The Delphi Method: Application to Elk Habitat Quality

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RESEARCH SUMMARY

Forest Service decision-making processes frequently need information that cannot be adequately met with existing knowledge and data, yet field data collection is often infeasible or untimely. Certain nonfield methods can provide defensible, timely information. Delphi is one such method.

Eleven elk habitat experts served as participants in our Delphi study. Each participant evaluated the summer cover quality of 171 elk habitat settings by rating them on a scale of 1 to 7 and recording their reasons for the ratings. These evaluation bases were then made known to all participants, who could then reassess their original judgments. This process of evaluation, feedback, and reevaluation was made (iterated) three times to obtain final summer cover ratings, and again to obtain summer forage quality ratings. Study results consist of habitat quality ratings and evaluations of the Delphi process.

Habitat quality ratings ranged from "very low" to "very high," with frequency forming a bell shape for both summer cover and forage quality. The quality of elk summer cover was highly related to the structure of site vegetation—tree size and stand density. Summer forage quality was highly related to the type of vegetation on the site—vegetation cover type and forest habitat type. Discriminant functions were developed capable of correctly classifying up to 90 percent of the sites into habitat quality classes based on site characteristics.

We also evaluated the Delphi process. The 11 research participants each devoted an average of slightly over 13 hours to this study. Significant improvements in participant agreement (consensus) on habitat quality ratings were achieved by means of the three-iteration process, but the median rating for each of the 171 settings rarely changed. No statistically significant difference was found in consensus between participants on the basis of their occupational status, expertise, or experience. However, a small but statistically significant difference was found between habitat quality ratings of managers/administrators and researchers/academics. Participants indicated satisfaction with the Delphi process and confidence in the habitat quality ratings.

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INTRODUCTION

Managers in the USDA Forest Service, like those in other public resource management organizations, are required to base decisions on careful evaluations of management actions. To ensure thoroughness in evaluation, a wide range of consequences are typically assessed, such as national economic development, environmental quality, regional development, and social well-being. To ensure consistency, comparability, and integrity in evaluations, formal procedures are adopted, sometimes requiring the use of sophisticated mathematical models. As a result, more, better, and different kinds of data, relationships, facts, and figures are needed. More than ever before, information fuels the furnaces of decision making.

But like money, information does not grow on trees. Information must be gathered by people using some process. Resource scientists extract information from data gathered through use of the scientific method, along with rigorously controlled experimental designs and meticulously collected measurements. Unfortunately, the constraints of scientific research often lead to information that is "too little, too late." When review of the scientific literature fails to provide needed information, resource managers gather their own, frequently employing procedures that emphasize speed and simplicity—"quick and dirty." While information so generated satisfies the data requirements of mathematical models, too often it lacks the scientific credibility needed to defend results.

Choice between information-generating methods need not be limited to "too little, too late" or "quick and dirty." A number of techniques currently exist whereby timely and credible information can be developed, namely the Nominal Group Technique and the Delphi Method. Both techniques produce information by systematically exploiting the opinions, ideas, experience, and knowledge of individuals, and neither technique involves onsite field measurements. The Delphi Method differs from the Nominal Group Technique by not requiring a face-to-face meeting of the group participants. This feature has two important implications. First, participants are not unduly influenced by the status or personal style of any other participant. Second, because participants need not congregate in one place, Delphi avoids the time and expense of travel and, consequently, can be relatively inexpensive to apply.

Delphi is not a panacea for all information woes. Indeed, there are instances where Delphi is inappropriate or where some other technique may be preferable. But Delphi does hold the promise of being able to provide quality information over a wide range of topics important to natural resource managers. The biggest impediment to application of Delphi may well be its lack of exposure. Resource managers are simply unacquainted with it.

This paper reports on the results of a study designed both to gather important information through Delphi and to evaluate several key features of the Delphi process. We intend to present information developed, and also describe and discuss Delphi so as to make resource managers more comfortable with it, aware of its potential, and willing to consider it along with other information gathering tools.

This study focuses on the quality of elk habitat in western Montana and the Delphi Method. We not only wanted to better understand elk habitat but the Delphi Method as well. Elk habitat quality data were developed through a Delphi process and then these data were assessed: (1) to determine the effect of vegetation type and structure on habitat quality; (2) to determine the effect of site-specific factors, such as temperature and moisture, on habitat quality; and (3) to develop a technique for assigning a quality rating to a habitat setting. These data were also assessed from several standpoints pertaining to Delphi—effect of iteration and number of participants on consensus, participant selection, and more.

METHODS

Because the methods used in this study are more confusing than complicated, it is best to separate discussion of the Delphi-oriented methods and the analytical methods used. The discussion is somewhat artificial in that while these methods are presented separately, they are in reality interconnected.

Delphi Methods

Delphi was developed by the RAND Corporation as a systematic tool for harnessing group knowledge pertaining to a wide range of program planning matters (Dalkey 1969). Delphi has three main features (Delbecq and others 1975): it uses written responses, participants typically remain anonymous, and the process uses a series of questionnaires to clarify areas of agreement and disagreement. Delphi aims to promote group consensus on some topic or issue by extending the adage that "two heads are better than one." Several heads are used. Consensus is not achieved immediately, if ever. Improvements in consensus result from an iterative process wherein participants assess an issue, document or justify their assessment, and are given opportunity to reassess their earlier position in light of information from other participants.

The several methodological components involved in this study are illustrated in figure 1. This and the next section discuss each component: the topic and why it was selected; how participants were identified and selected; the questionnaire or data-gathering instrument; how feedback was provided to the participants; the exit interview questionnaire used to conclude data collection; and a general description of the methods used to analyze data.

The Topic—Elk Habitat.—The range of topics to which Delphi can be applied is wide. Although almost any topic would do, we wanted to assess one representing an actual information need relevant to forest managers. We also wanted a topic of sufficient scope and complexity to be judged nontrivial, yet manageable. We considered topics from timber management, recreation management, wildlife management, and so on. The one we eventually selected involved measuring the quality of elk (*Cervus elaphus nelsoni*) summer forage and summer cover in Montana west of the Continental Divide. Although winter range is often considered a limiting factor for elk, summer habitat was selected for study because National Forest System lands contain a substantial portion of elk range that is predominantly summer range. Thomas (1979) describes forage as vegetation used for food by wildlife; cover is vegetation used by wildlife for protection from predators, to ameliorate conditions of weather, or in which to reproduce. No distinction was made between thermal (from heat) and hiding (from predators) cover.

Montana west of the Continental Divide was selected as the study's geographical scope because it is a major elk-producing area, and elk habitat considerations are often critical in forest management. The area is also large enough—western Montana is roughly the size of West Virginia—that obtaining similar information from field measurements would be essentially infeasible. Finally, the study area is relatively homogeneous ecologically.

Participant Selection.—As with any group process, Delphi requires participation by a set of individuals. The type of participants used in a Delphi project should depend on the nature of the topic being addressed. The topic of elk habitat quality called for participants with a specialized, technical knowledge consistent with the term "experts," recognized authorities on elk habitat. Unfortunately, because there is no directory of elk habitat experts, we needed to identify them ourselves.

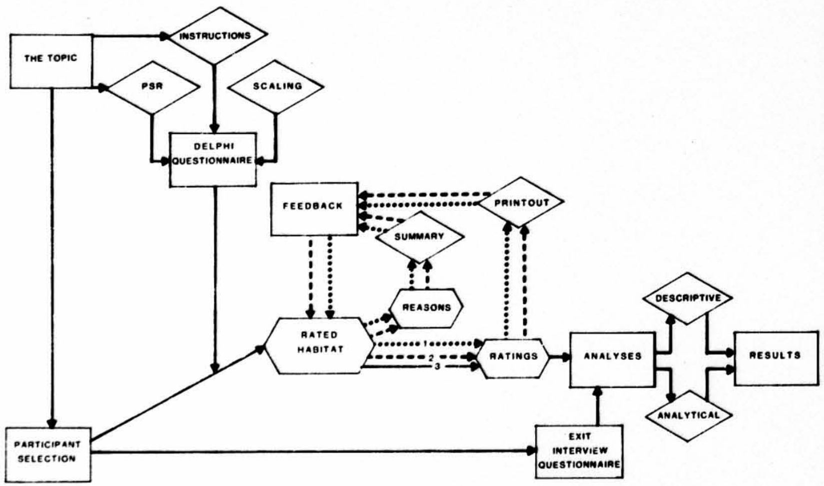


Figure 1.—Flowchart of study methodological components and their linkages.

Numerous direct and indirect ways exist for identifying elk habitat experts. We developed a composite procedure that actually consisted of several methods. The approach used could be called "networking," being similar to that used in sociological studies to identify a community's power structure (see, for example, Domhoff 1978).

Based on the study team's perception of people with substantial knowledge in elk habitat, a "starter" was selected. We attempted to identify a knowledgeable person who would not likely be judged by others as an expert. That person was interviewed and asked to list all experts on elk habitat management in western Montana:

> . . . Please identify all individuals that you consider to be experts. They may be from any occupational status, such as managers, teachers, administrators, researchers, or from the lay public. They need not be physically located in western Montana, but must be knowledgeable about it. Please include yourself, if appropriate.

The starter was then instructed to rank the identified persons in terms of the degree of expertise, from most to least, paying particular attention to correctly specifying the order of the top-three persons. Each of the top-three experts from the starter's list was then contacted and asked to identify and rank all experts, again paying particular attention to the order of the top three. All new top-three experts were then contacted and the process was continued until no new top-three experts were identified. This procedure was adopted so that we could later compare the ability of different approaches to identify experts.

To ensure procedural consistency, a standard interview format was always used. All interviews were either conducted in person or by telephone. Each individual contacted was free to use personal criteria for judging an expert. As was the case throughout the entire study, individuals were given the assurance of anonymity, that their identity and organizational affiliation would be held in the strictest confidence.

The Data-Gathering Instrument.—Any Delphi exercise must use some method to address the topic and obtain measurements—a data-gathering instrument. Although in Delphi this instrument is called a questionnaire, it need not look like a normal questionnaire. In our case, the data-gathering instrument consisted of pictorial site representations (PSR's), a scaling or classification procedure, and a set of instructions.

If this were a field study, actual measurements would be made on a site. The PSR's depicted conditions that might be found on an actual site. We identified 171 specific elk habitat settings (discussed later) representing various combinations of (1) vegetation cover type, and if forested, (2) groupings of forest habitat types (Pfister and others 1977), (3) tree size, and (4) stand density or stocking. For example, one of the 171 settings was a well-stocked stand of sawtimber-sized lodgepole pine trees growing on a spruce habitat type. There were 171 PSR's, one for each elk habitat setting.

Figure 2 shows that each PSR consisted of a written description of the vegetation and its environment, a black and white sketch showing a cross-sectional view of the vegetation, and an illustrative, color photocopy. Substantial thought went into the content and format of the PSR. The result represented a compromise between what was desired and what was physically and financially possible. For example, we wanted to use color prints exclusively, but they were prohibitively expensive. Similarly, while we wanted to use two photographs (near and far view), we could not accumulate a satisfactory set of photographs for all 171 elk habitat settings. Therefore, only near-view photographs were used.

The study team produced the PSR's. We obtained many color photographs from existing print and slide collections. If the needed photographs were either inadequate or not available, a study team member traveled to appropriate sites and took the photographs. An artist knowledgeable in vegetation structure drew the black and white sketches. The written descriptions were based on Pfister and others (1977). Initial descriptions were reviewed and revised by Robert D. Pfister. We assembled all materials into a master set. A local commercial operator duplicated the master set on heavyweight bond paper for each participant.

A scaling procedure was designed to classify PSR's into habitat quality groups, thereby providing a measurement of the quality of each PSR in terms of elk summer cover and forage. We chose to use a modified Q-sort Method (Selltiz and others 1959) and a seven-level scale. We sent each Delphi participant a set of 171 randomly ordered PSR's. The participants were told to look through the PSR's to get a feel for the range of conditions with which they were to work. They were then instructed to place each PSR into one of three groups according to elk habitat quality—high, medium, and low—initially for cover and then later in the study for forage. The high and low quality groups were then further subdivided into two groups, and the middle group was subdivided into three groups. Thus, each PSR was systematically placed into one of seven groups. Numerical codes were assigned to the groups of PSR's according to the following definitions:

Very low	(1)	—	The worst sites, with virtually no habitat value
Low	(2)	—	Poor, but with minimal elk habitat value
Low medium	(3)	—	The poorest of the medium sites
Medium	(4)	—	Adequate or average
High medium	(5)	—	The best of the medium site
High	(6)	—	Somewhat less than best but still high quality
Very high	(7)	—	The best sites

Participants were invited to adjust PSR's among groups to ensure that each PSR ultimately corresponded to the group's definition.

Participants were provided with other instructions that promoted consistency. The following instructions are typical, though specifically pertaining to summer cover measurements:

COVER TYPE: LODGEPOLE PINE

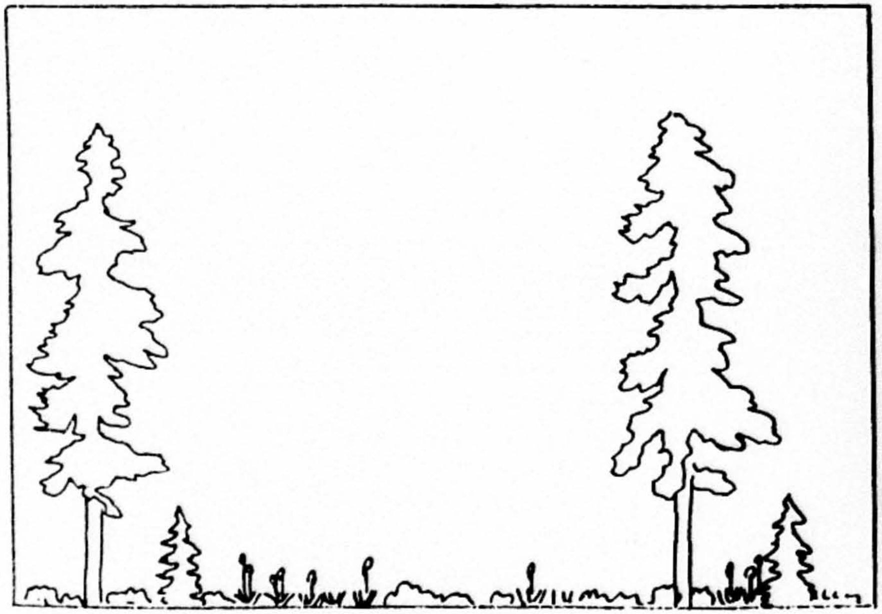
Stand Size: Sawtimber (>9" diam.)

Stocking Level: Poorly Stocked (11-40% tree crown cover)

HABITAT:

DOUGLAS-FIR - IV — Douglas-fir/blue huckleberry and Douglas-fir/twinflower (blue huckleberry phase) habitat types.

Closed canopy stands on relatively cold sites, usually bordered upslope by subalpine fir types. Stands range from 3000 to 6000 feet in elevation.
Understory dominated by shrubs such as blue huckleberry and spiraea, but also support beargrass.



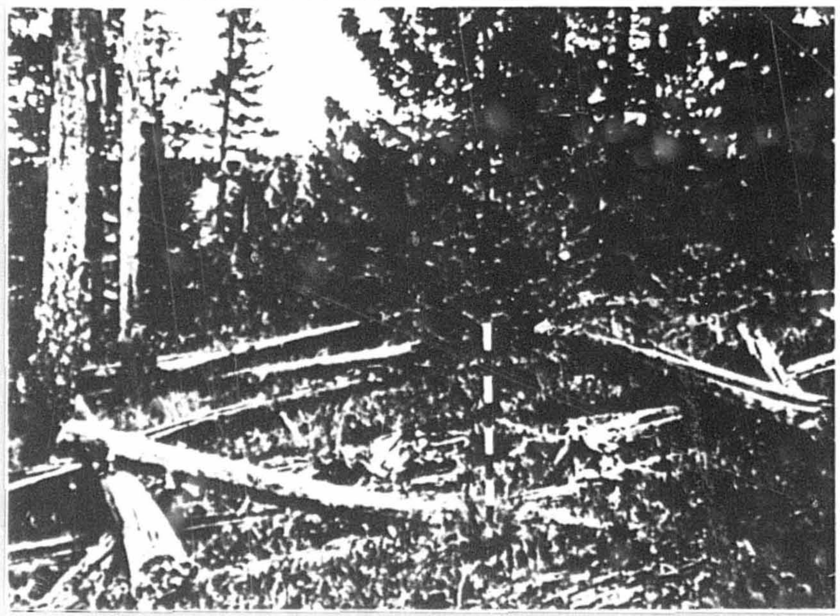


Figure 2.—Illustration of a pictorial site representation (PSR).

1. Your ratings are for elk habitat only.
2. Our concern at this point is for elk summer cover quality in western Montana. Do not complicate the situation by attempting to visualize winter cover, summer food value, and so forth. We are only interested in how valuable each site is for providing cover for elk during midsummer, prior to any range shifts that might occur due to the onset of the rut.
3. Remember that each PSR illustrates a specific site condition. Try to keep the general site characteristics in mind when doing the rating and don't get led astray by some minor peculiarity of a particular photo.
4. We are assuming there are no active roads in the vicinity and there has been no timber harvesting or other stand manipulation.
5. The PSR's are designed specifically to represent a range of conditions common in the forests of Montana west of the Continental Divide and should be evaluated in terms of that area.

Each participant was also provided a form on which to keep track of the time spent on aspects of the study. Participants were instructed to complete all tasks and return all material (in a stamped return envelope) by a specified date, usually about 2 weeks. Finally, participants were instructed not to discuss this study or their involvement with others.

Feedback.—A Delphi process is designed to promote group agreement (consensus) on a topic. This is accomplished by "controlled feedback" and "iterations." The feedback process allows participants to share with each other their personal basis for the judgments. The iteration (repeating) process allows participants to reassess their prior individual judgments in light of the summarized information (reasons, opinions) provided by all participants. There are two important aspects to the feedback process. One relates to acquisition of information by the study team and the other deals with presentation of summarized information to the participants. There is no standard format to provide feedback in Delphi. It must be tailored to the situation.

The study team devoted many hours to discussing alternative types of feedback. We selected two. One type involved summarizing the bases participants used for their judgment. The other type of feedback involved providing each participant with some quantitative information on how the PSR's were rated by other participants. Because all ratings were stored in computer data files, the study team already had information on how the PSR's were rated. The reasons given by participants for rating PSR's were obtained by a short questionnaire. When completed, the questionnaire provided the study team with a listing of the common characteristics associated with the PSR's in each category. The following directions were provided:

> . . . In the spaces provided, please list (complete sentences) up to three statements you would use to characterize the common elements represented by PSR's in quality category 1, quality category 2, and so forth. For example, "all PSR's in category 1 are very open, young stands with little crown cover."

Collecting feedback information was considerably easier than communicating it back to the participants. After all sets of reasons (common elements) were received from each participant, the reasons were evaluated by "content analysis" procedures (see Bowers 1970) to further identify common features. After several trials, content analyses were judged too unwieldy and were discontinued. To condense exhaustive amounts of written information into a manageable form, the study team chose to summarize stated reasons in the form of summary evaluations. One set of reasons was developed and provided to each participant. Each set consisted of seven pages, one for each rating category. Each page contained information in five categories—tree cover, tree size, habitat type, cover type, and other features. The order in which these categories appeared on a summary evaluation page was varied so as to preclude any bias introduced by a consistent order. A partial illustration of a page follows:

Category 1 - Very Low - Forage

I. Tree cover:*

Nonstocked – 20%
Poorly stocked – 35%
Medium stocked – 10%
Well stocked – 0%

.
.
.

V. Other:

Poor soils – 20%
Vegetation dries early – 20%

*Percentage indicates proportion of experts using or mentioning the characteristic in their reasons.

The study team carefully considered how to best communicate quantitative information about how the PSR's were rated. The issue was not to provide a comparison showing PSR ratings and how an individual participant related to others. Rather, the issue pertained to the amount of detail. Arguments against detail were based on the fear of exerting too much pressure on the participants to conform. Arguments in favor of detail were based on the premise that a participant is more likely to modify a judgment if that judgment is perceived to be nonconforming. We adopted the more detailed approach. Each participant was provided a computer printout of the ratings (rating printout), as partially illustrated:

	All experts combined				
PSR	Low	High	Median	Your rating	Difference
1	2	4	4	3	−1
2	4	4	4	4	0
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
171	6	7	6	6	0

The summary evaluations and the rating printouts constituted the feedback provided to each participant after the initial rating. Consistent with contemporary

Delphi literature and application, each interaction (including the first) with participants constitutes an "iteration." By convention, the first iteration has no feedback.

In principle, the number of iterations used in a Delphi project is open-ended, determined on the basis of some prespecified level of consensus desired. The iterative process continues until the consensus standard is met. But because we wanted to measure the effect that the number of iterations had on consensus, several iterations were needed. Because we did not believe the experts would agree to participate in a process with no finite limits, we decided to use three iterations for both the elk summer cover phase and the forage phase. This amount represented our judgment as to the minimum number of iterations needed to measure the effect of iterations on final consensus and the maximum burden we could reasonably place on the participants.

All feedback materials, and the 171 PSR's as previously sorted, were returned to each participant to begin the second iteration. The second iteration consisted of each expert reassessing first iteration judgments in light of the feedback materials. Individual PSR's were shifted from one habitat quality group to another. When reassessments were completed, participants again recorded their reasons and returned the materials. The process was iterated for a third time, thus completing the summer cover phase. The entire three-iteration process was repeated for summer forage.

Exit Interview Questionnaire.—After all habitat quality data had been gathered, the study team wanted to know the participants' reactions to the Delphi process. What were the strengths and weaknesses? Were seven Q-sort groups too many? Was the feedback adequate? These and other concerns were addressed in an exit interview questionnaire, available on request from the authors. The questionnaire was mailed to participants. Upon return of all questionnaires, data collection was complete and final analyses were started.

Analytical Methods

This section briefly describes the variables, methods, and conventions used to design the study and analyze the data. It does not provide enough detail to duplicate the analyses, but rather enough for the reader to develop a general comprehension. More details pertaining to analytical methods will be provided later, as appropriate, along with study results.

Variables.—This study used two classes of variables—primary and secondary. The primary variables resulted directly from the main thrust of the study, were the basis for the study's experimental design, and specified the way PSR's were characterized. Table 1 identifies and defines primary dependent and independent variables. All variables are measured on either nominal or ordinal scales, with analytical implications that will be discussed later.

The primary dependent variable used in this study consists of elk summer cover and forage quality ratings. For purpose of conducting statistical or numerical analyses, the habitat quality ratings were assigned numerical values ranging from 1 for very low to 7 for very high. Measures of central tendency for this type of ordinal scale data include the median (middle) and mode (most frequent) rating, but exclude the arithmetic mean. This study used the median rating to reflect a PSR's final, overall rating. The median was also used as a basis to reflect both variation in habitat ratings and consensus. We used the average or mean deviation from the median (MDM) as our measure of variation and consensus. This is calculated by summing the (absolute) deviations from the median over all participants and dividing by the number of participants. The higher this number, the more variation around the median. MDM is comparable to an unsquared version of the "variance" used in conjunction with a mean. If all 11 experts rated a situation as "medium" (4), the median would be 4 and the mean deviation from the median would be 0, thus achieving unanimity, complete agreement, or perfect consensus.

The forest habitat type group variable was created by the study team. To use all of the individual forest habitat types would have been too cumbersome and unnecessarily specific for our purpose. Therefore, the individual forest habitat types identified by Pfister and others (1977) were grouped into 18 habitat type groups. These are presented in appendix A, along with their constituent forest habitat types. The grouping represents a slight modification and updating of an elk habitat group scheme developed by Forest Service wildlife managers for use in western Montana (USDA Forest Service 1980).

While the forest habitat type group variable and the vegetation cover type variables can be used separately, we frequently combined them. These combinations correspond to major natural occurrences of habitat type groups and cover types in western Montana. Table 2 shows the 37 naturally occurring combinations of our 18 forest habitat type groups and 12 vegetation cover types. Depending on the purpose, some analyses used the combinations, while others used either the 18 habitat type groups or 12 cover types separately.

Similarly, combinations of tree size class and stand density classes were developed. Tree size (TS) was divided into three classes: seedling/sapling (S/S), poletimber (Pole), and sawtimber (Saw). Stand density (SD) was also divided into three classes: poor, medium, and well stocked. The ideal would have been an elk habitat represented by all possible combinations of tree size and stand density classes. This proved infeasible for two reasons. First, not all combinations of size and density occur naturally. An example is the poorly stocked seedling-sapling stands of western redcedar, a combination that basically does not naturally exist. Second, we wanted to keep the participants' workload within reason, and all combinations seemed unreasonable. To simplify matters, we adopted five combinations, instead of the potential nine:

Stand	Tree size class		
density class	S/S	Pole	Saw
Poor	X		X
Medium		X	
Well	X		X

Table 1.—Description of dependent and independent variables used in study

Type of variable	Name of variable	Measurement scale	Code or attribute	Definitions
Dependent	Cover quality and forage quality	Ordinal	1 or VL	Very low: worst sites. with virtually no habitat value
			2 or L	Low: poor. but with minimal elk habitat value
			3 or LM	Low medium: poorest of the medium sites
			4 or M	Medium: adequate or average
			5 or HM	High medium: best of the medium sites
			6 or H	High: somewhat less than the best but still high quality
			7 or VH	Very high: the best sites
Independent	Forest habitat type groups	Nominal	1 – 18	Groups of forest habitat types. (An aggregation of all land areas potentially capable of producing similar plant communities at climax: Pfister and others 1977)
Independent	Vegetation cover types	Nominal	1 – 12	Existing overstory vegetation. If forested. based on species forming a plurality of live-tree stocking (Green and Setzer 1974)
Independent	Tree size class	Ordinal or nominal	—	A classification of forest land based on size classes of growing stock trees on the area
			—	Stands at least 16.7 percent stocked with growing stock trees. with half or more of stocking . . .
			Saw-timber	. . . in sawtimber or poletimber trees. and sawtimber stocking at least equal to poletimber stocking (saw-timber trees are ≥9.0 inches dbh)
			Pole-timber	. . . in poletimber and/or sawtimber trees. and with poletimber stocking exceeding that of sawtimber (pole-timber trees are >5.0 to <9.0 inches dbh)
			Seedling and sapling	... in saplings or seedlings (seedling and sapling trees are ≤5.0 inches dbh)
Independent	Stand density class	Ordinal or nominal	—	A classification of forest land based on the density of trees on the area
			Poor	11 to 40 percent crown cover. or 16.7 to 60.0 percent normal stocking
			Medium	41 to 70 percent crown cover. or 60 to 100 percent normal stocking
			Well	71 to 100 percent crown cover. or 100 to 133 percent normal stocking

Because all treatment combinations are not present. this study used an incomplete block design. Depending on the purpose. some analyses used the combinations of size and density classes. while others used size or density classes individually. or both.

Let us recap the origins of the 171 PSR's. Of the 37 combinations of habitat type groups and cover types. three were nonforested. and the notions of tree size and stand density were not applicable. These nonforested combinations account for three PSR's. Of the remaining 34 combinations. one occurs only in medium and well-stocked stands: this situation resulted in three PSR's. The remaining 33 combinations could be represented by all five size and density combinations. These account for 165 (5 × 33) PSR's. In total. we used 171 (3 + 3 + 165) PSR's.

A large number of secondary variables were also used in supporting analyses:

Secondary dependent variables	Secondary independent variables
Mean deviation from median	Iteration
Exit interview results	Number of participants
Time record results	Participant characteristics
	Habitat type components

These variables were used both in conjunction with primary variables and separate from primary variables. Many variables listed are actually groups of more specific variables. For example. the answer to each question on the exit interview questionnaire represented a potential dependent variable. Similarly. for several analyses we used six components of habitat type as candidate independent variables—such as elevation. moisture. and temperature. Some secondary variables were measured on a nominal scale. such as habitat type components. But others were measured on a ratio scale. such as time.

Table 2.—Naturally occurring combinations of forest habitat type groups and vegetation cover types

Forest habitat type groups	Vegetation cover type											
	Hardwoods	Ponderosa pine	Douglas-fir	Lodgepole pine	Western larch	Engelmann spruce	Grand fir	Western redcedar	Subalpine fir	Whitebark pine	Forbs and grasses	Shrubs
Bottomlands	x											
Ponderosa pine		x										
Scree		x	x									
Douglas-fir I		x	x									
Douglas-fir II		x	x									
Douglas-fir III		x	x	x								
Douglas-fir IV			x	x								
Douglas-fir V		x	x									
Spruce	x			x		x						
Western redcedar/grand fir							x	x				
Subalpine fir I			x	x	x	x						
Subalpine fir II				x		x			x			
Subalpine fir III				x					x	x		
Subalpine fir IV				x		x			x			
Whitebark pine										x		
Mountain meadow											x	
Mountain grassland											x	
Mountain brush												x

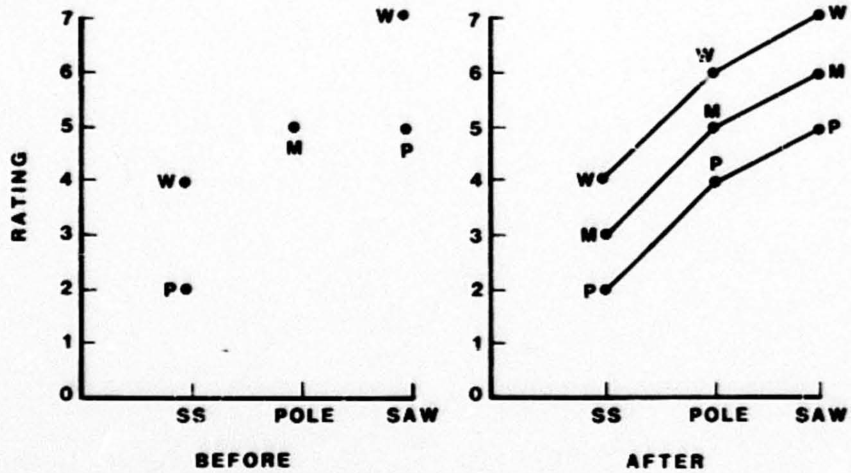


Figure 3.—Illustration of habitat quality ratings, before and after application of interpolation technique.

Ordinal-Level Data Interval-Level Analyses.—Table 1 indicates that habitat quality is measured on a seven-level ordinal scale—very low to very high. Considerable controversy exists concerning the appropriate statistical tests, models, and arithmetic operations that can be performed on ordinal data (see Kirk 1972). Specifically, researchers who have ordinal-scale data would like to apply analytical techniques compatible with interval-scale or ratio-scale data. Those techniques offer more choices and can extract more data. Without belaboring this controversy, the opposing viewpoints are: (1) under no circumstances can interval-scale or ratio-scale operations be applied to ordinal-scale data, and (2) go ahead, do it. The study team struck a compromise. Interval-level statistics were used for testing statistical hypotheses. But ordinal-level statistics were used for describing data and study results. Consequently, we used medians (appropriate for ordinal-level data), not means, to describe habitat quality results. But we also used regression and other analyses (appropriate for interval-level data) to investigate underlying habitat quality relationships.

Analyses Used.—Data files were maintained and analyzed through the services of the University of Montana Computer Center and its DEC-20 computer. The main analyses performed were analysis of variance, linear regression analysis, and discriminant analysis. Statistical analyses and data manipulation used computer software available through SPSS-X and Minitab. Except for the method used for interpolation, all other analyses were conducted in conventional ways.

The interpolation method requires additional explanation. Recall that to lessen the burden placed on the participants, PSR's were developed for only five of the nine combinations of tree size classes and stand density classes. A possible array of median habitat quality results is illustrated:

Stand density class	Tree size class S/S	Pole	Saw
Poor	2	—	5
Medium	—	5	—
Well	4	—	7

We felt an obligation to "fill-in-the-blanks." Study team member, Robert S. Loveless, Jr., developed a procedure for doing so. The procedure could be called "two-dimensional interpolation" and is based on the technique of Median Polish (see Velleman and Hoaglin 1981 or Tukey 1977). The procedure works by discovering and then using patterns within arrays. The array shown above has pattern, ordered from left to right and top to bottom. The missing values are numerically between or equal to those on either side, above, or below. All missing cell values are determined by multiplying the percentage diagonal change by the row or column differences and then adding that product to a leftmost or uppermost known value; this result is rounded to the nearest integer. Figure 3 illustrates the result of this interpolation process. The pattern embedded in the original data provides the basis for specifying the overall pattern.

Two final points regarding analysis should be mentioned. First, statistical tests were always conducted at the 0.05 level of significance. Second, the number of observations used in specific analyses frequently varied, depending on the purpose of the analysis. When necessary, observations were eliminated from analyses to achieve balance in experimental design; balance here refers to a situation where there is an equal number of observations in each analysis class or subclass.

RESULTS

During August 1982 the first packet of materials was sent to each participant. By August 1983 all data had been collected for summer cover and summer forage and the exit interview questionnaire had been completed. Results are divided into two sections—Elk Habitat Quality and the Delphi Process.

Elk Habitat Quality

This section describes the results of elk habitat quality ratings and provides results from three major types of analyses pertaining to those ratings. The first analysis assessed elk habitat quality as related to forest habitat type groups, vegetation cover type, tree size, and stand density. The second analysis assessed habitat quality from the standpoint of the underlying components of forest habitat type, such as site elevation and moisture. The third type of analysis developed a tool by which elk habitat settings can be classified or assigned to a habitat quality class based on site characteristics.

Descriptive Results.—The final measure of elk habitat quality is the median rating associated with the third iteration. Table 3 shows these medians expressed as letter designations (such as L for low), along with interpolated results for elk summer cover and forage. For both cover and forage, results for the 171 settings spanned the quality range from very low to very high. A comparison between cover and forage ratings, for an individual setting,

Table 3.—Final elk summer cover and forage quality ratings, by vegetation cover type, forest habitat type group, stand density class, and tree size class

Vegetation cover types	Forest habitat type groups	Stand density class	Tree size class: Cover: Seedling/sapling	Cover: Pole-timber	Cover: Saw-timber	Forage: Seedling/sapling	Forage: Pole-timber	Forage: Saw-timber
Hardwoods	Bottomlands	Poor	L	LM	M	HM	M	M
		Medium	LM	M	HM	M	M	M
		Well	LM	HM	H	M	M	M
	Spruce	Poor	LM	LM	M	VH	VH	H
		Medium	LM	M	HM	VH	VH	H
		Well	LM	M	H	VH	VH	H
Ponderosa pine	Ponderosa pine	Poor	VL	L	M	L	L	L
		Medium	VL	L	M	L	L	L
		Well	L	LM	M	L	L	L
	Douglas-fir I	Poor	VL	L	LM	L	L	L
		Medium	L	LM	M	L	L	L
		Well	L	LM	M	L	L	L
	Douglas-fir II	Poor	LM	M	M	LM	LM	LM
		Medium	LM	M	HM	LM	LM	LM
		Well	LM	M	HM	LM	LM	LM
	Douglas-fir III	Poor	VL	LM	M	M	LM	LM
		Medium	LM	M	HM	M	LM	LM
		Well	LM	HM	HM	M	LM	LM
	Douglas-fir V	Poor	VL	LM	M	L	L	L
		Medium	L	LM	M	L	LM	L
		Well	L	LM	M	L	L	L
	Scree	Poor	VL	L	L	VL	VL	VL
		Medium	L	L	LM	VL	VL	VL
		Well	L	LM	LM	VL	VL	VL
Douglas-fir	Douglas-fir I	Poor	L	LM	LM	L	L	L
		Medium	L	LM	M	L	L	L
		Well	L	LM	M	L	L	L
	Douglas-fir II	Poor	L	LM	M	LM	LM	LM
		Medium	LM	M	HM	LM	LM	LM
		Well	LM	M	HM	LM	LM	LM
	Douglas-fir III	Poor	L	LM	M	M	M	LM
		Medium	L	M	HM	M	M	LM
		Well	L	M	HM	M	M	LM
	Douglas-fir IV	Poor	L	LM	M	M	M	M
		Medium	LM	M	HM	M	M	M
		Well	LM	HM	H	M	M	M
	Douglas-fir V	Poor	VL	LM	M	LM	LM	LM
		Medium	L	LM	HM	L	L	L
		Well	L	M	HM	L	L	L
	Subalpine fir I	Poor	VL	HM	HM	H	H	H
		Medium	LM	HM	HM	VH	H	H
		Well	LM	HM	HM	VH	H	H
	Scree	Poor	VL	L	LM	VL	VL	VL
		Medium	L	L	LM	VL	VL	VL
		Well	L	LM	LM	VL	VL	VL
Lodgepole pine	Douglas-fir III	Poor	VL	LM	M	LM	LM	LM
		Medium	LM	M	HM	M	LM	LM
		Well	LM	HM	HM	M	M	LM
	Douglas-fir IV	Poor	VL	LM	M	M	LM	LM
		Medium	LM	M	HM	M	M	M
		Well	LM	HM	HM	M	M	M
	Subalpine fir I	Poor	L	LM	M	VH	HM	HM
		Medium	LM	M	HM	VH	H	H
		Well	LM	HM	H	VH	H	H

(con.)

Table 3. (Con.)

Vegetation cover types	Forest habitat type groups	Stand density class	Tree size class: Cover: Seedling/sapling	Cover: Pole-timber	Cover: Saw-timber	Forage: Seedling/sapling	Forage: Pole-timber	Forage: Saw-timber
	Spruce	Poor	VL	LM	M	H	H	H
		Medium	L	M	HM	H	VH	VH
		Well	LM	HM	H	VH	VH	H
	Subalpine fir II	Poor	L	M	HM	HM	M	M
		Medium	M	H	VH	HM	HM	HM
		Well	M	H	VH	HM	HM	HM
	Subalpine fir III	Poor	L	LM	M	M	L	L
		Medium	L	M	HM	LM	LM	LM
		Well	L	M	HM	LM	LM	LM
	Subalpine fir IV	Poor	L	LM	M	HM	M	M
		Medium	LM	M	HM	HM	M	M
		Well	LM	HM	H	HM	M	M
Western larch	Subalpine fir I	Poor	L	LM	M	VH	H	H
		Medium	LM	M	HM	VH	H	H
		Well	LM	HM	H	VH	H	H
Engelmann spruce	Subalpine fir I	Poor	L	LM	HM	VH	VH	H
		Medium	LM	M	H	VH	VH	H
		Well	M	HM	VH	VH	VH	H
	Subalpine fir II	Poor	L	M	M	H	H	HM
		Medium	M	VH	VH	H	H	HM
		Well	M	VH	VH	H	H	HM
	Subalpine fir IV	Poor	LM	M	M	HM	M	M
		Medium	M	HM	H	HM	HM	HM
		Well	M	H	VH	HM	HM	HM
	Spruce	Poor	LM	LM	LM	VH	VH	H
		Medium	M	HM	HM	VH	VH	H
		Well	M	H	VH	VH	VH	H
Grand fir	Western redcedar/grand fir	Poor	LM	M	M	HM	HM	HM
		Medium	M	H	H	M	H	H
		Well	M	H	VH	H	H	M
Western redcedar	Western redcedar/grand fir	Poor	—		M			HM
		Medium	—	M			HM	
		Well	—		VH			HM
Subalpine fir	Subalpine fir II	Poor	M	HM	HM	HM	HM	HM
		Medium	M	H	H	H	HM	HM
		Well	M	H	VH	H	HM	HM
	Subalpine fir III	Poor	VL	LM	M	M	M	LM
		Medium	L	M	HM	M	M	LM
		Well	LM	HM	H	LM	LM	LM
	Subalpine fir IV	Poor	VL	M	HM	HM	HM	HM
		Medium	LM	HM	H	HM	HM	HM
		Well	M	H	VH	HM	HM	HM
Whitebark pine	Subalpine fir III	Poor	VL	LM	M	L	L	L
		Medium	LM	M	HM	LM	LM	LM
		Well	LM	HM	HM	M	M	M
	Whitebark pine	Poor	VL	L	LM	M	M	M
		Medium	L	LM	M	M	M	M
		Well	LM	M	HM	M	M	LM
Forbs and grasses	Mountain meadow	—	—	VL	—	—	VH	—
	Mountain grassland	—	—	VL	—	—	HM	—
Shrubs	Mountain brush	—	—	LM	—	—	M	—

[1]Quality ratings in small print were developed by an interpolation process

shows both consistency and great divergence. Not unexpected, the mountain meadow setting had the greatest rating differences—"very low" for cover and "very high" for forage. On the other hand, the settings containing the scree habitat type received consistent ratings for cover and forage—consistently low.

Inspection of the ratings in table 3 also provides a preview of the analysis results presented later. Note that while the cover ratings generally increase with shifts from poorly stocked seedling-saplings to well-stocked sawtimber, the ratings are far more erratic between forest habitat type groups or vegetation cover types. Similarly, shifts between tree size and stand density classes do not seem to affect forage ratings, while cover type and habitat type groups do.

A general description of habitat ratings would not be complete without some indication of variation in the results. Appendix B contains a complete tabulation of variation levels, as reflected by the mean deviation from the median rating, for all elk habitat settings studied. The average of the mean deviations from the medians for cover was 0.5 and 0.4 for forage. That is, forage ratings were about 20 percent less variable than were cover ratings. Because each unit of deviation represents a class, the average deviations above correspond to about half a class interval. The most variation was found in cover ratings for several cases involving ponderosa pine or Douglas-fir cover types where the mean deviation from the median was 1.1 or more. The least variation (0.0) existed with forage ratings for scree and mountain meadow.

Figure 4 shows a frequency distribution of all 171 elk habitat settings in each habitat quality rating class for both summer cover and forage. These distributions are visibly "normal" in that they resemble a bell-shaped curve. In both cases, the median and modal class is "medium." While the middle five classes show a pattern of consistency between cover and forage, the extreme classes (very low and very high) show opposite patterns. Relatively more elk habitat settings are rated "very high" for forage than for cover (17 versus 6); and relatively more settings are rated "very low" for cover than for forage (16 versus 10).

Vegetation Structure and Type.—This line of analysis sought to determine the influence of the primary independent factors—cover type, tree size, and so forth—and their interactions on elk habitat quality. The main difficulty was that the desired analysis could not be performed directly because the experimental design was not balanced; that is, we did not have an equal number of observations associated with all combinations of levels for the independent variables. Consequently, we had to conduct three analyses that sequentially led to the final results. Desired balance was achieved by eliminating observations. Throughout these analyses, observations from all 11 participants were used. The largest data set contained 1,881 (11 × 171) observations and the smallest contained 1,452 observations.

The first series of analyses were one-factor analyses of variance. Their purpose was to determine which individual factor(s) had the largest and smallest effects on habitat quality ratings. All 1,881 observations were used. Each independent factor or factor combination was used in separate analyses, isolated from other factors. Table 4 combines the results and shows the degrees of freedom.

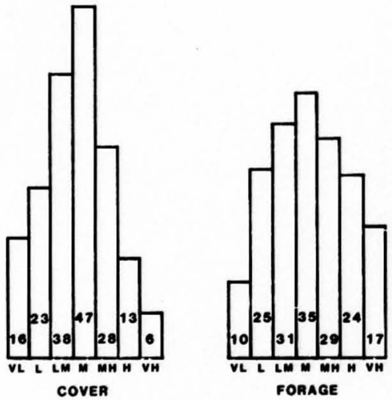


Figure 4.—Frequency distribution of 171 elk habitat settings, by final habitat quality ratings, for summer cover and forage.

Table 4.—One-factor analysis of variance showing the independent influence of six factors on elk summer cover and forage quality ratings

Source of variation	Degrees of freedom	Cover			Forage		
		SS	F	α	SS	F	α
Habitat type (HT)	17	1,215	31.4	<0.001	4,791	468.0	<0.001
Cover type (CT)	11	892	33.2	<0.001	2,766	149.3	<0.001
HT/CT	36	1,295	15.9	<0.001	4,809	223.1	<0.001
Tree size (TS)	3	663	86.5	<0.001	57	6.1	0.001
Stand density (SD)	3	2,260	442.4	<0.001	94	10.1	<0.001
TS/SD	5	2,727	374.6	<0.001	99	6.4	<0.001
Error	varies						
Total	1,880	5,457	—	—	5,913	—	—

sums of squares (SS), the F-statistic (F), and the statistical significance level (α) associated with each PSR component pertaining to cover or forage. Individually, all factors were highly significant. Inspection of sums of squares can indicate relative importance in accounting for variation in cover or forage ratings. The cover analysis indicates that structure of vegetation—TS, SD, TS/SD—is far more important to cover quality ratings than is type of vegetation—habitat type group (HT), cover type (CT), HT/CT. Of the two structure-oriented variables (TS and SD) the stand density variable (SD) is more significant, but tree size (TS) is also important. In contrast, the forage analysis shows that type of vegetation is more important to forage quality ratings than is structure. Furthermore, habitat type group (HT) alone is more important than cover type (CT) alone, explaining almost as much variation as the combination, HT/CT. But the problem with one-factor analyses is that they are incapable of assessing interaction of factors.

The second series of analyses were two-factor analyses of variance on cover and forage ratings. The data set needed to be reduced to 1,815 observations to achieve statistical balance. The two factors considered were the combinations of HT/CT and TS/SD. The purpose was to assess the role of the overall interaction between vegetation structure and vegetation type in habitat quality. Table 5 shows the results, reinforcing the importance of vegetation structure (TS/SD) for cover and vegetation type (HT/CT) for forage. But these analyses were performed to examine the interaction of vegetation structure and type. F-tests of the interaction between vegetation type and structure (A×B) were statistically significant for both cover and forage. However, that statistical significance clearly resulted from the enormous degrees of freedom in the error term. We judged the magnitude of the interaction effect, as indicated by sums of squares, to be trivial—too small for practical importance. We therefore elected to ignore interaction effects between structure (TS/SD) and type (HT/CT) of vegetation.

The third series of analyses were designed to assess the more restricted interaction of tree size (TS) or stand density (SD) with type of vegetation (HT/CT). The three-factor analysis of variance used again called for a reduction in the number of observations in order to achieve statistical balance. Table 6 contains the results. The pattern of statistically significant interaction terms is more pronounced in the cover than forage analysis. In fact, for forage, three of the four interaction terms were not statistically significant. The most substantial interaction found was between vegetation type (HT/CT) and tree size (TS) regarding cover ratings. Nevertheless, even for the significant terms, the magnitude of the interaction effects shown by their sums of squares was trivially small and overwhelmed by the main effects. Interaction effects were again ignored.

Table 5.—Two-factor analysis of variance showing the influence of HT/CT, TS/SD, and their interaction on elk summer cover and forage habitat quality ratings

Source of variation	Degrees of freedom	Cover			Forage		
		SS	F	α	SS	F	α
HT/CT (A)	32	1,069	43.8	<0.001	4,660	270.3	<0.001
TS/SD (B)	4	2,524	828.3	<0.001	62	128.8	<0.001
Interaction: A × B	128	298	3.1	<0.001	107	1.6	<0.001
Error	1,650	1,258	—	—	889	—	—
Total	1,814	5,150	—	—	5,718	—	—

Table 6.—Three-factor analysis of variance showing the influence of HT/CT, TS, SD, and their interactions on elk summer cover and forage quality ratings

Source of variation		Degrees of freedom	Cover			Forage		
			SS	F	α	SS	F	α
HT/CT (A)		32	759.0	29.6	<0.001	3,646.00	212.9	<0.001
TS (B)		1	439.0	547.0	<0.001	5.00	9.5	0.003
SD (C)		1	1,976.0	2,464.9	<0.001	54.00	100.9	<0.001
Interactions:	A × B	32	107.0	134.0	<0.001	24.00	1.4	ns[1]
	A × C	32	81.0	101.5	<0.001	40.00	2.3	<0.001
	B × C	1	6.9	8.6	0.004	.04	.1	ns
	A × B × C	32	50.6	63.1	<0.001	25.00	1.4	ns
Error		1,320	1,058.0	—	—	706.00	—	—
Total		1,451	4,479.0	—	—	4,500.00	—	—

[1] Statistically nonsignificant at 0.05 level

Table 7.—Final analysis of variance showing influence of various factors and their interactions on elk summer cover and forage quality ratings

Source of variation	Degrees of freedom	Cover SS	Cover F	Cover α	Forage SS	Forage F	Forage α
Habitat type (HT)	17	------	not included	------	4,791	468.0	<0.001
Cover type (CT)	11	------	not included	------	------	not included	------
HT/CT	36	1,295	15.9	<0.001	------	not included	------
Tree size (TS)[1]	3	663	86.5	<0.001	------	not included	------
Stand density (SD)[1]	3	2,260	753.5	<0.001	94	10.1	<0.001
TS/SD	5	------	not included	------	------	not included	------
Interactions	varies	------	not included	------	------	not included	------
Error	varies	1,239			1,028		
Total	1,881	5,457			5,913		

[1]Nonstocked was also considered a size and density class in these analyses.

Table 8.—Ranked effect of forest habitat type group/vegetation cover type combinations, tree size class, and stand density class on elk summer cover quality ratings, for final model[1]

Combinations: Cover types	Combinations: Habitat type groups	Contribution	Tree size class	Contribution
Subalpine fir	Subalpine fir I	1.6	Sawtimber	0.4
Western redcedar	Western redcedar/grand fir	1.6	Poletimber	.4
Engelmann spruce	Subalpine fir II	1.3	Seedling/sapling	-.7
Grand fir	Western redcedar/grand fir	1.2		
Lodgepole pine	Subalpine fir II	1.1		
Engelmann spruce	Subalpine fir IV	1.0	**Stand density class**	
Engelmann spruce	Spruce	.8		
Engelmann spruce	Subalpine fir II	.8	Well	1.1
Subalpine fir	Subalpine fir IV	.7	Medium	.4
Hardwoods	Spruce	.4	Poor	-1.3
Western larch	Subalpine fir I	.3		
Lodgepole pine	Subalpine fir I	.3		
Douglas-fir	Douglas-fir IV	.2		
Douglas-fir	Subalpine fir I	.2		
Ponderosa pine	Douglas-fir II	.2		
Hardwoods	Bottomlands	.2		
Lodgepole pine	Spruce	.1		
Subalpine fir	Subalpine fir III	0		
Douglas-fir	Douglas-fir II	0		
Lodgepole pine	Subalpine fir IV	-.1		
Lodgepole pine	Douglas-fir IV	-.2		
Ponderosa pine	Douglas-fir III	-.3		
Lodgepole pine	Douglas-fir III	-.3		
Shrubs	Mountain brush[2]	-.3		
Douglas-fir	Douglas-fir III	-.3		
Whitebark pine	Subalpine fir III	-.4		
Lodgepole pine	Subalpine fir III	-.4		
Whitebark pine	Whitebark pine	-.6		
Douglas-fir	Douglas-fir V	-.6		
Ponderosa pine	Douglas-fir V	-.7		
Douglas-fir	Douglas-fir I	-1.0		
Ponderosa pine	Douglas-fir I	-1.0		
Ponderosa pine	Ponderosa pine	-1.1		
Douglas-fir	Scree	-1.4		
Ponderosa pine	Scree	-1.7		
Forbs and grasses	Mountain meadow[2]	-2.5		
Forbs and grasses	Mountain grassland[2]	-2.5		

[1]Overall mean habitat rating = 3.6
[2]Tree size class and stand density class contributions are not applicable

Final judgments on the importance of various factors and their interactions were based on the knowledge gained in the one-factor, two-factor, and three-factor analyses. Statistical significance and simplicity were important considerations. A simpler model was selected over a more complex one if both were roughly equivalent in helping understand habitat quality. For example, while interaction terms were frequently found significant, their contribution to understanding habitat quality was small, but their addition to complexity was great. The three-factor model, without interactions, was selected as the best model for understanding summer cover quality. Summary analysis of variance results (table 7) shows that the sums of squares for stand density are clearly the most influential factor in explaining cover quality ratings, followed by the combination of habitat type group with cover type, and finally, tree size class. These factors account for 77.3 percent of the variation in cover quality. A two-factor model, consisting only of habitat type groups and stand density, was selected for understanding forage quality. In forage analyses containing interaction terms, the interactions were either statistically insignificant or so small they could be ignored. Furthermore, almost all variation explained by the combination TS/SD was accounted for by SD alone. Similarly, HT accounted for nearly all of the variation explained by the combination of HT/CT. Table 7 also displays analysis of variance results for forage. The factors shown accounted for 82.6 percent of the variation in forage quality ratings.

The cover model in table 7 can be presented in equation form as a three-factor statistical model without interaction terms:

$$C_{ijk} = \mu + (HT/CT)_i + TS_j + SD_k$$

This equation is interpreted as follows: the cover quality (C) of a specific elk habitat setting (ijk) is equal to the overall cover mean (μ), plus the contribution associated with its specific combination (i) of habitat type group and cover type (HT/CT), plus the contribution of its specific (j) tree size class (TS), plus the contribution of its specific (k) stand density class (SD). The overall cover mean (μ) for all elk habitat settings is 3.6. Table 8 shows the contributions associated with levels of all factors. Both the sign and magnitude of the contributions are meaningful. Consider the sign: if the sign of the contribution is positive, the cover value is greater than the overall mean; if negative, it is less. The first 17 combinations of HT/CT have positive contributions, the remainder are zero or have negative signs. Similarly, two levels of the tree size and stand density are positive, the other is negative. Poorly stocked stands or seedling-sapling trees tend to force the overall rating below the mean. The magnitude of the contributions is also important. The larger the contribution, the greater the effect, positive or negative. A contribution of 1.0 will have twice the effect on cover quality as will a value of 0.5. A well-stocked stand will tend to be rated at least two classes higher (1.1 + 1.3) than an identical situation, but under poor stocking.

The forage model reflected in table 7 can also be expressed as a two-factor statistical model without interaction terms:

$$F_{ij} = \mu + HT_i + SD_j$$

Here, the forage value (F) of a specific elk habitat setting (ij) is equal to the overall forage mean (μ), plus the contribution of a specific (i) habitat type group (HT), plus the contribution of a specific (j) stand density (SD) class. Table 9 contains these contributions. The overall forage mean is 4.1. All interpretations regarding sign and magnitude of contributions pertaining to forage are the same as discussed previously for cover.

Table 9.—Ranked effects of forest habitat type groups and stand density class on elk summer forage quality ratings, for final model[1]

Habitat type groups	Contribution	Stand density class	Contribution
Mountain meadow[2]	2.9	Poor	0.2
Spruce	2.4	Medium	.1
Subalpine fir I	2.2	Well	-.2
Western redcedar/grand fir	1.3		
Subalpine fir II	1.1		
Subalpine fir IV	.5		
Mountain grassland[2]	.4		
Mountain brush[2]	.3		
Bottomland	.1		
Douglas-fir IV	-.2		
Douglas-fir III	-.6		
Whitebark pine	-.6		
Douglas-fir II	-1.0		
Subalpine fir III	-1.0		
Douglas-fir V	-1.7		
Ponderosa pine	-1.9		
Douglas-fir I	-2.0		
Scree	-3.1		

[1]Overall mean habitat rating = 4.1
[2]Stand density class contributions are not applicable

Habitat Type Components.—For some purposes, assessing elk habitat quality in terms of vegetation type and structure may be adequate. For other purposes it is desirable to better understand why habitat quality varies. In this regard, the concept of forest habitat type is a key consideration because it is a composite of several environmental factors. In short, while habitat type per se is a taxonomic structure, it consists of environmental factors that actually cause variation in habitat quality.

The study team identified six major components of forest habitat type: type of understory vegetation, density of understory vegetation, elevation, topographic setting, moisture, and temperature. Each component was subdivided. For example, temperature was divided into hot, warm, moderate, and cool. Each of the 171 elk habitat settings was coded according to these components and subdivisions. A series of analyses were conducted to determine if the categories identified were statistically distinguishable from each other in terms of habitat quality ratings. Frequently they were not. When insignificant differences were detected, subdivisions were recombined into the following divisions:

Component	Divisions
Understory type	Primarily grasses (UT1) Primarily shrubs (UT2)
Understory density	Sparse or moderate (UD1) Dense or varied (UD2)
Elevation	Low or middle (E1) High or all (E2)
Topograpic setting	South or west face (TS1) All faces (TS2) Bottomland or benches (TS3)
Moisture	Dry or moderately dry (M1) Moderate or wet (M2)
Temperature	Hot or warm (T1) Moderate or cool (T2)

Figure 5 shows the percentage distribution of habitat quality ratings over all habitat type components and their associated divisions, for both cover and forage. For

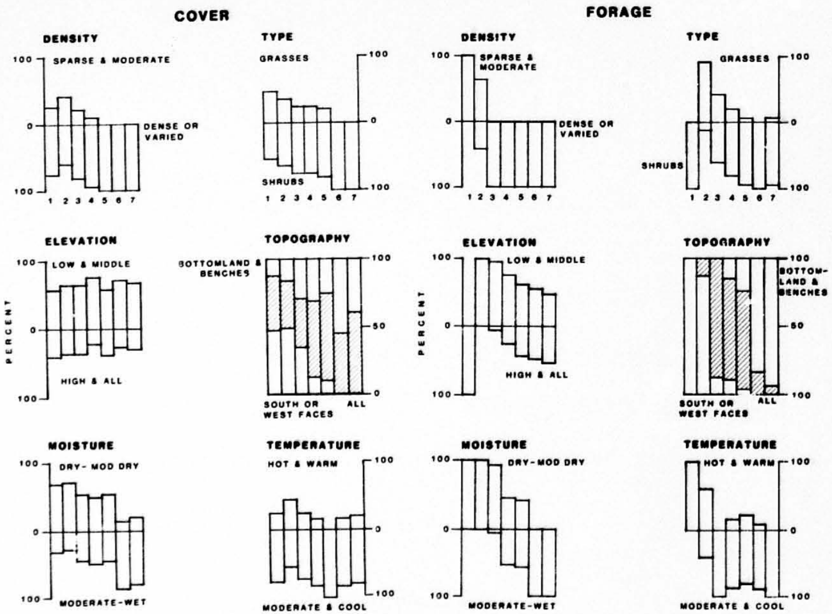


Figure 5.—Percentage distribution of 171 elk habitat settings, by final habitat quality ratings, for components of forest habitat type, summer cover, and forage.

these components to be useful in understanding elk habitat quality, trends should be present. Perhaps the most obvious trend pertains to site moisture and forage quality ratings. There, 100 percent of the PSR's rated very low or low (1 or 2) were from dry or moderately dry sites; conversely, 100 percent of the PSR's rated high or very high (6 or 7) were from moderate or wet sites.

A series of one-factor analyses were conducted to determine which single component of forest habitat type had the greatest effect on cover and forage quality. Table 10 shows these analyses. Because most components were highly significant, attention was focused on the sums of squares for further interpretation. Not surprisingly, habitat type components had little influence on cover quality ratings, the largest sums of squares accounting for only 61 of the 378 total. The same relationship was shown earlier in table 4 where the habitat type factor (not the components) was shown to be strongly related to forage but not to cover quality. Further examination revealed that the most important components for cover were topographic setting, density of understory vegetation, and moisture. The most important components for forage were topographic setting, moisture, and density of understory vegetation.

Subsequent analysis of habitat type components was thwarted for two reasons. First, because these components were not the primary independent variables used in this study, they played no role in the basic experimental design. When the set of elk habitat settings was selected to approximate a balanced experimental design, habitat type components were not considered as part of the balance. Consequently, multiple linear regression analysis was appropriate for use.[1] Second, habitat type components are not independent of each other. For example, wetter sites tend to be cooler sites and drier sites tend to be warmer sites. Because of the problem of nonindependence between components, regression results should be interpreted as indicative, not conclusive. The results are useful only in accounting for variation in habitat quality ratings, not in understanding the underlying biological causes and effects.

A multiple linear regression model was developed for both cover and forage quality. The levels associated with habitat type components were handled as "dummy variables." Table 11 shows the results of these analyses. For the forage model, 87 percent of the total variation in habitat quality ratings was explained by the six statistically significant habitat type components. Only about 19 percent of the total variation in cover ratings was explained by the two statistically significant components. This is not surprising because we have already

[1]When an analysis involves an unequal number of observations in a subclass, routine analysis of variance techniques cannot be used to determine the influence of various factors on a dependent variable. In such cases, multiple linear regression techniques must be used (Draper and Smith 1981).

Table 10.—One-factor analysis of variance showing the independent influence of six habitat type components on elk summer cover and forage quality ratings

Source of variation	Degrees of freedom	Cover			Forage		
		SS	F	p	SS	F	p
Understory density	1	43.6	22.1	<0.001	172.7	104.2	<0.001
Understory type	1	31.1	15.1	<0.001	88.2	40.9	<0.001
Elevation	1	1.8	.8	ns[1]	10.9	4.2	039
Topographic setting	2	61.2	16.2	<0.001	327.3	219.4	<0.001
Moisture	1	37.5	18.6	<0.001	251.9	212.1	<0.001
Temperature	1	12.4	5.7	.017	83.1	38.0	<0.001
Error				varies			
Total	170	377.8	—	—	452.6	—	—

[1]Statistically nonsignificant at 0.05 level

Table 11.—Linear regression models and analysis of variance showing the influence of several independent factors (habitat type components) on elk summer cover and forage quality ratings

MODEL:

Cover: C = 4.18 – 1.11(TS1) – 0.576(M1)

Forage: F = 6.5 – 1.35(M1) – 2.8(TS1) – 1.3(TS2) – 0.87(T1) – 0.62(E1) - 0.72(UT1)

ANOVA:

Source	df	SS	F	p	df	SS	F	p
Regression	2	70.2	19.2	<0.001	6	394.4	185.1	<0.001
Error	168	307.6	—	—	164	58.2	—	—
Total	170	377.8	—	—	170	452.6	—	—
		R^2 = 0.19				R^2 = 0.87		

shown cover to be closely associated with stand structure rather than habitat type. In both models, the topographic setting and moisture were statistically significant variables. Additionally, temperature, elevation, and the type of understory vegetation were statistically significant in the forage model.

Table 12 shows the effect of the statistically significant independent variables on cover or forage quality rating. The component levels shown with "+" indicate that when that level is present, it tends to increase the overall habitat quality rating; a "−" means the rating tends to be decreased. The statistically nonsignificant (nss) component levels mean that their effect on habitat quality is so variable (erratic) that no additional systematic positive or negative effect on habitat quality could be discerned, given the presence of the statistically significant variables already in the model. Consider forage quality. Sites consisting primarily of a grass understory have a statistically significant higher quality than those consisting primarily of shrubs. Similarly, understory density does not have a statistically significant effect on forage quality after moisture, temperature, and other habitat type components have been used to explain rating variability.

Classification Functions.—One of the most desired outcomes of our study was the development of a field-oriented tool to predict habitat quality. The typical tool for this purpose would be a multiple linear regression model. But a regression model requires the dependent variable, habitat quality, to be measured on an interval or ratio scale. Our habitat quality ratings were measured on an ordinal scale. However, another tool, discriminant analysis, was appropriate.

In discriminant analysis, the objective is to assign or classify a subject into one or more groups (the dependent variable), based on measurements taken on a set of independent variables. In our case, the "subject" corresponds to elk habitat settings and the "groups" correspond to the seven habitat quality classes. A typical discriminant analysis develops linear classification functions, one for each group associated with the dependent variable (seven in our case). The subject is then classified into the group based on the highest classification function score. The approach we took was to develop a sequential analysis procedure resembling a dichotomous key used in taxonomy.

Two general classes of independent variables were used: habitat type components (elevation, moisture, and so forth) and combinations of tree size class and stand density class (TS/SD). Habitat type component codes and groupings are the same as before. The combinations of TS/SD are coded as follows:

- C1 — Seedling and sapling, poorly stocked
- C2 — Seedling and sapling, well stocked
- C3 — Medium stocked, poletimber
- C4 — Sawtimber, poorly stocked
- C5 — Sawtimber, well stocked
- C6 — Nonstocked.

The sequential discriminant analysis allows a user to apply a procedure that systematically interprets an elk habitat setting until the "most likely" habitat quality rating has been assigned. Figure 6 displays this sequential procedure in the form of a dichotomous key. Its use can be illustrated with an elk habitat setting with the following characteristics: UT1, UD1, E1, TS1, M1, T1, and C4. All variables are binary (zero or one) and should be interpreted as discussed with previous regression analyses. If the description for the variable is present, the variable takes on a value of one; otherwise the value is zero. Using the equation associated with the first

[2]As with other statistical analysis procedures, discriminant analysis typically rests on a set of underlying assumptions. Perhaps the most critical is that of multivariate normality of the independent variable (Kleinbaum and Kupper 1978). Our analyses violate this assumption because all independent variables are discrete, handled as binary, dummy variables. This violation precludes rigorous statistical interpretation of the discriminant functions. It also means that the functions developed may not be optimal (Goldstein and Dillon 1978). However, our use of the functions is solely for classification purposes, and we make no claim regarding optimality.

Table 12.—Effect of habitat type components on elk summer cover and forage quality ratings

Component level		Cover	Forage
Understory type (UT)	— Primarily grasses	nss[1]	+
	— Primarily shrubs	nss	−
Understory density (UD)	— Sparse or moderate	nss	nss
	— Dense or varied	nss	nss
Elevation (E)	— Low or middle	nss	−
	— High or all	nss	+
Topographic setting (TS)	— South or west face	−	−
	— All faces	nss	−
	— Bottomland or benches	nss	+
Moisture (M)	— Dry or moderately dry	−	−
	— Moderate or wet	+	+
Temperature (T)	— Hot or warm	nss	−
	— Moderate or cool	nss	+

[1]Not statistically significant at 0.05 level.

Cover

If: $-4.20 + 8.07(C1) + 1.95(TS1) - 1.51(E1) + 2.22(UT1) - 1.59(UD1) > 0$ → Very low
↓ otherwise

If: $-5.70 + 3.55(C4) + 1.02(C3) - 9.86(C1) + 0.82(M1) + 1.82(TS1) + 3.63(UD1) > 0$ → Low
↓ otherwise

If: $-2.71 - 1.50(C5) + 5.96(C4) + 7.99(C1) + 4.20(TS1) - 0.73(E1) + 2.34(UD1) > 0$ → Low medium
↓ otherwise

If: $-6.27 + 10.36(C4) + 6.57(C3) + 7.35(C2) + 11.11(C1) + 2.81(M1) - 2.22(TS2) + 2.09(E1) + 4.25(UD1) > 0$ → Medium
↓ otherwise

If: $-0.44 - 1.55(C5) + 3.32(C2) - 1.74(T1) + 2.82(M1) + 4.02(TS1) > 0$ → High medium
↓ otherwise

If: $2.73 - 2.10(C5) - 1.24(T1) + 1.21(M1) - 1.92(TS2) > 0$ → High
↓ otherwise
↓ Very high

Forage

If: $-11.14 + 3.86(M1) + 4.81(TS1) - 3.58(E1) - 10.85(UT1) + 14.80(UD1) > 0$ → Very low
↓ otherwise

If: $-12.73 + 1.10(C2) - 2.09(T1) + 4.23(M1) - 3.20(TS2) + 8.26(TS1) + 3.60(E1) + 14.66(UD1) > 0$ → Low
↓ otherwise

If: $-7.02 + 1.89(C5) + 1.04(C3) + 2.01(C2) - 2.58(T1) + 5.97(M1) - 1.56(TS2) + 2.95(TS1) + 4.25(E1) > 0$ → Low medium
↓ otherwise

If: $-3.36 + 1.79(E1) + 5.74(TS1) + 1.98(TS2) + 1.75(M1) + 1.53(T1) > 0$ → Medium
↓ otherwise

If: $-6.11 - 11.15(UT1) + 20.54(TS1) + 10.25(TS2) + 4.41(M1) + 10.38(T1) + 1.79(C2) - 1.42(C3) - 2.78(C4) > 0$ → High medium
↓ otherwise

If: $-1.71 - 15.49(UT1) - 1.67(E1) + 10.78(TS2) + 10.78(T1) + 8.30(C2) - 3.29(C4) + 8.18(C5) > 0$ → High
↓ otherwise
↓ Very high

Figure 6.—Seven-class dichotomous key for discriminant analysis of elk summer cover and forage quality.

branch of the cover dichotomous key, calculate the score:

$$VL = -4.20 + 8.07(0) + 1.95(1) - 1.51(1) + 2.22(1) - 1.59(1) = -3.13$$

Following the instructions, the magnitude of the score (less than zero) indicates that this elk habitat setting is "otherwise," not "very low," and that computations should continue. The score for the second-step equation is +4.12. Because this score exceeds zero, the site would be assigned a "low" habitat quality rating.

The reliability of a discriminant analysis is indicated by its ability to correctly classify subjects—elk habitat settings. Overall, the sequential discriminant function procedure correctly classified 60 percent of the cover ratings and 67 percent of the forage ratings. Most misclassifications occurred within a more general rating, within the lows, mediums, and highs. For example, while the procedure had difficulty distinguishing between high and very high, it correctly classified all of the "high" quality sites. We repeated the sequential analysis using three habitat quality classes (low = very low and low; medium = low medium, medium, and high medium; high = high and very high). This approach correctly classified 84 percent of the sites for cover and 92 percent for forage. The dichotomous key for the three-habitat quality class analysis is shown in appendix C.

Delphi Process

Although the Delphi process is rather straightforward, there are several major decisions that must be made and can affect results. This section evaluates a wide range of study results pertaining to four major aspects of Delphi: (1) selection and number of participants, (2) consensus achieved and what affected it, (3) the data-gathering instrument or questionnaire used, and (4) time considerations such as how long parts of the Delphi process took.

Participant Selection and Number.—The participant identification process began with the "starter" identifying eight persons as experts in elk habitat for western Montana. If any of several other ways of identifying experts had been used the number of choices would have changed:

Selection method	Number of experts identified
Starter only	8
Any one identifier	2–19
All identifiers combined	30
Top-one method	2
Top-two method	5
Top-three method	13
Top-four method	15

Some 30 experts were identified by all persons contacted. If any one person had been contacted as our sole source of "expert" names, as few as two or as many as 19 persons would have been identified as expert. The number of experts identified by the "top" method quickly increases as the top-three method is approached and then levels off. We suspect that if a top-five method had been used, results would have been essentially the same as the top-four method.

A wide difference exists between individuals in their personal perception of who is an expert. That is why the top-three format identified 13 individuals, not three. Comparing individuals contacted, perceptions ranged from total agreement to total disagreement as to which persons constitute the top three experts. There was much more consistency in identifying experts in the top-one or top-two formats. Figure 7 illustrates a typical pattern in group dynamics, focusing on five individuals being identified as in the top-two format: the starter identified A and B; when contacted, A and B identified two new top-two experts (C and D); when C and D were contacted, only one new expert (E) was identified; when contacted, E identified two previously identified persons.

The participant selection method should be related to the number of participants desired. If a small number of participants is adequate, the top-one or top-two method might be appropriate. If a larger number is desired, the top-three, top-four, or all combined methods might have to be used. This study used all approaches because we had no idea how many experts would be identified by each method. We wanted a large group so that we could later simulate the outcome of using a smaller number of participants. Once the results were known, we selected the 13 experts identified by the top-three method to serve as participants in our Delphi project.

Is the process of identifying elk habitat experts affected by the occupational status, degree of expertise, or the amount of professional elk habitat experience on the part of those persons doing the identifying? To address this issue, each of the 13 experts was assigned a code reflecting occupational status, expertise, and experience. Experts were assigned to an occupational

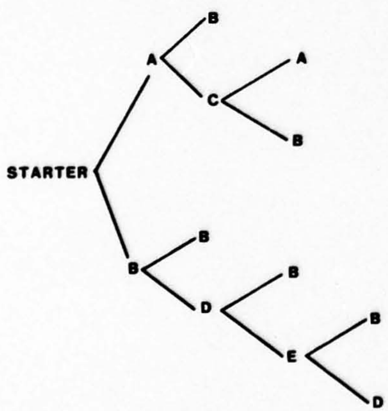


Figure 7.—Illustration of networking associated with a top-two procedure of expert identification.

category based on their current job—either managers/administrators or researchers/academics. Each expert was assigned to the upper or lower half of the expertise listing, based on the frequency of being identified as an expert. For example, based on the pattern of identification shown in figure 7, "B" (named six times) would be assigned to the upper half and "E" (named once) to the lower half. A measure reflecting experience was developed. Each expert's professional career was converted to an expression of "annual equivalents" of elk habitat experience. For example, 10 years of involvement at a 50 percent level of commitment was expressed as 5 years (or annual equivalents) of experience.

Does the occupation, expertise, or experience of an identifier affect the number of persons identified as experts? No. A series of one-factor analyses assessed whether, for example, the average total number of experts identified by managers/administrators (M/A) was significantly different from the average identified by researchers/academics (R/A). Table 13 shows that, overall, each person identified an average of 7.1 experts and that the M/A average was not significantly different from the R/A average. Similarly, simple linear regression analysis showed that the years of experience had no statistically significant effect on the total number of experts identified. In fact, we found no evidence that occupation, expertise, or experience had any effect on the number of experts identified.

Was there an occupational bias in the type of expert identified? That is, do identifiers from one occupational status tend to identify only others from that status as experts? Again no. A chi-square test of independence between occupational status of identifier and occupational status of the identified experts failed to detect a statistical dependency. The identifiers were not occupationally biased in their judgments.

Although the top-three method identified 13 experts, only 11 actually participated throughout the study. Two declined participation in the study for reasons unrelated to elk habitat quality ratings. The 11 who participated were distributed between occupational status and expertise levels as follows:

	Occupation status	
Level of expertise	M/A	R/A
Upper half	2	4
Lower half	4	1
	6	5

After all elk habitat ratings had been obtained, the question arose: Are the ratings related to the professional status of the participants? A series of one-factor analyses of variance were conducted. The dependent variable consisted of the final summer cover and forage quality ratings. As before, the independent factors of expertise and occupation were handled as having two levels each: M/A and R/A for occupation and upper and lower half for expertise. Experience was also treated as a factor, but with three levels. Because participants were divided almost evenly into three experience classes, we labeled the classes as most, least, and middle. Table 14 shows the resulting analyses of variance. Two points warrant mention. First, except for the experience factor in the forage analysis, all other factors were always statistically significant. That is, statistical evidence

Table 13.—Comparison of average number of experts identified per identifier, by method, occupation, expertise, and experience

Selection method	Overall average number of experts	Occupation		Expertise		Years of experience
		M/A	R/A	Lower	Upper	
Total	7.1	— nsd —[1]		— nsd —		nss[2]
Top-one	1.6	— nsd —		— nsd —		nss
Top-two	2.9	— nsd —		— nsd —		nss
Top-three	5.0	— nsd —		— nsd —		nss
Top-four	5.3	— nsd —		— nsd —		nss

[1] Not statistically different at 0.05 level.
[2] Not statistically significant at 0.05 level.

Table 14.—One-factor analysis of variance showing the independent influence of three participant characteristics on elk summer cover and forage quality ratings

Source of variation	Degrees of freedom	Cover			Forage		
		SS	F	α	SS	F	α
Experience	2	19.0	3.3	0.036	15.3	2.4	ns[1]
Expertise	1	128.9	45.5	<0.001	48.7	15.6	<0.001
Occupation	1	61.1	21.3	<0.001	41.0	13.1	<0.001
Error				varies			
Total	1,880	5,457.0	—	—	5,913.0	—	—

[1] Statistically nonsignificant at 0.05 level.

exists that habitat quality ratings varied with professional characteristics of the participating expert. Second, the effects of these factors were extremely small. Were it not for our desire to assess the implications of the effect professional status has on ratings, further analyses of professional status would have been discontinued. Instead, only the effect of the experience factor was judged to be so small that it would not be considered further.

To provide a direct comparison between the effect of professional status and vegetation characteristics on habitat quality ratings, a series of three-factor analyses were conducted. Expertise or occupation was treated (separately) as one factor, and combination of habitat type groups and cover types (HT/CT), along with combination tree size and stand density classes (TS/SD), constituted the other two factors. Analyses of variance indicated that the occupation or expertise factors are statistically significant. However, the effect was small. Whereas the factors pertaining to vegetation type and structure accounted for 70 to 80 percent of the variation in habitat quality ratings, professional status accounted for 2 percent or less. Nevertheless, cover and forage ratings do vary (at a statistically significant level), depending on the participant's occupational status or level of expertise. How much and in what way were they different? Based on subsequent investigations, the listing below provides some indication of these differences:

	Cover	Forage
Researchers/academics compared to managers/administrators	+0.4	+0.3
More expertise compared to less expertise	+.5	+.3

On the average, R/A systematically rate elk habitat higher than do M/A. Similarly, the more expert participants rate habitat higher than the less expert. The magnitude of these effects should be interpreted both in the context of the seven-level rating scale and overall rating means, 3.6 for cover and 4.1 for forage. Whether differences of these magnitudes are of practical significance is judgment that lies beyond the purview of this report. This much can be said: if only the less expert or only R/A had been selected as participants, resulting habitat ratings would have been systematically different. Caution: because there is a high correlation between the occupational and expertise classes, the differences shown above are not additive.

How many participants are needed for a Delphi experiment? That depends on a number of factors, particularly the cost of participation, importance of the results, and the inherent variability of the topic. A relatively large number of experts was selected to participate in this study so that the effect of smaller groups could be assessed.

One critical assumption must be made in comparing alternative numbers of participants: the nature of the feedback would not be affected by the number of participants. This assumption permitted us to neutralize the effect of feedback and simulate results if fewer than 11 experts had participated. To do this, results obtained after the third iteration with 11 participants (the assumed standard) were compared to results that would have been obtained with a lesser number of participants. The third iteration median involving the 11 experts amounts to consensual "truth" within the context of this Delphi application. First iteration results for each expert were individually compared to that standard when prospects of a single participant were evaluated.

Figure 8 shows a comparison between the third iteration standard and the range of results that could have occurred with different numbers of participants. For example, with two participants, the results could have ranged from an average deviation of more than 1.0, about 75 percent above the standard, to as little as 0.2, nearly 50 percent below the standard. If seven or more participants were used, the results would have been within 25 percent of the standard. Not all subsets of participants necessarily differ from the total 11. Indeed, there are specific groups of two, four, six, and more participants that could have been used such that their median ratings would have been virtually identical to those of the 11. However, the problem is that no *a priori* basis exists to select the "correct" individuals for any subset.

These comparisons tend to mask the great differences in study results that could have been obtained if fewer participants had been used. To illustrate, consider the extreme case of one participant. Figure 8 shows that if only one participant were used, that person's response could have been as much as 130 percent of the standard. Depending on which of the 11 individuals was asked to assess the forage quality of the mountain grassland situation, response would have ranged from "very low" to "very high" quality, the maximum possible range. While ranges for other situations were not necessarily that

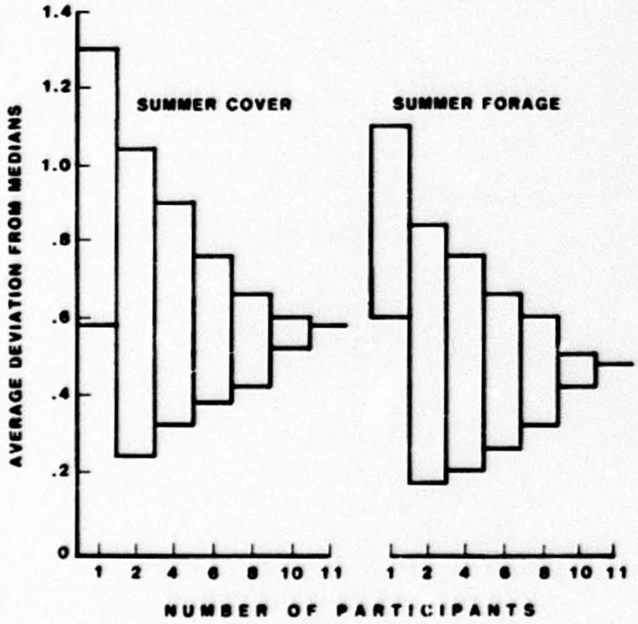


Figure 8.—Range of deviations from final consensus for elk summer cover and forage quality ratings, by alternative number of participants.

large, they were typically large enough to cast doubt on the wisdom of relying on a single individual's assessment.

The study team had expected large differences between the standard and small number of participants, but that as the number of participants increased, ratings would converge to the third iteration, 11-participant standard. Instead, the convergence pattern shown in figure 8 is nearly linear. Based on our research, we conclude that more participants are better than less, at least up to 11.

Effects on Consensus.—The ultimate objective in any Delphi application is to achieve or promote consensus among participants regarding some topic. While the word consensus has an intuitive meaning (general agreement), it has no direct quantitative interpretation. As discussed earlier, the quantitative measure of consensus we developed for each elk habitat setting (PSR) was the mean deviation from the median. Iteration, participant characteristics, number of participants, and more, will be discussed, all regarding their effect on consensus.

As the study progressed from the first to the third iteration, there was convergence toward consensus, but overall habitat quality ratings did not change. Table 15 shows that the overall average of the medians did not change with iteration. The same is also true for individual PSR's. With each iteration there were 171 opportunities for median ratings to change. In fact, only seven cover medians changed between the first and second iterations and only four changed between the second and third. Forage medians changed even less: five between the first and second and two between the second and third. In no case did any median change by more than one class. Basically, the first iteration provided a near-perfect approximation of the final results. If the purpose of the Delphi exercise were simply to determine median habitat quality ratings, one iteration would have been adequate.

But Delphi projects not only attempt to assess some topic, they also strive to promote consensus among participants. Consensus enhances credibility. The second point shown in table 15 is the consistent pattern of improvement in consensus for both summer cover and forage. The overall average deviation from the individual medians after the first iteration was about 0.8 of a class. This reduced by about a third between the first and second iterations, a statistically significant improvement in consensus. Average deviation from the medians dropped again, by about 15 percent, between the second and third iterations—once more a statistically significant change. Changes between the first and second iterations accounted for over three-fourths of the total convergence toward consensus. We strongly suspect that if a fourth iteration took place, virtually no additional improvement in our measure of consensus would have occurred. The fact that both the ultimate level of consensus and consensus improvement for forage were better than cover surprised us. Communication with participants specifically indicated that they were having much more difficulty with forage ratings than cover.

The pattern of group movement toward consensus resulted from individual response changes by each participant. The range of differences between individual participants and the group norm was substantial. Consider the case of first iteration cover, the largest range. While the overall group average deviation from the medians was 0.82, individual average deviations from the group norm ranged from as low as 0.50 to as high as 1.29, more than a twofold difference. By the third iteration the range had decreased considerably, to a low of 0.07 and a high of 1.05. Similar patterns can be noted for forage. The lowest individual average deviation from the medians was 0.07, for third iteration cover. That person's ratings and the group's median cover ratings agreed for 158 of the 171 elk habitat settings, and none of the 13 differences were ever by more than one class.

As each participant was given the opportunity to adjust ratings, the ratings were generally adjusted toward the group norm. The largest individual movement toward group consensus occurred between the first and second iterations where the differences between one participant's judgment and the overall medians were reduced by 64.7 percent, almost two-thirds. But more interestingly, some participants diverged from the overall medians. The largest divergence occurred between the second and third iterations for cover where the difference between one of the participants and the group norm increased by more than 35 percent. Therefore, the overall pattern of group convergence is a real mixture of individual participants converging toward and diverging from the group norm.

We conducted several statistical analyses on the effect of participant characteristics on consensus. All analyses treated the third iteration mean deviation from the medians as the dependent variable. Categories for the independent factors of occupational status, expertise level, and experience were as before. Two additional independent factors were added—confidence and time. One of the questions asked in the exit interview questionnaire dealt with how confident participants were with cover and forage results. Responses were handled as categories such as "very confident," "confident," and so forth. The study team also had records on how much time participants devoted to their assigned Delphi tasks. Time was handled as continuous variables in simple linear regression analyses.

Table 15.—Average median and mean deviation from medians for elk summer cover and forage quality ratings, by Delphi iteration

Characteristic	Iteration	Cover	Forage
Average median	1	[1]3.61	4.07
	2	3.62	4.09
	3	3.63	4.10
Mean deviation from medians	1	.82	80
	2	60	.50
	3	.52	.42

[1]Brackets denote no statistical difference at 0.05 level.

Analysis results shown in table 16 indicate that the level of consensus achieved for each participant was not related to the participant's occupation, expertise, experience, or the confidence each had in study results. In terms of consensus, managers/administrators did not differ from researchers/academics by a statistically significant amount. Participants expressing more confidence in study results did not differ from those expressing less. These results tend to confirm an advantage ascribed to Delphi—it overcomes participant status influence. Status can be based on occupation, expertise, or experience. However, movement toward consensus was significantly related to the amount of time devoted to Delphi tasks. Highly significant regression models explained about 55 percent of this variation in consensus, simply on the basis of time. Our study results indicated that movement toward consensus was related to what the participants did, not who they were.

The magnitude of measured consensus is intimately tied to the measurement scale, a seven-level scale in this study. As the number of levels on the measurement scale increases, so do the opportunities for choice or disagreements. Hence, one would expect more consensus with fewer scale levels than with more. To assess the effect of measurement scale change on consensus, an analytical measure was needed that could simultaneously reflect both changes in rating variability and changes in rating scale. The coefficient of variation (CV), expressed as a percentage, is such a measure:

$$\%CV = \frac{s}{\bar{X}} 100$$

where "s" denotes standard deviation and "X" the mean. Whereas mean deviation from the median (MDM) is an absolute measure of consensus, %CV is a relative measure, allowing comparisons between different configurations of the rating scale.

Table 16.—One-factor analysis of variance results showing extent to which consensus (mean deviation from medians) varies with five independent participant characteristics

Independent participant characteristic	Cover	Forage
Occupation	No	No
Expertise	No	No
Experience	No	No
Confidence in results	No	No
Time devoted	Yes	Yes

Different rating scale configurations amount to different arrangements of the grouping or sorting process. Because the participants were instructed to follow a specific procedure, habitat ratings could be rearranged to simulate four sorting outcomes—the original seven-level scale (D), two five-level scales (B and C), and a three-level scale (A), as shown in figure 9.

Habitat ratings were recoded, as appropriate, to simulate the three new grouping arrangements. Original and recoded ratings were used to compute %CV for each of the 171 PSR's. A two-factor analysis of variance was conducted where %CV was the dependent variable, and the four grouping arrangements along with the three iterations constituted levels of the two independent factors. The data sets contained 2,052 observations (171 PSR's × 3 iterations × 4 grouping arrangements). Analysis results indicate that the iteration means and grouping means were significantly different while their interaction was not. The result pertaining to iterations was expected because statistically significant movement toward consensus with increased iterations has already been demonstrated and discussed. The fact that statistically significant differences were found between grouping means, but that the interaction between grouping and iteration was not significant, signifies that the differences in group means did not depend on iteration. The differences were present in all iterations.

Based on the analysis of variance just discussed, the listing below provides insight into the consequences of alternative grouping arrangements:

Grouping arrangement	%CV Cover	%CV Forage
A	28	21
B	23	16
C	28	26
D	21	19

The lower the %CV, the smaller the relative variation. Brackets indicate nonsignificant differences. Note first that not all %CV for various groupings are significantly different from each other. Most surprisingly, the forage %CV for grouping A and grouping D are not statistically different. That means that relative consensus would not have been increased if the participants sorted into three-class scale consisting of low, medium, and high habitat quality classes rather than into the seven classes that were actually used. However, a marked statistical increase should be noted for cover rating. The %CV value of 28 percent was reduced to about 21 percent with movement from grouping A to grouping D. This degree of increase toward consensus associated with different grouping arrangements is roughly equivalent to the increase observed when going from the first to the third iteration. Substantial increases toward consensus are apparently possible by the use of a scale with fewer classes, but the possible increases may not actually take place. We know of no way to distinguish beforehand between situations where increases toward consensus would take place (as for cover) and situations where consensus either is not increased or is actually decreased (as for forage, especially grouping C).

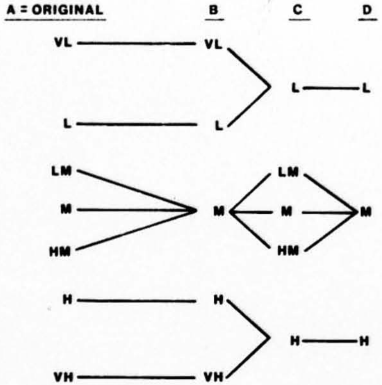


Figure 9.—Four alternative grouping arrangements.

Data-Gathering Instrument and Feedback.—There were several unique ways by which the Delphi process was implemented in this study. The data-gathering instrument was one. It consisted mainly of pictorial site representations (PSR's) and the Q-sort process. Additionally, the method of providing feedback was somewhat unique. This section presents our findings on these topics. The basis for our findings was the exit interview questionnaire administered after all habitat quality ratings had been obtained.

The first thing participants dealt with was the set of 171 PSR's representing a variety of elk habitat settings. Each PSR consisted of three parts—a photocopy of a color photograph depicting the setting, a sketch illustrating a cross-sectional view of the vegetation, and a written narrative description of the setting. We asked the participants how adequate these components were as a basis for rendering judgment on habitat quality. Table 17 shows the percent adequacy associated with various combinations of the three components with respect to cover and forage. First, the vast majority of participants felt that together all three components were adequate to accomplish the needed tasks. Second, the photocopy was consistently judged to be inferior to either the sketch or the narrative. While the combination of the sketch and narrative was highly adequate for both cover and forage ratings, the narrative was clearly more useful. In the case of forage, the narrative alone was almost as adequate as it was in combination with any other component. On the other hand, the narrative and the sketch were needed to provide the highest indication of adequacy for cover ratings.

These results are consistent with previous results. Earlier analysis of variance discussions showed that vegetation structure was important to understanding

Table 17.—Percentage distribution of adequacy judgments for pictorial site representation (PSR) components and component combinations, by elk summer cover and forage

Component and combination	Percent adequacy	
	Cover	Forage
Single component		
Photo (P)	27.3	18.2
Sketch (S)	54.6	45.5
Narrative (N)	63.6	72.7
Two components		
P and S	27.3	18.2
P and N	36.4	63.6
S and N	81.8	63.6
Three components	81.8	81.8

cover ratings and that the type of vegetation played a dominant role in forage ratings. The type of vegetation was primarily described in the PSR's by the narrative, which was the most important PSR component for forage ratings. Information on vegetation structure was clearly shown in the sketch, but was also contained in the narrative. The combination of these two components was judged adequate by most participants for cover ratings.

The participants' low regard for the photo component was not expected. Was the negative reaction due to photographic quality? Probably not, in our study. We asked the participants to compare several alternative ways of constructing the photo component on a five-level scale ranging from "much inferior" to "equivalent" to "much superior." Comparisons were made between color photocopy, color print, and black and white prints. While about half the respondents thought color prints would have been "superior" to color photocopies, the other half thought they would be "equivalent." On the other hand, over 90 percent of the participants indicated that either color photocopies or color prints were "superior" or "much superior" to black and white prints. The lack of support for the photo component was probably unrelated to topics of color versus black and white or print versus photocopy. Rather, several participants complained that the subject matter portrayed in the photocopy did not correspond to the topic of the PSR. The problem was not that the photocopy was inconsistent with the PSR topic, but rather that the photocopy was insufficient. Each photocopy represented only one of a large number of possible portrayals, all of which were consistent with the topic. For example, while our PSR may accurately depict a seedling/sapling stand, numerous such stands do not look like the one shown in the PSR. The problem was that the topic was far broader than that which could be captured in a single photo, regardless of whether it was a print or photocopy, color, or black and white.

The next thing participants had to deal with was the sorting process, the Q-sort technique. When the study team chose to use a sorting procedure that resulted in each PSR being placed into one of seven habitat quality

groups, the concern was whether seven groups were too few to adequately assess habitat quality. The countervailing pressure was that it is more difficult to sort items into more groups. We asked the participants to judge both the ease and the adequacy for alternative grouping arrangements. Because the patterns of response pertaining to cover and forage were virtually the same, they were combined. Table 18 shows a progression from "very easy" to "very difficult" and from "too general" to "far too specific" as the number of sorting groups increased from three to seven. The median participant assessment for the three-group arrangement was "very easy" and "too general." The median assessment for the seven groups actually used was "difficult" and "too specific." We strongly suspect that if more than seven groups were used, the median assessment would have been "very difficult" and "far too specific."

The final Delphi-related topic was feedback. Recall there is no standard format for providing feedback in the Delphi process and that the study team chose to provide feedback in the form of summary evaluations and rating printouts. The exit interview questionnaire asked participants how useful the feedback was in helping them reevaluate PSR's and whether the amount of feedback was correct. Table 19 shows an interesting pattern of response, again combining the near-identical response pertaining to cover and forage. Participants were almost evenly divided on the amount of feedback provided; about half said it was "about right" and about half said it was "too much." This applied both to the summary evaluations and the rating printouts. Usefulness was a different story. The summary evaluations were generally judged to be either "neutral" or "useful." The rating printouts were not as well received. While almost one in five found the printouts "very useful," about a third of the participants found the printouts "harmful." We interpret the response of "harmful" as a participant's reaction against the pressure to change earlier ratings and thus conform to the group norm.

Time Costs.—Costs must be assessed when evaluating Delphi or any other information-developing procedure. There are two kinds of costs—those borne by the study team and those borne by the participants. Study team costs consisted of expenses and personnel time. But because so many aspects of this study were driven by research considerations, rather than simply data gathering, detailed cost records were not maintained. Principal expense items, however, include salaries, costs to produce the sets of PSR, mailing, and computer use for data analysis.

Participant costs consisted entirely of their time. Based on their detailed records, participants on the average, each devoted about 13 hours and 20 minutes to this study. Table 20 shows that the second phase (forage) took about a fourth less time than the first phase (cover), and that each respective iteration generally took less time. There was a substantial range in the amount of time individual participants devoted to the study—as much as nearly a tenfold difference in the case of third-iteration cover. We point to an earlier result: the degree of consensus achieved was strongly related to the

Table 18.—Percentage distribution of judgments of ease in sorting and adequacy in classifying for four alternative grouping arrangements, cover and forage phases combined

Distribution of judgments	Grouping arrangements			
	D:3 strata	C:5 strata	B:5 strata	A:7 strata
	Percent			
Ease				
Very easy	54.6	—	—	—
Easy	31.8	36.4	13.6	—
Moderately difficult	9.1	50.0	59.1	40.9
Difficult	4.6	13.6	27.3	31.8
Very difficult	—	—	—	27.3
Adequacy				
Far too general	36.4	—	—	—
Too general	55.5	59.1	27.3	—
About right	9.1	36.4	36.4	31.8
Too specific	—	4.5	31.8	40.9
Far too specific	—	—	4.5	27.3

Table 19.—Percentage distribution of judgments of amount and usefulness of feedback information, cover and forage phases combined

Distribution of judgments	Type of feedback	
	Summary evaluations	Rating printout
	Percent	
Amount		
Far too little	—	—
Too little	9.1	—
About right	40.9	45.4
Too much	50.0	54.6
Far too much	—	—
Usefulness		
Very harmful	—	—
Harmful	9.1	31.8
Neutral	40.9	13.6
Useful	50.0	36.4
Very useful	—	18.2

Table 20.—Mean and minimum-maximum for participant time involved in study, by phase

Phase	Mean	Min-max
	Minutes	
Cover —1	186.1	79-345
—2	144.8	60-337
—3	100.1	20-195
Total	431.0	190-862
Forage —1	129.2	70-260
—2	129.6	35-302
—3	77.8	30-168
Total	336.6	135-690
Questionnaire	32.2	17-45
Overall	799.8	345-1,546

amount of time devoted to tasks: overall, those participants tending toward the low end of the time range were significantly further away from the consensual standard than were those devoting more time.

Information provided by participants allowed a detailed breakdown of the time devoted to specific activities for each iteration. The listing below shows an approximate average time distribution (cover and forage combined) for the 2.5 hours devoted to first-iteration activities:

Specific activities	First iteration
	Minutes
Three-strata sorting	56
Seven-strata sorting	39
Sorting review	30
Evaluation form	33
	158

The initial three-strata sorting took the most time—almost an hour—to accomplish. While sorting, participants kept track of time needed to sort the first 25 PSR's, the second, and so forth. Respondents averaged about 24 seconds per PSR over the first 25; this dropped by about a fourth to 17 seconds per PSR for the final sortings.

The listing below shows the approximate distribution of time devoted to second and third iteration activities, cover and forage combined:

Specific activities	Second and third iterations
	Minutes
PSR refamiliarization	10
Study rating printout	8
Study summary evaluations	8
Reevaluate, resort	62
Evaluation form (second iteration only)	25
	113

Several weeks usually elapsed between iterations, so the 10 minutes devoted to the first activity was little other than getting reacquainted time. Only about 16 minutes on the average were devoted to reading and evaluating feedback materials, substantially less time than the study team devoted to preparing materials. Then about an hour was spent resorting or rearranging the PSR's, presumably on the basis of the feedback materials.

DISCUSSION

Our study objective was to apply and evaluate the Delphi Method as a means for acquiring useful information for forest management decisions. We chose to focus on elk habitat quality, a topic that was both meaningful and complex. One advantage of the Delphi approach is that it permits investigations into a broad scope of subject matter. A field measurement study with a scope as broad as this Delphi-based study would likely prove impractical, if not infeasible.

It is difficult to judge how well study objectives were met. If satisfaction with outcome is any indication, our purposes were accomplished. The study team is quite satisfied with the study results, both in terms of increasing our understanding of Delphi and our understanding of elk habitat quality. The participants apparently shared this feeling. One of the questions asked in the exit interview questionnaire was how satisfied participants were with the Delphi process. Over 80 percent indicated they were either "satisfied" or "very satisfied," with the remainder indicating "neutral." This degree of satisfaction is heartening for two reasons. First, we doubt that a well-designed and executed field study would be rated substantially different from this Delphi application. Second, considering that all participants had extensive background in biological science and its inherent field orientation, the satisfaction indicated for a social science methodology is somewhat unexpected.

If the success of an information-gathering procedure can be judged on the basis of confidence in results, this Delphi application can again be regarded as successful. The exit interview questionnaire also asked participants how much confidence they had in the (anticipated) final habitat ratings, given knowledge of their involvement and the project's process only. Table 21 shows that the vast majority of participants were "confident" in the habitat quality ratings, both for cover and forage. While the participants had not seen the final outcomes, they were thoroughly familiar with the sorting process, feedback materials, and reevaluations. In a similar manner, an assessment of a field-oriented study is usually judged on the basis of its experimental design, measurement technique, and so forth, not on the basis of the actual measurements obtained. In that regard, we suspect that a well-designed and executed field study would not typically rate any higher than this Delphi application.

In total, this study obtained 11,286 measurements and remeasurements on elk habitat quality. Participants devoted about 147 hours to providing those measurements, or approximately 47 seconds per measurement and remeasurement. This translates to slightly over 18 days of participant time. One advantage of the Delphi process is it does not require face-to-face group participation. A procedure requiring that kind of interaction could easily consume all 18 days in travel time alone. If the average daily wage rate for participants was $200, this study would have cost slightly over $3,600. That amount would not support much field-based data collection. On balance, Delphi appears to be a highly cost-effective means of obtaining these types of resource management data.

Table 21.—Percentage distribution of judgment of confidence in final, anticipated, study results

Confidence	Cover	Forage
Very confident	9.1	—
Confident	72.7	81.8
Neutral	—	18.2
Nonconfident	18.2	—
Very nonconfident	—	—
Total	100.0	100.0

Opportunities to use Delphi results clearly depend on the topic addressed. In general, data gathered by the Delphi process could be used like comparable data gathered by a field study or any other procedure. For example, the habitat quality ratings readily lend themselves to a computer mapping routine that could develop an elk habitat quality map similar to a soil type map. We envision plastic overlays—one for cover and another for forage. These displays could be used to assess spatial forage-cover relationships of elk habitat. Study results could also be used to evaluate management opportunities, particularly those involving vegetation manipulation. Would replacing a sawtimber stand with seedling saplings improve elk forage? If only a fixed number of acres could be thinned, in which habitat types should the thinning be concentrated to promote maximum forage?

Opportunities to extend Delphi to other applications seem nearly endless. Opportunities are mostly limited by the knowledge, skills, and imagination of the persons applying Delphi, not by Delphi itself. We can readily envision applying the process to questions of long-range environmental consequences of timber harvest activities, habitat requirements for grizzly bear, extramarket valuation, and more. But the most fruitful opportunities to extend Delphi to other applications are best known by natural resource managers who know their specific information needs and priorities. This method takes time and thoughtful planning, but is totally implementable by field managers. Results of this study should increase awareness of Delphi and its potential applications.

Earlier in this paper we criticized some of the nonfield methods being used to develop decision-making information. We feel that the Delphi process is far more satisfactory—capable of giving rise to more credible, defensible information. Whether or not it is the best nonfield data collection technique will probably vary with situation and circumstance. But Delphi is not an alternative to field data collection and scientific experimentation; quality information and advances in scientific knowledge and understanding can result only from scientific exploration involving onsite measurement and experimentation. Yet the Delphi process need not be in conflict with scientific exploration. The two can be complementary. Analysis and evaluation of Delphi-based information can provide testable hypotheses for subsequent scientific inquiry. This study's results contain many such hypotheses. Moreover, Delphi could be used to integrate and synthesize the current state of scientific knowledge to answer questions and address issues about which the state-of-the-art science, by itself, is silent. This may well be an important use of the Delphi Method. For as nature abhors a vacuum, decision makers abhor silence. When decision-making information needs cannot be met with onsite measurement and experimentation, Delphi could be used to fill the void.

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APPENDIX A: COMBINATIONS OF FOREST HABITAT TYPES COMPRISING HABITAT TYPE GROUPS

Habitat types	Habitat type group
Ponderosa pine/bluebunch wheatgrass	Ponderosa pine
Ponderosa pine/Idaho fescue	
Douglas-fir/bluebunch wheatgrass	Douglas-fir I
Ponderosa pine/Idaho fescue	
Douglas-fir/ninebark	Douglas-fir II
Douglas-fir/snowberry (snowberry and pinegrass phases)	
Douglas-fir/pinegrass (pinegrass and kinnikinnick phases)	Douglas-fir III
Douglas-fir/dwarf huckleberry	
Douglas-fir/blue huckleberry	Douglas-fir IV
Douglas-fir/twinflower (blue huckleberry phase)	
Douglas-fir/snowberry (bluebunch wheatgrass phase)	Douglas-fir V
Douglas-fir/pinegrass (bluebunch wheatgrass and ponderosa pine phases)	
Subalpine fir/*Clintonia*	Subalpine fir I
Subalpine fir/*Galium*	
Subalpine fir/twinflower	
Subalpine fir/*Menziesia*	Subalpine fir II
Subalpine fir/beargrass	Subalpine fir III
Subalpine fir/wood rush	Subalpine fir IV
Subalpine fir/grouse whortleberry	
Spruce/horsetail	Spruce
Spruce/*Clintonia*	
Spruce/dwarf huckleberry	
Grand fir/*Clintonia*	Redcedar-grand fir
Western hemlock/*Clintonia*	
Western redcedar/(various types)	
Whitebark pine-subalpine fir	Whitebark pine
Whitebark pine	
All hardwoods	Bottomlands
—	Mountain meadow
—	Mountain grassland
—	Mountain brush
	Scree

APPENDIX B: MEAN DEVIATIONS FROM MEDIANS FOR FINAL ELK SUMMER COVER AND FORAGE QUALITY RATINGS BY VEGETATION COVER TYPE, FOREST HABITAT TYPE GROUPS, STAND DENSITY CLASS, AND TREE SIZE CLASS

Vegetation cover types	Forest habitat type groups	Stand density class	Cover: Seedling/ sapling	Cover: Pole-timber	Cover: Saw-timber	Forage: Seedling/ sapling	Forage: Pole-timber	Forage: Saw-timber
Hardwoods	Bottomlands	Poor	0.5		0.9	0.3		0.7
		Medium		0.6			0.5	
		Well	.3		.7	.7		.5
	Spruce	Poor	.4		.7	.3		.4
		Medium		.3			.2	
		Well	.5		.6	.4		.2
Ponderosa pine	Ponderosa pine	Poor	.3		1.0	.1		.3
		Medium		.6			.1	
		Well	.5		.9	.3		.2
	Douglas-fir I	Poor	.5		.9	.2		.2
		Medium		.5			.2	
		Well	.4		.7	.2		.3
	Douglas-fir II	Poor	.5		1.1	.6		.5
		Medium		.5			.4	
		Well	.5		.6	.5		.5
	Douglas-fir III	Poor	.3		.8	.6		.4
		Medium		.5			.7	
		Well	.4		.5	.5		.5
	Douglas-fir V	Poor	.5		1.1	.2		.2
		Medium		.5			.4	
		Well	.4		.6	.2		.3
	Scree	Poor	.1		.5	0		0
		Medium		.5			0	
		Well	.5		.5	0		0
Douglas-fir	Douglas-fir I	Poor	.4		.6	.2		.4
		Medium		.3			.2	
		Well	.4		.6	.5		.4
	Douglas-fir II	Poor	0		1.1	.5		.3
		Medium		.3			.5	
		Well	.5		.6	.5		.5
	Douglas-fir III	Poor	.4		1.1	.5		.4
		Medium		.1			.5	
		Well	.5		.5	.4		.4
	Douglas-fir IV	Poor	.2		.5	.5		.5
		Medium		.4			.5	
		Well	.7		.4	.5		.4
	Douglas-fir V	Poor	.5		1.2	.5		.3
		Medium		.5			.2	
		Well	.4		.5	.1		.2
	Subalpine fir I	Poor	.4		.6	.6		.1
		Medium		.4			.6	
		Well	.3		.5	.4		.1
	Scree	Poor	.1		1.1	0		0
		Medium		.8			0	
		Well	.4		.6	0		0
Lodgepole pine	Douglas-fir III	Poor	.3		.6	.7		.4
		Medium		.3			.5	
		Well	.3		.3	.5		.5
	Douglas-fir IV	Poor	.2		.8	.5		.5
		Medium		.4			.5	
		Well	.3		.4	.3		.5

(con.)

APPENDIX B. (Con.)

Vegetation cover types	Forest habitat type groups	Stand density class	Tree size class: Cover, Seedling/sapling	Cover, Pole-timber	Cover, Saw-timber	Forage, Seedling/sapling	Forage, Pole-timber	Forage, Saw-timber
	Subalpine fir I	Poor	.4		.6	.3		.5
		Medium		.3			.5	
		Well	.5		.5	.2		.1
	Spruce	Poor	.5		.9	.5		.4
		Medium		.4			.2	
		Well	.5		.5	.2		.5
	Subalpine fir II	Poor	.4		.6	.5		.6
		Medium		.7			.4	
		Well	.9		.4	.5		.5
	Subalpine fir III	Poor	.5		1.0	.5		.5
		Medium		.4			.6	
		Well	.5		.4	.5		.5
	Subalpine fir IV	Poor	.5		.9	.8		.8
		Medium		.5			.7	
		Well	.5		.5	.7		.7
Western larch	Subalpine fir I	Poor	.5		.8	.2		.4
		Medium		.5			.5	
		Well	.4		.5	.2		.4
Engelmann spruce	Subalpine fir I	Poor	.4		.5	.4		.3
		Medium		.3			.3	
		Well	.4		.4	.4		.3
	Subalpine fir II	Poor	.6		.5	.5		.7
		Medium		.6			.4	
		Well	.5		.1	.7		.5
	Subalpine fir IV	Poor	.5		.8	.6		.6
		Medium		.5			.5	
		Well	.3		.5	.6		.6
	Spruce	Poor	.5		.9	.3		.5
		Medium		.7			.2	
		Well	.4		.3	.2		.2
Grand fir	Western redcedar/ grand fir	Poor	.6		.7	.5		.6
		Medium		.7			.6	
		Well	.8		.2	.4		.6
Western redcedar	Western redcedar/ grand fir	Poor	—		.9	—		.5
		Medium	—	.4		—	.4	
		Well	—		.3	—		.7
Subalpine fir	Subalpine fir II	Poor	.6		.5	.5		.4
		Medium		.6			.5	
		Well	.6		.2	.2		.5
	Subalpine fir III	Poor	.4		.6	.7		.5
		Medium		.5			.6	
		Well	.5		.6	.7		.4
	Subalpine fir IV	Poor	.5		.7	.7		.5
		Medium		.4			.6	
		Well	.7		.5	.7		.6
Whitebark pine	Subalpine fir III	Poor	.5		1.1	.6		.5
		Medium		.5			.6	
		Well	.5		.4	.5		.6
	Whitebark pine	Poor	.5		.8	.5		.5
		Medium		.5			.5	
		Well	.5		.5	.5		.5
Forbs and grasses	Mountain meadow	—	—	.1	—	—	0	—
	Mountain grassland	—	—	.1	—	—	.9	—
Shrubs	Mountain brush	—	—	6	—	—	.5	—

APPENDIX C: THREE-CLASS DICHOTOMOUS KEY FOR DISCRIMINANT ANALYSIS OF ELK SUMMER COVER AND FORAGE QUALITY

Cover

If: $+4.20 + 2.79(UD1) + 2.20(TS1) + 0.73(M1) - 10.60(C2) - 9.79(C3) - 7.31(C4) - 11.00(C5) > 0 \rightarrow$ **Low**

↓ **otherwise**

If: $+3.45 + 1.97(TS1) - 1.39(TS2) + 3.01(M1) - 1.12(T1) - 1.88(C3) - 7.02(C4) > 0 \rightarrow$ **Medium**

↓ **otherwise**

↓

High

. . . **Overall correct classification: 84%**

Forage

If: $-14.17 + 14.58(UD1) + 2.77(E1) + 9.27(TS1) - 2.50(TS2) - 4.35(M1) + 1.08(C2) > 0 \rightarrow$ **Low**

↓ **otherwise**

If: $-17.97 - 1.45(UT1) + 20.91(TS1) + 17.74(TS2) + 4.37(M1) + 18.01(T1) + 6.46(C1) + 8.33(C2) + 5.78(C3) + 4.82(C4) + 7.48(C5) > 0 \rightarrow$ **Medium**

↓ **otherwise**

↓

High

. . . **Overall correct classification: 92%**

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