SNOW SINKING STUDIES

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ABSTRACT

In snow covered regions, predator-prey relationships change with snow conditions. Some snow conditions are advantageous to the predators while other snow conditions favor the prey species. To understand the relationship between bearing pressure imposed by the various animals and how deep they sink into the snowpack, and different snow parameters, 193 measurements were taken over a 13 year period. Most of the sampling was done in Yellowstone National Park on the Northern range at four to six locations three to four times each winter. Curves were developed to predict how far an animal or object having a known bearing pressure will sink into a snowpack of a given depth and density. Equipment developed and procedures used will be described. Results have been combined into a graph to simplify use. Data is particularly important to evaluating animal's ability to move through snow and predator-prey relationships involving snow, but can also be used to evaluate how deep oversnow vehicles, helicopters with snow pads, skis or snow shoes sink into the snowpack.

INTRODUCTION

Predator-prey relationships often involve snow. It appears that sometimes the snow conditions favor the predator and other times it favors the prey. In an attempt to define this relationship, it is necessary to determine how deep into the snowpack each individual will sink under different snow conditions. In conjunctions with some other snow studies in Yellowstone National Park, measurements were made of sinking depth for a variety of bearing pressures. It was determined that it would be impractical to carry enough weight into the field to replicate bearing pressures for anything but very small mammals. It was intended to obtain data over a large range of bearing pressures so that it would encompass everything from small mammals (less than 3 kPa) to large ungulates (150 kPa) rather than specific species. It was decided to use a small fish scale and apply different downward pressures to a hardwood dowel and plastic water bottle to determine how far into the snowpack each would penetrate. To see if the total area was a factor, the penetration of both a hiking boot and snowshoe were also measured.

METHODS

A wooden dowel with a 3.3 cm diameter (area of 8.7 cm^2) was cut to a length of 66 cm. A small hole was drilled near the end of the dowel with sufficient diameter to pass a length of nylon cord. A knot was tied in the parachute cord to make a loop approximately 3 cm diameter. Units were etched on the dowel with permanent ink. The plastic water bottle had a diameter of 8.6 cm (area of 58 cm^2). The cap was removed and replaced with a ring and lid from a Mason jar. A hole was cut in the lid to pass the wooden dowel. A guide slightly larger than the dowel was glued to the bottom of the bottle. This would keep the dowel straight when inserted into the bottle. A round dial fish weighing scale with a capacity of 15 kilograms was purchased. Equipment is shown in Figure 1. A snowshoe (area of 1988 cm^2) and hiking boot (area of 250 cm^2) were part of the equipment. A note form was developed and duplicated. A standard Federal snow sampling set completed the equipment.

In the field, a level site without drifting was selected. The depth that an individual would sink with all of their weight on one foot with a hiking boot and on one snowshoe was recorded. Air temperature and depth of new snow were also recorded. The dowel was positioned vertically above the snowpack and various pressures in about 2.2 kg increments were applied with depth of penetration recorded for each pressure. This was repeated up to about 11 kg pressure or to the pressure where the dowel either reached the ground surface or where it penetrated deeper than the dowel's length. Then the dowel was inserted into the plastic bottle and 2.2 kg pressure applied (Figure 2). The bottle was moved about 10 cm distance and 4.4 kg pressure applied, moved again and applying increasing pressure in 2.2 increments until the total pressure was about 11 kg or until the bottle penetration approached the total depth of snow. Total snow depth was recorded. Five snow samples were taken with the standard Federal

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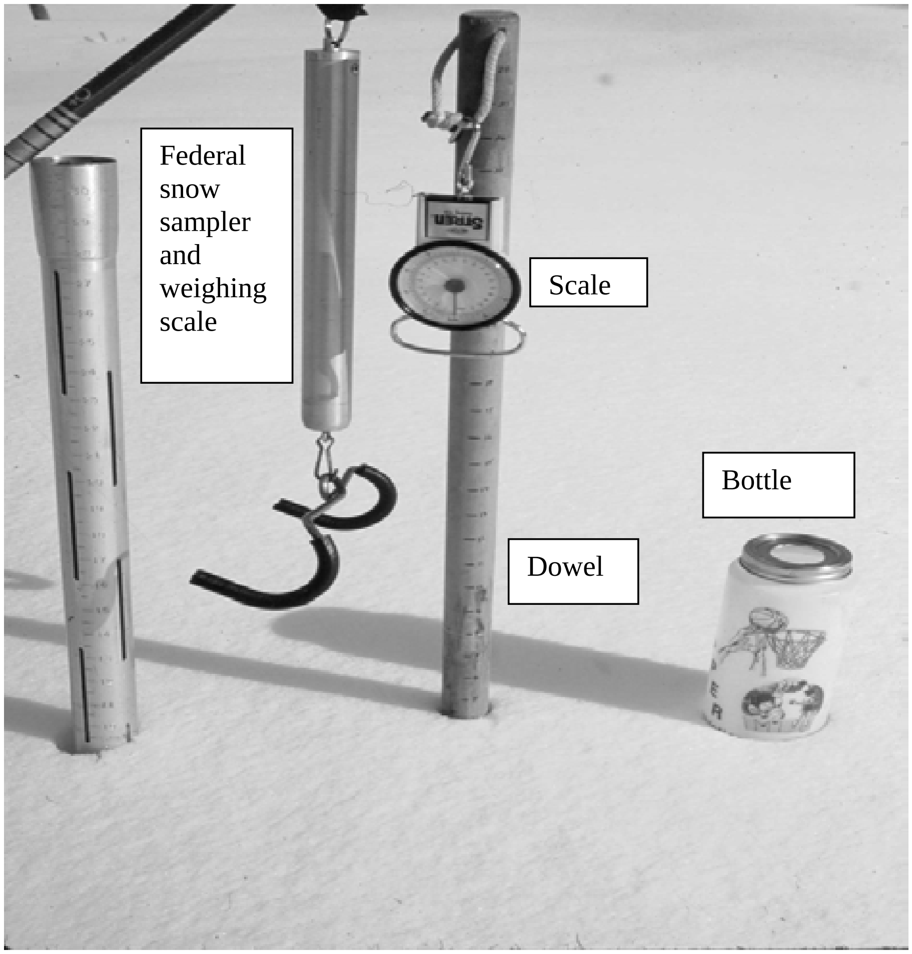

Figure 1. Equipment used for the snow sinking studies.


Figure 2. Dowel inserted into bottle for lower pressure measurements.

snow sampler in close proximity to the sinking samples. Average snow depth, snow water equivalent (SWE), and snow density were calculated. Overmeasure of SWE by Federal snow sampler cutter was adjusted to represent "true" SWE (Farnes et al.,1983). Air temperature and depth of new snow were recorded. Six locations between Yellowstone National Park headquarters at Mammoth, and Cooke City, Montana were sampled near the first of the month January through April for 13 years (Figure 3). A few additional samples were taken at random areas.

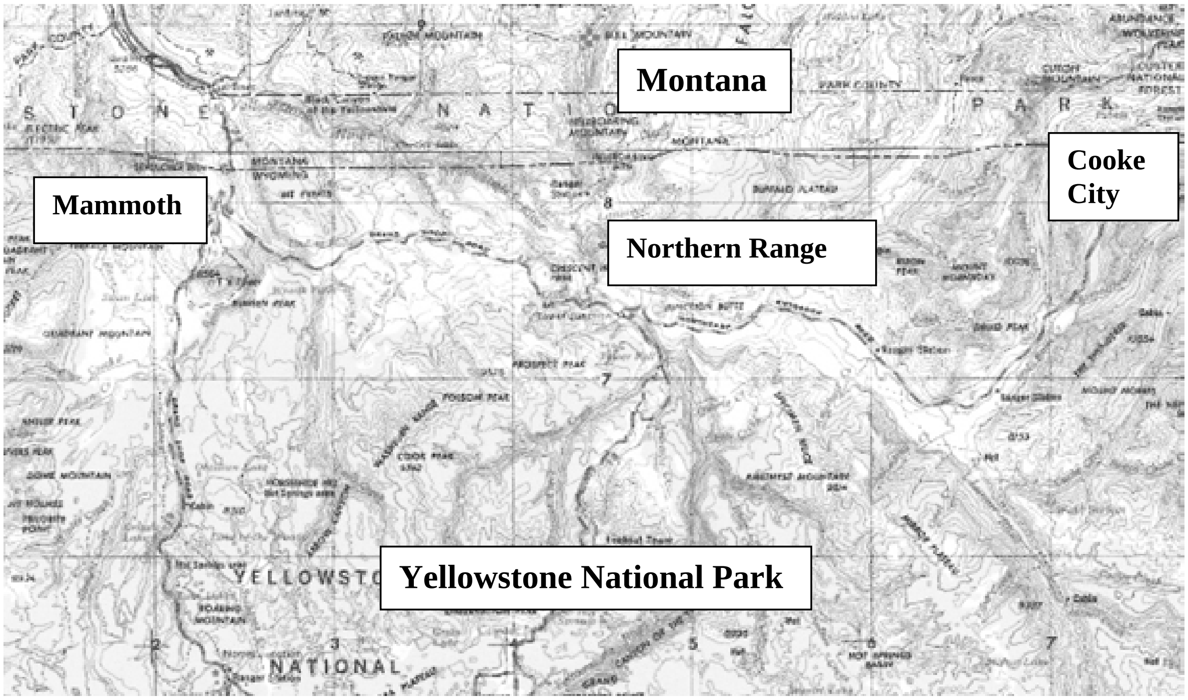

Figure 3. Snow sampling locations were between Mammoth and Cooke City in Yellowstone National Park

RESULTS AND DISCUSSION

Pressure applied to the snow surface radiates outward from that object. The amount depends on snow conditions, mainly density. The snow compacts below the object as pressure is applied. When the compaction becomes great enough to support the pressure being applied, the object stops moving. This is illustrated in Figure 4. Generally, objects sink further into light density snow as more of the pressure is distributed horizontally. With more dense snow, the pressure is more confined directly under the object and the sinking depth is less. Larger bearing areas such as snowshoes do not sink into the snow as much as the dowel or bottle or an animal footprint when subjected to the same pressure. This is related to how the pressure is distributed into the snowpack and is thought to be a function of the ratio of the area to the perimeter.

The 193 samples were obtained over a wide variety of conditions, temperatures, snow depths and densities. Deepest snow measured was just over one meter depth. The variation of sinking depths for applied pressures is shown in Figure 5.

Observations were tabulated in an EXCEL spreadsheet. The area of dowel, bottle, snowshoe, and boot were used to calculate the pressure for each weighing increment. The penetration for each observation was computed as percent of total depth. Curves of penetration vs. snow density were developed for each pressure increment. Curves for the snowshoe and boot were compared with the smaller diameter dowel and bottle to see if there was a bias related to the total bearing area. Curves for each pressure measured were plotted. These included all dowel and bottle observations at different loadings as well as for the snowshoe and hiking boot measurements. Density at 0, 25, 50, 75, and 100 percent sinking depths were noted from each of these curves and were then used to obtain plotting points for uniform increments of pressure. A family of curves was then developed to cover the range of pressure from small animals to large ungulates as shown in Figure 6.

This figure can also be used to evaluate sinking depths of over snow vehicles, skis, snowshoes, or snowboards. Snow depth and density can be obtained from SNOTEL or Climatological stations or direct measurement. Pressure of various animals can be determined from Table 1 or computed using the area of the footprint and weight of the animal or equipment. Pressure exerted by some common animals and humans are shown in Table 1 (Farnes, 1997). For four-legged animals, the pressure is that for two feet. For humans, it is for one foot.

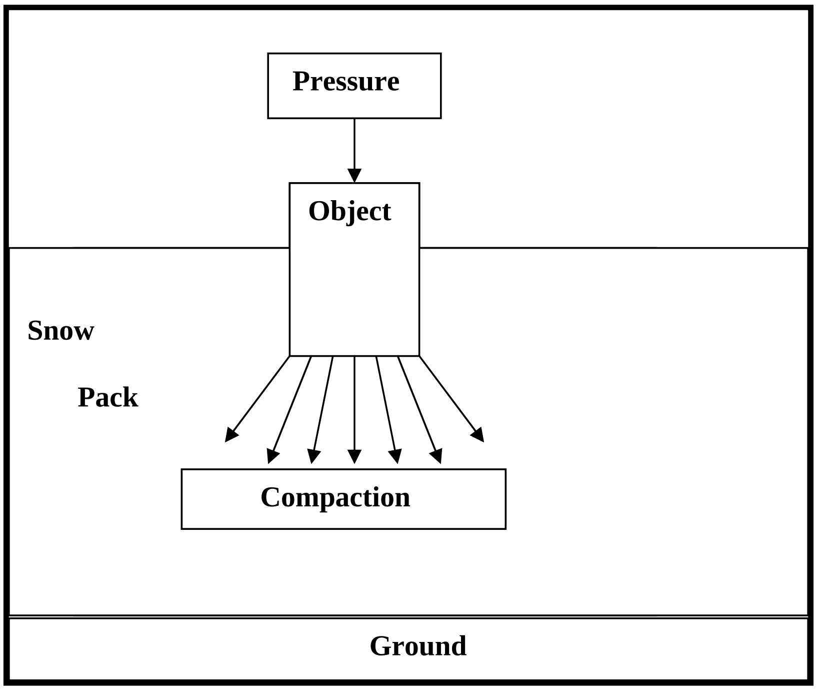

Figure 4. Pressure applied to an object in the snowpack radiates outward.

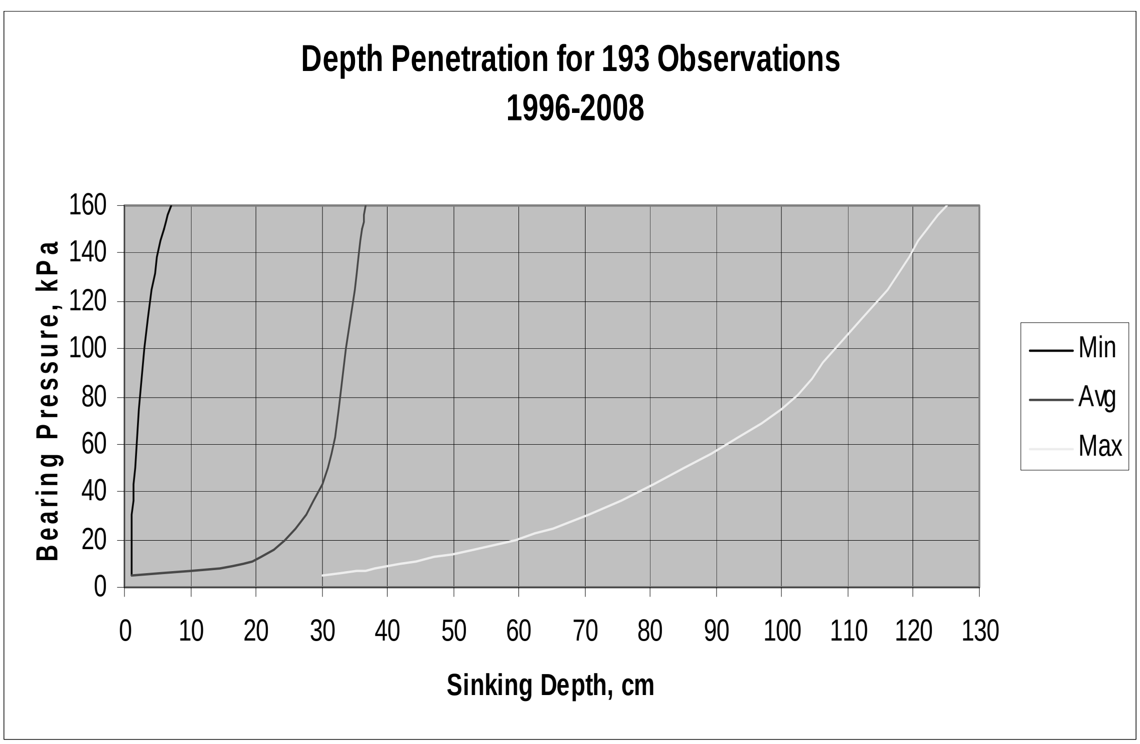

Figure 5. Variation of minimum, average and maximum sinking depths for various applied pressures.

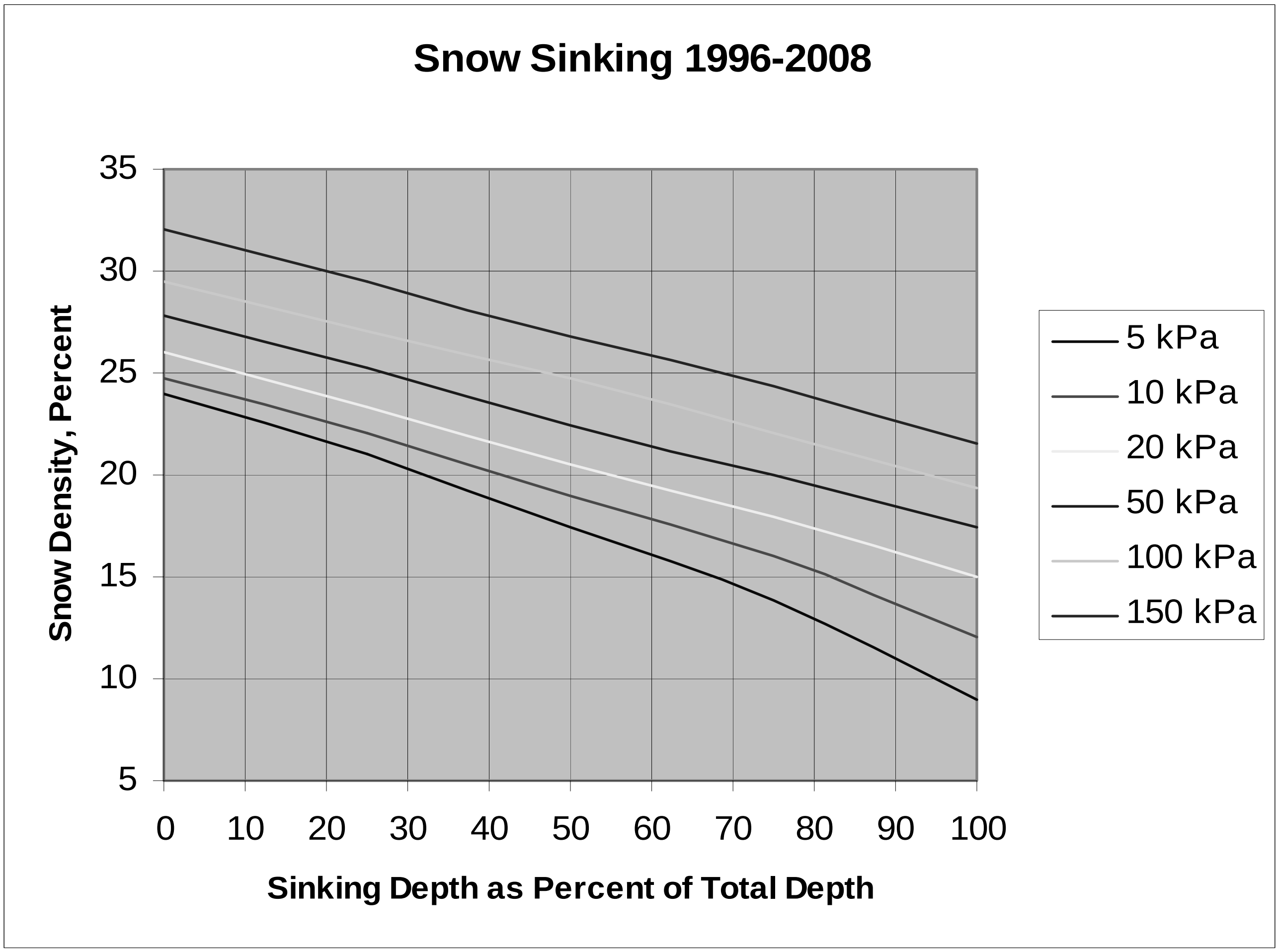

Figure 6. Curves for estimating sinking depths for various applied pressures.

SPECIES	WALKING PRESSURE, kPa
Bison	145
Elk	145
Moose	117
White-tailed Deer	69
Mule Deer	62
Grizzly Bear	46
Black Bear	34
Mountain Lion	19
Coyote	19
Wolf	17
Lynx	9
Snowshoe Hare	3
Human	28
Human on Skis	17
Human on Snowshoes	6

Table 1. Approximate bearing pressure exerted by various walking animals.

CONCLUSIONS

By knowing snow density and bearing pressure imposed by different animals, it is possible to estimate how far into the snow each will sink. For example, a wolf walking in 20 percent density snow that was 30 cm deep (6 cm SWE), would sink about 15 cm into the snowpack (Figure 6 and Table 1). This provides an indication of how much effort is required to travel through the snowfield and whether the advantage is with the predator or its prey. It also provides an indication of the energy required just to travel across snow covered areas. It can also be a factor in winter mortality as increased energy that is required for locomotion reduces fat reserves. When sinking depth is greater than the knee joint, considerable effort is required to move through the snow. Extreme effort is required for locomotion when sinking depth approaches or exceeds the belly height. Also, the maximum snow depth and snow water equivalent that ungulates can obtain forage and thresholds that induce migration are critical snow parameters affecting mortality (Farnes et al., 1999).

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