SNOW SAMPLING BIAS IN THE BOREAL FOREST

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ABSTRACT

Three different sampling bias, common in sampling of the snowpacks of the Boreal forest, are investigated. "Lazy sampling," or avoidance by the observer of sampling beneath tree canopies may cause overestimates of about 10 per cent. "Selective sampling," when the observer selects openings between trees where the snow cover is smooth and even, can cause overestimates of approximately 15 per cent. Snow courses located in "cleared strips" in the forest may overestimate the snowpack water equivalent by 16 - 17 per cent or more. The paper represents a detailed examination of the spatial variations in snow depth, density and water equivalent in a piece of subarctic woodland.

INTRODUCTION

This paper examines the detailed spatial distribution of the snow cover in a piece of subarctic woodland. The paper investigates quantitatively three kinds of sampling bias that occur in this type of terrain.

The spruce and fir trees of the open subarctic woodlands intercept the snow falling upon them reducing the amount of snow that can reach the ground beneath them. Most of this snow blows or falls off the branches into the open spaces between the trees (Miller, 1966). There is usually not much subsequent drifting of this snow at the snow surface. A correlation between the spatial distribution of trees and the spatial distribution of the snowpack water equivalent results and this is the cause of the sampling bias discussed in this paper.

We can,in this context,distinguish three ways in which a snow sample can be biased. The first is when the observer avoids sampling directly beneath tree branches. We might call this the "lazy sampling" error for future reference.

The second type of sampling error occurs when the observer selects spots that look representative for sampling. The main criterion for selection is that the snow cover be smooth and even and not exhibit any apparent local spatial variations. This usually occurs in wider openings between trees. We will call this the error due to "selective sampling." This error or the error described below applies to many 10-point snow courses sited in forests. Because repeated surveys are to be made at such snow courses, openings between trees are usually chosen as sites for individual sampling points. This may improve the usefulness of the snow course as an index of snow on the ground. However, the associated bias of the snowpack water equivalent should be recognized. The same reasoning applies to snow pillows and, to some extent, to snow gauges located in forest openings.

The third type of sampling error is quite similar and results when strips, usually 3 - 5 meters wide are cleared in a forest in order to provide a location for a snow course. This removes vegetation that might otherwise interfere with the sampling tube measurements.

One further incentive for using this technique is that the linear clearing is easily spotted from the air and thus suited and quite popular for helicopter-borne snow surveys. This error will be referred to as the error due to "cleared strips." A study of snow accumulation and melt in a cleared strip was made by Gary (1974). It illustrates the effect of a clearing on the water equivalent of the snow cover in its vicinity.

METHOD

A surveyed sampling grid was used for the simulation of the three types of bias (Figure 1).

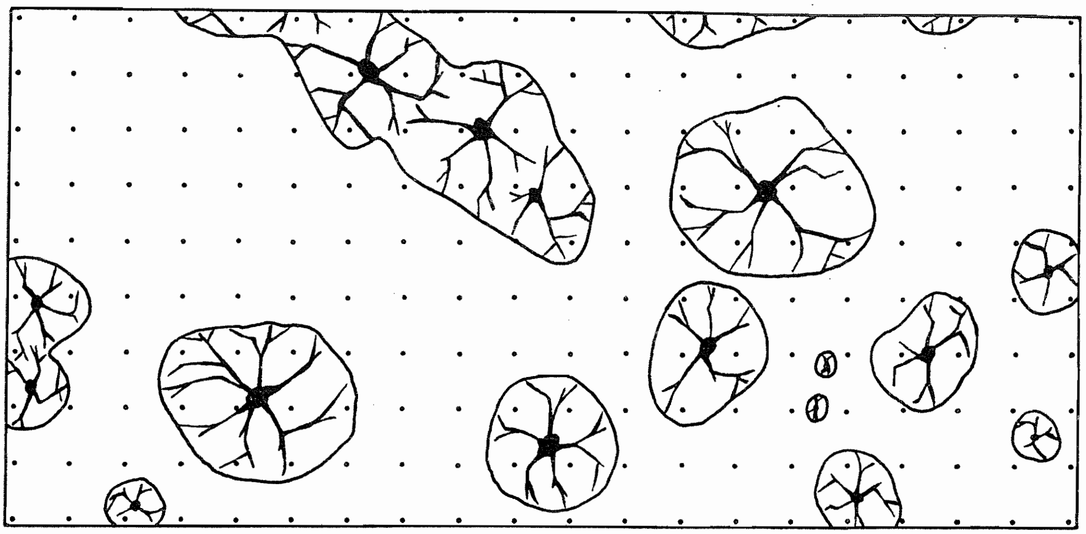

Figure 1. The snow sampling grid

The grid was located near Schefferville in open, mature woodland of a crown density of about 20 per cent. The site was located on level terrain, well away from the nearest forest boundary. There was no snow on the trees at the time of the survey, except for a few flakes that accumulated towards the end of the survey. The survey was undertaken in the morning and early afternoon of March 18, 1973, just before a snow storm began.

A randomly oriented base line was chosen and from this line a square grid was established. The size of the grid was 10 x 20 meters with an interval of one meter between the grid intersections.

Snow depths and water equivalents were measured at each grid intersection using two lengths of a Standard Federal snow sampler. In this particular survey an axe was needed on five occasions in order to take the sample exactly at its surveyed location. The procedure employed when the sampler hit vegetation inside the snow cover was to move the point 20 centimeters away from the observer. If vegetation was still encountered, the point was moved 20 centimeters towards the observer from the surveyed point. The subsequent steps, though not needed in the present survey, would have been 20 centimeters to the left of the surveyed point, then 20 centimeters to the right of the surveyed point. If the surveyed point coincided with a tree trunk a zero was recorded for both the depth and the water equivalent. The procedure above tends to bias the sample towards zeros and towards higher water equivalents than would have been recorded at the surveyed point. However, the procedure was needed only in less than 5 per cent of the cases so the bias is slight.

Sampling conditions were good for an accurate survey. The sky was overcast with light snowfall towards the latter part of the survey and the ambient air temperature was about -10°C. The site was relatively free from brush vegetation, and there were no internal crusts of sufficient thickness to be noted in the survey. The overall accuracy of the sample is therefore regarded as excellent.

The vertical projections of the canopies within and adjacent to the sampling grid were mapped (Fig. 1). Using this map, the sample was stratified according to distance from the outer edge of the branches of the nearest tree.

The three types of bias were simulated using this stratified sample. Using the average from the entire sampling grid as control, the lazy sampling error was determined from the samples falling outside the edges of the tree canopies. The distance from trees required for the snow cover to appear smooth and even was determined to be approximately one meter, using the depth samples. The effect of cleared strips was simulated using the samples falling more than 1.5 meters outside the nearest canopy edge (to simulate a clearing more than 3 meters wide).

RESULTS

There is an obvious correlation between the spatial distributions of trees and snow depths and water equivalents (Figure 2). Snow density tends to be lowest beneath trees and increases towards a value of about 0.22 - 0.24 gcm^{-3} in the wider openings between the trees (Figure 3).

If we average the depths falling at different distance intervals outside the tree canopies we find that the snow cover within the nearest 0.5 to 1.0 meters outside the tree branches often has a marked slope. So, if representative looking sites are sampled, then the snow cover within the nearest meter outside trees is most likely avoided (Figure 3).

Figure 3 also shows the changing distribution of water equivalents as samples are taken at increasing distances outside the tree canopies. The average water equivalent increases quickly near the trees and then more gradually further away from the trees.

The coefficients of variation decline sharply with increasing distance from the nearest tree (Figure 3). The snow density is, not unexpectedly, less influenced by the presence of trees than are either the depth or the water equivalent. A deviation appears in the graph representing the coefficient of variation for snow density. Its cause is unknown, but it may be caused by asymmetric effects of a prevailing wind direction or perhaps by differential effects of solar radiation on the density of the snow just outside the edges of the tree canopies.

The results of the different sampling errors are shown in Figure 4. The lazy sampling procedure gives an error of approximately 10 per cent. Sampling of representative looking sites gives an overestimate of about 15 per cent. The present set of measurements which indicates a trend of increasing water equivalent with distance from trees, suggests that cleared strips in the forest, depending on their width, may cause overestimates of 16 to 17 per cent or more.

The standard deviation of the sample decreases as the bias increases. This is a result of the smoother, more even snow cover away from the trees and the absence from the sample of the low values beneath the trees. Thus, a low value of the standard deviation or the standard error is not necessarily an indicator of an accurate snow sample obtained in the Boreal forest. In fact, if the sample has a very low standard deviation we could suspect it to be biased.

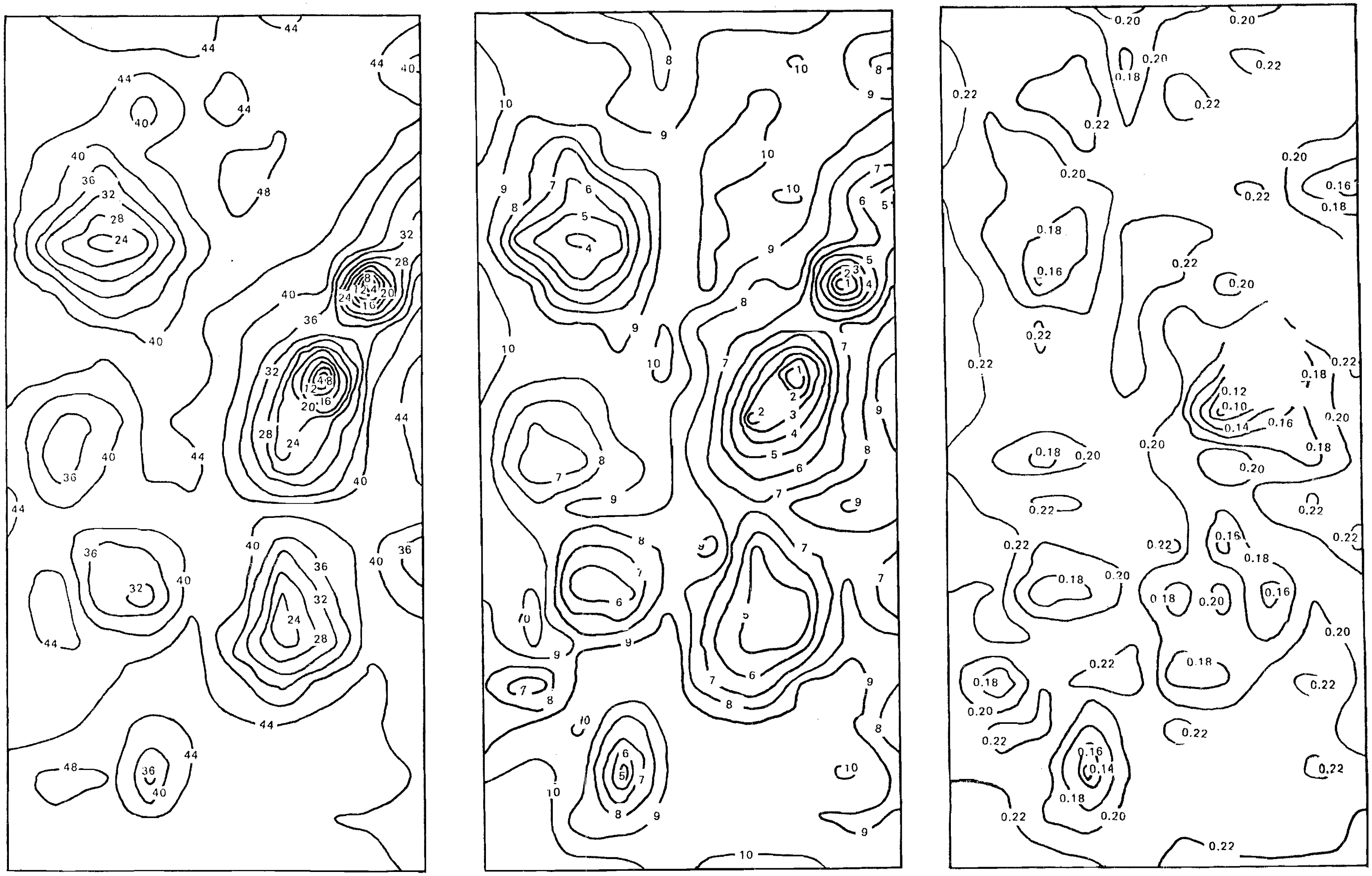

Figure 2. Snow depths (in), water equivalents (in) and densities (gcm^{-3}) at the surveyed grid

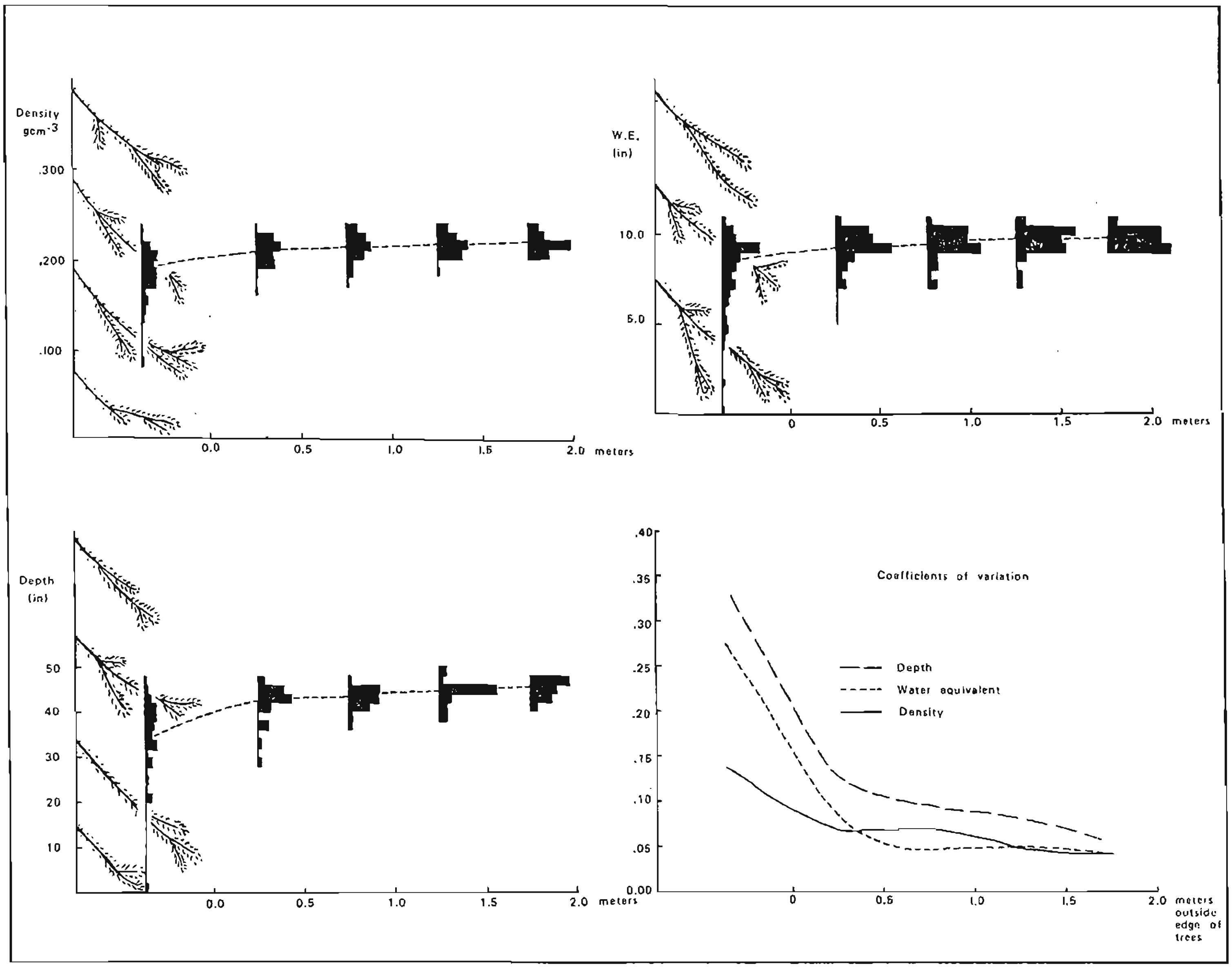

Figure 3. Change in the distributions and the coefficients of variation as samples falling within increasing distances from trees are removed

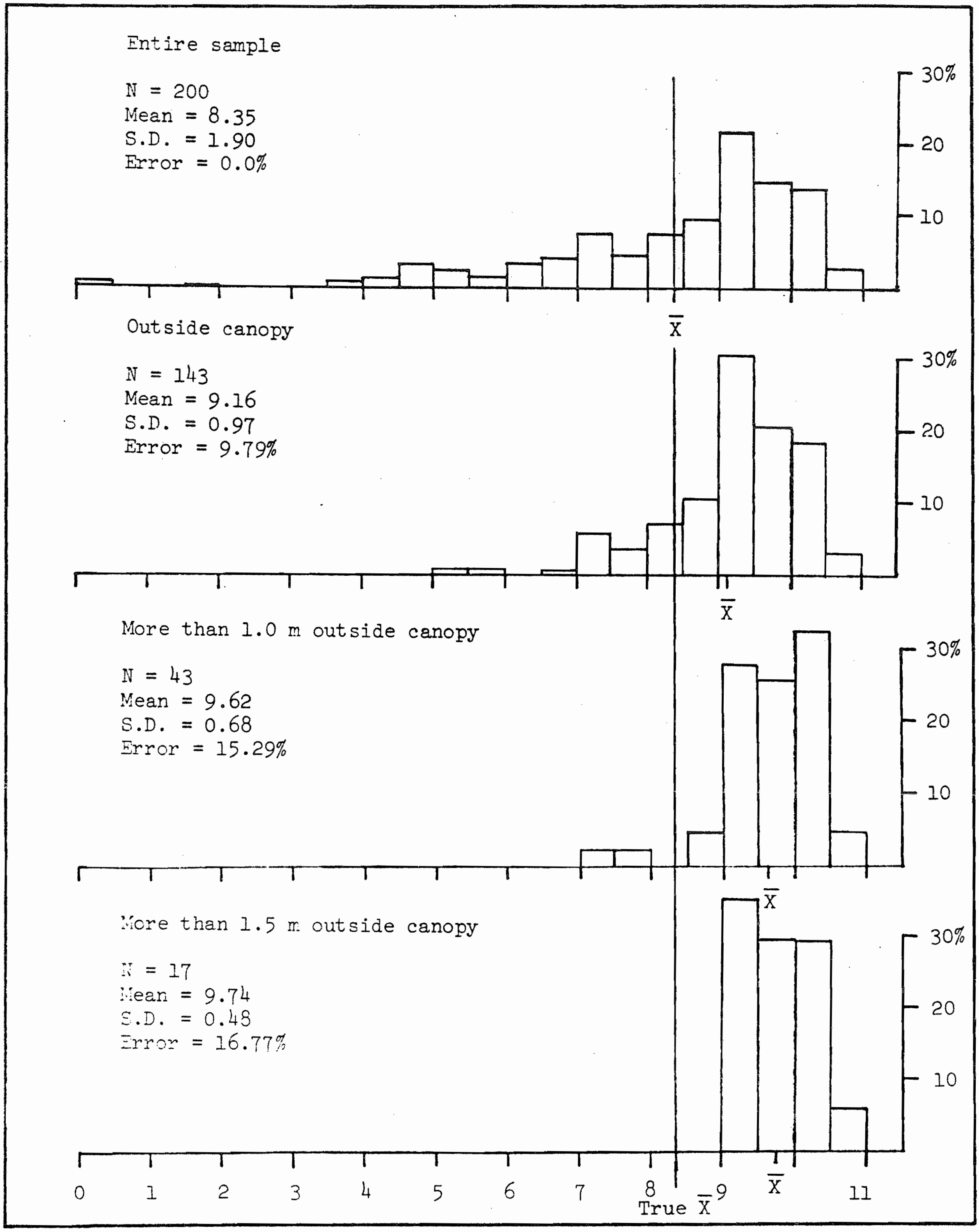

Figure 4. Effects of Lazy Sampling, Selective Sampling and sampling in Cut Strips

TESTS AGAINST EXISTING SNOW COURSES

The "new snow course" at Schefferville was sampled simultaneously with the grid survey. This snow course was established by the Staff of the McGill Sub-Arctic Research Laboratory to provide an index of snow accumulation that would not be affected by snow drifting and accumulation of wind-blown snow. To this end, a site was selected in a forested area of relatively even density southeast of the Schefferville airstrip. The site lies more than 200 meters away from the nearest larger clearing and is located within 100 meters of the present sampling grid. The sampling points of this 20-point snow course are located in openings between the trees and could best be described as consisting of "selective sampling" sites. The "new snow course" survey yielded a water equivalent of 9.65 inches which indicates an overestimate of 15.56 per cent relative to the surveyed grid.

Another snow course that has been used as the official Schefferville snow course is the "Schefferville 10-point snow course." A number of reports and papers have been published on snow surveys at this snow course (Harrison, 1963; Adams and Findlay, 1966; Adams et al., 1966; Cowan, 1966; Rogerson, 1967; Grevatt, 1969; The Staff, 1969). This snow course was modified in 1968-69, when the runway clearing was widened. The former "Stake 1" was moved to become the present "Stake 10." The other sampling points were re-numbered accordingly. Thus, for example, the present stakes 7, 8 and 9 were stakes 8, 9 and 10 prior to 1968-69. The snow course is located just northeast of the Schefferville airstrip and is oriented approximately perpendicular to the airstrip. Briefly described, the first two sampling points are located just beyond the clearing for the runway, in open forest. Points 3 and 4 are located on a string bog that parallels the runway. Point 5 is located in the forest on the far side of the bog, fairly close to the forest edge. Point 6 is located somewhat farther into the forest but is within the zone influenced by drifting. Points 7, 8 and 9 are located in open woodland and are relatively free from disturbance by accumulation of wind-blown snow. Point 10 is situated a short distance away from the shore of a small lake and is influenced by snow drifting from that lake. Several authors have tested the representativeness of this snow course (Adams et al., 1966; Adams and Findlay, 1966; Cowan, 1966). In these tests, an 11th point, "Stake 0" or "Open", located just outside the McGill Sub-Arctic Research Station has at times been included.

The Schefferville 10-point snow course was sampled by a different observer 11 days after the present survey giving an average water equivalent of 12.08 inches (Table 1).

TABLE 1

Schefferville 10-point snow course 30.3.73

Point	Depth (in)	Water eq. (in)	Density (gcm^{-3})
1.	62.8	17.6	0.280
2.	61.3	17.7	0.288
3.	28.1	7.3	0.259
4.	16.0	5.2	0.325
5.	53.0	17.9	0.337
6.	44.3	13.4	0.302
7.	40.5	9.9	0.244
8.	39.8	9.3	0.233
9.	42.6	10.5	0.246
10.	47.8	12.0	0.251
Mean		12.08	

(Source: MSARL files)

When this value is corrected for an intermediate snowfall of 0.61 inches, the average becomes 11.47 inches. This value is 37.4 per cent greater than the water equivalent for the surveyed grid.

According to published results and snow survey records on file at the McGill Sub-Arctic Research Laboratory, "Stake 0" usually has a water equivalent approximately one third to one half of the average water equivalent for the 10-point snow course. If we add this 11th point and assume its water equivalent to be one third of the 10-point average, then the 11-point average becomes 10.74 inches which is 28.6 per cent greater than for the surveyed grid.

The measured water equivalents and densities (Table 1) show quite clearly that the Schefferville 10-point snow course receives a considerable amount of its water equivalent through deposition of wind-blown snow. This is particularly evident at points 1 and 2 (near the runway clearing), points 5 and 6 (near the bog edge) and Stake 10 (near the small lake). Wind removal of snow occurs at points 3 and 4. Only points 7, 8 and 9 are relatively undisturbed by accumulation of wind-blown snow as is indicated by the low densities which are quite similar to those measured at the surveyed grid. They are located in woodland of a crown density similar to that where the surveyed grid was located.

If we average the water equivalents for points 7, 8 and 9 and correct for intermediate snowfall, the average becomes 9.29 inches. It is known that none of these samples fell beneath a tree so if we assume a "lazy sampling error" and correct the sample accordingly, the water equivalent becomes 8.46 inches. This is 1.3 per cent greater than the average for the surveyed grid. If we assume an error corresponding to "selective sampling," the corrected average becomes 8.05 inches which is 3.5 per cent below the average for the surveyed grid.

The snow water equivalent of open woodland, if measured well away from open areas, is probably quite representative of the general snowpack water equivalent in the Schefferville area. The woodland cannot lose snow by drifting for the windspeeds at the snow surface in the forest are generally well below the threshold for erosion. Therefore, woodland, when associated with open areas, acts as a "snow sink" and can only gain snow by drift transport. This gain occurs mainly in a boundary zone approximately 100 meters wide along forest edges (Granberg, 1975). Loss by evaporation of intercepted snow may be an important factor in southern forests but it is probably not significant in the cold Schefferville winter. Snow does, occasionally, lodge in the trees in the woodlands near Schefferville, but it is generally blown off at least the upper parts of the trees already during snowfall. In addition, because of the large incidence of snow drifting in the area, the open areas may well lose more snow by evaporation of the airborne snow which exposes a large surface area to the frequently dry air, providing favorable conditions for evaporation. It is therefore not likely that evaporation from a forest of a crown density of 20 per cent can account for the respectively 37.4 or 28.6 per cent greater water equivalent indicated by the Schefferville 10 or 11-point snow course, when compared to the surveyed grid. The uniform results from the surveyed grid, the corrected 20-point snow course and the corrected average from points 7, 8 and 9 of the Schefferville 10-point snow course suggest that the Schefferville 10 or 11-point snow course overestimates the water equivalent of the Schefferville snow cover, apparently as a result of accumulation of wind-blown snow but also as a result of sampling in openings between the trees.

If the water equivalents from points 7, 8 and 9 of the Schefferville 10-point snow course are averaged and corrected for "lazy sampling" or "selective sampling," the estimate will probably be within better than ± 10 per cent of the true snowpack water equivalent. This presumes that the error introduced by the sampling equipment is zero, and that the sampling conditions are ideal. Similarly, if the water equivalent measured at the "new snow course" is corrected for "selective sampling," an accurate estimate of the Schefferville snowpack water equivalent would be obtained. The proper correction factor, however, may vary depending on, for example, the amount of snow on the ground. To calibrate a given snow course, a surveyed grid sampling scheme of the type described in this paper could be employed at different times of the winter and for different snow conditions.

It should be noted that all of the present surveys used uncorrected Standard Federal sampler readings. Several investigators have shown that some snow samplers may overestimate the snow water equivalent (Work et al., 1965; Beaumont, 1967; Goodison, 1978). In Schefferville, a survey by F.H. Nicholson and the author indicated an overestimate of approximately 8 per cent for the present sampler, used in snow conditions similar to those during the present surveys. If this overestimate is valid also for the present survey, the true water equivalent for the surveyed grid would be in the order of 7.7 inches. The uncorrected 20-point snow course reading would, accordingly, overestimate the true water equivalent of the snow cover by as much as 25.3 per cent. For the Schefferville 10-point and 11-point snow course the overestimate, using uncorrected readings, may, according to the present survey, be as large as 49.0 and 39.5 per cent respectively.

CONCLUSIONS

The present survey stresses an already known fact, namely that when snow covers are sampled by traverse survey methods or by surveyed random sampling grids, it is imperative that each sample be taken exactly in ths predetermined location. The magnitude of the error when exact sampling procedure is not adhered to was simulated and is, according to the present survey in woodland of 20 per cent crown density, +9.79 per cent for "lazy sampling," +15.29 per cent for "selective sampling" and +16.77 per cent or more for "cleared strips."

The Schefferville 10-point snow course overestimates the snowpack water equivalent by perhaps as much as 30 per cent, apparently as a result of accumulation of wind-blown snow but probably also as a result of the sampling points being located outside tree canopies. Points 7, 8 and 9 of that snow course, when averaged and corrected for "lazy sampling" or "selective sampling," give a fairly good estimate that is probably within ± 10 per cent or better of the true snowpack water equivalent for the Schefferville area. This is also the case for the 20-point "new snow course" when the measured water equivalents have been corrected for "selective sampling."

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