Clarification of some api characteristics in relation to caribou ((*Rangifer tarandus*)

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Abstract: A total of 2 177 comparisons of api hardness vs. density in northern Saskatchewan, southeastern Manitoba and northeastern Finland revealed no consistent correlation (*r* varied from +.70 to -.17).

A total of 1 395 comparisons of horizontal hardness of the top layer of api to vertical hardness of the same layer of api in southeastern Manitoba, northeastern Finland and far eastern middle Finland revealed no consistent correlation (*r* varied from +.99 to -.20). Therefore one cannot substitute density for hardness nor horizontal hardness of the top layer for vertical hardness of the top layer in the terms of the Värriö Snow Index.

Key words: snow, snow index, *Rangifer*

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Introduction

One of the better-known attributes of api (snow on the ground) is that it affects different species of animals in different ways. For subnivean mammals (Penny and Pruitt 1984), invertebrates (Aitchison 1978, 1985) and plants it acts, primarily, as an insulating blanket. In contrast, for some supranivean animals such as large ungulates it acts to hinder movement. Moreover, its morphological variations act to influence digging for subnivean food. These latter features are those which affect caribou (*Rangifer tarandus*). In a series of studies I have shown (Pruitt, 1959; 1979; 1981; 1985) that one may quantify these features and construct a mathematical model that agrees with the observed movements and behaviour of *Rangifer*, not only in North America but in Finland as well. This model I have called the Värriö Snow Index (Pruitt 1979).

The most important characteristics of api affecting caribou are hardness, density, thickness and duration. Hardness (Klein, *et al.* 1950) is the force (in grams per cm^2) necessary to collapse or break the physical bonds between crystals of api. Density, on the other hand, is a ratio of the amount of ice in a given sample and the amount of space or air in the same volume. Density is quite easy to measure in the field; simple "kitchen hardware" devices can suffice. Hardness, in contrast, requires special, expensive instruments, is incovenient to measure and the results are difficult to reproduce consistently. Considerable practice with a spectrum of api types is necessary before achieving reliable and consistent results. Therefore, one of the questions frequently asked is why not use density instead of hardness when measuring the morphological parameters of api to determine the Värriö Snow Index?

For animals such as caribou, on which the api exerts negative effects by impeding walking as well as when digging the different types of feeding craters (Pruitt 1979), the critical parameter is hardness. The animal must exert muscular force in order to break the inter-crystal bonds so that the leg or foot can scoop through the api (Davydov 1963; Fancy and White 1985). But could one derive hardness from some mathematical manipulaton of density data?

Another question, or objection, commonly raised is why bother taking vertical hardness of the top layer of the api as well as horizontal hardness of this same layer? Would they not be the same or very similar? Horizontal hardness is much easier to measure. The rationale for using vertical hardness is that caribou excavate feeding craters by downward strokes of a front leg so that the hoof travels downward and backward. Caribou also periodically plunge the muzzle into the api and withdraw it with a horizontal and backward movement. This has been interpreted as "smelling for lichens" (Miller 1976; Helle 1984) but it could also provide a contact between the api surface and pressure sensors in the muzzle or mentum (Pruitt 1979).

Materials and methods

Previous to 1957 density and thickness were the main properties of api considered in relation to *Rangifer* (e.g. Formozov 1946; Nasimovich 1955). In the winter 1957-58 I began collecting hardness as well as density data in relation to *Rangifer tarandus groenlandicus* movements and behaviour (N=462). I also have collected records of horizontal and vertical hardness of the top layer in several studies (*Rangifer tarandus tarandus* and *R.t. fennicus*) (N=241). In addition I am indebted to R.R.P. Stardom for permission to include some of the api data from his pioneering study (Stardom 1975) of winter ecology of woodland caribou (*Rangifer tarandus caribou*) at Taiga Biological Station in Manitoba (N=472). I am also indebted to J. Schaefer for permission to include some of the api data from his study (Schaefer 1988) of the effects of forest fire on woodland caribou at Taiga Biological Station (N=597). I am indebted to the students in my university classes in Boreal Ecology who have put in long days doing repetitive api control stations at Taiga Biological Station (51° 02'40"N. Lat., 95° 20'40"W. Long.) in Feburary 1985, 1986, 1987 and 1988 (N=406). These latter data sets derive from three types of transects in two different topographic situations each year: "undisturbed", "ski trail" (two passes by 6 to 12 people on skis, left overnight to stabilize) and "snowmobile trail" (two passes by one person driving a Bombardier Élan, left overnight to stabilize), along a protected stretch of the Blind River and across the centre of You Bay exposed to southerly winds.

Results and discussion

The questions may rephrased as null hypotheses:

(1) There is no consistent correlation between vertical and horizontal hardness of the top layer of api and (2) There is no consistent correlation between hardness and density. Tables 1 and 2 show that there is, indeed, no consistent correlation. For the first statement *r* varies from -.20 to +.99 (I discarded the record for "1986 TBS You bay undisturbed" because it consisted of only 3 observations.); for the second statement *r* varies from -.17 to +7.0. Thus the null hypotheses were not disproven. In each of these cases, some types of disturbance of the api resulted in closer correlation than others, but, again, no consistent pattern emerged.

Table 1. Api horizontal hardness of top layer vs. vertical hardness of top layer (Descending values of *r*)

	r	N
1986 TBS You Bay undisturbed	1.00	3
1988 TBS Blind River ski trail	.99	8
1987 TBS You Bay ski trail	.98	8
1977 January-February, Varriö Subarctic Research Station, Finland	.98	161
1985 TBS You Bay undisturbed	.97	10
1985 TBS Schaefer caribou data	.93	332
1988 TBS You Bay snowmobile trail	.86	12
1988 TBS You Bay ski trail	.86	12
1986 TBS Blind River ski trail	.84	60
1988 TBS You Bay undisturbed	.78	8
1986 TBS Schaefer caribou data	.65	265
1986 TBS Blind River undisturbed	.64	37
1985 TBS You Bay snowmobile trail	.62	20
1985 TBS Blind River ski trail	.61	9
1987 TBS Blind River snowmobile trail	.56	14
1986 TBS Blind River snowmobile trail	.51	60
1987 TBS You Bay undisturbed	.49	12
1986 TBS You Bay ski trail	.39	15
1985 TBS You Bay ski trail	.38	20
1988 TBS Blind River snowmobile trail	.36	6
1984 Finland, Kainuu region (March)	.32	241
1987 TBS Blind River ski trail	.27	14
1987 TBS You Bay snowmobile trail	.24	8
1988 TBS Blind River undisturbed	.22	6
1986 TBS You Bay snowmobile trail	.17	14
1985 TBS Blind River undisturbed	-.03	18
1985 TBS Blind River snowmobile trail	-.07	8
1987 TBS Blind River undisturbed	-.20	14

Such a fortuitous agreement may have been the one described by Skogland (1978). An extreme case may be observed in spring when during diurnal heating the hardness of the api may become quite low. In contrast, at night the api may freeze, resulting in vastly increased hardness but with the density essentially unchanged.

The lack of consistent variation in correlation between horizontal hardness and vertical hardness of the top layer occurs not only in the central taiga of North America but in Finland as well. Finnish api occurs in a warmer, damper and more maritime environment than does that in the continental climate of Manitoba or northern Saskatchewan. Correlation in Finland ranged from $r = .98$ in the vicinity of Värriö Subarctic Research Station (feral *Rangifer tarandus tarandus*) (Pruitt 1979) to $r = .32$ in Kuhmo in the Kainuu region of far eastern middle Finland *(Rangifer tarandus fennicus)*(Pruitt 1985).

From these results one can conclude that one cannot substitute horizontal hardness for vertical hardness of the top layer nor density for hardness of the api when calculating the Värriö Snow Index.

Table 2. Api hardness vs. density correlation (Descending values of *r*)

	r	N
1985 TBS You Bay ski trail	.70	48
1986 TBS Blind River snowmobile trail	.69	53
1977 January-February, Värriö Subarctic Research Station (Finland)	.64	161
1988 TBS You Bay snowmobile trail	.61	26
1988 TBS You Bay undisturbed	.61	28
1957-58 Saskatchewan "Occasional caribou"	.60	85
1986 TBS You Bay snowmobile trail	.55	42
1986 TBS You Bay ski trail	.53	45
1986 TBS Blind River ski trail	.52	56
1987 TBS You Bay undisturbed	.49	46
1957-58 Saskatchewan "Caribou concentration"	.48	129
1986 TBS You Bay undisturbed	.47	11
1988 TBS Blind River ski trail	.44	20
1988 TBS You Bay ski trail	.44	20
1988 TBS Blind River undisturbed	.43	28
1987 TBS Blind River undisturbed	.42	48
1971-72 Stardom's caribou-api data	.41	472
1985 TBS You Bay undisturbed	.35	144
1985 TBS You Bay snowmobile trail	.35	42
1987 TBS Blind River ski trail	.35	43
1988 TBS Blind River snowmobile trail	.35	18
1957-58 Saskatchewan "no Caribou"	.33	248
1985 TBS Blind River ski trail	.32	29
1987 TBS Blind River snowmobile trail	.26	38
1985 TBS Blind River snowmobile trail	.19	21
1986 TBS Blind River undisturbed	.19	72
1987 TBS You Bay ski trail (2 passes)	.19	26
1987 TBS You Bay snowmobile trail (2 passes)	.14	41
1987 TBS You Bay snowmobile trail (1 pass)	.13	42
1985 TBS Blind River undisturbed	.07	65
1987 TBS You Bay ski trail (1 pass)	-.17	30

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