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SIMPLE METHODS OF COMPARING WINTER SNOW CONDITIONS ON ALPINE AND SUBALPINE RANGES OF DALL'S SHEEP AND MOUNTAIN GOATS IN ALASKA

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Abstract: A simple, inexpensive method was designed whereby 1 person could rapidly estimate winter show depth and relative hardness on accessible Dall's sheep (*Ovis dalli*) winter ranges. The method was repeatable and permitted statistical comparisons between areas and years. It also enabled evaluation of snow conditions relative to sheep's foraging ability. Another method utilizing simple aerial photography was used to estimate percent gross snow cover on winter ranges of both Dall's sheep and mountain goats (*Oreamnos americanus*). Again, statistical comparisons could be made between areas and years. Distribution and density of both species were cor-related with percent snow cover.

In examining winter habitats, it is often useful to be able to compare snow conditions between areas, between winters, or in relation to an animal's ability to obtain food. For example, the relationships between snow cover and caribou (*Rangifer tarandus arcticus*) feeding behavior were studied by Pruitt (1981), and between snow cover and feeding strategies of wild mountain reindeer (*R. tarandus tarandus*) by Skogland (1978), while Lent and Knutson (1971) examined muskox (*Ovibos moschatus*)/snow relationships. The methods used by these investigators, while depicting accurately the variable pro-files of snow layers, were relatively complicated and used expensive instruments such as the ramsonde penetrometer.

During a study comparing 3 herds of Dall's sheep, I needed a simple, economical method by which to compare gross snow conditions between their alpine winter habitats and between years. Also, I wanted to relate snow conditions to the animals' ability to reach forage. The method I developed enabled 1 person to obtain statistically useful data under harsh conditions with relative ease and speed.

In a later study of mountain goats, I needed to compare snow conditions between winter ranges of sub-herds and between winters, but was unable to use the previous method because of difficult topography. I devised another procedure to assess percent snow cover from aerial photographs.

METHODS

Snow Depth and Hardness

This method was described briefly in a previous paper concerned primarily with Dall's sheep management (Nichols 1976). However, I believe it is worth expanding upon in view of its potential usefulness to other biologists.

Snow depth was measured with a 6-joint, tubular avalanche probe (Mountain Safety Research, Inc., 631 S. 96th St., Seattle, WA 98108). Each joint is about 45.7 cm (18 in) in length. The entire probe is 274 cm (108 in) in length; however, it can be used at any length desired in multiples of 45.7 cm (18 in). The point is slightly larger in diameter than the remainder, making it somewhat easier to push through and remove from hard snow than a simple cylindrical rod.

I painted the entire probe with light-colored epoxy paint, then drew on it in black paint a scale with each 2.5 cm (1 in) marked and numbered. Numbers should be clear and easy to read because it is difficult to bend down in heavy winter clothing and on snowshoes. The probe was then waxed to reduce friction with the snow.

In use, snow depth was read directly by pushing the probe vertically to the ground. Some practise was necessary to avoid catching the point in the semi-frozen tundra.

Because Dall's sheep rarely feed in snow deeper than 30 cm (12 in) (Hoefs and Cowan 1979; Nichols pers. obs.), I decided, for practical purposes, to measure relative snow hardness only to a maximum depth of 46 cm (18 in). I used a Chatillon #719-40 "push-pull" scale graduated from 0-40 lb (0-18.2 kg) in 0.5 lb increments. This is a cylindrical spring scale, 2.2 cm (0.88 in) in diameter and 32.3 cm (12.75 in) long with a hook on one end for measuring "pull" and a 0.5 cm (0.19 in) diameter rod extending from the opposite end to measure "push". The scale includes a sliding marker which records the maximum reading. Because the cylindrical scale is made of smooth stainless steel, I wrapped it in several places with rough tape to make it less slippery when used with mittens.

Two pressure probes were used, each a steel rod approximately 122 cm (48 in) in length and 0.64 cm (0.25 in) in diameter. Attached to the bottom of one rod was a circular disk of 1.0 cm^2 area (1.13 cm diam) and to the other a disk of 0.5 cm^2 area (0.80 cm diam). At the top of each rod was attached a short sleeve making a socket approximately 2.5 cm (1 in) deep into which could be inserted the pressure-measuring rod of the scale. Each rod was marked with tape 46 cm (18 in) from the bottom as a quick reference to the maximum snow depth to be measured. This instrument is somewhat similar to the spring penetrometer mentioned by Skogland (1978) but is adapted to penetration and measurement of harder snow.

In use, the 1.0 cm-tipped rod was placed gently on the snow surface, the scale's "push" rod inserted in the socket, the scale's recording indicator set to zero, and the rod pushed slowly and steadily into the snow by pressing with the scale while supporting the snow probe against bending with the other hand. Again, practise was necessary to learn how to avoid faulty readings as the probe broke through snow or ice layers. This combination would record maximum pressures to 18.2 kg/cm^2 (258 lb/in^2). Should the snow or ice layers prove too hard for penetration with the 1 cm-tipped rod, the 0.5 cm-tipped rod was used, recording pressures up to 36.4 kg/cm^2 (516 lb/in^2). Larger tips could be adapted for softer snow if necessary.

Transects were established in sheep winter habitat on relatively flat areas where sheep feeding was known to occur. I used 5 transects on each area, each of which consisted of 10 stations located 10 paces apart. Each line began from a marked point and was run on a compass course. At each station, 1 depth and 4 hardness measurements were taken. It was necessary to take more of the latter because of variation in hardness even in the space of a few centimeters.

Fifty depth and up to 200 hardness measurements were obtained from each 5 transects. Points falling on bare ground were considered as "0" in depth, but were ignored for hardness.

Observations were recorded on a cassette recorder kept inside my parka (batteries rapidly lost power in the cold) with an extension microphone clipped to my collar. Thus, it was possible to conduct the entire survey along on snowshoes and with minimal removal of mittens.

When it appeared that snow was hard enough to cause sheep difficulty in pawing feeding craters, I took a series of depth/hardness measurements around the perimeters of craters where they had been successful in reaching forage, and around a number where they had attempted unsuccessfully to paw through. These measurements were used to estimate those conditions of snow depth and hardness that limited the animals' ability to reach feed.

Percent Snow Cover

Percent of ground covered by snow was estimated from line transects drawn on aerial photographs. Photographs were taken using a 35 mm camera and fine-grained, black and white film from a light aircraft flown approximately 914 - 1219 m (3000 - 4000 ft) higher than the highest point to be examined and distant enough to include the area of interest. This height produced a photograph taken about 90 deg from the plane of the mountain slope. I selected mountain slopes bounded by obvious physiographic features - such as canyons, side valleys, etc. - to make it easier to relocate the sites in future sessions as well as to bound transect lines. Details of each photograph were recorded as taken using a cassette recorder for future reference. Overcast conditions gave a softer light, eliminating harsh shadows that later could be mistaken for bare ground, and a yellow filter enhanced contrast.

After development, photographs were enlarged to 8 x 10 in (20.3 x 25.4 cm) prints using high-contrast paper. Five randomly-selected, horizontal lines were drawn with a fine-point pen on each phototograph within known winter habitat (ususally above tree line). Under magnification, marks were made where each line intersected an interface between snow-covered and bare ground. The portion of each line covered by snow was determined by accumulating lengths of each snow-covered segment using sharp dividers. The total length of the snow-covered portion was divided by the total length of the line to give the percentage of that line covered by snow.

Average percent snow cover and its standard deviation for each area photographed could then be calculated from the 5 transect lines. These, in turn, could be compared with other areas by standard statistical tests.

DISCUSSION

Snow Depth and Hardness

To test the accuracy of the method, 3 simultaneous surveys were done with the stations for each point set at approximately 1 m apart. Analysis of variance showed no difference in either average depth or hardness ($P > 0.25$) between them. I concluded the method was sufficiently accurate to show real differences between areas or survey dates.

On 1 of my study area, I conducted 4 snow surveys throughout a winter (16 Nov., 11 Dec., 31 Jan., and 10 Mar.) to learn what changes occurred over time and to see whether there was any preferable time period in which to do annual surveys. Snow depth and hardness increased significantly ($P < 0.05$) between the first 2 surveys, and hardness increased ($P < 0.01$) between the second and third. There was no difference found ($P > 0.10$) in either parameter between the last 2 surveys despite several heavy snowfalls. I concluded that in this area, snow accumulated on these exposed ridges until it crusted from wind-packing or thawing and refreezing. After a sufficiently hard crust was formed and colder mid-winter temperatures stabilized, further accumulation was removed from the smooth, crusted surface by wind action. Therefore, snow surveys were conducted annually between late January and early March when I assumed conditions would be sufficiently stable to be representative. Using this technique, I was able to compare successfully and relatively easily snow depth and hardness between areas and years.

One weakness in the method was that with the scale used, I was able to measure snow hardness only to a maximum of 36.4 kg/cm^2 (516 lb/in^2). Any ice layers encountered that could not be penetrated with this pressure were recorded as having a hardness of 36.4 kg/cm^2, thus underestimating average snow hardness. This occurred rarely unless the majority of the snow cover was so hard that sheep could not paw through anyway.

Hardness and depth measurements taken in undisturbed snow around sheep feeding craters that were successfully pawed to forage level ($N = 61$) or were attempted but unsuccessful ($N = 15$) were compared. Indices attained by multiplying mean depth by mean hardness were plotted by frequency of occurrence (Fig. 1) and suggested that below an index of 60, all pawing was successful while above an index of 179, no pawing was successful. Thus, average snow conditions as determined by this method could be used to compare or predict winter severity relative to the animals' ability to reach snow-covered forage.

Average winter snow indices over a period of 5 years were compared with lambing success the following spring on 3 herds of Dall's sheep under study (Fig. 2). A significant negative correlation was found between an increasing index (mean depth x mean hardness) and lambing success ($P = 0.02$).

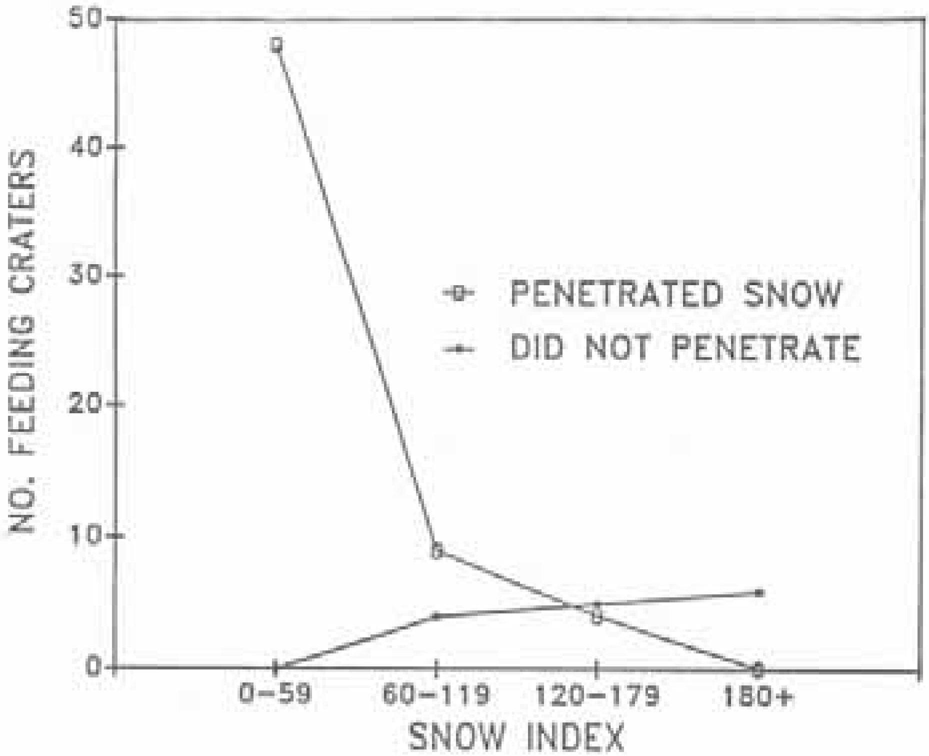

Figure 1. Dall's sheep ability to paw feeding craters through snow as indicated by measurements adjacent to craters. (Snow Index = mean snow depth x mean snow hardness)

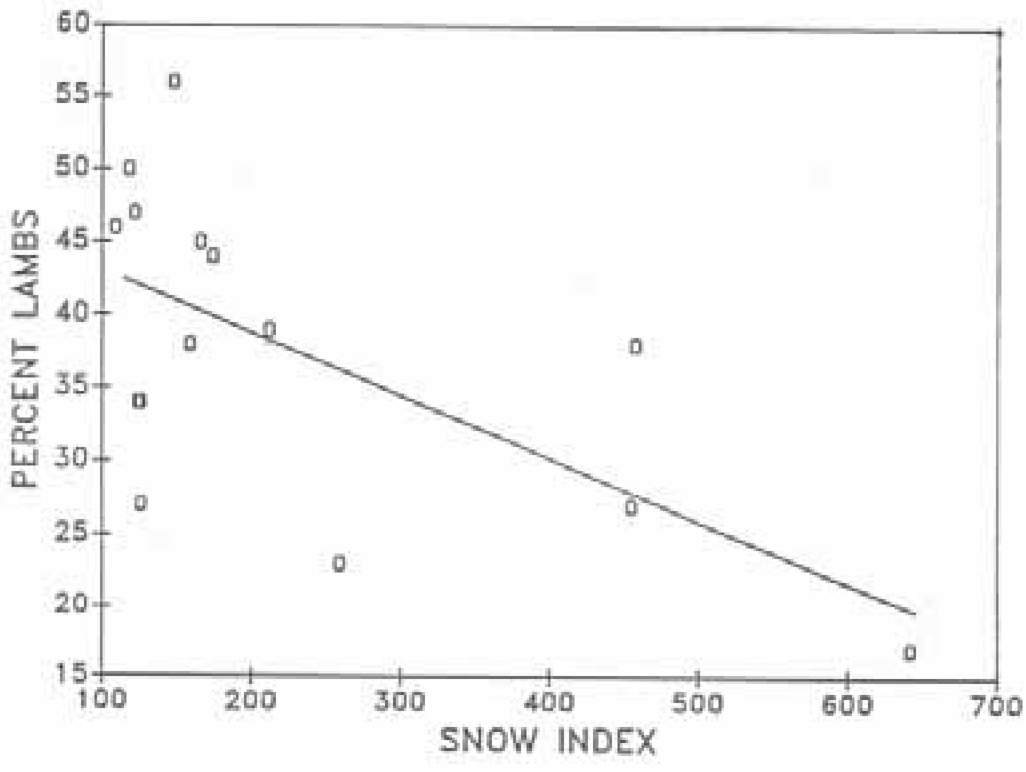

Figure 2. Relationship of snow index (mean snow depth x mean snow hardness) to the ratio of lambs per 100 ewes the following spring. Three Dall's sheep herds over 5 winters (df=13, r=0.6208, P=0.02)

Percent Snow Cover

The 5 transect lines drawn on each photograph proved adequate for estimating percent snow cover on the slope photographed. No improvement in accuracy could be detected by using 10 lines.

Statistical analyses showed that both differences and similarities in snow cover could be demonstrated within and between portions of both sheep and mountain goat winter ranges by this method, and between years. Results appeared to agree closely with observations of winter distribution and abundance and helped explain why most animals used, or did not use certain portions of their habitat.

Average percent snow cover over a 3-year period was examined for the species using each general winter range. Snow cover was higher on ranges used by both sheep and goats than on that used only by sheep ($P < 0.005$), and higher still on ranges used only by goats than on that used by both sheep and goats ($P < 0.001$). Thus, it appears that sheep distribution is limited by average winter snow cover, and that goats can tolerate much higher snow cover than sheep.

Both technique described have been demonstrated to provide useful management and research information about mountain big game in winter. Both are simple to use, fast, and relatively economical; they should be adaptable to other areas and studies.

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