PHILIP G. LANGLEY
Forest Data Corporation
Walnut Creek, California

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Quality Assessment of Late Seral Old-Growth Forest Mapping

ABSTRACT

A program was undertaken to assess the consistency of the late seral old-growth (LSOG) classification maps developed for the Sierra Nevada Ecosystem Project. The effort included sampling to gather data appropriate for assessing the accuracy of LSOG ratings assigned to specific mapped areas and for making such assessments. The assessment focuses on the correlation observed between patch ratings assigned by the LSOG mapping team and structural characteristics of the forest as observed on the ground. In the mixed conifer forest type, the classification accuracies ranged between 44% in the higher LSOG rating classes and 78% in the lower classes at the patch level. Consequently, the LSOG maps prepared by the SNEP team can serve as a basis for stratifying the Sierra Nevada into broad groups of late successional forest structural patterns. However, a high level of variation in structural components should be expected for any given LSOG class when making statements concerning the structural composition of patch ratings specific to given mapped polygons.

INTRODUCTION

This report describes the results of a quality assessment of late seral old-growth (LSOG) patch ratings assigned by the Sierra Nevada Ecosystem Project (SNEP) mapping team early in 1994. The assessment focuses on (1) the structural characteristics of biological material (e.g., live trees, snags, and down matter) characteristic of each assigned patch rating as observed on the ground and (2) the occurrence of human entry or management activity at some time in the past in sample patches.

To construct the maps, a team was assembled in one place for several days. Working in groups, they constructed LSOG maps by drawing on group members' special knowledge of each area, previously constructed resource maps, aerial photographs and other data. Large polygons, up to several thousand acres in size, were constructed encompassing land areas of apparently similar forest characteristics. Each polygon was more finely characterized as consisting of one to five patch types, depending on the heterogeneity within-polygons. In addition, each polygon was stratified into a major forest type. Revisions were made to patch proportions later, with different people on some national forests.

The attributes used by the mapping team for identifying patches having various levels of late successional characteristics include such items as forest type, number of large trees, number of snags, dominant species, and canopy closure. After the patch types were identified, an LSOG rating was assigned to each patch type within a polygon. The sum of the products of the proportion of patch area times the patch rating (estimated on a scale of 1 to 5) yielded the LSOG rating for a whole polygon.

The quality assessment described in this chapter was undertaken to learn about the reliability of the assigned polygon ratings as they relate to late seral forest structures observed on the ground. Because the polygon ratings depend on the proportion and rating of patch types within polygons, the problem can be addressed at the patch level to bring the scale of the assessment task within reasonable bounds.

Knowledge about the reliability of assigned patch ratings, and thus polygons, is important to assure the proper charac-

Sierra Nevada Ecosystem Project: Final report to Congress, vol. II, Assessments and scientific basis for management options. Davis: University of California, Centers for Water and Wildland Resources, 1996.

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terization of the LSOG rating levels and spatial distribution of late seral forests in the Sierra Nevada. It is also important for any large-scale stand projections that may be attempted in the future. The key questions this quality assessment attempts to answer, therefore, are

- How consistent are the patch ratings assigned by the mapping team based on structural characteristics of the forest as observed on the ground?
- What are the structural characteristics of each assigned LSOG rating when measured on a scale of 1 to 5?

BACKGROUND

While preparing the LSOG maps, the mapping team had access to previously prepared orthophotos (e.g., rectified, scaled, and mosaicked aerial photographs), data files, and each mapper's unique individual experience in different parts of the study area. With such a diversity of input, it is natural to expect that the LSOG maps in different regions of the Sierra Nevada would exhibit a high degree of variability when compared with ground conditions. Furthermore, the LSOG maps are based on site-specific, current predictions of forest parameters that can be reliably assessed only on the ground and not from aerial photographs, previously prepared maps, or even human memory.

To objectively address the two questions posed, it would seem prudent to employ sample data that have been collected during the normal course of other ongoing forest surveys, such as the U.S. Forest Service's Forest Inventory and Analysis (FIA) program or their management-plan mapping and inventory programs. However, to assess the quality of any particular map set, it is necessary to have data that are specific to a known geographical area. Furthermore, the accompanying test data should be consistent with the categorical partitioning of the maps being tested.

None of the maps made during the course of other surveys, nor their accompanying field data, conform to the scale, range, or structure of the SNEP maps. Therefore, to evaluate the current LSOG maps, it became necessary to obtain at least some new data describing the forest structure and late seral stage at specific sample sites within the areas covered by these maps. Problems arose, however, as we endeavored to devise a sampling plan to gather data for the quality assessment.

First, in order to assess quality at the patch level efficiently, it is necessary to target the patches directly for possible inclusion in a sample. Unfortunately, though the mapping team estimated the proportion of each polygon occupied by each patch type, they made no attempt to delineate patch boundaries or otherwise locate patches within polygons. Therefore, sampling patches directly on a global basis, would have required an expensive data organizational and field sampling procedure. The most practical alternative we saw was to draw a random sample of polygons, with probability proportional to their area, and then have the mappers delineate the patch boundaries within the selected polygons. Obviously, this raised the possibility that bias might enter the process, because sample patches would be spatially clustered within sample polygons and not drawn completely at random from the whole population of polygons at a known relative frequency. This was a risk we nevertheless had to accept.

Second, selecting polygons according to a basic randomization scheme provided no control over the number of patches in each type or rating that would appear in the sample. The result is that, although we would have a variable probability random sample of polygons, we would have a cluster sample of patch types within polygons thus compromising, to an unknown degree, the validity of any statistical tests that assume a complete randomization of observations over the entire project area. Given the geographic scope of the LSOG program, the short time span available for completion, and the exploratory nature of the results expected, we elected to proceed with the sampling plan.

METHODS

Sampling Plan

A plan was devised for obtaining the sample data necessary to assess the quality of the LSOG maps in conformance with the two questions we posed. The strategy we used is called stratified two-stage sampling with variable probabilities of selection in the first stage. In this plan, a stratum contains all the mapped LSOG polygons in a major forest type as determined by the mapping team. However, because of time and cost constraints, only the mixed conifer forest type was sampled sufficiently for evaluation purposes. Even in the mixed conifer type, we were unable to obtain a representative distribution of data throughout the entire SNEP area. To help remedy this deficiency, plot data from the U.S. Forest Service Forest Inventory and Analysis (FIA) program were used to expand the geographical coverage over more of the mixed conifer forest type.

Data from the FIA field plots were reformatted so that the same structural components could be extracted from them as were obtained from the SNEP plots. Then, if feasible, we planned to combine the two data sets to obtain quality assessments that could be extrapolated to more forest types in the SNEP area. It turned out to be not feasible, however, to combine the two data sets because of significant differences between several pairs of common structural variables. Therefore, separate analyses were done for each set.

For SNEP sampling, the first-stage sample units consist of the mapped polygons within a stratum (major forest type). Polygon selection was random, with probability proportional to polygon area. The sample in the second-stage consists of ground plots deployed within each sample first-stage unit (polygon). Before deploying field plots, however, each sample polygon was exhaustively partitioned into patches. This partitioning was performed by members of the original mapping team and was necessary to help ensure that all designated patch types within primary sample polygons would be sampled in the field. Also, it was specified that a minimum of two field plots be measured in each patch type occurring in a sample polygon so that within-patch averages could be estimated. The field plots were rectangular in shape and oriented with the long side parallel to the slope. A 2-chain-by-4-chain plot, 0.8 acres in size, was used to sample snags and down material. A 0.4-acre subplot was used to measure live trees greater than 24 in dbh (diameter breast height).

The FIA field plots were deployed before this study was contemplated and, therefore, independently of the SNEP polygon structure. Hence the data extracted from them were used solely in the context of single plot locations.

Data Items

During the field phase of the SNEP data collection effort, plots were deployed in the mixed conifer types on the Eldorado, Lassen, Sequoia, and Stanislaus national forests. The variables recorded on the SNEP field plots total 30 data items: 24 of these are structural components and 6 pertain to past occurrences of human intrusions and site quality.

The 6 specific items for intrusions and site quality are presence of an intermediate canopy, site class on a scale of 1 to 5, salvage harvest, selection harvest, tree thinning, and other human intrusion. All but site class are binary values.

The structural variables comprise number of live trees, number of snags, and down material. The 9 variables for number of live trees by 2 in classes are hardwoods 24–28 in dbh, 30–38 in, and greater than or equal to 40 in; true firs 24–28 in, 30–38 in, and greater than or equal to 40 in. The variables for number of snags by 2 in classes are hardwoods, with or without bark, 24–28 in dbh, 30–38 in, and greater than or equal to 40 in; true firs 24–28 in, 30–38 in, and greater than or equal to 40 in; and other conifers 24–28 in, 30–38 in, and greater than or equal to 40 in. The variables for down material of irregular length are true firs 20–28 in, measured at the large end, 30–38 in, and greater than or equal to 40 in and other conifers 20–28 in, 30–38 in, and greater than or equal to 40 in.

The data items extracted from the FIA database include the same structural variables as the SNEP plots. However, the human intrusion and site data comprise three instead of six variables:

1. presence of an intermediate canopy
2. site class on a scale of 1 to 5
3. a history code that is not compatible with the SNEP items concerning human intrusions

Analyses of SNEP Data

As the plot data came in, they were processed through a specially prepared program that screened for omissions, obvious mistakes, and internal consistency. Then, each variable was expanded to a per-acre basis and written to a new data file in a format compatible with our statistical analysis programs.

Discriminant Analysis

Discriminant analysis (DA) is a useful tool for obtaining a better understanding of the relationships among a set of independent variables and the population groups to which they belong. It is also used to classify individual entities, such as field plots, into unique groups based on those variables.

The specific problem that we address is how well it is possible to cluster the structural variables found on each field plot into discrete LSOG ratings as specified by the mapping team. We used discriminant analysis in three situations: (1) at the plot-level using SNEP data, (2) at the patch level using SNEP data, and (3) at the plot-level using FIA data.

Table 22.1 shows how the discriminant analysis distributed the SNEP plots for each of the mappers' assigned ratings into new ratings based on structural characteristics, including the intrusion and site variables. For example, in our set of 400 sample plots, the LSOG mappers assigned 58 plots to LSOG rating 1. Based on the structural characteristics measured in the field, however, the DA assigned 69.0% of those 58 plots to rating 1, 17.2% to rating 2, 10.3% to rating 3, and 1.7% each to ratings 4 and 5. The percentage of plots in each rating class for which the mappers' ratings correlate consistently with structural characteristics are shown in the diagonal elements of the classification matrix. These are the boldface values in table 22.1.

There are 10 variables that appear to be significant to the classification process at a probability level less than 0.10 (e.g., 90% level of confidence). These are:

1. intermediate canopy; probability of F .0003
2. site class; probability of F .0380
3. select harvest; probability of F .0002
4. other intrusions; probability of F .0677
5. live hardwood, 24 in–28 in; probability of F .0006
6. live hardwood, greater than or equal to 40 in; probability of F .0792
7. other conifer, 30 in–38 in; probability of F .0647
8. other conifer, greater than or equal to 40 in; probability of F .0000
9. hardwood snags, 30 in–38 in; probability of F .0000
10. down conifer, 30 in–38 in; probability of F .0101

Discriminant analysis is subject to the assumptions of normality in the independent (structural) variables, class by class, although the requirements for DA are less stringent than those for other statistical procedures. The data used in our analyses adhere to the normality assumptions in various degrees, that is, some variables appear to be close to normal (based on observing histograms), and others are definitely non-normal. The canopy, site class, and intrusion responses are especially susceptible to the non-normality condition when the sample size is small because, in reality, they are discrete binomial or multinomial variables rather than continuous variables. Therefore, while the probability levels reported for the significance tests may indicate the relative importance of specific variables, they are not absolute and must be viewed with some skepticism.

Table 22.1 shows the results of a discriminant analysis wherein the intrusion and site variables are included with the structural variables. Table 22.2 shows the results of a similar analysis that includes the structural variables only. A comparison of these two tables suggests that human intrusion factors strongly influence the LSOG rankings. Thus, the rankings should not be taken to reflect primarily seral stages, because they combine existing structural characteristics with those reflecting human influences.

The smaller set of variables used to obtain table 22.2 is roughly 5.5% less effective in reducing the classification error than the full set used for table 22.1. The largest difference between tables 22.1 and 22.2 shows up in rating class 3, where only 34% of the plots correspond to the structural characteristics observed on the ground compared with 46% as shown in table 22.1. The comparison indicates also that the canopy, human intrusion, and site variables, taken together, account for about 11% of the total classification accuracy in table 22.1.

When incorporating structural variables only in the DA, There are eight variables that appear to be significant to the classification process at a probability level less than 0.10:

1. live hardwood, 24 in–28 in; probability of F .0002
2. live hardwood, 30 in–38 in; probability of F .0880
3. live true firs, 24 in–28 in; probability of F .0451
4. other conifers, 30 in–38 in; probability of F .0171
5. other conifers, greater than or equal to 40 in; probability of F .0000
6. hardwood snags, 30 in–38 in; probability of F .0000
7. down conifers, 20 in–28 in; probability of F .0430
8. down conifers, 30 in–38 in; probability of F .0083

It is important to note that the values shown in tables 22.1 and 22.2 reflect the structural characteristics of the forest at the plot-level, not at the patch level, thus encompassing both within- and between-patch variability. Table 22.3 shows the results of a discriminant analysis at the patch level using the same plots as those used in tables 22.1 and 22.2 but averaged at the patch level. Only structural components are used for generating table 22.3, however, because the human intrusion variables, being discrete, cannot be averaged among plots within a patch. Hence table 22.3 should be compared with table 22.2.

According to the classification statistics computed by the discriminant analysis, there is a 49.5% reduction in classification error due to the structural components when averaged at the patch level. In the plot-level analysis of table 22.2, there is only a 30.3% reduction, indicating that 19.2% of the reduction in classification error is due to the within-patch averaging of structural components. The main differences among the LSOG rating assignments can be seen by comparing the two classification tables, especially the diagonal elements.

When incorporating structural variables at the patch level, we obtain five variables that appear to be significant to the classification process at a probability level less than 0.10:

1. live other conifers, 30 in–38 in; probability of F .0093
2. live other conifers, greater than or equal to 40 in; probalbility of F .0048
3. hardwood snags, 30 in–38 in; probability of F .0000
4. down other conifers, 20 in–28 in; probability of F .0537
5. down other conifers, 30 in–38 in; probability of F .0036

TABLE 22.1

SNEP plot-level data, mixed conifer forest type, classification matrix for all variables. Total number of correct classifications = 199 (49.8%).

Mappers' Rating	Number of Plots	Rating Assignments from DA%					
		1	2	3	4	5	Total
1	58	**69.0**	17.2	10.3	1.7	1.7	100
2	114	13.2	**63.2**	18.4	5.3	0.0	100
3	94	9.6	36.2	**45.7**	7.4	1.1	100
4	128	7.8	26.6	29.7	**32.8**	3.1	100
5	6	16.7	33.3	16.7	0.0	**33.3**	100
Total	400						

TABLE 22.2

SNEP plot-level data, mixed conifer forest type, classification matrix for all variables. Total number of correct classifications = 177 (44.3%).

Mappers' Rating	Number of Plots	Rating Assignments from DA%					
		1	2	3	4	5	Total
1	58	**63.8**	24.1	8.6	1.7	1.7	100
2	114	15.8	**62.3**	16.7	5.3	0.0	100
3	94	11.7	44.7	**34.0**	8.5	1.1	100
4	128	8.6	35.2	25.8	**27.3**	3.1	100
5	6	0.0	33.3	33.3	0.0	**33.3**	100
Total	400						

These results seem to indicate that the LSOG classifications assigned by the mapping team are more consistent at the patch level than the plot-level, because there is obviously a substantial within-patch variability in structural components that is absorbed by averaging plots within patches. On the other hand, the overall differences among LSOG ratings are less significant at the patch level than at the plot-level.

Analyses of FIA Data

In terms of structural components and intrusion variables, the FIA data set yielded classification results similar to the SNEP data when subjected to discriminant analyses. However, when the SNEP and FIA data sets were made factors in a two-way multivariate analysis of variance (MANOVA), the two sets tested as being significantly different at the .05 probability level. Because of this, it was inappropriate to combine the two sets of data directly in one large discriminant analysis. Instead, the results from the two data sets were reported separately.

When employing the FIA data set, we again concentrated on the mixed conifer forest type with data obtained from the Lassen, Plumas, Sequoia, and Stanislaus national forests. Only plot-level data were used, of course, because the FIA plots were not deployed in concert with SNEP polygons or patches. Both structural components and intrusion factors were used in analyzing the FIA data. However, the intrusion variables were different here than in the SNEP data, as noted earlier.

In table 22.4, it appears that the rating assignments made by the DA are clustered somewhat more tightly around the diagonal elements than for any of the SNEP analyses. Also, the results seem to be somewhat more accurate, because correct classifications were obtained 53.0% of the time compared with the 49.8% correct classification rate shown in table 22.1, a modest increase. No explanation is available for these differences.

On the other hand, the averages of many of the structural components are significantly different when comparing the SNEP and FIA data sets. This indicates either that they represent different geographical areas or that the measurement standards and/or definitions for structural components mean different things to different people. There is credence to the notion that the FIA plots represent different geographical areas than the SNEP plots. We obtained no FIA plots from the Eldorado National Forest, where many SNEP Plots are located, and conversely, there are no SNEP plots in the mixed conifer type in the Plumas, Sierra, or Tahoe National Forests, where FIA plots are located. If, indeed, there are significant differences among the structural variables between geographical subareas, then each major forest type should be further stratified into smaller spatial units such as national forests, counties, or natural watersheds.

TABLE 22.3

SNEP patch-level data, mixed conifer forest type, classification matrix for all variables. Total number of correct classifications = 87 (59.6%).

Mappers' Rating	Number of Plots	Rating Assignments from DA%					
		1	2	3	4	5	Total
1	14	**64.3**	28.6	7.1	0.0	0.0	100
2	46	6.5	**78.3**	15.2	0.0	0.0	100
3	40	2.5	40.0	**52.5**	5.0	0.0	100
4	43	2.3	23.3	30.2	**44.2**	0.0	100
5	3	0.0	33.3	0.0	0.0	**66.7**	100
Total	146						

Only three variables in the FIA data set are sufficiently significant to seriously affect the results if removed from the analysis:

1. Intermediate canopy; probability of F .0794
2. Live hardwoods, greater than or equal to 40 in; probability of F .0655
3. True fir snags, 30 in–38 in; probability of F .0620

Structural Characteristics

From the analyses of both the SNEP and FIA data, we obtained table 22.5, showing the average value (e.g., number of pieces per acre) of each structural component by LSOG rating class. This table may be useful because it shows the average structure of the forest in each LSOG rating class as these ratings are currently thought of by the mapping team. By working with this table, it should be possible to construct definitions for the expected structural composition of LSOG rating classes and, perhaps, correlate the structural composition of patches to the variables used by the mappers to assign ratings in the first place.

CONCLUSIONS

Because of limitations in the geographical scope of the data we were able to obtain, this discussion is limited to portions of the mixed conifer type as defined by the LSOG mapping team.

The LSOG maps prepared by the SNEP team can serve as a tool for stratifying the Sierra Nevada into broad groups of late successional forest structural patterns. Our analyses indicate, however, that there is a high level of structural diversity for any given assigned patch rating.

The amount of diversity in stand structures within patches of different LSOG ratings is exemplified in tables 22.2 and 22.3. In table 22.2, "correct" assignments of patch rating at the plot-level ranged from 27% to 64% with an average classification accuracy of only 44.3%. For the patch level averages shown in table 22.3, "correct" assignments of LSOG ratings were made between 44% and 78% of the time, with an average accuracy of 59.6%; this would indicate that considerable smoothing takes place when averaging at the patch level.

When accuracies such as these are combined at the polygon level, substantial variations are likely to occur, particularly because different combinations of patch ratings occur in different polygons having similar overall LSOG ratings. Within polygons, the classification accuracies vary considerably among rating classes at the patch level. When assessing polygons, therefore, it may be useful to note the patch ratings within the polygons being evaluated to obtain an indication of reliability at the polygon level.

The magnitude of the classification errors shown in this report indicate that it would be dangerous to attempt detailed site-specific predictions of forest structure at the plot, patch, or even polygon levels directly from the LSOG maps. On the other hand, it may be feasible to use the LSOG ratings with structural values to simulate average stand development over larger land areas, such as national forests, counties, or large watersheds. The average values of structural components, such as those shown in table 22.5, illustrate the kind of data that might be used for this purpose. There is a problem, however, in that the values in table 22.5 were derived from plot-level data. To be utilized properly, the SNEP LSOG maps require data that are averaged at the patch level. Unfortunately, no large quantity of data exists to satisfy this condition over the range of the Sierra Nevada Ecosystem Project. Also, it would be difficult to obtain such data because, except for a few sample polygons, no patch boundaries within polygons are defined on the maps.

Returning to the primary questions posed in the introduction, how consistent are the patch ratings assigned by the mapping team based on structural characteristics of the forest? At the patch level, the mappers were consistent in making rating assignments about 60% of the time overall, at least

TABLE 22.4

FIA plot data, mixed conifer forest type, classification matrix for all variables. Total number of correct classifications = 98 (53.0%).

Mappers' Rating	Number of Plots	Rating Assignments from DA%					
		1	2	3	4	5	Total
1	10	**50.0**	50.0	0.0	0.0	0.0	100
2	77	14.3	**63.6**	19.5	1.3	1.3	100
3	49	12.2	26.5	**53.1**	6.1	2.0	100
4	43	4.7	27.9	27.9	**34.9**	4.7	100
5	6	0.0	16.7	33.3	0.0	**50.0**	100
Total	185						

TABLE 22.5

SNEP and FIA plot-level data, average values of structural variables pieces per acre.

	LSOG Rating Class									
	1		2		3		4		5	
Variable	**SNEP**	**FIA**	**SNEP**	**FIA**	**SNEP**	**FIA**	**SNEP**	**FIA**	**SNEP**	**FIA**
Live trees										
Hardwood, 24"–28"	.34	.00	.59	.32	.37	.67	1.00	.51	.83	.39
Hardwood, 30"–38"	.23	.00	.24	.14	.13	.21	.23	.15	.83	.00
Hardwood, >=40"	.00	.00	.13	.03	.08	.01	.01	.06	.00	.00
True firs, 24"–28"	.09	2.21	2.39	2.73	3.03	3.77	3.34	3.79	6.25	4.26
True firs, 30"–38"	.17	.74	1.45	1.31	2.42	2.09	3.16	2.26	3.33	2.69
True firs, >=40"	.26	.32	.46	.49	1.14	.94	1.21	.69	2.08	.89
Other conifers, 24"–28"	2.16	3.15	3.36	3.64	3.59	4.65	3.98	5.88	2.50	4.80
Other conifers, 30"–38"	1.16	1.77	2.48	2.33	2.13	3.86	3.85	4.06	.42	3.68
Other conifers, >=40"	.26	1.12	1.23	.90	1.36	1.73	3.22	1.81	3.33	2.67
Snags										
Hardwood, 24"–28"	.11	.00	.03	.02	.05	.04	.09	.01	.42	.00
Hardwood, 30"–38"	.02	.00	.00	.01	.01	.03	.04	.04	.83	.00
Hardwood, >=40"	.02	.00	.00	.01	.00	.01	.00	.01	.00	.00
True firs, 24"–28"	.02	.24	.36	.25	.51	.33	.62	.62	.21	.60
True firs, 30"–38"	.11	.24	.19	.13	.29	.22	.56	.43	.62	.87
True firs, >=40"	.00	.00	.08	.10	.25	.19	.25	.23	.21	.47
Other conifers, 24"–28"	.17	.20	.31	.22	.48	.20	.28	.20	.21	.40
Other conifers, 30"–38"	.17	.28	.36	.31	.37	.30	.40	.30	.00	.20
Other conifers, >=40"	.11	.12	.23	.05	.33	.17	.47	.15	.00	.33
Down Material										
True firs, 20"–28"	.19	.40	1.41	.85	1.64	.93	1.84	1.12	2.08	2.80
True firs, 30"–38"	.04	.24	.55	.50	.73	.33	.85	.45	1.46	1.73
True firs, >=40"	.04	.00	.43	.11	.65	.20	.62	.02	1.46	.53
Other conifers, 20"–28"	1.53	2.08	1.96	2.32	2.47	2.14	2.54	1.60	2.71	1.60
Other conifers, 30"–38"	.62	1.20	1.46	.77	1.17	.57	1.31	.47	3.12	.80
Other conifers, >=40"	.28	.08	.90	.27	.84	.16	1.06	.15	1.67	.13

in the mixed conifer forest type. The reliability of these assignments is higher in the lower rating classes (about 65% for classes 1 and 2) and lowest in the higher ratings (about 44% for class 4).

What are the structural characteristics of each assigned LSOG rating when measured on a scale of 1 to 5? Table 22.5 summarizes these results to the extent they are known at present.

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Number Cruncher Statistical System. Product 5.3, Advanced Statistics. Jerry L. Hintze, Kaysville, Utah. This is the statistical software package used for this study.

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