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# Resource Inventory Notes

BLM-87

NONPARAMETRIC STATISTICAL PROCEDURES FEB. 1980  
FOR COMPARING TWO POPULATIONS



*Biplotea*

by

Gary W. Fowler<sup>1/</sup>

**ABSTRACT:** The Wilcoxon (Mann-Whitney U), Mood, and Smirnov tests are presented to test for differences between two populations when the assumptions of the pertinent parametric tests are not met. A point and interval estimator for the location difference between two populations is also presented. All procedures are used to compare the lengths of two populations of legal size brown trout.

**INTRODUCTION:** In many natural resource experimental and sampling situations, two independent samples are obtained by either taking a random sample from each of two populations or by assigning two treatments at random to a set of relatively homogeneous sampling units. The sampler then wants to make inferences about differences between the two populations or treatments based on sample data.

The parametric tests for comparing the two populations are the t-test for comparing two means and the F-test for comparing two variances. The assumptions underlying these tests are (1) mutually independent random samples, (2) the variable (characteristic) of interest is normally distributed, and (3) measurement is on at least an interval scale. The t-test is also based on the assumption of homogeneous variances.

In many situations, measurement is not on at least an interval scale, variances are not equal, and/or the underlying distribution is not normal with sample sizes too small to make use of the Central Limit Theorem. Nonparametric procedures should be used in these situations.

The objective of this paper is to present the Wilcoxon (Mann-Whitney U), Mood, and Smirnov tests to test for differences between the two populations or treatments. A point and interval estimator is also presented for location differences between the two populations. All procedures assume two mutually independent random samples, continuous random variables, and a measurement scale that is at least ordinal. All procedures are used to compare the lengths of two populations of legal size brown trout.

**EXAMPLE:** Six and 8 legal size brown trout (*Salmo trutta*) were collected from Area 1 (Meadows Area) and Area 2 (old Pipeline Area), respectively, in Cooks Run, a stream in Iron County, Michigan, using electrofishing techniques.<sup>2/</sup> The lengths in inches

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<sup>2/</sup> The data were collected in August, 1978, in cooperation with the Fisheries Division, Michigan Department of Natural Resources, Crystal Falls, Michigan.

## Published by:

USDI, Bureau of Land Management, D 460  
Denver Service Center, Denver Federal Center, Bldg. 50  
Denver, Colorado, 80225

of these trout are shown in Table 1.  $Y_i$  is the length of the  $i$ th trout and  $n$  is the number of trout sampled from Area 1.  $X_j$  is the length of the  $j$ th trout and  $m$  is the number of trout sampled from Area 2.

Table 1. Lengths in inches and sample statistics of legal size brown trout from areas 1 and 2.

Area 1				Area 2			
OBSERVATION NO. (i)	$Y_i$	OBSERVATION NO. (i)	$Y_i$	OBSERVATION NO. (j)	$X_j$	OBSERVATION NO. (j)	$X_j$
1	13.8	4	13.0	1	10.8	5	10.2
2	17.0	5	14.6	2	12.0	6	10.3
3	10.5	6	14.4	3	12.2	7	12.1
				4	11.8	8	10.0

AREA 1		AREA 2	
sample size:	$n = 6$		$m = 8$
mean:	$\bar{Y} = 13.88$		$\bar{X} = 11.18$
variance:	$s_Y^2 = 4.5457$		$s_X^2 = 0.8879$
skewness coefficient:	$\hat{\gamma}_1 = -0.04$		$\hat{\gamma}_1 = -0.10$
kurtosis coefficient:	$\hat{\gamma}_2 = -0.81$		$\hat{\gamma}_2 = -1.94$

The two areas were similar in average stream width, velocity, and discharge. Area 1 had a greater average stream depth, more square feet of undercut banks and weed beds, and less square feet of overhanging brush and submerged logs.

I will assume that the two samples of trout obtained by electrofishing are two mutually independent random samples from two populations.

**NONPARAMETRIC PROCEDURES:** In comparing two populations using independent random samples from each population, the sampler should be aware of the following nonparametric statistical procedures: (1) the Wilcoxon or Mann-Whitney U test, (2) point and interval estimates for location differences, (3) Mood's test, and (4) the Smirnov test.

**Wilcoxon (Mann-Whitney U) Test:** The Wilcoxon or Mann-Whitney U test (Conover 1971, Lehman 1975) should be used to test for the difference between population distribution functions when the difference takes the form of the observations for one population being, in general, larger than the observations from another population. For the two-sided test, the null hypothesis  $H_0: P(X < Y) = 1/2$  is tested against the alternative hypothesis  $H_1: P(X < Y) \neq 1/2$ .  $Y$  and  $X$  are the random variables associated with populations 1 and 2, respectively.

If it is assumed that the difference between population distribution functions is strictly a difference in location, then the null hypothesis  $H_0: \mu_Y = \mu_X$  is tested against the alternative hypothesis  $H_1: \mu_Y \neq \mu_X$ , where  $\mu_Y$  and  $\mu_X$  are the population means of the random variables  $Y$  and  $X$ , respectively.

The two independent samples of size  $n$  and  $m$  from the populations with random variables  $Y$  and  $X$ , respectively, are pooled. The smallest observation (value) of the pooled data is given a rank of 1 while the largest value is given a rank of  $N$  where  $N = n + m$ . The Wilcoxon statistic can be either

$$(1) W_s = \sum_{i=1}^n s_i \text{ or } W_r = \sum_{j=1}^m r_j$$

where  $s_i$  is the rank assigned to the  $i$ th observation from the sample of size  $n$ ,  $r_j$  is the rank assigned to the  $j$ th observation from the sample of size  $m$ , and  $W_s + W_r = N(N+1)/2$ . I will use  $W_s$  as the test statistic.

The decision rule for the Wilcoxon test is: Reject  $H_0$  if  $W_s \leq W_{s_{\alpha/2}}$  or  $W_s \geq W_{s_{1-\alpha/2}}$ ; otherwise Accept  $H_0$ .  $W_{s_{\alpha/2}}$  and  $W_{s_{1-\alpha/2}}$  are the lower and upper critical values of the Wilcoxon statistic  $W_s$ , and  $\alpha$  is the level of significance. The large sample ( $n$  and  $m > 10$ ) normal approximation for  $W_s$  and the midrank procedure for handling tied observations can be found in Lehman (1975).

The Mann-Whitney U test is the same as the Wilcoxon test except for a constant. The Mann-Whitney U statistic  $U_s = W_s - n(n+1)/2$ .  $U_s$  is the number of pairs  $(Y_i - X_j)$  where  $Y_i > X_j$  for  $i = 1, \dots, n$  and  $j = 1, \dots, m$ . Tabled critical values are more commonly found for  $U_s$  than for  $W_s$  (Conover 1971, Lehman 1975).

For the trout example, the pooled ranks of the raw data ( $s_i$  and  $r_j$ ) for the two samples with  $n = 6$  and  $m = 8$  are shown in Table 2. From Table 2,  $W_s = \sum_{i=1}^6 s_i = 64$ .  $U_s = 64 - 21 = 43$ . Assuming  $\alpha = 0.05$ ,  $U_{s_{0.025}} = 8$  and  $U_{s_{0.975}} = 40$  ( $U_{s_{0.975}} = nm - U_{s_{0.025}}$ ). Since  $U_s > 40$ , we reject  $H_0$  and find that the brown trout from Area 1 are significantly longer than those from Area 2. ( $\bar{Y} - \bar{X} = 13.88 - 11.18 = 2.70$ ). The parametric t-test for comparing means gave the same results.

The Wilcoxon test has an asymptotic relative efficiency (A.R.E.) (Conover 1971, Lehman 1975) of 0.955 when compared to the two-sample t-test for independent samples

Table 2. Pooled ranks of the raw data ( $s_i$  and  $r_j$ ) and the deviation form of the data ( $s_i'$  and  $r_j'$ ) from the two samples with  $n = 6$  and  $m = 8$  for the trout example.

i or j	AREA #1				AREA #2			
	$Y_i$	$s_i$	$Y_i - \bar{Y}$	$s_i'$	$X_j$	$r_j$	$X_j - \bar{X}$	$r_j'$
1	13.8	11	-.083	7	10.8	5	-.375	6
2	17.0	14	3.117	14	12.0	7	.825	11
3	10.5	4	-3.383	1	12.2	9	1.025	13
4	13.0	10	-.883	4	11.8	6	.625	9
5	14.6	13	.717	10	10.2	2	-.975	3
6	14.4	12	.517	8	10.3	3	-.875	5
7					12.1	8	.925	12
8					10.0	1	-1.175	2

when all of the assumptions of the t-test are met. Thus, the Wilcoxon test is only slightly less powerful than the t-test under such circumstances. The lowest the A.R.E. can be regardless of the underlying distribution of the random variables is 0.864. The Wilcoxon test can be considerably more powerful than the t-test for certain distributions.

The Normal Scores and Savage tests are more powerful than the Wilcoxon test under certain circumstances (Lehman 1975).



**Point and Interval Estimators:** A nonparametric point estimate can be made of the location difference  $\Delta$  between two populations with the use of the ordered pairs  $(Y_i - X_j)$  (Hollander and Wolfe 1973). The estimate is

$$(2) \hat{\Delta} = \text{median}(Y_i - X_j).$$

The ordered pairs  $(Y_i - X_j)$  for  $i = 1, \dots, 6$  and  $j = 1, \dots, 8$  for the trout example are shown in Table 3. There are  $nm = 48$  pairs ordered from smallest to

Table 3. Forty-eight ordered pairs  $(Y_i - X_j)$  for the trout example.

$Y_i - X_j$								
-1.7	.3	1.6	2.3	2.7	3.6	4.3	5.0	
-1.6	.5	1.7	2.4	2.8	3.6	4.4	5.2	
-1.5	.8	1.8	2.4	2.8	3.8	4.4	6.2	
-1.3	.9	2.0	2.5	3.0	3.8	4.6	6.8	
-.3	1.0	2.2	2.6	3.0	4.1	4.8	6.7	
.2	1.2	2.2	2.6	3.5	4.2	4.9	7.0	

largest.  $\hat{\Delta} = 2.64$  for the trout example. The parametric point estimate of  $\Delta$  is  $\hat{\Delta} = \bar{Y} - \bar{X} = 2.70$ .

A nonparametric confidence interval can also be calculated for  $\Delta$  with the use of the ordered pairs  $(Y_i - X_j)$  (Hollander and Wolfe 1973). The lower and upper bounds are  $\hat{\Delta}_L = (Y_i - X_j)_{\alpha/2}$  and  $\hat{\Delta}_U = (Y_i - X_j)_{1-\alpha/2}$ , respectively. The  $(1-\alpha)\%$  confidence interval for  $\Delta$  is  $[\hat{\Delta}_L, \hat{\Delta}_U]$ .

$\hat{\Delta}_L = 0.5$  and  $\hat{\Delta}_U = 4.6$  for the trout example with  $\alpha = 0.05$ . Therefore, the 95% confident interval for  $\Delta$  is  $[0.5, 4.6]$ . The parametric 95% confidence interval for  $\Delta$  based on the t-statistic is  $[0.87, 4.53]$ . The parametric confidence interval assumes that  $Y$  and  $X$  are normally distributed while the nonparametric confidence interval applies regardless of the distributions of  $Y$  and  $X$ .

**The Mood Test:** The Mood test (Conover 1971) should be used to test the difference between population distribution functions when the difference is strictly a difference in dispersion or variance or scale. It assumes that the two populations have the same location. Since this is usually not true, an approximate procedure must be used. The approximation becomes better as  $m$  and  $n$  increase. For the two-sided test, the null hypothesis  $H_0: \gamma^2 = 1$  is tested against the alternative hypothesis  $H_1: \gamma^2 \neq 1$ , where  $\gamma^2 = \sigma_Y^2 / \sigma_X^2$  and  $\sigma_Y^2$  and  $\sigma_X^2$  are the variances of the random variables  $Y$  and  $X$ , respectively.

The Mood statistic is

$$(3) M_s = \sum_{i=1}^n (s_i - \frac{N+1}{2})^2$$

where  $s_i$  is the pooled rank of the  $i$ th observation from the sample of size  $n$ . When there is a location difference, the approximate Mood statistic is

$$(4) M_s' = \sum_{i=1}^n (s_i' - \frac{N+1}{2})^2$$

where  $s_i'$  is the pooled rank of the  $i$ th observation  $Y_i - \bar{Y}$ .  $Y_i - \bar{Y}$  for  $i = 1, \dots, n$  and  $X_j - \bar{X}$  for  $j = 1, \dots, m$  are pooled together to obtain the pooled ranks

$s_i'$  ( $i = 1, \dots, n$ ) and  $r_j'$  ( $j = 1, \dots, m$ ).  $Y_i - \bar{Y}$  and  $X_j - \bar{X}$  are the deviation form of the data.

The pooled ranks of the deviation form of the data for the trout example

(Table 2) yield  $M_s' = \sum_{i=1}^6 (s_i' - 7.5)^2 = 103.5$ . Critical values for Mood's statistic can be found in Laubscher et al. (1968). Assuming  $\alpha = 0.05$ , the lower critical value  $M_{s,0.025}' = 43.5$  and the upper critical value  $M_{s,0.975}' = 151.5$ . The decision rule for Mood's test is: Reject  $H_0$  if  $M_s' \leq M_{s,0.025}'$  or  $M_s' \geq M_{s,0.975}'$ ; otherwise accept  $H_0$ . For the trout example, the Mood test shows no significant difference between the variances of the two populations. The parametric F-test for comparing two variances barely accepted  $H_0$  ( $F_{5,7} = s_Y^2/s_X^2 = 5.12$  and  $F_{.975;5,7} = 5.29$ ).

When the assumptions of the F-test are met, Mood's test has an A.R.E. of 0.76 relative to the F-test. The Mood, Siegel-Tukey, and Freund-Ansari tests can all be used to test for equal variances with small sample sizes; however, the Mood test appears to be most powerful (Conover 1971). There are more powerful nonparametric procedures available for larger sample sizes (Hollander and Wolfe 1973).

**The Smirnov Test:** The Smirnov test (Conover 1971) should be used to test for the difference between population distribution functions when the difference is any type of difference (e.g., location, dispersion, skewness, etc.). If the difference is unknown or it is known that there are at least two types of differences, the Smirnov test should be used.

For the two-sided test, the null hypothesis  $H_0: F(Y) = F(X)$  is tested against the alternative hypothesis  $H_1: F(Y) \neq F(X)$  where  $F(Y)$  and  $F(X)$  are the cumulative distribution functions (c.d.f.'s) of  $Y$  and  $X$ , respectively. If  $F(Y)$  lies above  $F(X)$ , values of  $X$  tend to be larger than values of  $Y$ . If  $F(Y)$  is steeper than  $F(X)$ , values of  $X$  have more dispersion than values of  $Y$ .

The Smirnov statistic is

$$(5) D_{n,m} = \max |S_n(Y) - S_m(X)|$$

which is the maximum vertical distance between the two sample c.d.f.'s  $S_n(Y)$  and  $S_m(X)$ .

For the trout example,  $S_n(Y)$ ,  $S_m(X)$ , and  $|S_n(Y) - S_m(X)|$  are shown in Table 4 for all values of  $X$  and  $Y$ .  $S_n(Y)$  and  $S_m(X)$  are plotted in Figure 1.  $D_{6,8} = 0.833$

Table 4.  $S_m(X)$ ,  $S_n(Y)$ , and  $|S_n(Y) - S_m(X)|$  for all values of  $Y$  and  $X$  for the trout example

Y	X	$S_m(X)$	$S_n(Y)$	$ S_n(Y) - S_m(X) $	Y	X	$S_m(X)$	$S_n(Y)$	$ S_n(Y) - S_m(X) $
10.5	10.0	1/8	0	0.125	13.0	12.1	7/8	1/6	0.708
	10.2	2/8	0	0.250		12.2	1	1/6	0.833
	10.3	3/8	0	0.375		13.0	1	2/6	0.667
		3/8	1/6	0.208		13.8	1	3/6	0.500
	10.8	4/8	1/6	0.333		14.4	1	4/6	0.333
	11.8	5/8	1/6	0.458		14.6	1	5/6	0.167
	12.0	6/8	1/6	0.583		17.0	1	1	0

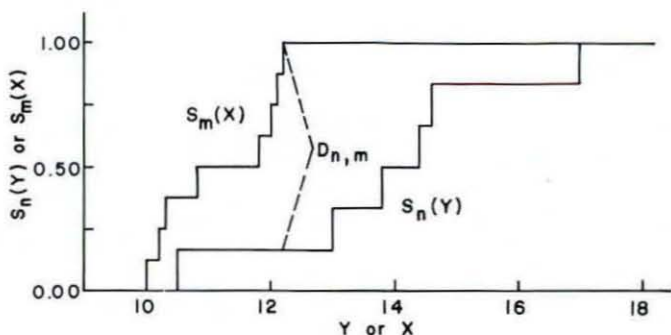


Figure 1.  $S_m(X)$ ,  $S_n(Y)$ , and  $D_{n,m}$  for the trout example.

(Table 4, Figure 1), and the critical value  $D_{0.05;6,8} = 0.667$ . Since  $D_{6,8} > 0.667$ , the two distributions are significantly different in some way. Figure 1 indicates that the values of  $Y$  tend to be larger and more dispersed than the values of  $X$ .  $Y$  also appears to be less negatively kurtotic than  $X$  (Table 1).

A table of critical values of  $D_{n,m}$  can be found in Conover (1971).

**CONCLUDING REMARKS:** For the trout example, the nonparametric statistical procedures show that the two populations of legal size brown trout are significantly different. The Smirnov test shows that the populations are different in some way(s). Examination of the two sample c.d.f.'s indicates that the length of trout in Area 1 appears to be greater and more dispersed than that of Area 2. The Wilcoxon test and the confidence interval show that the length of trout in Area 1 is significantly larger than that of Area 2. The Mood test shows no significant difference between the variances of the two areas even though the sample variance of Area 1 is about 5 times the sample variance of Area 2. Remember that the sample sizes are relatively small, the approximate Mood statistic was used, and the A.R.E. of Mood's test relative to the F-test under the assumptions of the F-test is 0.76. The results, in general, show that the length of trout in Area 1 are larger and more dispersed than Area 2. This agrees with 7 years of data from these two areas.

The Smirnov test is more sensitive to differences in location accompanied by other differences (e.g., variance, skewness, etc.). The Wilcoxon test is more sensitive to differences only in location. The Mood test is more sensitive to differences only in dispersion and assumes equal locations.

The nonparametric procedures presented in this paper should be used for the 2-sample case when the assumptions of the appropriate parametric procedures can not be met and sample sizes are small. They are easy to use and tables of critical values are readily available. Large sample approximations are available for all tests and modifications can be made for tied observations (Conover 1971, Lehman 1975).

I strongly believe that nonparametric procedures should be used more widely where they are applicable. For small sample sizes, such procedures compare more favorably with parametric procedures as deviations from the assumptions of parametric procedures increase. For many distributions, nonparametric procedures are considerably more powerful than parametric procedures.

#### LITERATURE CITED

- Conover, W.J. 1971. Practical Nonparametric Statistics. John Wiley and Sons, Inc. New York. 462 p.
- Hollander, M. and D.A. Wolfe. 1973. Nonparametric Statistical Methods. John Wiley and Sons, Inc. New York. 503 p.
- Lehman, E.I. 1975. Nonparametrics. Holden-Day, Inc., New York. 457 p.
- Laubscher, N.F., Steffens, F.E. and DeLange, E.M. 1968. Exact critical values for Mood's distribution-free test statistic for dispersion and its normal approximation. Tech. 10:497-508.



100% Mark With 3P Sample or Multistage 3P Cruising:  
Which Method Should A Forest Manager Use?

By: William H. Carson, Jr. <sup>1/</sup>

Abstract: This paper presents two simple equations which can help a forest manager decide which 3P system to choose: 100% Mark with 3P Sample or Multistage 3P Cruising.

Standard 3P procedures (100% mark with 3P sample) are effective, but can become costly when a large number of trees must be visited. Multistage 3P cruising (USDA For.Serv., 1976; Estola, 1979) significantly reduces the number of trees that must be visited on large sales. Both systems have inherent cost and time factors which should be considered by a forest manager.

The following equations can be used to compare the cost or time requirements of each system:

1. 100% Mark with 3P Sample

$$\text{Total Time} = \frac{\text{Total Estimated Volume (or Acres)}}{\frac{\text{Volume (or Acres)}}{\text{Marked and 3P Sampled/Crew/Unit of Time}}}$$

2. Multistage 3P Cruising

$$\begin{aligned} \text{Total Time} &= \frac{\text{Total Estimated Volume (or Acres)}}{\frac{\text{Volume (or Acres)}}{\text{Marked}} \div \frac{\text{Crew}}{\text{Unit of Time}}} \\ &+ \frac{\text{No. of 3P Plots Required}}{\text{No. of 3P Plots completed/Crew/Unit of Time}} \end{aligned}$$

The following example was developed using representative data from Ponderosa Pine sales in the Black Hills:

Given: Sale Area = 200 Acres

100% Mark with 3P Sample requires 70 sample trees

Multistage 3P Cruise requires 100 sample trees  
(100 plots; 700 tree visits)

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A two-man crew can 100% mark with 3P sample 10 acres/day regardless of the number of sample trees.

A two-man crew can multistage 3P cruise 20 plots/day.

A two-man crew can mark 20 acres/day.

Substituting in equations 1. and 2. :

$$\begin{array}{lcl} \text{Time} & = & \frac{200 \text{ Acres}}{10 \text{ Acres/day}} = 20 \text{ days} \\ 100\% & & \end{array}$$

$$\begin{array}{lcl} \text{Time} & = & \frac{200 \text{ Acres}}{20 \text{ Acres/day}} + \frac{100 \text{ Plots}}{20 \text{ plots/day}} = 15 \text{ days} \\ \text{Multistage} & & \end{array}$$

In this case a Multistage 3P Cruise would be more economical than a 100% Cruise with 3P Sample. If the sale had been less than 100 acres, the 100% Cruise with 3P Sample would have been more economical.

#### LITERATURE CITED

- Estola, J. D. 1979. Variable radius plot and 3 P Timber Sampling. Resource Inventory Notes BLM 11:1-6.
- USDA Forest Service. 1976. Timber Sale Preparation Handbook. Amendment No. 2. Chapters 12 and 13.

# ERRATA

There are several substantive errors in "Computing Optimum Plot Sizes for Wildlife Inventories", an article which appeared in Resource Inventory Notes (BLM 23, July, 1979). These errors are the responsibility of both the editor and the author of the article. An alert reader, after working with the formulas, brought these mistakes to the attention of the editor. In turn, the editor passed these comments on to the author, who was invited to correct them. These corrections are listed below:

1. Page 9, 2. Number of Necessary Plots, first paragraph, should read:

Suppose we accept the precision that a sample of 10 plots of one hectare each will give (after Wensel, 1976). Now, to calculate the number of plots of other sizes that meet the same precision, use this formula:

2. Page 9, 2. Number of Necessary Plots, second formula (example), should read:

$$= \left[ \frac{.93}{.50} \right]^2 \times 10 = 35 \text{ plots}$$

3. Page 11, first line of the page, the x should be omitted.

4. Page 11, first formula, should read:

$$n_s = \left[ \frac{\text{C.V.}_s}{0.5} \right]^2 \times 10 = \left[ \frac{.5s}{.5} \right]^{-0.27} \times 10 = 10s^{-0.54}$$

5. Page 11, the table should read:

Plot Size		C.V.	$n_s$	Area Sampled	
1.0	hectare	0.50	10	10	Hectares
0.8		0.53	11	9.0	
0.5		0.60	15	7.3	
0.3		0.69	19	5.7	
0.2		0.77	24	4.8	
0.1		0.93	35	3.5	
0.05		1.12	50	2.5	
0.01		1.74	120	1.2	

6. Page 12, mid-page, the equation should read:

Set it equal to zero.

$$0 = (4.6 \text{ b s}^{-0.54}) - (5.4 \text{ as}^{-1.54})$$

7. Page 13, first paragraph, should read:

$$\text{Error of the estimate} = \frac{C.V. \times t}{\sqrt{n}}$$

8. Page 13, second paragraph, should read:

$$\text{Error of the estimate} = \frac{C.V. \times t}{\sqrt{n}}$$

9. Page 13, fourth paragraph, the following changes should be made:

$$\frac{T_v \text{ 1 hectare}}{T_v \text{ minimum}} = \frac{90}{61} = 148\%$$

$$\frac{T_v \text{ 0.5 hectare}}{T_v \text{ minimum}} = \frac{73}{61} = 120\%$$

10. Page 14, under Data Points, the following change should be made:

s	Tv
.10	62.4

11. Page 15, under Summary, should read:

$$(T_v = n (b s + a))$$

and

$$T_v = 10 bs^{0.46} + 10 as^{-0.54}$$

#### Current Literature

Please order directly from sources listed.

#### GENERAL

General Technical Report INT 51. A computer Program for Applying Ridge Regression Techniques to Multiple Linear Regression.

USDA Forest Service, Intermountain Forest and Range Experiment Station,  
507 25th Street, Ogden, Utah 84401

Technical Report 377. The Effect on Signal-Noise Ratio and Bandwidth on Vehicle Identification Using the Acoustic Sensor.

Technical Paper 366. User Performance under Several Automated Approaches to Changing Displayed Maps.

Technical Report 389. A Comparison of Speed and Accuracy of Interpretation of Two Tactical Symbologies.

U. S. Army Research Institute for the Behavioral and Social Sciences,  
5001 Eisenhower Avenue, Alexandria, Virginia 22333

---

Kessell, Stephen R. Gradient Modeling

New York: Springer-Verlag  
(Dept. S-181, 175 Fifth Avenue, N. Y., N.Y. 10010), \$39.80

---

General Technical Report PNW 82. Selection, Management, and Utilization of Biosphere Reserves.

USDA Forest Service, Pacific Northwest Forest and Range Experiment Station,  
809 NE 6th Avenue, Portland, Oregon 97232

---

Hamilton, David. "Setting Precision for Resource Inventories: The Manager and the Mensurationist". Journal of Forestry (Vol. 77, No. 10), October, 1979, pp. 667-670.

#### FORESTRY

General Technical Report INT 51. Photo Series for Appraising Thinning Slash in Northern Idaho.

Research Paper INT 228. Gross Cubic-Volume Equations and Tables: Outside Bark for Pinyon and Juniper Trees in Northern New Mexico.

Research Paper INT 218. Forest Regions of Montana.

USDA Forest Service  
Intermountain Forest and Range Experiment Station  
507 25th Street  
Ogden, Utah 84401

---

Research Note RM 375. Effects of Tree Distribution and Canopy Cover on Classification of Ponderosa Pine Forest from LANDSAT 1.

Research Note RM 373. Aerial Stand Volume Table for Plains Cottonwood in Eastern Colorado.

USDA Forest Service, Rocky Mountain Forest and Range Experiment Station,  
240 W. Prospect Street, Ft. Collins, Colorado 80526



General Technical Report NC 49. A Generalized Forest Growth Projection System Applied to the Lake States.

USDA Forest Service, North Central Forest Experiment Station  
1992 Folwell Avenue, St. Paul, Minnesota 55108

---

General Technical Report PNW 78. Relative Density: The Key to Stocking Assessment in Regional Analysis - A Forest Survey Viewpoint.

An Overview of Regional Forest Inventory Systems in the United States (Reprint).

Research Note PNW 333. Method of Estimating Ground Fuels under Two Inches in Diameter in Southwestern Ponderosa Pine Stands.

Research Note PNW 331. What Program Managers and Project Leaders Should Know about Publications but Usually Learn the Hard Way.

A Trap to Measure Populus and Sulix Seedfall (Reprint).

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Predicting Slope Stability from Aerial Photos (Reprint).

General Technical Report PSW 29. Coding Hazardous Tree Failures for a Data Management System.

USDA Forest Service, Pacific Southwest  
Forest and Range Experiment Station  
P. O. Box 245, Berkeley, CA 94701

#### RANGE SERVICE

Progress Report RSC 3687-5. LANDSAT Range Resource Information System Project.

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OUTDOOR RECREATION

Research Bulletin Number 107. Estimating the Demand for Outdoor Recreation in the Sawtooth Valley, Idaho.

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Moscow, Idaho 83843

Research Note PNW 327. Using Photography for Recreation Research.

USDA Forest Service, Pacific Northwest Forest  
and Range Experiment Station  
809 NE 6th Avenue  
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Green, Daniel. "Can Potential Recreation Areas be Inventoried in the Office".  
Journal of Forestry (Vol. 77, No. 10), October, 1979, pp. 670-672.

WILDLIFE

How to Demonstrate the Importance of Fishery Resources to Interdisciplinary Planning Teams (Reprint).

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Meetings

1980

- March 6-7 Forest Inventory for Nonindustrial Private Woodlands.  
Location: West Lafayette, Indiana. Contact: Business  
Office, Continuing Education, Room 110, Stewart Center,  
Purdue University, West Lafayette, Indiana 47907.
- April 23-25 Fifteen Years of Forest Management in Three Days. Sponsors:  
University of Wisconsin - Stevens Point, Forest Inventory  
Working Group - Society of American Foresters, Wisconsin-  
Michigan Section - Society of American Foresters, and  
University of Wisconsin - Extension. Location: Stevens  
Point, Wisconsin. Contact: Extended Services, University  
of Wisconsin - Stevens Point, Wisconsin 54481.

- July 14-18      Course in Remote Sensing
- July 21-25      Course in Multiple-Level Sampling Design  
Location (both): Ft. Collins, Colorado  
Contact: Dr. Warren E. Fraizer, College of Forestry and  
National Resources, Colorado State University,  
Ft. Collins, Colorado 80523
- November 30 -      Arid Land Resource Inventories: Developing Cost Efficient  
December 6      Methods. Sponsors: Society of American Foresters, USDA  
Forest Service, Bureau of Land Management, Mexican  
Association of Professional Foresters, and Subsecretariat,  
Forestry and Wildlife, Government of Mexico. Location:  
La Paz, Mexico. Contact: H. Cyde Lund, USDA Forest  
Service, 240 W. Prospect Street, Ft. Collins, CO 80526.

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