# An Appraisal of the Loop Transect Method For Estimating Root Crown Area Changes

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One of the most serious problems confronting the range technician, administrator, and user alike has been the lack of a suitable quantitative method for evaluating range condition and trend. Because of the heterogeneity of the flora on most ranges, the amount of sampling required to obtain a good estimate of the population with available techniques has been large.

Range technicians are constantly striving to improve their sampling techniques, and one of the most noteworthy efforts in this direction has been made by the Forest Service (Parker, 1951). As described by Parker this technique incorporates many ideas from other measurement methods and has been designated the "3-step Method." Step 1 of the 3-Step Method involves the use of a loop three-fourths of an inch in diameter to record hits on vegetation, litter, rocks, and other items. It is with this loop procedure that the present study is concerned.

The data obtained from the loop readings are intended to serve as benchmarks for future readings. Presumably, the changes recorded in the loop readings for a specific item over a period of time, coupled with other extensive wide-scale estimates, are indicative of trends. The reliance which the observer can place on his conclusions regarding trends depends largely on the magnitude of differences recorded by the loop and on his knowledge of and experience with the vegetal type under consideration.

Because the loop readings constitute an important part of the 3-Step Method, it is essential to have some knowledge of the sensitivity of the loop in detecting changes. Several observers have reported on investigations designed to test this matter of sensitivity. Parker[2] used belt transects on which he counted plants of the rhizomatous sweet sagebrush *(Artemisia discolor)*. Then, by means of a series of loop readings before and after removals of portions of the sweet sagebrush population he was able to correlate changes in loop hits with changes in population. He found close agreement between actual percentage removals and percentage removals as determined from the mean loop readings of 12 transects. Pechanec[3] made a detailed study of the loop procedure and concluded that the number of 100-foot loop transects required for a 10-percent sampling error (P=0.33) in measurement of range condition was 40 for open forest, 40 for sagebrush-bitterbrush, and 40+ for meadow types.

A comparison of the line interception, vertical point quadrat, and loop techniques as used in measuring basal area of grassland vegetation was reported by Johnston (1957). On one of the four sites studied, Johnston found that 50-foot loop transects were more efficient than 100-foot ones and that 68 of these 50-foot lines were required to sample the dominant species to within 10 percent of their true means (P=0.05). To sample the dominant species on the other three sites accordingly required 2, 11, and 25 loop transects 100 feet long. Much greater sampling intensity was required to achieve the 10-percent accuracy with secondary species. Although these data confirm the findings

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[2] *Parker, Kenneth W. Final report on development of a method for measuring trend in range condition of national forest ranges. (Unpublished report on file U. S. Forest Service, Washington, D. C.) 1951.*

[3] *Pechanec, Joseph F. Progress report on Flagtail condition and trend methods study. (Unpublished report. Pac.. NW Forest and Range Expt. Sta., Portland, Oreg.) 1951.*

of Pechanec, Johnston's requirements are substantially lower because they are based on dominant species only, whereas Pechanec computed the requirement for each of several criteria and then attempted to strike a reasonable compromise. Parker (1950) found that in a mixed grama (*Bouteloua* spp.) type, 200 loops per line gave a more reliable estimate than 100 in all vegetal densities, especially in the very low densities. Where perennial ground cover exceeded 20 percent, Parker felt the difference in accuracy between 100 and 200 loops did not justify reading the 200.

In a study of artificial populations, Curtis and McIntosh (1950) showed that the practice of recording an item as present within a quadrat when any part of it touched the quadrat boundary—a practice followed in the loop technique—resulted in overrepresentation, particularly of the more numerous species. These investigators also showed that the number of species recorded is governed largely by quadrat size and that a very small quadrat may record only a small percentage of the total species even though a large number of such quadrats are observed. The deficiency of the loop technique in detecting rare species was recognized and provided for by Parker (1951).

Suggestions for improving the efficiency of the loop technique have been made by Short (1953) and Sharp (1954 and 1955). These suggestions are concerned mainly with the mechancial aspects and recording procedures of the method. Sharp (1954) found the loop method reasonably well adapted for obtaining quantitative records of vegetational and other site factors on the salt-desert shrub type of southern Idaho. He stressed the necessity for plumbing the loop and clearly defining standards of measurement.

Although the ability of the loop to detect changes in plant populations based on single-stemmed plants with basal areas approximately the same size has been tested by Parker as cited previously, the only test known to the writer involving the correlation between loop readings and changes in plant populations based on root crown areas was reported by Hutchings and Holmgren (1959). In their test, loops reduced to chart scale were applied to quadrat charts on which changes in mountain brome (*Bromus carinatus*) had been recorded by pantograph over a 21-year period. In general, they found that loop estimates of plant area were considerably higher than actual area and that this bias (ratio between actual percent basal area and loop estimate) was affected by both size and number of plants.

The importance of being able to predict change in plant area from loop estimates is evident when one considers that many of the changes that occur on the range consist of increases or decreases in root crown area. Further test of the ability of the loop method to measure change in plant area is the object of the present study.

## The Area

The area selected for study was a portion of the Upper Snake River Experimental Range on the U.S. Sheep Experiment Station near Dubois, Idaho. The range in which the transects were located had been grazed only in the fall for the past 30 years and consequently was in good condition. The vegetation was adequately described by Mueggler (1950) under the heading Paddock 1.

The dominant species in the area in order of abundance were threetip sagebrush (*Artemisia tripartita*), arrowleaf balsamroot (*Balsamorhiza sagittata*) and bearded bluebunch wheatgrass (*Agropyron spicatum*). The latter two species were chosen for study along with common comandra (*Comandra umbellata*) which, from the standpoint of herbage production, was exceeded only by balsamroot and tapertip hawksbeard (*Crepis acuminata*) among the forbs.

The composition and abundance of the vegetation on the study site was comparable to what might be found on many sagebrush-grass ranges in good condition. Because of their abundance, the three species utilized in this study were more amenable to sampling techniques than the majority of species encountered on poorer ranges.

## Methods

Eight belt transects 100 feet long and 9 inches wide were established by outlining them with heavy string. Each transect was then divided longitudinally into three equal strips, and one of these strips was randomly selected to receive the 100-foot steel tape. The tape was stretched to bisect the appropriate strip. A coil spring, turnbuckle, swivel snaps, and harness rings were attached to the tape as suggested by Sharp (1955). The strip method of positioning the tape was adopted, in preference to running it down the middle of each transect, simply to insure that each one-third of the belt would have an equal opportunity of receiving the loop sampling. This precaution was probably unnecessary.

In order to minimize the error encountered in plumbing the loop when the tape was stretched some distance above the ground, the transects were located in areas relatively free of *Artemisia*. When browse species did interfere, they were removed so that the tape could lie close to the ground.

A complete inventory of the root crown area occupied by wheatgrass, balsamroot, and comandra was taken on every transect; only these species were considered throughout the en-

**Table 1. Observations on three species taken from eight belt transects.**

| Item | Wheatgrass | Balsamroot | Comandra |
|---|---|---|---|
| Total plants (number) | 2,329 | 272 | 249 |
| Total root crown area (cm.$^2$) | 4,641 | 6,320 | 24 |
| Average size of root crown area (cm.$^2$) | 1.99 | 23.2 | .09 |
| Mean area (cm.$^2$)[1] | 239.3 | 2,048.3 | 2,238.7 |
| Total loop hits (number) | 95 | 43 | 1 |

[1] $\frac{\text{Total area examined}}{\text{No. of individuals}}$

tire sampling procedure. Root crown diameters were measured in millimeters and later converted to areas expressed in square centimeters. The writer is well aware that plants do not produce root crowns in circles and, consequently, that areas computed from diameters of assumed circles are not precise, but such computed areas were considered to be sufficiently accurate for the purpose. In those cases where a root crown was particularly irregular, the observer recorded his diameter measurement on a scrap of paper and secured that paper to the root crown. This was important because if that root crown was to be removed later in the study the diameter measurement made at the time of removal might be quite different from the original one without this safeguard.

The tape was stretched and loop readings taken at 6-inch intervals; i.e., 200 readings per transect. Random removals of root crown areas followed by loop readings were made three times on each transect. Loop hits were recorded in a manner that permitted separation of those occurring at ½-foot and foot marks. These data provided two indices of change of 100 loops each and one index of change of 200 loops for each change on every transect. Since three removals (changes) were made, there were six 100-loop and three 200-loop indices for each transect.

Removals were accomplished with the aid of a 9- by 12-inch wire grid subdivided into twelve 3- by 3-inch units (Figure 1). Out of the 120 units contained in each 10-foot segment of transect, 12 were chosen at random for the first removal making a total of 120 units out of 1,200 (10 percent) for the 100-foot plot. If one-half or more of the root crown of a plant fell within a chosen unit, the entire plant was clipped at ground level and its area recorded. Plants clipped in this manner were considered removed in subsequent loop readings. This same procedure was followed in making the second and third removals except that 240 units (20 percent) were chosen in each instance. Note that all changes in basal area were in the nature of reductions and were accomplished by reduction in number of plants rather than portions of individual plants—a feature that did not affect the size-class structure of the population. This is important because such removal of entire plants probably parallels only one rather exceptional pattern of ecological change.

## Results and Discussion

The influence of both size and number of plants on loop hits is evident in Table 1 which shows the relations between species before any changes were made. The root crowns of balsamroot occupied more area than those of wheatgrass, although the wheatgrass plants were about nine times more numerous. Wheatgrass, in spite of its smaller total area, was hit by more than twice as many loops as balsamroot. Comandra is of interest because it was represented by almost as many plants as balsamroot and consequently had a similar mean area, yet its total root crown area was insignificant by comparison. Because of its very small average size and large mean area, comandra was hit by only 1 of 1,600 loops. Balsamroot, on the other hand, with its similar mean area but much larger individuals was hit by 43 loops. Although no test was made of dispersion, there was no evidence of strong aggregation in any of the populations sampled.

Evidence concerning the accuracy of the loop technique as a descriptive measure was obtained from the regression of root crown area on loop hits. The regression equations and their respective standard errors of estimate (Snedecor, 1946) are shown in Table 2.

The smallest standard error of estimate was 110 in the case of wheatgrass where 100 loop readings per transect were made at the ½-foot marks on the tape. In this instance the scatter of points around the regression line indicated that two times out of three the actual root crown area of wheatgrass would fall within approximately 110 square centimeters, plus or minus of the area estimated by the loop readings. In the case of balsamroot the standard error of estimate was lowered considerably by reading 200 loops per transect instead of 100, but in no instance with either species was it low enough to be acceptable. It is obvious that loop hits did not give a satisfactory index to the surface area occupied by root crowns because the errors of estimate varied from one-fourth to one-half of the mean values. It should be emphasized here that the errors of estimate shown in Table 2 are based on a 33-percent probability level; they would be approximately twice as large at the 5-percent level.

Another way of looking at the relation of root crown area to loop estimate is through the ratio of actual root crown area percentage to loop hit percentage. Regression coefficients ($b$), based on such ratios, and their standard errors ($s_b$) are as follows:

| | Wheatgrass | | Balsamroot | |
|---|---|---|---|---|
| | b | $s_b$ | b | $s_b$ |
| Loop readings per transect: | | | | |
| 200 | 0.1300 | 0.0066 | 0.4177 | 0.0219 |
| 100 at foot marks | .1286 | .0125 | .3734 | .0398 |
| 100 at ½-foot marks | .1115 | .0063 | .3230 | .0303 |

FIGURE 1. Random plant removals being made with the aid of a wire grid divided into 12 units.

The point worthy of note here is the fairly consistent nature of the ratio between actual root crown area percentage and loop hit percentage. For example, the largest standard errors of the regression coefficients, which are measures of consistency, are only about 10 percent of the regression coefficients in the case of balsamroot where 100 loops were read at the foot and ½-foot marks and in the case of wheatgrass where 100 loops were read at the foot marks ($P = 0.33$). In all other cases, the standard errors are approximately 5 percent of the regression coefficients. In effect, this means that even though loop readings do not provide reliable estimates of root crown area (as shown in Table 2), they may serve a useful purpose where the size-class structure of the population remains unchanged or if some means of adjusting them can be devised. For a full discussion of the theoretical aspects of the relation between loop index and actual plant area in percent and of the effects of plot size, number and size of plants, plant distribution, and plant shape on loop indices, the reader is referred to Hutchings and Holmgren (1959).

The previously mentioned studies of Pechanec and Johnston indicate that acceptable accuracy in describing vegetation with the loop technique may be obtained only with large numbers of transects. The loop technique was not intended to be a descriptive measure, and the reporting of its inaccuracies in this respect is incidental to the primary objective of this investigation, which was to test the ability of the loop to detect *change* in root crown area.

When the average root crown areas of the eight transects, as determined by actual measurement, were compared with the average loop readings, the changes in root crown areas were fairly accurately reflected by the changes in loop hits. Table 3 illustrates this relation for wheatgrass, balsamroot, and the two combined.

Out of the 27 indices of change provided by the loop hits as shown above, only 4 of them differ from the actual by 10 percent or more with a maximum difference of 11 percent. Eleven differ by from 6 to 9 percent, and the remaining 12 are within 5 percent or less of the actual change. There was little to be gained with either species by increasing the number of loop readings from 100 to 200 per transect.

It is apparent from Table 3 that averages of the eight transects of 100 loops each provided

**Table 2. Factors in regression of root crown area on loop hits for wheatgrass and balsamroot, P = 0.33.**

| Loop readings per transect | Wheatgrass: Regression equation[1] | Wheatgrass: $s_{y \cdot x}$[2] | Balsamroot: Regression equation[3] | Balsamroot: $s_{y \cdot x}$[2] |
|---|---|---|---|---|
| 200 | $Y = 117.58 + 34.60X$ | 119.09 | $Y = 54.75 + 135.39X$ | 202.05 |
| 100 at foot marks | $Y = 276.19 + 37.11X$ | 175.01 | $Y = 332.15 + 153.27X$ | 294.97 |
| 100 at ½-foot marks | $Y = 162.59 + 53.35X$ | 110.02 | $Y = 266.88 + 146.27X$ | 298.55 |

[1]Mean Y= 422.40 for mean X in each equation for wheatgrass.
[2]$s_{y \cdot x}$=standard errors of estimate.
[3]Mean Y=600.37 for mean X in each equation for balsamroot.

**Table 3. Changes in root crown areas and corresponding loop hits based on averages of eight transects for wheatgrass and balsamroot.**

| Order of removal | Root crown area remaining | | Loop hits, foot marks | | Loop hits, ½-foot marks | | Total loop hits | |
|---|---|---|---|---|---|---|---|---|
| | Cm.² | Percent | Number | Percent | Number | Percent | Number | Percent |
| | | | (Wheatgrass) | | | | | |
| 0 | 580 | 100 | 5.4 | 100 | 6.5 | 100 | 11.9 | 100 |
| 1 | 510 | 88 | 4.4 | 81 | 5.0 | 77 | 9.4 | 79 |
| 2 | 349 | 60 | 3.6 | 67 | 4.5 | 69 | 8.1 | 68 |
| 3 | 250 | 43 | 2.4 | 44 | 3.5 | 54 | 5.9 | 50 |
| | | | (Balsamroot) | | | | | |
| 0 | 790 | 100 | 2.4 | 100 | 3.0 | 100 | 5.4 | 100 |
| 1 | 726 | 92 | 2.0 | 83 | 2.6 | 87 | 4.6 | 85 |
| 2 | 532 | 67 | 1.6 | 67 | 1.9 | 63 | 3.5 | 65 |
| 3 | 353 | 45 | 1.0 | 42 | 1.6 | 53 | 2.6 | 48 |
| | | | (Wheatgrass plus balsamroot) | | | | | |
| 0 | 1,370 | 100 | 7.8 | 100 | 9.5 | 100 | 17.3 | 100 |
| 1 | 1,236 | 90 | 6.4 | 82 | 7.6 | 80 | 14.0 | 81 |
| 2 | 881 | 64 | 5.2 | 67 | 6.4 | 67 | 11.6 | 67 |
| 3 | 603 | 44 | 3.4 | 44 | 5.1 | 54 | 8.5 | 49 |

estimates within 10 percent of the changes that actually occurred on the site studied in about 9 out of 10 cases. This close accordance is probably a result of two factors. One was the peculiar type of change imposed in which the size-class structure of the populations was not altered; in this respect, the technique employed was analogous to that used by Parker[4] in his sweet sagebrush test. The other was the ideal condition in this experiment for accurate loop placement; this will be discussed further in the following paragraphs.

Another way of evaluating the ability of the loop technique to detect change is presented in Table 4.

Bear in mind that this table has to do with change *per se* without regard for the magnitude of either the actual change, or the loop estimate, or the relation between them. Since the matter of inconsistencies in reading or recording loop hits enters into a discussion of Table 4, it deserves explanation.

From the standpoint of relocation and position of the steel tape, this study was conducted under ideal conditions. The tape remained in place throughout the entire series of readings and removals accomplished on each transect. In addition, the tape was stretched as close to the ground as possible so that plumbing the loop rod was not a problem, and the same individual read the loops before and after each removal. In spite of these precautions 30 inconsistencies appeared in the data for wheatgrass and 8 for balsamroot. For the most part, these consisted of hits recorded at one reading and missed in subsequent readings or vice versa, even though no change in vegetation had been made at the point of error. Although there is no way now of determining the importance of the two sources of inconsistencies, reading and recording, that of the latter is probably minor.

Table 4 shows that, of the 48 loop estimates of change obtained for wheatgrass, 20 were influenced in some manner by one or more inconsistencies made in the process of reading or recording a loop transect. Of those 20, 12 showed a decrease, 4 showed no change, and 4 showed an increase when there was, in fact, a decrease in every case. On the other hand, of the remaining 28 loop estimates for wheatgrass which were not so misread, 24 showed a decrease and 4 showed no change when there was an actual decrease in every case. If the 12 estimates that showed a decrease even though influenced by inaccurate readings are added to the 24 not so influenced, it is apparent that the loop was successful three times out of four (36 estimates out of 48) in reflecting a decrease in basal area. The above 12 estimates definitely should be considered because it is extremely doubtful that inconsistencies of the type experienced in this study will ever be eliminated from the technique.

In the case of balsamroot, the proportion of successful loop estimates was slightly more than half (24 out of 42). In only four instances, all influenced by obvious inconsistencies, did a loop estimate indicate a change in the

**Table 4. Number of loop-transect estimates of decrease in basal area, consistent or not in reading or recording loop hits.**[1]

| Results of loop transect estimates | Wheatgrass | | Balsamroot | |
|---|---|---|---|---|
| | Inconsistent[2] | Consistent | Inconsistent[2] | Consistent |
| Decrease | 12 | 24 | [3]6 | 18 |
| No change | 4 | 4 | 1 | [4]17 |
| Increase | 4 | 0 | 0 | 0 |
| Total | 20 | 28 | 7 | 35 |
| Grand total | 48 | | 42 | |

[1] Removals (decreases) were made in all cases except the six explained in footnotes 3 and 4.

[2] Number of loop-transect estimates influenced by one or more inconsistencies made in the process of reading or recording.

[3] No change made in four instances, yet loop indicated decrease.

[4] No change made in two instances, and loop indicated none.

[4] *See footnote 2.*

wrong direction for either species.

Although more than half the 249 comandra plants were removed, the loop failed to detect any loss because only one loop hit was recorded on this species during the entire test (Table 1).

Under usual field conditions where different tapes may be used, where end stakes may be moved by livestock or other means over the years, and where plumbing the loop rod creates a serious problem, errors in reading may be expected to occur more frequently. This emphasizes the importance of avoiding slipshod practices in the application of the loop technique. Perhaps it would be more profitable to spend less time in accurate marking and devote the time saved to putting in more transects.

To have some idea of the reliability of the loop as an indicator of change is desirable to be sure, but knowledge of the relation between the magnitude of loop change and the magnitude of actual change is even more useful. In an attempt to describe such a relation, the following procedure was adopted.

The data obtained in this study yielded forty-eight 100-loop estimates of change in wheatgrass and forty-two such estimates for balsamroot, together with an equal number of actual change values secured by measurement. They also yielded twenty-four 200-loop estimates and actual values for each species. The individual differences—expressed as percentages — between the loop estimates of changes and the measured changes provide what is probably the best means of describing the relation between the two. Fiducial limits, derived from these differences at the 5-percent probability level, for different numbers of loop transects are shown in Table 5.

It is evident from this table that wheatgrass is more amenable to sampling by the loop

**Table 5. Approximate fiducial limits of mean differences between measured changes in basal area and corresponding changes in loop hits.[1] P=0.05**

| Wheatgrass | | Balsamroot | | Wheatgrass plus balsamroot | |
|---|---|---|---|---|---|
| Number of transects[3] | Fiducial limit[2] | Number of transects | Fiducial limit[2] | Number of transects | Fiducial limit[2] |
| | Percent | | Percent | | Percent |
| 2 | 288 | 2 | 308 | 2 | 178 |
| 4 | 51 | 4 | 55 | 4 | 32 |
| 8 | 27 | 8 | 29 | 8 | 17 |
| 16 | 17 | 16 | 18 | 16 | 10 |
| 42 | 10 | 48 | 10 | .... | .... |
| | | 200 loops per transect | | | |
| 2 | 132 | 2 | 277 | 2 | 118 |
| 4 | 23 | 4 | 49 | 4 | 21 |
| 8 | 12 | 8 | 26 | 8 | 11 |
| 10 | 10 | 39 | 10 | 9 | 10 |

[1] Computed from the relation $\sqrt{s^2t^2/n}$.

[2] Because basal areas and loop hits are expressed in different terms, a change in one cannot be compared directly with a corresponding change in the other unless both changes are converted to a common term which, in this case, is percentage. Example: If we have 800 cm.$^2$ and six loop hits before treatment and 600 cm.$^2$ and five loop hits after treatment, there has been a decrease of 25 percent in cm.$^2$ and of about 17 percent in loop hits. The difference between these two expressions of change (25-17) is 8 percent. The fiducial limits listed in the table are derived from a population of such percentage differences and are thus expressed in percent.

[3] 100 loops per transect.

technique than balsamroot; for the same number of transects the fiducial limits are always larger in the case of balsamroot. Note that for wheatgrass the error inherent in using loop-hit changes based on 100 loops per transect as an index to real changes can be reduced to 10 percent only if 42 transects are sampled. The same degree of accuracy can be achieved with 10 transects if the number of loops read per transect is doubled. The slight additional effort required to read and record 200 loops per transect is more than justified by this substantial reduction in number of transects. In contrast, the error reductions accomplished for balsamroot by doubling the number of loops were only minor.

In the computation of Table 5, consideration was given to the probability that the successive changes in basal area made in this study were not independent —the second removal was related to the first, and the third to the second and thus to the first—and that therefore a common error term was not appropriate. In exploring this matter of independence, four different methods of computation were used. The four standard deviations thus obtained were so closely in accord that a common error term was considered appropriate, and values derived from variance analyses were chosen for the computations.

In the practical application of the loop technique as described by Parker (1951), wheatgrass and balsamroot would be considered key indicator species on the study area and would be recorded separately on the field forms. However, in the final classification of condition on the transect cluster summary forms, their total combined value would be considered more important than their individual values. The advantage of combining species can be seen in Table 5. A fiducial limit of 10 percent can be achieved for wheatgrass and balsamroot together with only 16 transects, whereas 42 and 48 transects, respectively, are required for the same degree of accuracy when the species are considered separately.

The matter of accuracy is of prime importance in the interpretation of changes recorded by the loop technique. It was brought out earlier in this paper that acceptable accuracy in describing vegetation with the loop may be achieved only with large numbers of transects. This is apparently also true with respect to measurement of change in individual species. When species are grouped, accuracy is considerably improved for a given sampling intensity although acceptable accuracy may still require more sampling than is practicable.

It should be emphasized, however, that the results reported herein are conditioned by the following factors: (1) average size of plants, mean area, and frequency (number of loop hits); (2) the fact that all changes made were in the nature of successive reductions in basal area; (3) use of a technique in which reductions were made by removing entire plants rather than portions of individual basal areas (in retrospect, it would have been more meaningful to make changes by removing portions of individual plants, although this would have introduced additional error in measurement of the plant portions); (4) the fact that plants left after removals remained constant in size, i.e., the size-class structure of the population was unchanged. Where these factors are substantially different, results will also be different. Predictions concerning reaction of the loop technique to variations in the above factors are presented by Hutchings and Holmgren (1959) from studies of theoretical and artificial populations.

## Summary

The ability of the loop technique to detect and measure changes in root crown areas was tested on the Upper Snake River Plain near Dubois, Idaho.

Loop readings were made at 6-inch intervals before and after measured changes on eight belt transects 100 feet long and 9 inches wide. Changes consisted of random removals of individual plants made three times on each transect. Conditions were ideal for accurate loop placement.

Three species were used: (1) wheatgrass which was represented by a large number of small plants; (2) balsamroot, by a small number of large plants; and (3) comandra, by a small number of small plants. Both size and number of plants strongly influenced the adequacy of the loop method as an index to change (Table 1). Out of a total of 1,600 loop placements, 95 hits were recorded on wheatgrass, 43 on balsamroot, and only 1 on comandra.

Inconsistencies in reading or recording loop hits occurred 30 times for wheatgrass and 8 times for balsamroot in spite of strict precautions taken to prevent them.

The standard errors of estimate for the regression of root crown area on loop hits as shown in Table 2 suggest that acceptable accuracy in describing vegetation with the loop technique may be difficult to obtain. However, the loop technique was not designed to provide description but rather to provide an index to change. Ratios of actual root crown area percentage to loop hit percentage were fairly constant, which means, in effect, that even though loop readings do not provide reliable estimates of root crown area, they may serve a useful purpose where plant size remains relatively constant or if some means of adjusting them can be devised.

An empirical comparison of changes in root crown areas and loop hits based on eight-transect averages showed fairly close agreement (Table 3). On the other hand, large fiducial limits ($P = 0.05$) were evident when error was assessed on the basis of the complete population of differences between estimated and measured changes (Table 5). Under the conditions encountered in this experiment, acceptable accuracy in measurement of change in individual species was achieved only with a large number of transects. By grouping species, accuracy was considerably improved for a given sampling intensity, although acceptable accuracy may still require more sampling than is practicable.

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