpendicular to the bisecting line.

Different randomly generated numbers were used to mark drop points along each of the transects. As the transect was traversed, a 1/8 yd PVC piping rectangle was placed on the ground at each of the drop points. An ocular estimation of plant composition within the rectangle was taken and recorded for the following practical/significant categories; lichen, moss, grass, forb, bush (*Salix*), birch (specifically *Betula nana*), barren, and water. When one species was abundant enough to be considered alone this was done, but for small plants such as lichen where several species took up minimal area, groups were used as meaningful categories. In all, 24 transects were walked and over 1200 drop-points were collected for this site.

Species richness is the measure of taxonomic diversity in a given area, it counts the number of species in a given area. Pastures with a higher number of forage species had greater richness. Here, it is was used to measure forage species only. Richness transects were designed in the same way the composition transects were; the total pasture was bisected (the same line was used for composition and richness in the west taiga) and transects were established perpendicular according to new randomly generated numbers. Two sites were done in 2006; one in the west and one in the east taiga.

In the course of walking the transect lines a sample of roughly ten grams wet weight was collected for each species identified. For each transect a species list was compiled of all of the species identified giving data on richness by transect. Data was also compiled at the pasture level by counting the total number of species from all of the transects.

Samples that were collected in paper bags along the richness transects were dried in tents to prevent wind disturbance or mold build up and to stop the metabolic processes within the cell for an objective nutritional analysis. Over 200 samples were collected from both sites. New samples and new species not identified in 2005 were first sent to Ulaanbaatar (the capital of Mongolia) for species identification by the botany department at the University of Mongolia, Ulaanbaatar. After identification and verification, samples were sent to Alaska. The University of Alaska, Fairbanks' Reindeer Research program and myself processed the samples in October 2006 to remove impurities such as dirt or dead cell matter which does not reflect the state of forage when it is consumed by reindeer in the field. After preparation and grinding they were shipped to different labs for analysis.

Fecal samples were also collected for diet composition. In all, analysis of the 2006 samples included diet composition through the University of Washington, Seattle; *in-vitro* digestibility at the University of Alaska, Fairbanks' Reindeer Research Program; and nutritional analysis at the Soil and Plant Laboratory School of Natural Resources and Agricultural Sciences in Palmer, Alaska. The diet composition from the University of Washington will be done in September 2007 so there is no data for that available here. Nutritional analysis included measures of; crude protein, protein, phosphorus, calcium, magnesium, sulfur, and zinc. The *in-vitro* digestibility is a method pioneered by the Reindeer Research Program which uses rumen fluid from fistulaeted reindeer. In future years fiber analysis will also be conducted but the samples collected this year were not large enough given all of the other tests and a limited amount of space on pack horses to take the samples out of the taiga.

RESULTS:

Results from the floral survey in 2005 confirmed two main points of interest. The first was that forage in the North of Mongolia is unique compared to other locations around the world. Species such as *Cladonia stygia* (lichen), *Gentiana algide* (forb), and *Helictotrichon mongolicum* (a grass endemic to Mongolia) have limited ranges or are simply not found in other sites around the world where reindeer are managed. In some cases, the samples collected in the taiga expanded the known range of species not previously found outside of southern Russia. Such was the case for the lichen *Cetraria kemarevii elenkin*. Information on behavior and palatability also confirmed that forage preference was different compared to other groups of reindeer around the world. For instance, the graph from the University of Alaska/Salvard Peninsula reindeer shows Salix species to be consumed in low concentrations which is also the typical global trend.[2] But, based on preliminary observational data, the reindeer in Mongolia consume significantly more Salix forage in their summer diet. Observations of the camp sites showed intense foraging on brush which was often stripped almost bare close to camp. Farther from camp the brush was more foliated, confirming the geographically constricted grazing patterns of the reindeer. It was clear from further data collection and observation in 2006 that two species of brush; *Betula nana* and *Salix pyrolifolia* are the dominant summer forage consumed by reindeer. Nutritional analysis in 2006 showed a marked increase in protein in the Mongolian samples compared to Alaskan samples. Since protein is one of the limiting resources in reindeer diets, it makes sense that they would have a greater

[2] This interpretation was confirmed by Greg Finstead, head of the Reindeer Research Program at the University of Alaska, Fairbanks.

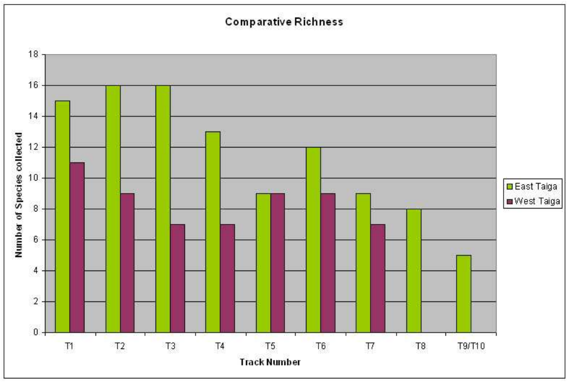
preference for it.[3]

Results from 2006 included the species composition data, richness, and lab analysis. Raw data for all three can be found in Appendix 4-6.

Richness data conducted in the east and west taiga revealed significant variation in range richness. The east taiga had higher numbers of species and greater distribution for those species across the pasture (more open and dispersed populations as opposed to localized/isolated communities).

	East T.	West T.
Total Number of Species Collected (richness)	27	17
Total Number of Samples Collected	108	59
Average Number of Species per Transect	10.8	8.4

Table 1. Summary and comparison of richness in east and west taiga demonstrating higher richness in the east taiga.



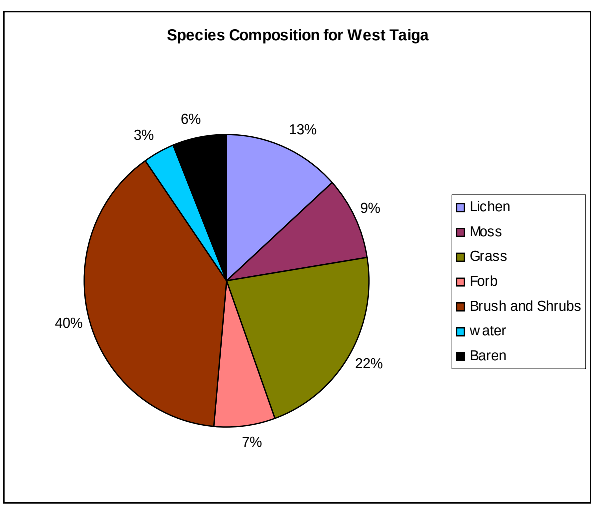
Graph 2. Graph of richness measure broken down by transect to reveal consistent pattern of higher diversity in the east taiga.

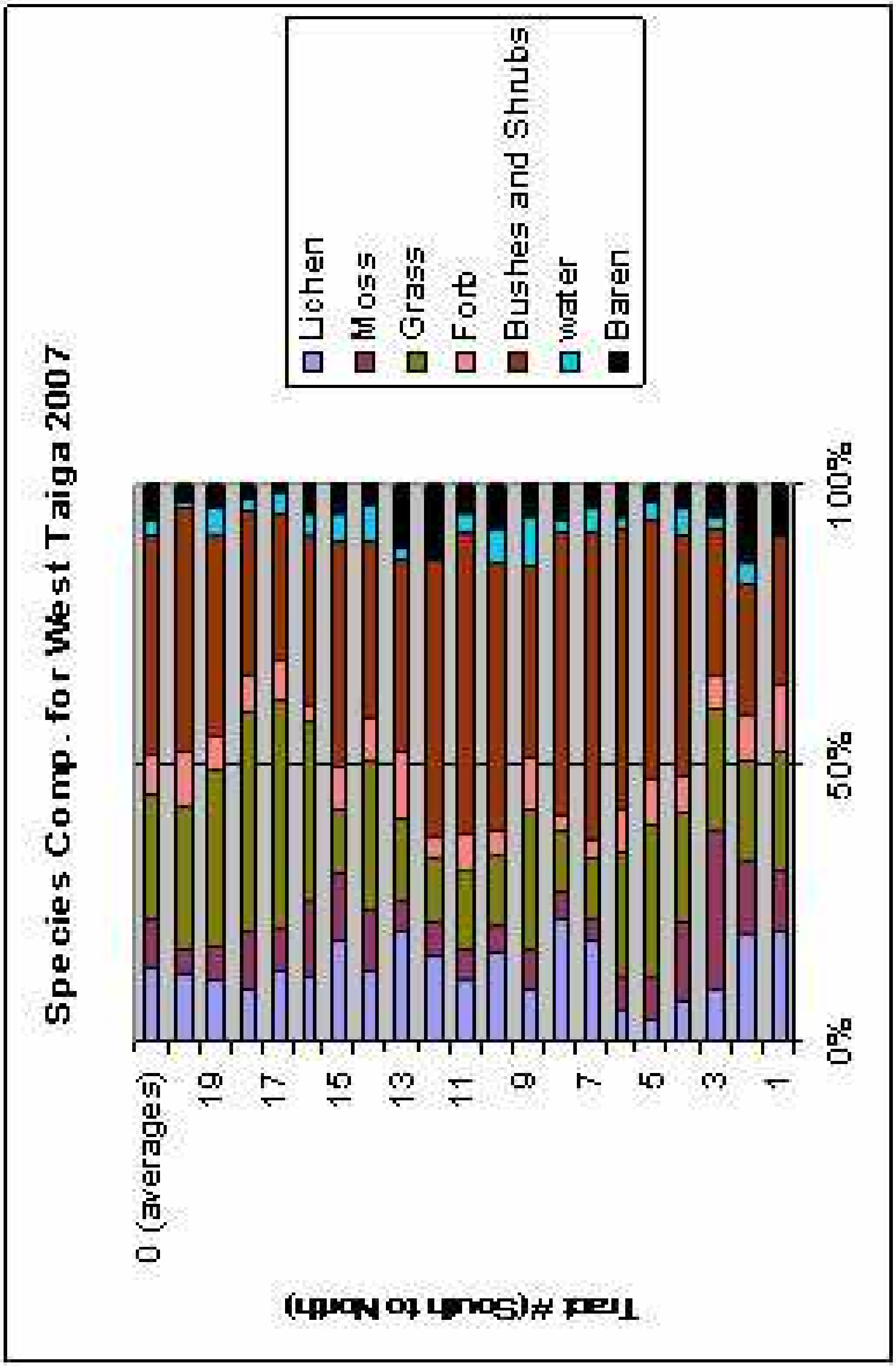
Broken down by transect, the trend of lower diversity in the west taiga is apparent. It should be noted as well that Track 9 and Track 10 in the East taiga were closest to the Tsaatan camp where trampling and overgrazing reduce natural biodiversity. Fewer species were collected at the last two tracks because time constraints cut both studies

[3] Comparison done through unpublished data provided by the University of Alaska, Fairbanks; Reindeer Research Program and Greg Finsted.

short (note that the west taiga data only goes to seven transects). Still, enough samples and data were collected at both sites to represent overall trends in forage richness including the conclusion that richness was higher in the east taiga. This correlated with the herd demographic data collected in 2006 [Appendix 1].

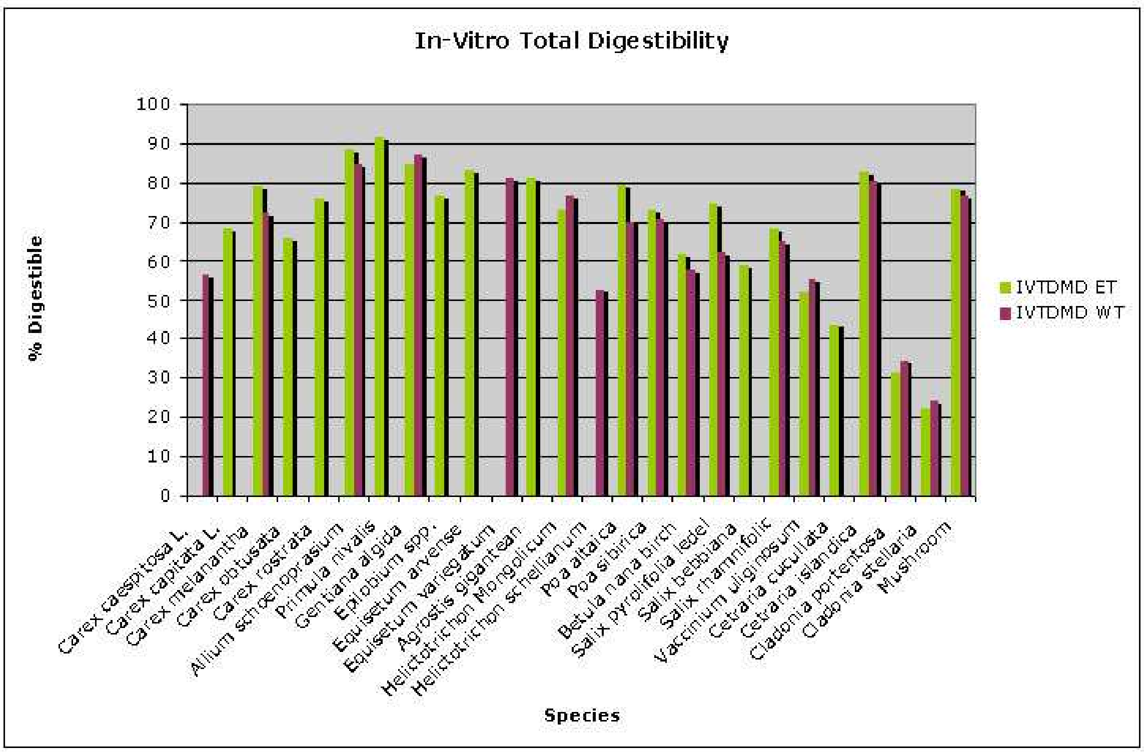
Forage composition in the west taiga was largely a trial run. In the future, this purely descriptive method can be matched to data on diet composition, the first round of which is being processed in Washington and will be complete in September. Eventually, the data on diet composition which shows what the reindeer are selecting from available forage, can be used with composition data to screen different pastures for compatible-seasonal-diet. For instance, if we know that one camp is dominant in lichen and summer diet composition includes lower lichen concentration then this camp is probably not an optimal summer camp (This is a very simple explanation that uses what has already been found in other studies about summer vs. winter diets). Based on the composition data Graph 3 was put together which illustrates the forage composition of each transect. As previously described, the west taiga camp was a wide valley with wetlands following a stream through the center and transitioning to lichen/rock up less severe inclines (compared to the east taiga). A relatively uniform distribution in the graph confirms an overall equal distribution of forage species.





Graph 3. (**previous page**) Overall species composition of west taiga pasture by major forage group.
Graph 4. (**above**) Species composition in west taiga by transect; visually confirms consistent plant dispersion throughout valley.

Overall trends in digestibility are preliminary compared to forage analyzed at other locations around the world. However the overall trend is that digestibility in the taiga is lower than it is in Alaska across most plants. This is the case for species found in both Alaska and Mongolia. Lichen was especially low in digestibility when compared to established Alaskan data. This can have potentially serious impacts on the herd since lichen is the primary forage during the winter months.

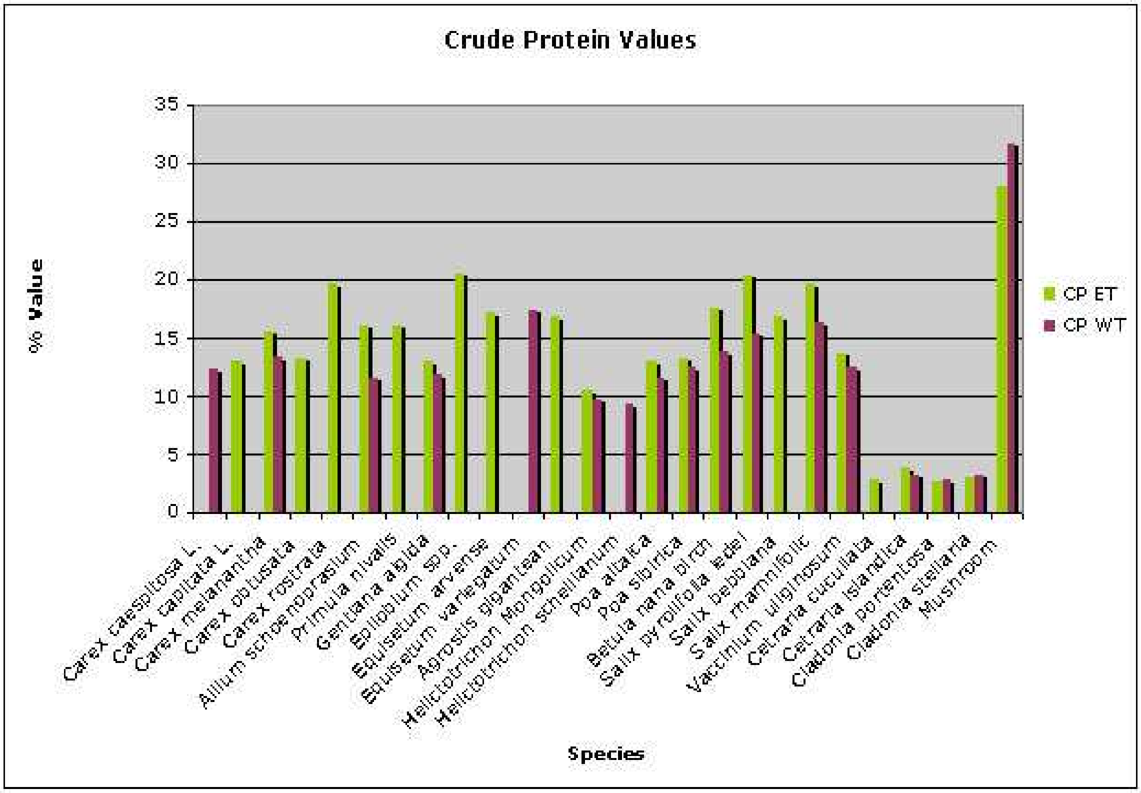


Graph 5. Results for digestibility for each species. Species are grouped according to their taxonomy; lichens together, brush/Salix, forbs, etc.

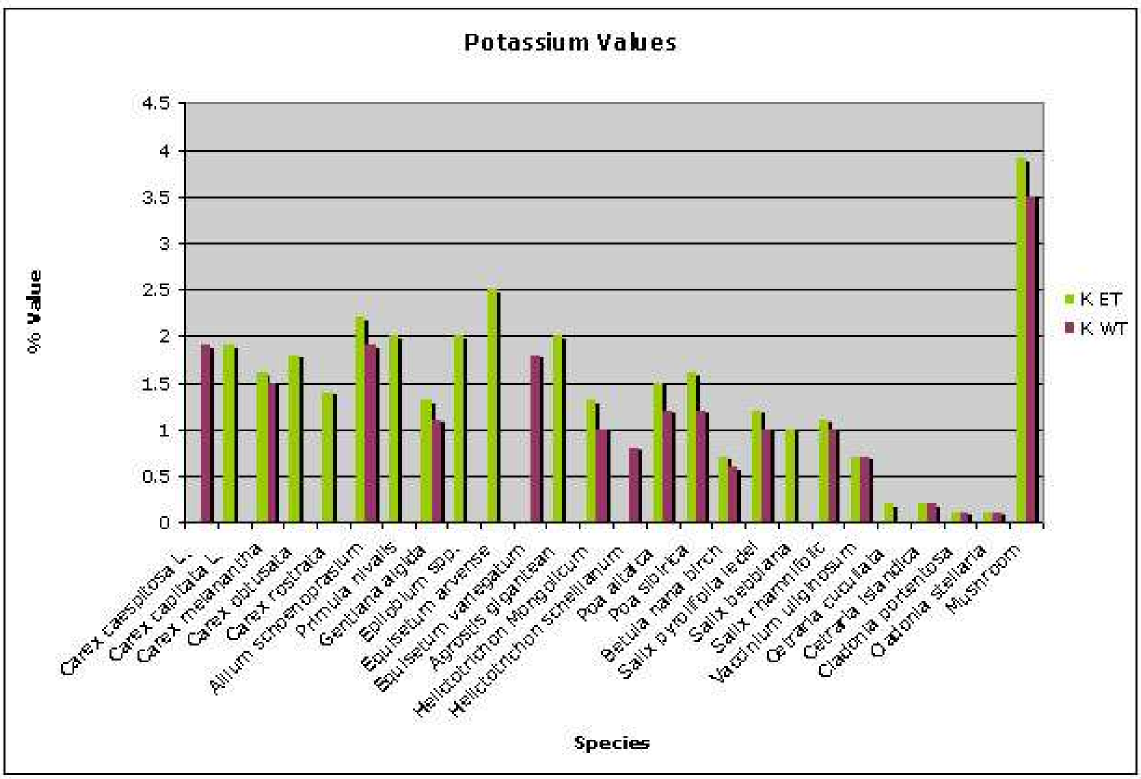
Low digestibility results in caloric waste and lower energy yields for the same amount of energy expenditure during foraging and digestion. Since lichen are mainly used for their energy yields (carbohydrates), as a defense against declining body condition during winter months, losing energy is costly and in extremes leads to starvation. To counteract the low digestibility reindeer will have to consume more but the environment rarely produces a surplus of forage compared to more productive biomes. However, it is important to consider the limitations of these results. It is unclear how significant the data are in the long term since plants were collected in mid-late august when plants were just beginning to senesce. In the process of senescence the plants draw minerals into the ground where they can be incubated in the roots through the winter. Senesce also naturally decreases the digestibility of plants. In the future, collections earlier in the growing period will help to confirm these findings.

Nutritional analysis measured crude protein and trace elements found in the collected samples. Results are also preliminary but reveal important insights into certain species. Comparatively, the dominant brush species for reindeer in Mongolia, *Betula nana*, which reindeer in Alaska and most other places in the world do not eat, has a much higher protein content in the taiga. Similar comparison for nutrients has proven difficult because of a lack of data especially for different times in the growing season. However, insights into specific species or groups is possible which contributes to the nutritional understanding of the pasture and can ultimately be used to promote proper nutrition for the herd. The following graphs show trends such as high calcium levels in select forbs such as the Epilobium species and *Primula nivalis* while magnesium values are higher in green plants such as forbs and grasses. The most striking trends are the lack of minerals and elements in lichen including; crude protein, potassium, magnesium, sulfur, phosphorous, copper, manganese, and zinc and their presence in mushrooms which are high in; crude protein, potassium, phosphorous, copper, iron, and zinc. Mushrooms also have high salt concentrations. *Equisetium varriegatum*, of the horsetail family, has the second highest salt concentrations, both *E. varriegatum* and mushrooms have outlier values of salt concentrations several times the average. *E. varriegatum* also has the highest level of iron; ~4x higher than lichen, the second highest group. Iron is one of the few minerals found in medium-raised levels in lichen. *E. aravense,* a closely related species also in the horsetail family, has very high levels of certain minerals including calcium and sulfur. Based on the two species identified and analyzed here, it appears that species from the horsetail family have high levels of select minerals but not the same minerals. Observational data from 2006 showed calves eating *E varriegatum* more aggressively than adults. Finally, selenium values were among the most variable, this included variation within groups and within the same species in different geographic locations. Such results are likely to be due to variable levels in the soil, preventing or inhibiting uptake and absorption. Interestingly, selenium values are higher overall in grasses, but lower in sedges and forbs. This despite the fact that grasses and sedges are both graminoids.

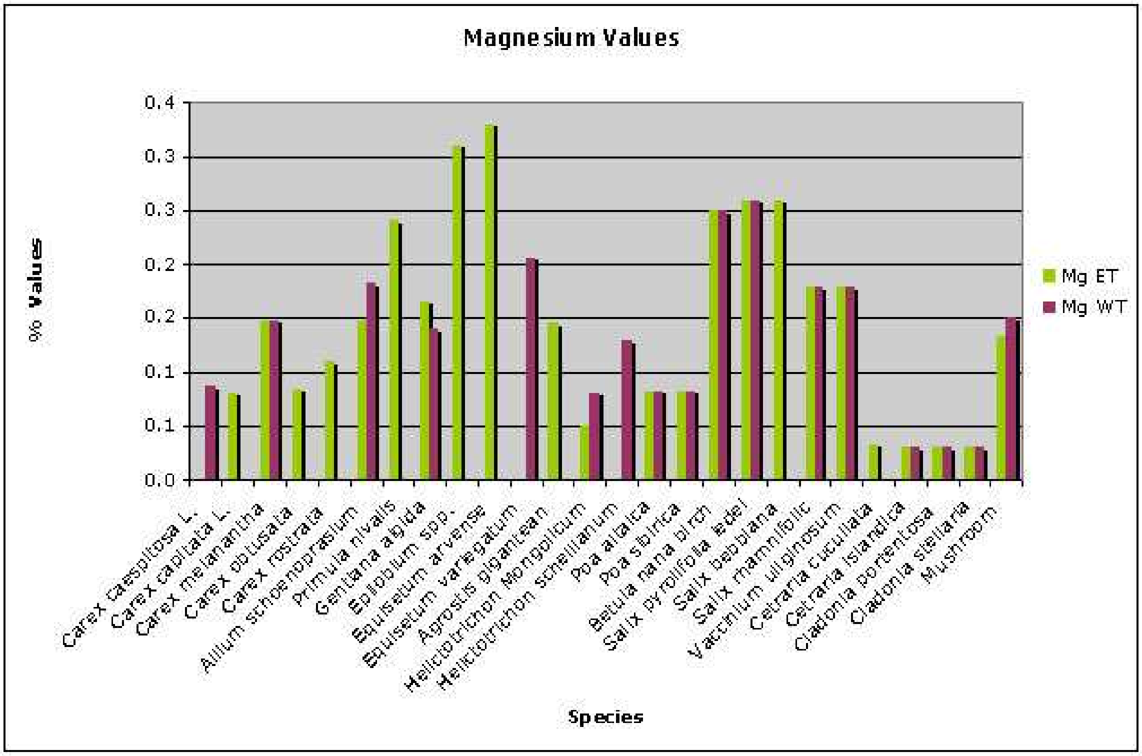
Graph 6 - 17. (**next pages**) Results for nutritional analysis for crude protein and micro-nutrients. Each graph is broken down by compound rather than species so that different species can be compared by nutrient and to avoid problems of scale on the y-axis. Green bars are the east taiga, purple is the west taiga.



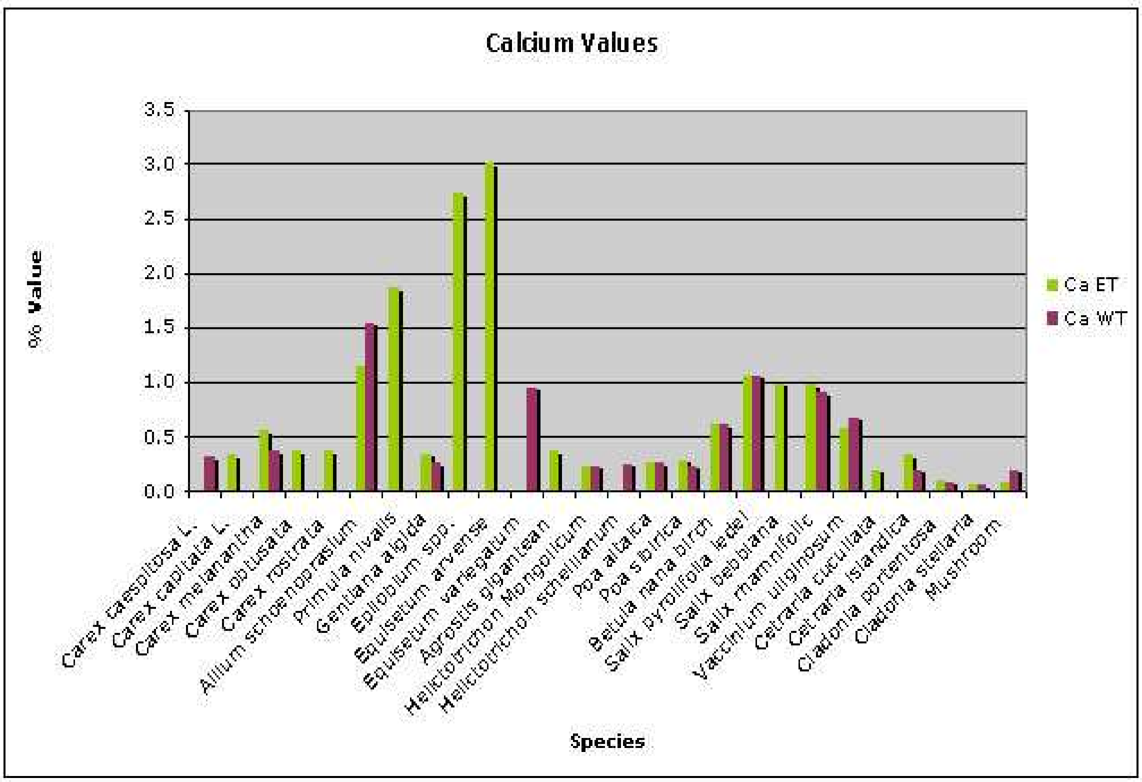
Crude Protein Values
% Value
35
30
25
20
15
10
5
0
CP ET
CP WT
Carex caespitosa L.
Carex capitata L.
Carex melanantha
Carex obtusata
Carex rostrata
Allium schoenoprasium
Primula nivalis
Gentiana algida
Epilobium spp.
Equisetum arvense
Equisetum variegatum
Agrostis gigantean
Helictotrichon Mongolicum
Helictotrichon schellianum
Poa altaica
Poa sibirica
Betula nana birch
Salix pyrolifolia ledel
Salix bebbiana
Salix rhamnifolic
Vaccinium uliginosum
Cetraria cuculata
Cetraria islandica
Cladonia portentosa
Cladonia stellaria
Mushroom
Species



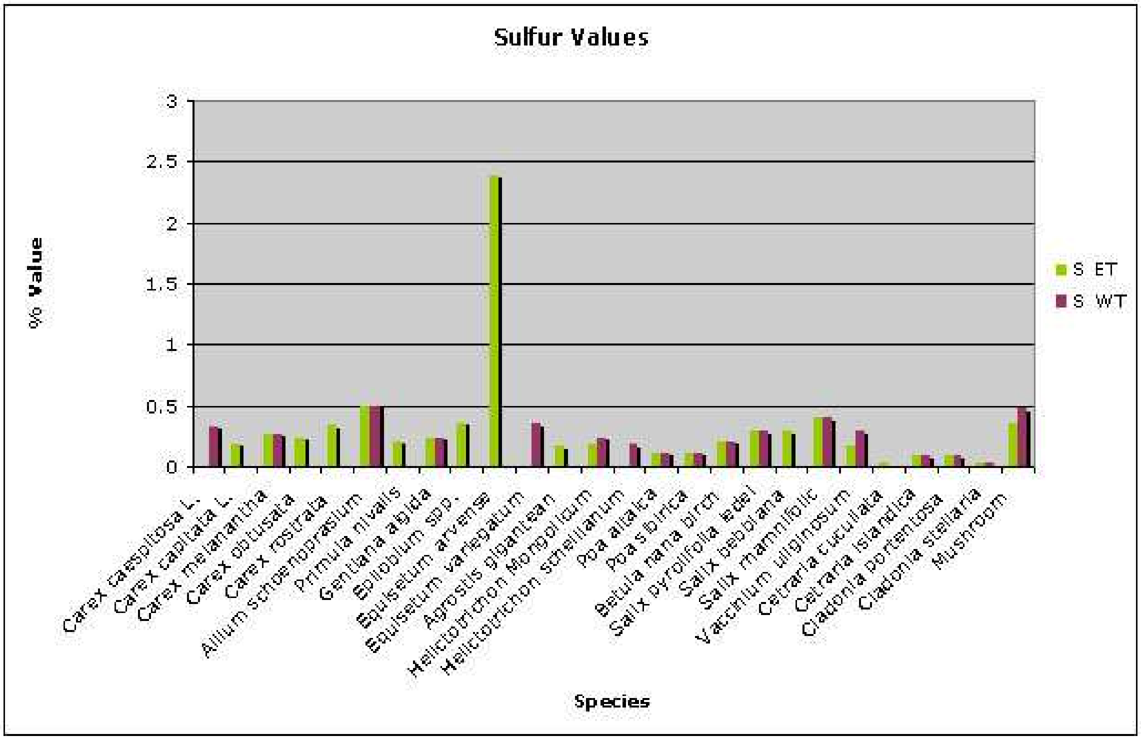
Potassium Values
% Value
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
K ET
K WT
Carex caespitosa L.
Carex capitata L.
Carex melanantha
Carex obtusata
Carex rostrata
Allium schoenoprasium
Primula nivalis
Gentiana algida
Epilobium spp.
Equisetum arvense
Equisetum variegatum
Agrostis gigantean
Helictotrichon Mongolicum
Helictotrichon schellianum
Poa altaica
Poa sibirica
Betula nana birch
Salix pyrolifolia ledel
Salix bebbiana
Salix rhamnifolic
Vaccinium uliginosum
Cetraria cuculata
Cetraria islandica
Cladonia portentosa
Cladonia stellaria
Mushroom
Species

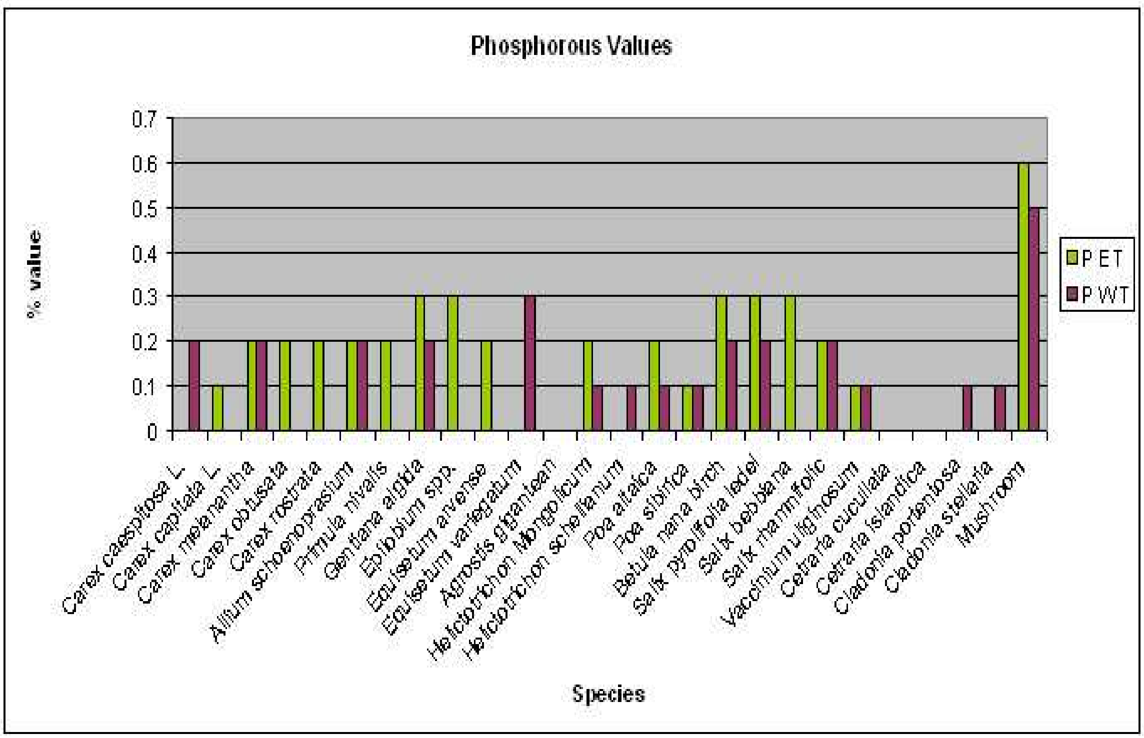


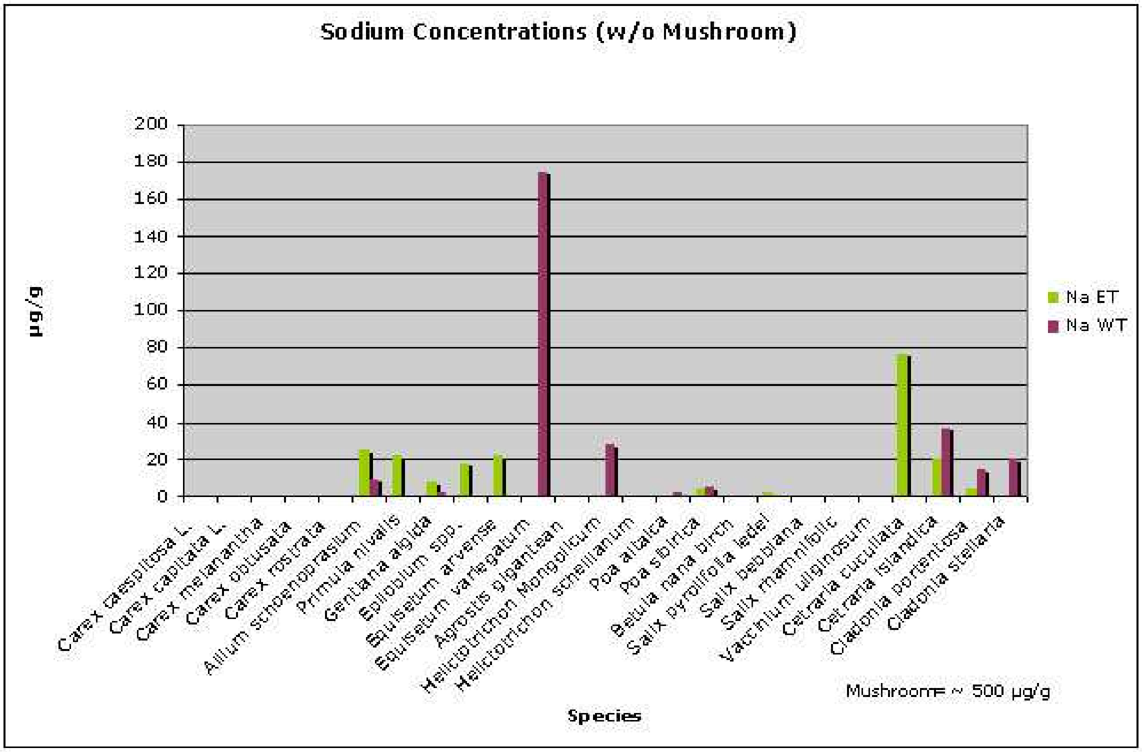
Magnesium Values
% Values
0.4
0.3
0.3
0.2
0.2
0.1
0.1
0.0
Mg ET
Mg WT
Carex caespitosa L.
Carex capitata L.
Carex melanantha
Carex obtusata
Carex rostrata
Allium schoenoprasium
Primula nivalis
Gentiana algida
Epilobium spp.
Equisetum arvense
Equisetum variegatum
Agrostis gigantean
Helictotrichon Mongolicum
Helictotrichon schellianum
Poa altaica
Poa sibirica
Betula nana birch
Salix pyrolifolia ledel
Salix bebbiana
Salix rhamnifolic
Vaccinium uliginosum
Cetraria cucullata
Cetraria islandica
Cladonia portentosa
Cladonia stellaria
Mushroom
Species



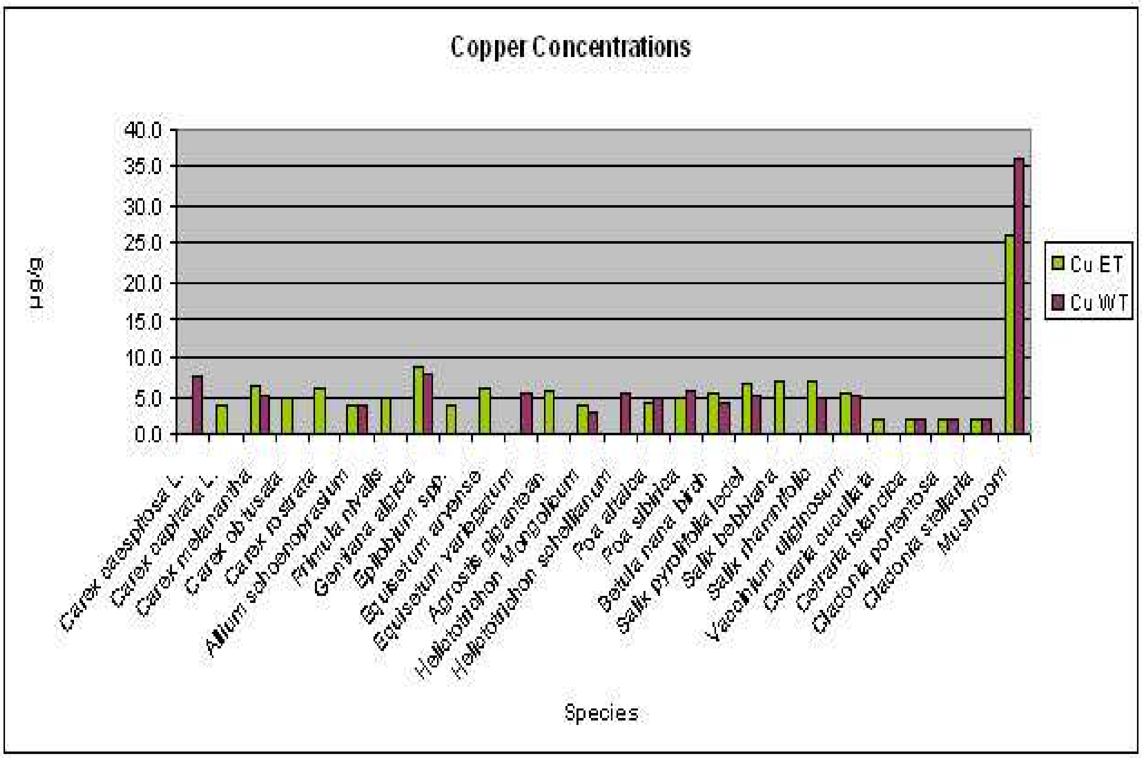
Calcium Values
% Value
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Ca ET
Ca WT
Carex caespitosa L.
Carex capitata L.
Carex melanantha
Carex obtusata
Carex rostrata
Allium schoenoprasium
Primula nivalis
Gentiana algida
Epilobium spp.
Equisetum arvense
Equisetum variegatum
Agrostis gigantean
Helictotrichon Mongolicum
Helictotrichon schellianum
Poa altaica
Poa sibirica
Betula nana birch
Salix pyrolifolia ledel
Salix bebbiana
Salix rhamnifolic
Vaccinium uliginosum
Cetraria cucullata
Cetraria islandica
Cladonia portentosa
Cladonia stellaria
Mushroom
Species


Sulfur Values
% Value
Species
S ET
S WT
Carex caespitosa L.
Carex capitata L.
Carex melanantha
Carex obtusata
Carex rostrata
Allium schoenoprasium
Primula nivalis
Gentiana algida
Epilobium spp.
Equisetum arvense
Equisetum variegatum
Agrostis gigantean
Helictotrichon Mongolicum
Helictotrichon schellianum
Poa altaica
Poa sibirica
Betula nana birch
Salix pyrolifolia ledel
Salix bebbiana
Salix rhamnifolic
Vaccinium uliginosum
Cetraria cucullata
Cetraria islandica
Cladonia portentosa
Cladonia stellaria
Mushroom

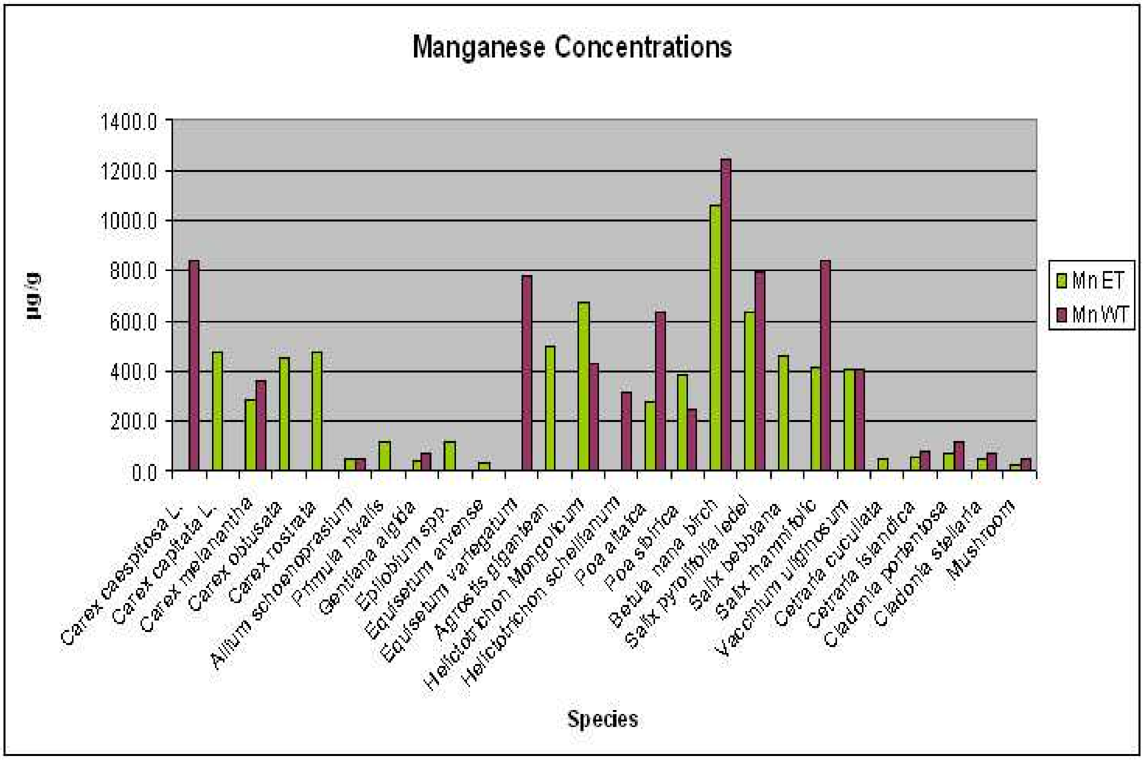

Phosphorous Values
% value
Species
P ET
P WT
Carex caespitosa L.
Carex capitata L.
Carex melanantha
Carex obtusata
Carex rostrata
Allium schoenoprasium
Primula nivalis
Gentiana algida
Epilobium spp.
Equisetum arvense
Equisetum variegatum
Agrostis gigantean
Helictotrichon Mongolicum
Helictotrichon schellianum
Poa altaica
Poa sibirica
Betula nana birch
Salix pyrolifolia ledel
Salix bebbiana
Salix rhamnifolic
Vaccinium uliginosum
Cetraria cucullata
Cetraria islandica
Cladonia portentosa
Cladonia stellaria
Mushroom

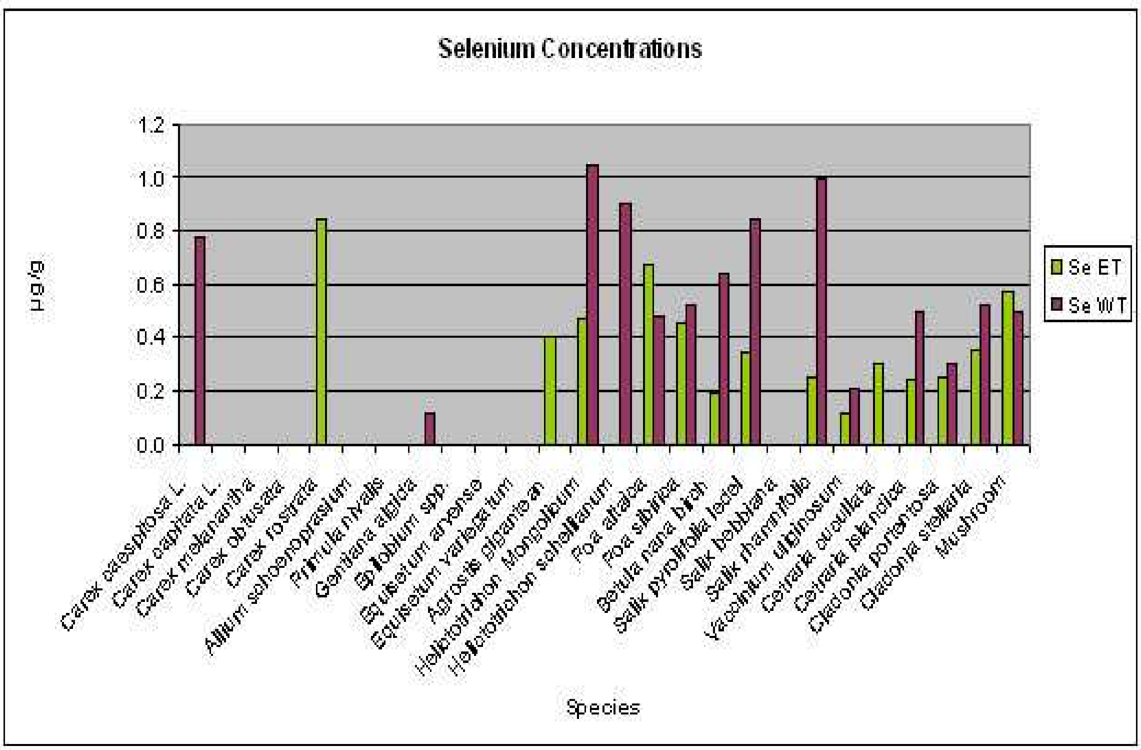


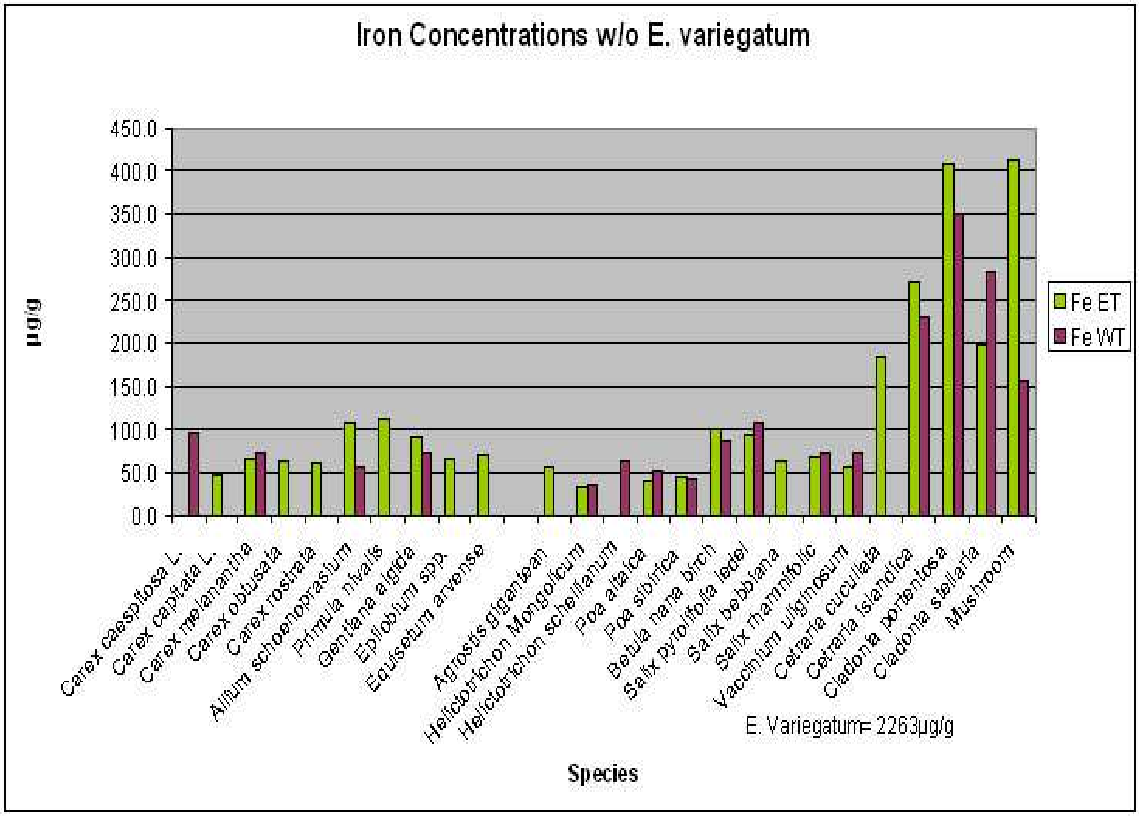
Sodium Concentrations (w/o Mushroom)
µg/g
200
180
160
140
120
100
80
60
40
20
0
Na ET
Na WT
Carex caespitosa L.
Carex capitata L.
Carex melanantha
Carex obtusata
Carex rostrata
Allium schoenoprasium
Primula nivalis
Gentiana algida
Epilobium spp.
Equisetum arvense
Equisetum variegatum
Agrostis gigantean
Helictotrichon Mongolicum
Helictotrichon schellianum
Poa altaica
Poa sibirica
Betula nana birch
Salix pyrolifolia ledel
Salix bebbiana
Salix rhamnifolic
Vacchium uliginosum
Cetraria cucullata
Cetraria islandica
Cladonia portentosa
Cladonia stellaria
Mushroom= ~ 500 µg/g
Species

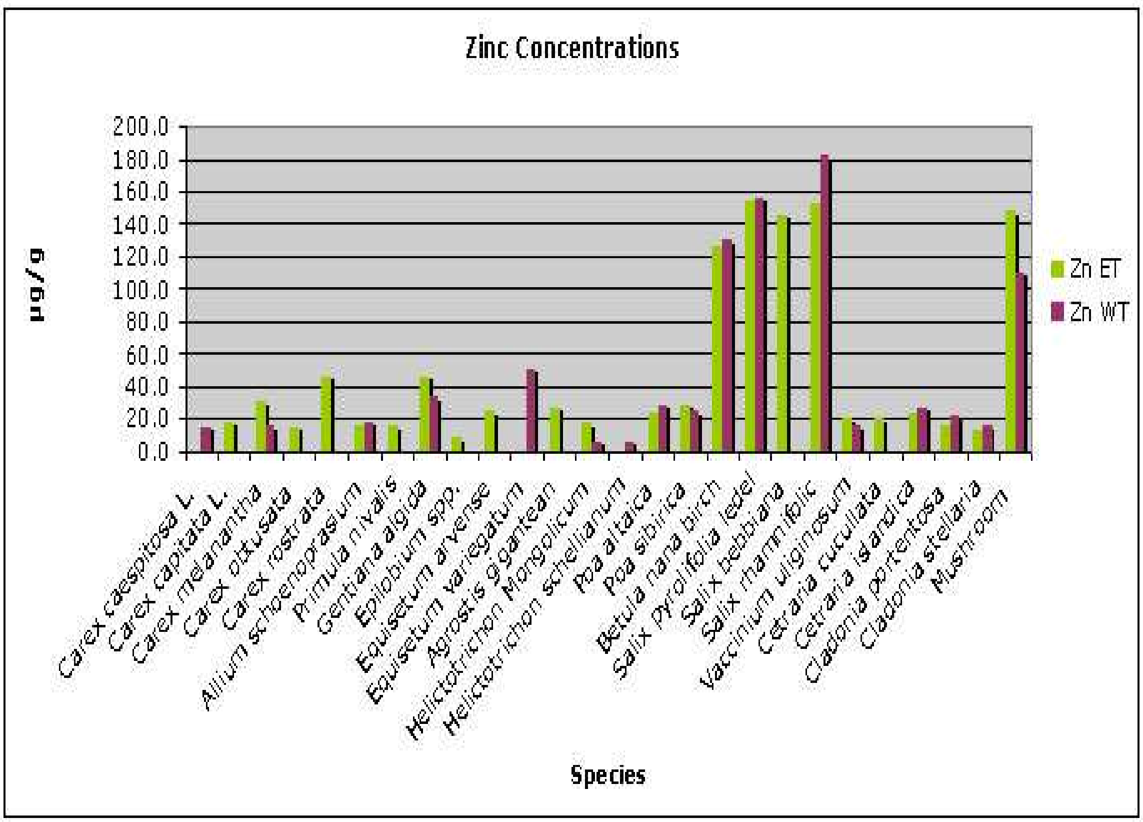


Copper Concentrations
µg/g
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Cu ET
Cu WT
Carex caespitosa L.
Carex capitata L.
Carex melanantha
Carex obtusata
Carex rostrata
Allium schoenoprasium
Primula nivalis
Gentiana algida
Epilobium spp.
Equisetum arvense
Equisetum variegatum
Agrostis gigantean
Helictotrichon Mongolicum
Helictotrichon schellianum
Poa altaica
Poa sibirica
Betula nana birch
Salix pyrolifolia ledel
Salix bebbiana
Salix rhamnifolia
Vacchium uliginosum
Cetraria cucullata
Cetraria islandica
Cladonia portentosa
Cladonia stellaria
Mushroom
Species


Manganese Concentrations
µg/g
1400.0
1200.0
1000.0
800.0
600.0
400.0
200.0
0.0
Mn ET
Mn WT
Carex caespitosa L.
Carex capitata L.
Carex melanantha
Carex obtusata
Carex rostrata
Allium schoenoprasium
Primula nivalis
Gentiana algida
Epilobium spp.
Equisetum arvense
Equisetum variegatum
Agrostis gigantean
Helictotrichon Mongolicum
Helictotrichon schellianum
Poa altaica
Poa sibirica
Betula nana birch
Salix pyrolifolia ledel
Salix bebbiana
Salix rhamnifolic
Vaccinium uliginosum
Cetraria cucullata
Cetraria islandica
Cladonia portentosa
Cladonia stellaria
Mushroom
Species


Selenium Concentrations
µg/g
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Se ET
Se WT
Carex caespitosa L.
Carex capitata L.
Carex melanantha
Carex obtusata
Carex rostrata
Allium schoenoprasium
Primula nivalis
Gentiana algida
Epilobium spp.
Equisetum arvense
Equisetum variegatum
Agrostis gigantean
Helictotrichon Mongolicum
Helictotrichon schellianum
Poa altaica
Poa sibirica
Betula nana birch
Salix pyrolifolia ledel
Salix bebbiana
Salix rhamnifolic
Vaccinium uliginosum
Cetraria cucullata
Cetraria islandica
Cladonia portentosa
Cladonia stellaria
Mushroom
Species


Iron Concentrations w/o E. variegatum
µg/g
450.0
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
Fe ET
Fe WT
Carex caespitosa L.
Carex capitata L.
Carex melanantha
Carex obtusata
Carex rostrata
Allium schoenoprasium
Primula nivalis
Gentiana algida
Epilobium spp.
Equisetum arvense
Agrostis gigantean
Helictotrichon Mongolicum
Helictotrichon schellianum
Poa altaica
Poa sibirica
Betula nana birch
Salix pyrolifolia ledel
Salix bebbiana
Salix rhamnifolic
Vaccinium uliginosum
Cetraria cucullata
Cetraria islandica
Cladonia portentosa
Cladonia stellaria
Mushroom
E. Variegatum= 2263µg/g
Species


Zinc Concentrations
µg/g
200.0
180.0
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
Zn ET
Zn WT
Carex caespitosa L.
Carex capitata L.
Carex melanantha
Carex obtusata
Carex rostrata
Allium schoenoprasium
Primula nivalis
Gentiana algida
Epilobium spp.
Equisetum arvense
Equisetum variegatum
Agrostis gigantean
Helictotrichon Mongolicum
Helictotrichon schellianum
Poa altaica
Poa sibirica
Betula nana birch
Salix pyrolifolia ledel
Salix bebbiana
Salix rhamnifolic
Vaccinium uliginosum
Cetraria cucullata
Cetraria islandica
Cladonia portentosa
Cladonia stellaria
Mushroom
Species

DISCUSSION:

Unlike most ruminants, reindeer live in some of the coldest inhabited ecosystems in the world where low vegetative biomass couples with low nitrogen-content flora to create an unusually inhospitable environment. This is especially true during the long winters where permafrost gives way to very short growing seasons. Therefore, it is particularly important that reindeer nutrition is carefully considered in systems that seek to utilize reindeer as a sustainable resource. Compared to other domesticated ruminants, it is surprising how little is known about the mechanisms of reindeer metabolism, and the nutritional requirements of the species. This, despite the fact that reindeer have been successfully herded for millennia by various indigenous groups throughout the circumpolar regions of the globe.

For the Tsaatan, this problem is amplified by the loss of traditional wisdom during Soviet occupation including information concerning effective utilization of range and general reindeer nutritional needs. Persecution of traditional practices, and mandated shifts to cash-based industries in past decades has stifled the Tsaatan's ability to be successful reindeer herders. Though reindeer thrive in harsh environments, the environmental balance in this system is at times tenacious; pollution, traffic, and climate [23] must balance with the slow regeneration and low biomass of taiga ecosystems. This forces people who depend on reindeer to continually adapt their management strategies, searching for new pastures and offering sensitive ecosystems an opportunity to renew.

One proposed solution to nutritional deficiency in the herd is harvesting greens from Salix species which can be dried and stored for winter feeding. Studies using similar techniques of harvested winter supplements showed a dramatic increase in body condition [30]. Other research has confirmed that supplemental feeding helps with energy and protein intake during the winter months giving the reindeer, especially breeding females responsible for gestation and lactation [35], a marked advantage in the next year's life cycle [41]. Supplying winter feed/forage with higher concentrations of protein and nutrients has been shown to have a positive effect on milk quality, calf birth weight, initial growth and mortality [34]. Using local forage already available avoids the problems of transitioning diets that many supplemental fed reindeer experience initially [18]. Such supplemental feeding is a common practice for reindeer around the world, particularly in the European-arctic circle where scientists have conducted numerous feed trials on the proper qualities of locally harvested supplemental feed [2, 27].

Other possibilities for the Tsaatan community include salt supplements and/or bone meal. Some herders currently use salt supplements, purchasing a course unrefined salt from the local city twice a year. But the amount and frequency that reindeer receive the salt is highly variable since each herder offers it at different times and not to all reindeer. For instance, it is often used to call lactating females in so they can be milked; males who wander farther and stay away longer often miss out on salt rations. Though the regulatory effects of salt including Na+ (and K+) ions is well studied in many organisms, previous research has shown that Na+ (and K+) is positively correlated to dry matter digestibility *in vitro* [40]. That is to say that as Na+ concentrations increase, so does digestibility. Increasing digestibility can lead to more nourishment for reindeer allowing them to better utilize ingested forage. K+ ions are very often found in bone meal along with Ca and PO4. It is another supplemental feeding option since ground bone meal is cheap/free, readily available from herders who have to slaughter reindeer or hunt wild animals, easy to process, and rich in minerals.

It may seem contradictory that much research on reindeer has been cited here and yet I have insisted that the overall level of knowledge of reindeer is low. This acknowledges that much of the research that has been done on reindeer is done for the direct benefit of reindeer herders all over the world [24]. This is a positive trend for herds in the global community but it does not always apply to the basic understanding of reindeer nutrition or to the specific management system in Mongolia. For instance, there is a large body of data on feed analysis and winter conditions/responses. But much of this data does not A) apply to the unique system of reindeer management employed by the Tsaatan, and B) does not necessarily reflect an equal amount of work in other areas of reindeer nutrition such as *ad lib* or free range feeding habits.

This research has approached the first step in reviving a dynamic system of management for Tsaatan herds. By collecting data on different pastures a baseline has been compiled from which conclusions previously based on hunch or assumption can be made. While more data is necessary, some policy adaptations are already being explored within the community. These policy recommendations come from an intimate dialog between Tsaatan herders and international experts and collaborators.

Since the Tsaatan do constrict the movement of their reindeer through capture and release but also do not currently harvest supplemental food for their herd, the animals need to conform to the herbivore optimization model [15, 36], establishing an appropriate density and grazing level that supports growth in their ecosystem instead of over or under grazing. But the ecological constraints of the taiga such as short growing seasons, low biomass, and long regeneration times (especially for lichen) make this a fine balance. Geographically confined to the south by the climatologically inappropriate steppe habitat and politically constrained to the North by the Russian border, the Tsaatan may not have enough grazing grounds or an adaptive enough pasture rotation to support their reindeer. Observations in the west taiga revealed heavy historical use with slow and potentially insufficient regeneration to support its use in 2006. Concentrated capture-release management that restricts the available pasture is partly addressed through the Tsaatan's nomadic lifestyle but weather, terrain, tradition, and access to material goods at markets also constrain Tsaatan movement.

The capture-release method of management has been partly criticized in this work for limiting grazing patterns but it is vital for the Tsaatan's lifestyle and not necessarily contraindicated with sustainability. There is hope for the Tsaatan reindeer; careful management can exploit the lack of competition from other grazers that their reindeer currently enjoy [25] and intensive management by the Tsaatan can increase the potential for successful herd dynamics.

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