VEGETATION DATA COLLECTION IN TEMPERATE FOREST RESEARCH NATURAL AREAS

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Since 1927 more than 300 research natural areas have been reserved by Federal land management agencies. Many more have been preserved for science and education by State and local governments, and public and private organizations.

A major goal in reserving research natural areas is to have them serve as comparisons with managed, utilized, and artificial ecosystems. This goal cannot be met without some baseline from which to determine what (if any) changes are occurring or have occurred in natural areas.

Surprisingly, despite long advocacy of research natural area reservation by scientists and conservationists in general, and actual reservation by governmental agencies in particular, it is difficult to find reports of significant research performed in established natural areas. As Cowan (1968) points out, ". . .few people have appreciated the unique research opportunities presented by our existing preserved areas."

The glaring lack of knowledge about reserved areas became apparent when uniform and comparable information about national parks, nature reserves, etc., was collected on checksheets in accordance with the instructions of International Biological Program (IBP) Handbook No. 4 (Peterken 1967). We found that many Federal natural areas had little or no qualitative or quantitative description and, in fact, the plant and animal communities of most nonfederal natural areas have not been adequately described either. It is apparent that some framework or system is needed to encourage baseline description of natural areas so that they may serve the purpose for which they were established.

Obtaining baseline data for the Federal research natural areas alone could be costly. However, if a framework could be provided through which interested nonprofessionals under the consulting supervision of professional ecologists, foresters, or botanists were encouraged to collect such data, these collections could be made at minimal cost. And if a framework would be provided so that these data would be generated in a rather standardized way, they would be even more valuable. This manual is intended to serve as such a framework for the collection of baseline vegetation data.

Most concerned individuals agree that the minimum information that should be available for each area is a description of the biotic communities and environmental factors such as soil, landform, geologic complex, etc. As much data should be accumulated as time and talent will permit. Each additional piece of information will build a base for further work and may stimulate further studies. If circumstances permit only the collation of all currently available research information for an area, this will serve as a valuable base for future studies and is, therefore, worthwhile. If circumstances permit a reconnaissance survey of the vegetation, that is further progress. But we will not make full use of our natural areas until the processes governing production of organic matter, the flow of energy, and the cycling of nutrients have been worked out for each area. At least for the immediate future, productivity and nutrient cycling will probably remain in the realm of the professional ecologist. The eventual achievement of these goals will, however, depend on the availability of sound baseline data. A necessary start toward this goal can be provided by nonprofessionals utilizing this manual under the supervision of professional ecologists.

OBJECTIVES

The focus of this manual is on temperate forest vegetation.[1] The specific objectives of the manual are to:

[1] *There is a recognized need for a similar framework for the collection of information on water, wildlife, soils, etc.*

(1) identify qualitative and quantitative information, especially regarding vegetation, important for research natural areas, and (2) describe methods by which this information can be obtained.

The manual is intended primarily for interested individuals who have training in the biological sciences to the baccalaureate level or above who are not professional ecologists, but who are willing to work under the consulting supervision of professionals. In particular it is hoped that high school and junior college biology teachers will be stimulated to work on research natural areas in their localities through the use of this manual.

Identical sampling techniques cannot always be used successfully to characterize all types of vegetation. While the specific methods presented are intended primarily for temperate forest communities, the remainder of the background material and discussion of types of information pertinent to research natural areas has general applicability. Some of the methods might also be modified for use in the collection of quantitative data in nonforest vegetation.

PART I – METHODS

This part of the manual presents procedures and methods for sampling a natural area to provide information that can be used to monitor vegetation changes over time. The following steps are presented in a checklist format as a convenient outline that should normally be followed.

1. Read the entire handbook ( ).

Some readers will want, and need, much more elaboration of both the prefield and field procedures, or will want to consider alternative methods that might be used (or recommended by the supervising ecologist). Pertinent details on prefield and field procedures, and on some alternative methods are contained in Part II.

2. Obtain permission to conduct study ( ).

One may not work in a research natural area without the permission of the managing agency. Natural areas may be managed by a Federal agency, such as the USDA Forest Service, or by State, county, or local government, or by a foundation, such as the Nature Conservancy. After the agent responsible for the area is satisfied that you are working under adequate consulting supervision, agrees with your objectives, and has granted approval, you are ready to begin.

3. Gather information pertinent to the area ( ).

3a. Check natural area file ( ).

The only starting place you may have is the natural area file of the managing agency. Some information will be available from records of the procedural establishment of a scientific research natural area, and more information may have been brought together during completion of the International Biological Program (IBP) checksheet for the area. Figure 1 shows a portion of a completed checksheet for an area.

3b. Check with government agencies (personnel and files), colleges, knowledgeable individuals, nature clubs, etc. ( ).

Your consulting ecologist may be able to give you valuable leads to follow. The object is to determine the history of this unit of land, including both natural and man-caused events. First sources to be checked are Federal, State, county, and local governmental agencies dealing with any aspects of land management in the region and the nearest center of higher education. Consult the life science and natural science departments of these institutions for leads to further information. Members of these departments can often provide information about private clubs and nonprofessional naturalists who can be valuable sources of documents, maps, reports, flora and fauna lists, and historical activities.

Look also to the experts in the science departments for advice on sampling, taxonomic problems, and plant collection and storage facilities.

3c. Answer basic questions about the area ( ).

Before you enter the natural area for purposes of sampling and description, you should have answers to the following questions (the details of background information collection are contained in Part II):

1. Who initiated the action that resulted in reservation of the natural area?
2. Why was it reserved?
3. What is the most unique characteristic of the area?
4. Where and exactly how big is it?
5. What work has already been done in the area? What information has already been gathered by agencies or individuals?
6. What is known about the geology and soils of the area?

Figure 1. – Sample pages from a completed IBP Natural Area Check Sheet.

INTERNATIONAL BIOLOGICAL PROGRAMME

SECTION CT : CONSERVATION OF TERRESTRIAL BIOLOGICAL COMMUNITIES

CHECK SHEET (Mark VII) FOR SURVEY OF IBP AREAS*

To be completed with reference to the GUIDE TO THE CHECK SHEET

Serial Number

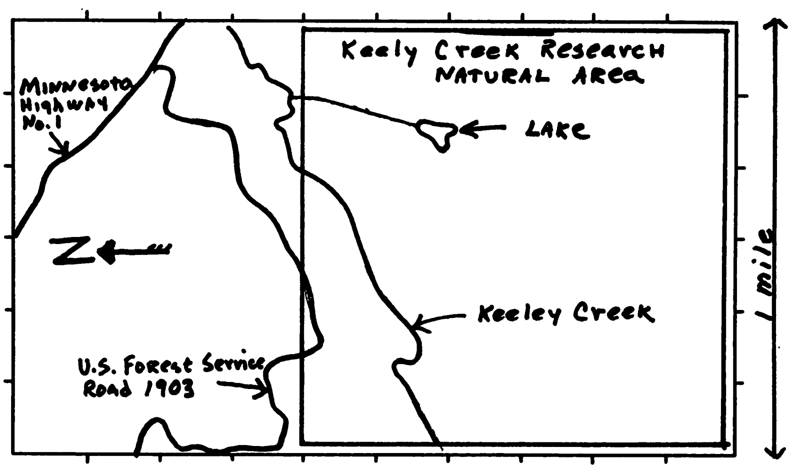
For Data Centre Use only

1.

1. Name of surveyor Robert R. Ream and Lewis F. Ohmann
2. Address of surveyor U.S. Forest Service
North Central Forest Experiment Station
St. Paul, Minnesota, U.S.A. 55101
3. Check Sheet completed (a) on site ✓ (b) from records ✓
4. Date Check Sheet completed 10 June 1968

2.

1. Name of IBP Area Keeley Creek Natural Area
2. Name of IBP Subdivision (or serial letter) —
3. Map of IBP Area* showing boundaries attached? Yes ✓ No ....
4. Sketch map of IBP Area*. Please mark direction of north, the scale and grid numbers where applicable.



* For " IBP Area ", read IBP Area and/or IBP Subdivision.

For Data Centre Use only

3. **Location of IBP Area***

1. Latitude 47° 47' N Longitude 91° 42' W
2. Country U.S.A.

State or Province Minnesota County Lake

(State or Province .... County ....)

4. **Administration**

National 1. Official category Research Natural Area (USDA Forest Service)

2. Address of administration Director,
North Central Forest Experiment Station
Folwell Ave.,
St. Paul, Minnesota USA 55101

International Class

3.

Included in U.N. List	Rejected from U.N. List	Area with formal conservation status	No formal cons. status
(A)	(B)	(C)	(D)

5. **Characteristics of IBP Area***

1. Surface area (state units of measurement) 640 Acres
2. Altitude (state units of measurement) Maximum 1580 feet

Minimum 1500 feet

6. **Climate**

Nearest climatological station :

1. Name Duluth (nearest class-1 station)
2. Climatological station on IBP Area*? Yes .... No ✓
3. If (2) not, distance from edge of IBP Area* (state units) 80 miles
4. Direction from IBP Area* SSW
5. Additional data sheet attached? Yes .... No ✓

For Data Centre Use only

7. **Vegetation and Soil**

1

Vegetation

Community Reference Number	Vegetation Code: Primary Structural Group	Class	Group	Formation	Sub-Formation	Plant communities (give usual name using full Latin names of a species where applicable)	Area (state units) Acres
1	1	A	1	7	a	Pinus banksiana (SAF-1)	284
2	1	A	1	7	a	Picea mariana (upland) (SAF-7)	52
3	1	A	1	7	a	Abies balsamea - Betula papyrifera (SAF-5)	80
4	1	A	2	1		Populus tremuloides (SAF-11)	42
5	1	A	1	2	a	Picea mariana (lowland) (SAF-12)	108
6	1	A	2	2		Larix laricina (SAF-38)	8
7	1	C	1	3		Open sedge bog (A-25)	32
8	1	B	2	2	e	Alnus lowland shrub	34
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							

Please give information about further communities on a separate sheet.

7. What is the recent (Pleistocene) history of the area (i.e., glacial, volcanic, coastal emergence or submergence, etc.)?

8. What direct or indirect influences has man had on the area?

3d. Establish a working file ( ).

Set up an organized working file of all background information. It will be of value in designing the sampling procedure, evaluating results, and describing the area. At the completion of the study, copies of this file should accompany each set of data that is deposited for future comparison.

3e. Compile background information ( ).

Only after the above kinds of background information have been synthesized should you plan to undertake extensive fieldwork.

4. Conduct preliminary fieldwork ( ).

4a. Reconnoiter the area ( ).

The first preliminary fieldwork should be an extensive reconnaissance of the area, preferably with your consulting ecologist or individuals who know the area well. You should be equipped with airphotos (if they exist), and topographic, geologic, and soils maps; these will help to familiarize you with all aspects of the landscape. Look for gross vegetation differences.

4b. Check plant collection regulations ( ).

In checking the flora, how many plant species can you already identify? If a collection for the area is not already available, perhaps this is the proper time to begin collecting plant species for identification and voucher specimens. Be sure to check regulations pertaining to collection procedures for the area.

5. Design sampling procedure ( ).

The next step is to design the sampling procedure you will use to provide baseline information for future comparison. You will have to decide if you should sample the entire natural area as one unit, or if it should be split into several uniform areas on the basis of soil, topography, or vegetation differences that will make the sampling more meaningful. In stratifying you will want to consider such things as upland versus lowland vegetation, forest versus nonforest vegetation, and soil or bedrock differences that may have influenced species distributions. Here is where much of the background material you have collected, especially history of disturbance and vegetation and soils maps, will be of value.

5a. Obtain professional advice ( ).

At this point you should (if possible) also obtain advice from ecologists, botanists, and zoologists in educational institutions and land management agencies in the area. Take the time to show as many qualified individuals as possible what information you have about the area and what possible stratifications you and your consultant think could be useful. Obtain opinions on suitable sample stratification, complexity of vegetation, separation of vegetation components, and number and size of sample plots. You, in consultation with your supervisor, will have to consider the expert opinions in the context of time, manpower, and finances available to do the sampling.

5b. Locate sample stands ( ).

On a suitable map (U.S. Geological Survey topographic or vegetation map, for example) plot the location of stands to be sampled within the uniform unit(s) you have decided to sample. Use a grid and random numbers to locate a point within the area for each stand to be sampled. You will have to decide how many stands you can sample and how many will give you an adequate representation of the structure and composition of the vegetation present. The number of sample stands can be increased or reduced as the sampling proceeds. Be sure to record the location of the sample stands on airphotos and maps so the stands can be found again for future sampling.

5c. Check for homogeneity of sampling area vegetation ( ).

Before you begin actually locating sample plots in the stands you should be sure the stand vegetation is uniform (homogeneous) over a large enough area to contain the sample plots. It should be uniform in the sense that it contains no obvious changes in plant composition. If the stand is located on a uniform slope of one aspect and has had a uniform history, it will usually be a reasonably homogeneous unit of vegetation (but not necessarily in a statistical sense). It would be inaccurate to present sample data as representative of a single stand when the sample plots were placed within two quite different types of vegetation. For example, if the sample area covered the north slope, the top, and part of the south slope of a hill, the plots could represent strongly differing environmental and vegetational conditions. Or, if half the sample area was coniferous and through some historical event (such as repeated wildfire) the other half was broadleaf deciduous, sampling plots in each and combining the data as representative of one stand would be describing a vegetation type that doesn't really exist.

6. Select sampling methods ( ).

Once you are ready to begin establishing sample units, decisions must be made concerning plot versus plotless techniques, and size and number of units for each component of the vegetation. The extensive reconnaissance will have helped you become familiar with the flora and vegetation. This familiarity, along with the advice you obtained from local botanists or ecologists, will be the basis for your decision. Your advisers will base their opinions on knowledge of similar areas and how they were sampled, and on the reliability of the results. Thus, they can provide a good estimate of which techniques will do the job most efficiently.

Some possible plot numbers, shapes, sizes, and vegetation components to be sampled in the plots, are given in table 1. Which, if any, of these you choose will depend on the general characteristics of the vegetation being sampled. The 1/100-ha. (1/40-acre) plot size traditionally used by ecologists was shown to be inefficient in terms of both statistics and time when tested in one forest type (Lindsey *et al.* 1958). Thus, a mature hardwood forest of all-aged trees might be best sampled using relatively few large, rectangular plots. On the other hand, a larger number of smaller plots is generally preferred over a few large plots from a statistical point of view. Thus, a dense, mature even-aged conifer stand might be sampled more efficiently with a relatively large number of small (1/100 ha.) plots.

Sampling the less numerous large-diameter trees with a large plot and the more numerous small-diameter trees with smaller plots should also be considered.

Under restricted time and manpower conditions (assuming forest vegetation) a minimum of 20 nested plots for sampling the various stand components is recommended. The number of plots used, however, should be a function of both the size of the area being sampled and the complexity of the vegetation. The plot sizes given in table 1 are based on a 10-percent sample for the tree component on a minimum stand size of 5 acres. For complex vegetation as many as 40 or more plots may be necessary to do the job. One could measure 10 plots and examine the data; if the data for the common species are quite variable, another 10 plots can be measured, etc., until the variability in the data for the common species seems reasonable.

Unless time efficiency is more critical than statistical reliability, most ecologists agree that the plot shape should be rectangular and that the long axis of the plot should cross any contours and soil or vegetation banding (Bormann 1953).

6a. Prepare forms for field notes ( ).

Systematic data collection dictates the use of well-designed data forms. Whenever possible, species names and other appropriate items should be preprinted on the data forms so that as few entries as possible need be made in the field. This will tend to reduce errors of data omission as well as recording errors. Ideally, the data form should be designed so that most of the blanks will be filled; blanks remaining after sampling will then be readily noticed as possible omission errors and can be corrected while still in the field. Another common source of error is transposing numbers when recording values, or placing values in the wrong row or column of the data form. Try not to use code numbers for species names while in the field, even though you plan to use them in later automatic data processing, because code numbers are easily misrecorded. To shorten the process of recording species names (if not preprinted on the form) write the species name the

Table 1. – Possible plot shapes and sizes

Vegetation component sampled	Minimum number of plots	Plot shape: Circular radius		Rectangular dimension		Plot area	
		Meters	Feet	Meters	Feet	Hectares	Acres
Trees over 2.54 cm. d.b.h.[1]	20	5.65	18.62	15 x 6.66	50 x 21.78	1/100	1/40
	10	7.98	26.33	30 x 6.66	100 x 21.78	1/50	1/20
	5	11.29	37.24	60 x 6.66	200 x 21.78	1/25	1/10
	3	15.96	52.66	120 x 6.66	400 x 21.78	1/12	1/5
Trees under 2.54 cm. d.b.h. and tall shrubs	20 or more	1.13	3.72	4 x 1	13.2 x 3.3	1/2,500	1/1,000
Low shrubs, forbs, ferns, fern allies, and ground characteristics	20 or more	.56	1.86	2 x 0.5	6.6 x 1.6	1/10,000	1/4,000

1/ Larger diameter size classes may be sampled using larger plots and smaller diameter size classes using smaller plots.

first time you enter it on a data sheet, place an abbreviated form of the name alongside the full name, and use the abbreviated form when entering that species again. Wherever possible, design the data form to allow preprinting of the most common species. Data collected from each size plot should be recorded on a separate form. If data are collected for different plant groups (tree seedlings and the tall shrubs, for instance) on one plot, either record them on separate forms or separate them on one form.

In addition to the data form for plot sampling, prepare a general information data form to record the date of sampling, stand and plot identifications, airphoto identification, stand elevation, percent slope, age of dominant trees, height of canopy, other components (if desired), and your impressions of the stand (fig. 2). If you are collecting information on soils or soil samples, you might include this information on the general information data form. Another item to include here is plant species that you observed in the stand but which did not occur within any of the sample plots.

7. Conduct fieldwork ( ).

7a. Locate plots ( ).

Each sample plot should be randomly located within the stand if time and manpower are not critical, or if the sampling is intensive on a rather small area. If possible, the extra time and effort required for plot randomization is worthwhile from the standpoint of statistical analysis. When plots are located randomly, extra care should be taken in describing their position; random plots are much harder to relocate than plots spaced equidistant from each other.

The most workable method for randomization may be to lay down baselines at right angles along two edges of the stand. Using these as axes and pairs of random numbers as coordinates, position each sample plot within the space between the two axes. Measurement of the

GENERAL INFORMATION DATA FORM

Col.
1 [E I _ 1] Card Identification
5 Stand Number
8 Air Photo No.
17 Township
19 Range
21 Section
23 ¼ Sect. NE-1 SE-2
24 40 SW-3 NW-4
25 Crew Leader + Crew
26 Month (Oct.=0)
27 Day
29 Year
31 Elevation
35 Per Cent Slope
37 Aspect________
40 Position on Slope
1=ridgetop 3=midslope 5=valley
2=upper 4=lower
41 Location
1=interior 3=peninsula
2=island 4=lake shore

Col.
Distance to water body of over 5 acres (meters) 42
Geologic Type
01=Slate 03=Redrock 05
02=Gabbro 04=Granite 06
45
Surface Material
01=Ground Moraine 04=Lacustrine
02=Outwash 05=Bedrock
03=End Moraine
47
Insolation 49
Ages of larger trees in stand
Height 53
Species________ Age 55
Height 58
Species________ Age 60
Height 63
Species________ Age 65
Height 68
Species________ Age 70
Height 73
Species________ Age 75

Figure 2. – Form for recording general environmental data within each sample stand.

distances from the axes to the sample site need not be exact, for initial location pacing the distances will be sufficient (Greig-Smith 1964). But for relocation purposes you may want to determine the distances more exactly after the plot has been established.

If randomization of plot location is not a practical alternative in your situation, use some random procedure to select the location of the first sample plot. You can devise your own method for doing this; the point is that you want to select your first sample plot without bias. You can, for example, use random numbers to select the direction and distance from the original random point you used to select the stand location. After the first sample plot is located, space each of the remaining plots equidistant from the first plot. The spatial configuration will depend on what the sample area is like. Many workers prefer to distribute the plots in blocks; for 20 plots you might use five rows of four plots each. Space the plots to cover most of the stand but leave a buffer zone between the plots and the edge of your sample area.

7b. Establish plots and permanently mark locations ( ).

Laying out sample plots can be a time-consuming procedure, but it needs to be done with care to ensure accuracy in sampling and relocation.

Rectangular plots are probably best established by using a long steel measuring tape (200 ft./60 m.) to determine one side of the plot and by permanently marking the two corners. Plot width can then be determined during each sampling by using a line (or rod, etc.) held perpendicular to the established side. Be sure to record the bearing of the established side. Once the side for the largest plot is known, the lengths and widths of other plots nested within it can be determined by measurement along the established side. The smaller plots should be nested within the larger plots in a consistent manner so that permanent marking can be restricted to one or two corners of the large plot and the nested plots can be relocated by measurement (fig. 3).

If time is critical, establishing circular plots may be faster than rectangular plots. Find the plot center and determine the outer limits of the large plot by use of a rangefinder or, less efficiently, by use of a line. The nesting of the smaller plots in this case can be around the center point of the large plot, or where more than one of each size nested plot is desired, they may be established along one or more cardinal axes through the large plot (fig. 4). If the smaller plots are nested around the center point of the large plot, it is probably better

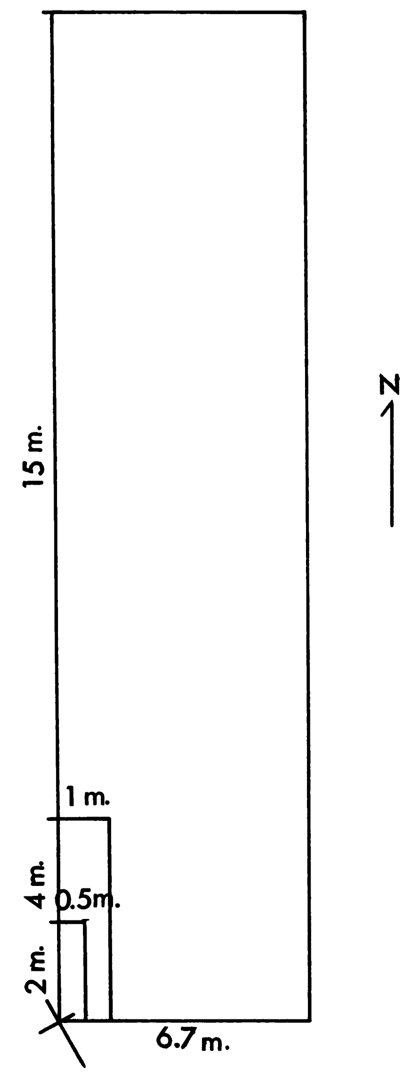


Figure 3. – Nest of rectangular plots with permanent marker at one corner of all three plots. Long axis of this nest is north-south for ease in relocation.

not to place the permanent marker at the center but at some standard distance from the plot center to avoid disturbing the low vegetation (fig. 5).

Because this type of survey is designed to generate baseline data, that is, data that can be used to compare changes occurring in the natural area over time, it is essential that plots be permanently marked and their location recorded in detail so they can be sampled in the future. Mark with aluminum pipe or cedar post the plot corner(s) or center. The plot number should be marked on the pipe or post. This number, along with location distances and directions, should be filed with

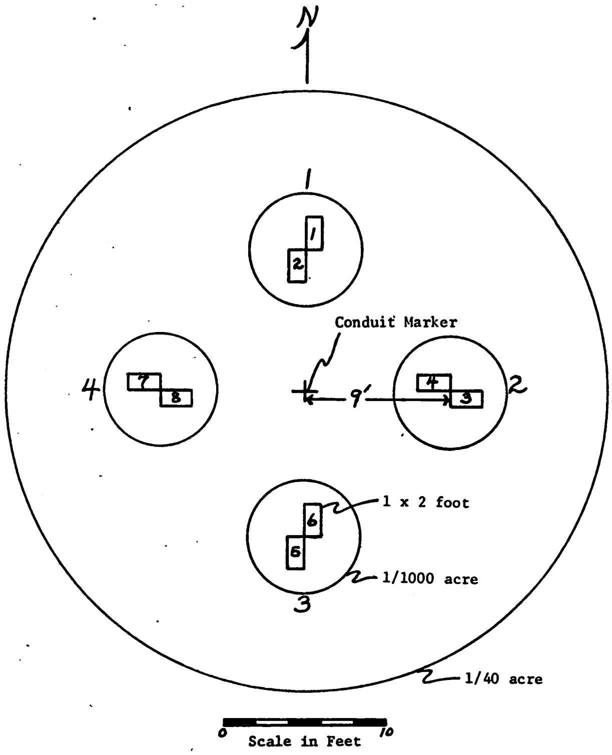


Figure 4. – *Subplot location and numbering sequence. The numerals outside the circular plots are the milacre plot numbers; those inside the rectangular plots are the 1- by 2-ft. plot numbers.*

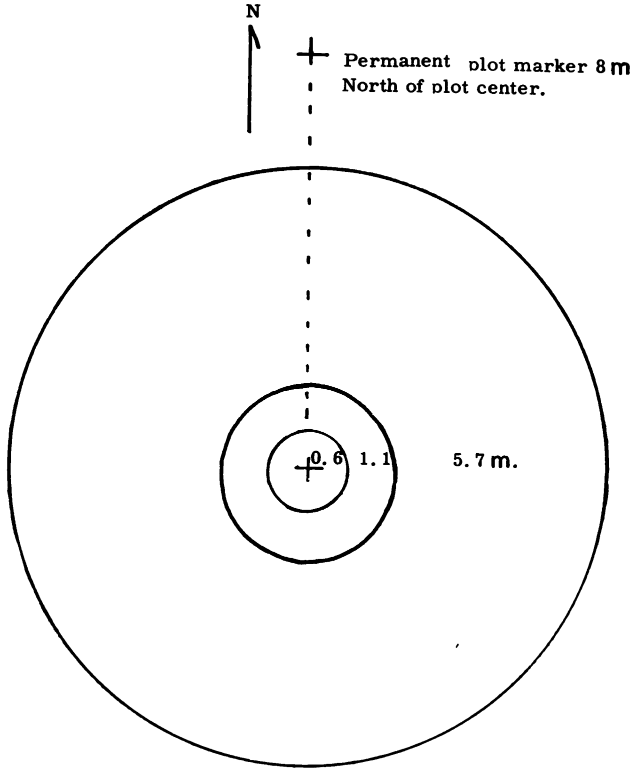


Figure 5. – *Nest of circular plots with permanent marker 8 m. due north of plot center for use in relocation.*

each copy of the data. The plot identification number should also appear on the completed data sheets for the plot. A diagrammatic representation of the plot distribution and nesting for each stand is a good document to include with the records. However the plots are marked – plot center, corner, or standard distance and direction – all should be marked the same. Consistency is vital in vegetation sampling for baseline purposes.

7c. Sample the vegetation ( ).

In practice, the smallest plots should be measured first, then the intermediate, and finally the largest. The reason is that the most delicate plants are recorded in the smallest plots. Moving through the area in measuring the woody plants in the larger plots will result in damage to the plants in the small plots, making cover estimates and species identification difficult.

A major problem in sampling will be plant identification. You may have trouble identifying some species because not every plant will be in fruit or flower during the sampling period. As a general rule, identify every plant to the species level where possible; but if there is a chance of frequent misidentification, go only to the level where identification is positive.

7c-1. Sample the trees ( ).

Depending on the vegetation being sampled, one or more plots may be used to record, by species name, the diameter at breast height (d.b.h.) to the nearest 0.25 cm. (1/10 in.) of each individual stem over 2.54 cm. (1 in.) in d.b.h. (fig. 6). If it seems best to use different-sized plots to sample the trees over 2.54 cm., you will have to decide at what diameter to split the class. Ecologists often use two classes: 2.54 cm. to 10 cm. (saplings), and more than 10 cm. (trees).

If the administering agency has no objection, spray a spot on each stem with a durable paint at the time of diameter measurement. This accomplishes two objectives: it assures that each tree stem is measured once and only once, and it also makes the plot easier to find in the future, as long as the paint remains visible. Nonpermanent marks can also be used to ensure measurement; for example, a small cloth sack filled with crushed chalk will leave a mark visible for days when

TREE STRATUM DATA FORM

Stand No. 01 Plot No. 09 Uniform Area No. 01
Plot size 1/10 Acre Plot shape circular Date 7/3/69 Crew Ohmann-Karnes
Permanent Plot Identification Number 01-01-09
Permanent plot location description: (see map).
Coordinate Q 337 feet south on stand Baseline I - Plot located 83 ft West from Q.
Coordinate R 83 feet west on stand Base Line II - Plot located 337 ft south from R.

species	dbh in.	area ft^2	species	dbh in.	area ft^2	species	dbh in.	area ft^2	species	dbh in.	area ft^2
Jack Pine (JP)	9.0	0.442	Balsam Fir (F)	2.0	0.022	Paperbirch (B)	1.5	0.012	Blackspruce (BS)	5.2	0.147
JP	11.0	0.660	F	1.8	0.018	B	1.6	0.014	BS	2.3	0.029
JP	10.0	0.545	F	1.3	0.009	B	1.7	0.016	BS	3.0	0.049
JP	10.2	0.567	F	3.6	0.071	B	1.1	0.007	BS	7.0	0.267
JP	8.9	0.432	F	6.3	0.216	B	1.7	0.016	BS	4.1	0.092
JP	10.7	0.624	F	6.2	0.210	B	6.8	0.252	BS	5.9	0.190
JP	8.7	0.413	F	2.3	0.029	B	1.1	0.007	BS	5.7	0.177
JP	11.7	0.747	F	1.3	0.009	B	2.2	0.026	BS	1.2	0.008
JP	9.5	0.492	F	3.5	0.067	B	1.6	0.014	BS	2.0	0.022
JP	9.2	0.462	F	1.6	0.014	B	1.5	0.012	BS	2.0	0.022
JP	12.1	0.798	F	4.6	0.115	B	4.4	0.106			
JP	7.8	0.332	F	1.8	0.018	B	1.8	0.018			
JP	10.2	0.567	F	2.3	0.029	B	7.3	0.291			
			F	4.1	0.092	B	6.3	0.216			
			F	2.5	0.034						
			F	4.3	0.101						
			F	4.1	0.092						
Total	no.	area	sub/Total	no.	area		no.	area		no.	area
TREES	13	7.081		6	0.826		4	0.865		5	0.893
SAPLINGS	—	—		11	0.320		10	0.142		5	0.130

Figure 6. – Example of completed tree stratum data form.

hit against a tree. There is, however, a legitimate question about the advisability of introducing any unnecessary materials into a research natural area.

7c-2. Sample seedlings and tall shrubs ( ).

An intermediate-sized plot should be used to record (1) by species name, the number of individual stems of all tree species under 2.54-cm. (1-in.) d.b.h., and (2) by species name, the number of stems of the tall shrub species. An estimate of species dominance can also be obtained by placing stems over 15 cm. (6 in.) tall into diameter classes (measured at 15 cm. (6 in.) above ground) by use of a template (fig. 7). While the diameter classes can be of any desired range, 1-cm classes have been used with some success (Ohmann and Ream 1971b). Data sheets for recording seedling and tall shrub numbers by diameter class are difficult to preprint because one cannot readily predict how many diameter classes will occur in any one plot. A form can be

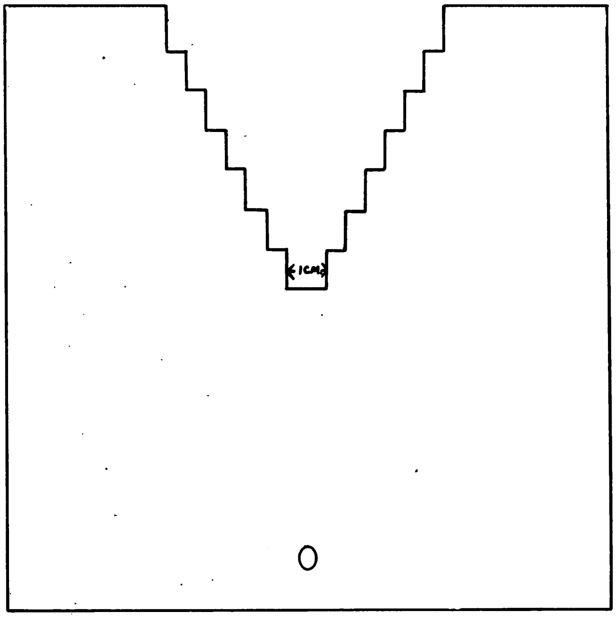


Figure 7. – *Template of 1 cm. size class determination of tall shrubs.*

prepared that has a limited number of diameter classes and provision for adding additional ones. It is probably best to enter the species name and diameter class for this stratum as the sample is taken (fig. 8).

Another satisfactory way of obtaining a measure of species dominance is to read the amount of cover each species projects onto a tape measure stretched along one edge of the large plot. Start at the zero end of the tape and record, by species name, the cover to the nearest cm. along the tape. Record the actual cm. covered by each species; for example, *Corylus cornuta* 0 to 6; 11 to 22; 123 to 131 cm., etc. The direct readings can be later converted to percent cover. There is likely to be overlap as more than one species can occupy the space above the tape. You will need to devise a separate data form if you choose to measure dominance through this line intercept of cover method.

7c-3. Sample the low shrubs, forbs, etc. (   ).

The smallest plots are used to record, by name, the percent projected ground cover for each species of low shrub, forb, fern, and fern ally, and actual cover of selected ground surface characteristics (fig. 9). Estimate the cover of the largest plant species first; you may then wish to move or bend some of the taller stems to better estimate the cover of the smaller species and the ground surface characteristics.

An object of known percent cover is often a valuable aid in making estimates. One can determine the projected cover his hand will have, or the amount of cover the diameter class template of the shrub stratum projects. The reason for estimating cover is to obtain some measure of dominance in addition to frequency. After a bit of practice you will become reasonably proficient at estimating cover, at least for the common species. If you feel your results would be more reproducible by assigning species to cover classes than by trying to estimate cover more closely, you can use the following (or some other) classes: (1) less than 1 percent cover, (2) 1 to 5 percent, (3) 6 to 25 percent, (4) 26 to 50 percent, and (5) 51 to 100 percent.

After percent cover is recorded for the low shrub and forb species, record the percent cover for the ground surface characteristics. This is good practice for estimating cover because these characteristics normally add up to 100 percent (there is negligible overlap in their foliage or area).

Cover for items measured in this plot can also be estimated through use of the line-intercept method just as for the tree-seedling and tall-shrub categories.

If cover estimates of the plant species in the small plots are deemed unnecessary and if frequency is the only characteristic recorded, sampling can be done more rapidly and two or more plots per nest can be established.

7d. Complete sampling of first plot (   ).

After the sample has been taken, take a few minutes to look over the data forms for obvious errors. Then proceed to the next plot.

8. Summarize data (   ).

The objective of data reduction is to summarize the raw data collected for the various vegetation components on all sample plots.

8a. Summarize tree stratum data (   ).

Examples of how the raw data for this component can be summarized are shown in figures 6 and 10 and table 2. The area equivalents were added after sampling by reference to a conversion table. Ten 1/10-acre plots were used to sample the stratum. To save space, not all the raw data from the plots are shown. For instance, figure 6 would actually be continued on another form for plot 01 because there were more stems of balsam fir than would fit on this sheet, and also more species. Figure 10 was produced later as a worksheet on which to summarize for the tree size class by species, occurrence in plots, number of stems, and basal area. Another worksheet would be prepared for the sapling size class. This step is not essential – one could transfer totals

SHRUB STRATUM DATA FORM

Stand No. 01 Plot No. 09 Uniform Area No. 01
Plot size milacre Plot shape circular Date 7/3/69 Crew OHMANN & KARNES

Permanent location within nest: milacre plot center located 15 feet due east of 1/10 acre plot center of permanent plot 01-01-09.

TALL SHRUB			TREE SEEDLING		
Species	Diameter class	Number stems	Species	Diameter class	Number stems
Green alder	00	01	Balsam fir	00	08
	01	03		01	01
	02	01		03	01
Round-leaf dogwood	00	02	Red maple	00	01
	01	05			
Mountain maple	00	01	Aspen	00	01
	01	02			
	03	01			

Figure 8. – Example of completed shrub stratum data form.

directly to the summary sheet, but this method facilitates separation of the values for the two size classes and also helps to ensure accuracy. Table 2 presents the data summarization process for the tree component of the stand. Another table would be produced in the same manner for the sapling component.

The number of plots each species has occurred in, the number of total stems counted in the plots, and the total basal area those stems represent are the basic data brought forward from the tree stratum forms and worksheet for each species. All other information on the summary sheet is derived from these three values.

8a-1. Summarize percent frequency data (   ).

The calculation for percent frequency is simply the percent of plots in which the species occurred as a rooted individual. Thus, in the summary table for the tree size class, jack pine (*Pinus banksiana*) occurred in 10 out of a possible 10 plots and therefore has a frequency percent of 100 (10/10 x 100 = 100 percent), while aspen (*Populus tremuloides*) occurred in only 1 of the 10 plots examined and so has a frequency value of 10 (1/10 x 100 = 10 percent).

8a-2. Summarize average density data (   ).

Plot size in this example was 1/10 acre, and thus it is easy to express density on a per-acre basis. One hundred eight jack pine trees occurred on the 10 plots; the average is 10.8 stems per plot, or 108 stems per acre. Only 19 black spruce (*Picea mariana*) stems occurred on the 10 plots, for an average of 1.9 stems per plot or 19 stems per acre. Since this example is too easy, let's suppose only eight 1/10-acre plots were used and the same number of stems were counted. The value for jack pine would then be (108/8) or 13.5 stems per 1/10-acre plot or (13.5 x 10) 135 stems per acre. The average

Stand No. ________ Uniform Area No. ____________

Plot Size _____ Plot Shape ________ Date _______ Crew ____________

Permanent location within nest:

SPECIES Name	Code	PLOT NUMBER 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Not Rooted in Plot No.	
ADP CARD Col.	8-10	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39	41	43	45	47	49	51	53
Arcto uva	031																						
Chima umb	032																						
Gaulth hisp	033																						
Gaulth pro	034																						
Rosa acic	035																						
Rubus idae	036																						
Rubus pub	037																						
Vaccin Ang	038																						
Vaccin myr	039																						
Aralia nud	050																						
Aster mac	051																						
Clint bor	052																						
Coptis groe	053																						
Cornus can	054																						
Epilob ang	055																						
Frag vesca	056																						
Galium tri	057																						
Goodye rep	058																						
Goodye tes	059																						
Lathy ochro	060																						
Linn bore	061																						
Maianth can	062																						
Lyco annot	020																						
Lyco clavat	021																						
Lyco compla	022																						
Lyco lucidu	023																						
Lyco obscu	024																						
Bare Rock	001																						
Live Wood	002																						
Dead Wood	003																						
Bare Ground	004																						
Litter	005																						
Call. schr.	006																						
Clad. alpest	007																						
Clad.rangif	008																						
Clad. mitis	009																						
Clad. sylv.	010																						
Dicranum sp	011																						
Hylo splend	012																						
Hypnum cris	013																						
Polytri sp.	014																						

Figure 9. — Example of low shrub, herb, and moss-lichen strata data form.

TREE SIZE-CLASS WORK SHEET

Stand No. 01 Uniform Area No. 01

Item	Jackpine		Balsam fir		Paper birch		Black spruce		Red maple		Aspen	
Plot no.	Stems no.	Area ft^2	Stems no.	Area ft^2	Stems no.	area ft^2	Stems no.	Area ft^2	Stems no.	Area ft^2	Stems no.	Area ft^2
01	13	7.081	6	0.826	4	0.865	5	0.873	–	–	–	–
02	10	5.999	13	1.598	3	0.752	–	–	4	0.930	–	–
03	10	5.369	11	1.234	1	0.352	–	–	–	–	–	–
04	15	6.621	9	1.218	–	–	–	–	1	0.398	–	–
05	14	7.617	17	2.311	–	–	2	0.239	–	–	–	–
06	7	3.465	5	0.631	–	–	1	0.226	–	–	–	–
07	8	4.096	14	1.990	2	0.293	4	0.902	–	–	1	0.326
08	8	4.044	10	1.375	2	0.185	7	1.552	–	–	–	–
09	10	5.333	14	1.806	4	0.889	–	–	–	–	–	–
10	13	7.074	4	0.528	4	0.739	–	–	1	0.102	–	–
Number of plots	10		10		7		5		3		1	
Number of stems	108		103		20		19		6		1	
Basal area	56.699		13.517		4.075		3.792		1.430		0.326	

Figure 10. – Example of completed tree size-class worksheet.

Table 2. – Tree stratum summary sheet for Stand No. 01, Uniform Area No. 01

Species	Plots occurred in	Stems	Basal area	Frequency	Density	Basal area	Relative frequency	Relative density	Relative dominance	Importance value
	Number	Number	$Ft.^2$/acre	Percent	Stems/acre	$Ft.^2$/acre	Percent	Percent	Percent	Percent
Jack pine	10	108	56.699	100	108	56.7	27.8	42.0	71.0	46.9
Balsam fir	10	103	13.517	100	103	13.5	27.8	40.1	16.9	28.3
Paper birch	7	20	4.075	70	20	4.1	19.4	7.8	5.1	10.8
Black spruce	5	19	3.792	50	19	3.8	13.8	7.4	4.7	8.6
Red maple	3	6	1.430	30	6	1.4	8.3	2.3	1.8	4.1
Aspen	1	1	.326	10	1	.3	2.8	.4	.4	1.2
Total		257	79.839	360	257	79.8	99.9	100.0	99.9	99.9

density of all tree-sized stems in this stand is 257 stems per acre. This is derived by dividing the total number of stems (257) by the number of plots (10) to get the average per plot, and then multiplying by the expansion factor (10) to derive stems per acre (257/10 x 10 = 257). The total stems per acre could also be derived by adding the values for the individual species; computing both ways will provide a cross-check on computations.

8a-3. Summarize dominance (average basal area) data ( ).

Each stem diameter can be converted to its area equivalent through reference to a conversion table, or through use of the equation: Area = $\pi\left(\frac{\text{d.b.h.}}{2}\right)^2$, where $\pi = 3.1416$. The area values have been summed for each species in all 10 plots on the worksheet (fig. 10). The total measured basal area for jack pine is 56.699 ft.^{2}. The average basal area per 1/10-acre plot is then 5.67 (56.699/10) ft.^{2}, or 56.7 (5.67 x 10) ft.^{2} per acre. The one stem of aspen equals 0.33 ft.^{2} of basal area for an average of 0.033 ft.^{2} per 1/10 acre or 0.3 ft.^{2} per acre. As with density, the total basal area per stand can be determined, and computations cross-checked, by adding the individual species values or by dividing the total measured basal area of all sample plots (79.839 ft.^{2}) by the number of plots (10) and multipying by the expansion factor for an acre (79.839/10 x 10 = 79.8 ft.^{2} per acre).

8a.-4. Summarize relative frequency (RF) data ( ).

In addition to the three absolute values for density, frequency, and dominance described above, one can calculate relative values for each. Percent relative frequency is computed from the percent frequency column of table 2 as follows:

$$\text{Species RF} = \frac{\text{percent frequency of EACH species}}{\text{percent frequency of ALL species}} \times 100.$$

This value represents the percent of total frequency that is contributed by each species. The RF for all species should total 100 percent. In our example jack pine has a frequency value of 100; this is 27.8 percent of the total frequency for the stand:

$$\text{Jack pine RF} = \frac{100}{360} \times 100 = 27.8 \text{ percent.}$$

8a-5. Summarize relative density (RD) data ( ).

This value represents the percent of total stems that is contributed by each species. It is computed as follows:

$$\text{Species RD} = \frac{\text{number of stems counted for EACH species}}{\text{number of stems counted for ALL species}} \times 100.$$

Thus, in our example, 108 of a total of 257 stems in the tree class were jack pine, or:

$$\text{Jack pine RD} = \frac{108}{257} \times 100 = 42.0 \text{ percent.}$$

Note that relative density values also total 100 percent and thus may serve as a cross-check on the computation for each species.

8a-6. Summarize relative dominance (basal area (RDom) data ( ).

This value represents the percent of total basal area there is contributed by each species. It is computed as follows:

$$\text{RDom} = \frac{\text{basal area of EACH species}}{\text{basal area of ALL species}} \times 100.$$

In our example, jack pine has a measured basal area of 56.669 ft.^{2} out of a total of 78.839 ft.^{2} for all species, thus

$$\left(\frac{56.669}{79.839} \times 100\right) \text{RDom} = 71.0 \text{ percent.}$$

8a-7. Summarize importance value (IV) data ( ).

The relative values of frequency, density, and dominance can be combined as an overall importance value by averaging them:

$$\text{IV} = \frac{\text{RD} + \text{RF} + \text{RDom}}{3};$$

or, in our example,

$$\text{Jack pine IV} = \frac{27.8 + 42.0 + 71.0}{3} = 47.5 \text{ percent.}$$

This can be interpreted as meaning that, based on the characteristics measured, jack pine is the most important species in the tree size class.

When the same calculation has been performed for the sapling size class stems, the tree-stratum summary for the stand may look like that in the upper part of table 3.

8b. Summarize shrub stratum data ( ).

The raw data to be summarized for this stratum include those for the tree seedlings (0 to 0.25 cm. (0- to 1-in. d.b.h.)) and the tall shrubs on intermediate-sized plots. The data can be recorded on two separate forms or on one form (see fig. 8). The 00 class represents stems under 15 cm. (6 in.) tall, which are not placed in a diameter class for basal area estimate.

Table 3. – Stand data summary for Stand No. 01, Uniform Area No. 01

Item	Plot frequency	Density	Basal area	Cover	Relative frequency	Relative dominance	Relative density	Importance value
	Percent	Stems/acre	$Ft.^2$/acre	Percent	Percent	Percent	Percent	Percent
Tree size class:								
Pinus banksiana	100.0	107	57.1	--	28.2	71.8	42.4	47.5
Abies balsamea	100.0	103	13.5	--	28.2	17.0	40.6	28.6
Betula papyrifera	72.7	19	3.8	--	20.5	4.8	7.6	11.0
Picea mariana	45.5	17	3.4	--	12.8	4.3	6.8	8.0
Acer rubrum	27.3	6	1.4	--	7.7	1.7	2.2	3.9
Populus tremuloides	9.1	1	.3	--	2.6	.4	.4	1.1
Total	354.6	253	79.5	--	100.0	100.0	100.0	100.0
Sapling size class:								
Abies balsamea	100.0	502	15.3	--	23.9	81.5	79.8	61.7
Acer rubrum	90.9	47	.6	--	21.7	3.2	7.5	10.8
Betula papyrifera	72.7	46	1.3	--	17.4	6.8	7.2	10.5
Picea mariana	72.7	24	.7	--	17.4	3.7	3.9	8.3
Picea glauca	45.5	4	.1	--	10.9	.6	.7	4.1
Sorbus americana	27.3	4	.8	--	6.5	4.1	.7	3.8
Pinus banksiana	9.1	1	.1	--	2.2	.1	.1	.8
Total	418.2	629	18.8	--	100.0	100.0	99.9	100.0
Seedling size class:								
Abies balsamea	40.0	950	3.3	--	47.1	69.1	57.6	57.9
Sorbus americana	20.0	200	1.3	--	23.5	25.8	12.1	20.5
Betula papyrifera	15.0	350	.1	--	17.6	3.1	21.2	14.0
Acer rubrum	5.0	100	.1	--	5.9	1.0	6.1	4.3
Populus tremuloides	5.0	50	.1	--	5.9	1.0	3.0	3.3
Total	85.0	1,650	4.8	--	100.0	100.0	100.0	100.0
Tall shrub class:								
Corylus cornuta	55.0	5,100	3.5	--	21.6	33.0	26.4	27.0
Dierviila lonicera	65.0	7,250	1.5	--	25.5	14.3	37.5	25.8
Alnus crispa	30.0	3,900	4.2	--	11.8	39.4	20.2	23.8
Amelanchier spp.	30.0	950	.9	--	11.8	8.2	4.9	8.3
Acer spicatum	40.0	1,150	.3	--	15.7	3.1	5.9	8.2
Lonicera hirsuta	15.0	400	.1	--	5.8	.8	2.1	2.9
Lonicera canadensis	10.0	150	.1	--	3.8	.3	.8	1.7
Cornus rugosa	5.0	350	.1	--	2.0	.7	1.7	1.4
Cornus stolonifera	5.0	100	.1	--	2.0	.2	.5	.9
Total	255.0	19,350	10.7	--	100.0	100.0	100.0	100.0
Low shrub class:								
Vaccinium angustifolium	100.0	--	--	13.6	47.6	55.7	--	51.7
Gaultheria procumbens	90.0	--	--	7.6	42.9	31.4	--	37.1
Vaccinium myrtilloides	15.0	--	--	2.8	7.1	19.7	--	9.4
Rosa acicularis	5.0	--	--	.3	2.4	1.2	--	1.8
Total	210.0	--	--	24.4	100.0	100.0	--	100.0
Forbs, ferns, and fern allies:								
Pteridium aquilinum	50.0	--	--	23.5	14.7	48.9	--	31.8
Aster macrophyllus	85.0	--	--	16.4	25.0	34.0	--	29.5
Gramineae	75.0	--	--	2.4	22.1	5.0	--	13.5
Maianthemum canadense	65.0	--	--	3.2	19.1	6.5	--	12.8
Aralia nudicaulis	30.0	--	--	1.6	8.8	3.3	--	6.1
Trientalis borealis	10.0	--	--	.4	2.9	.7	--	1.8
Cornus canadensis	10.0	--	--	.3	2.9	.6	--	1.8
Melampyrum lineare	10.0	--	--	.2	2.9	.4	--	1.7
Clintonia borealis	5.0	--	--	.2	1.5	.5	--	1.0
Total	340.0	--	--	48.1	100.0	100.0	--	100.0
Ground surface characteristics:								
Litter	100.0	--	--	77.2	29.9	77.1	--	53.5
Other mosses	85.0	--	--	12.9	25.4	12.9	--	19.1
Calliergonella schreberi	50.0	--	--	4.8	14.9	4.8	--	9.9
Dead wood	40.0	--	--	3.2	11.9	3.1	--	7.5
Other lichens	25.0	--	--	1.2	7.5	1.2	--	4.3
Dicranum spp.	20.0	--	--	.6	6.0	.6	--	3.3
Hypnum cristacastrensis	10.0	--	--	.1	3.0	.1	--	1.5
Cladonia rangiferina	5.0	--	--	.2	1.5	.1	--	.8
Total	335.0	--	--	100.2	100.0	100.0	--	100.0

The data for each group are then transferred to a worksheet for summarizing by species the number of stems, basal area, and number of plots in which a rooted individual occurred. A worksheet (fig. 11) is very useful for this stratum because it will allow easy compilation of the data required on the summary sheets. The number of plots on which a species occurred in this case is based on the rooted presence of at least one stem (of any diameter class) of that species per plot. In this example, 20 milacre plots, two within each 1/10-acre plot, were used to sample the stratum. The number of stems counted were summed by species and by diameter class for the entire 20 plots.

To determine the total estimated area for green alder (*Alnus crispa*) in the example:

Class	*Stems*		
00	10	–	–
01	27	x 0.00021135 =	0.0059 ft.^{2}
02	41	x 0.00190220 =	0.0780 ft.^{2}
Total	78		0.0839 ft.^{2}

The values from the worksheet are transferred to the summary sheet (table 4). For each species the number of plots on which it occurred, the number of stems counted (regardless of height or diameter class), and the total basal area estimate of stems over 15 cm. (6 in.) tall is recorded. As in the tree stratum, these three values are used to determine the summary characteristic values for the species in the stand. Frequency is the percent of the plots in which each species occurred; thus, beaked hazel (*Corylus cornuta*) was rooted in 11 of the 20 plots for 55 percent frequency. Density per acre is determined by averaging the total number of stems of each species per 1/1,000-acre plot and expanding to an acre; for example, bush honeysuckle (*Diervilla lonicera*) had a total of 145 stems in 20 plots (145/20) = 7.25 per 1/1,000-acre plot = 7,250 stems per acre. Basal area is derived in the same way; for example, green alder had a total basal area estimate of 0.0839 ft.^{2} for 20 plots $(\frac{0.0839}{20})$ = 0.004195 ft.^{2} per 1/1,000-acre plot = 4.2 ft.^{2} per acre.

TALL SHRUB WORK SHEET

Stand No. 01 Uniform Area No. 01

Species	Green alder				Beaked hazel					Round-leaf dogwood			Moutain maple					
Plot Number / Diameter Class	00	01	02	total	00	01	02	03	total	00	01	total	00	01	02	03	total	
01	01	03	01	05						02	05	07	01	02	–	01	04	
02	–	05	–	05	03	08	05	01	12				03				03	
03	03			03	06	02	03		08				01				01	
	etc.									etc.			etc.					
18	02			02		06			06				01	01			02	
19		06	08	14		01			01				01	01			02	
20		04		04	02	03	01	01	07				01				0	
Total stems	10	27	41	78	46	31	20	05	102	02	05	07	17	05		01	23	
Total plots				6					11			1					8	
Total basal area	–	0.0059	0.0780	0.0839	–	0.0066	0.0380	0.0264	0.0710	–	0.001	0.001	–	0.0011	–	0.0053	0.0064	

Figure 11. – Example of completed tall shrub worksheet.

Basal area (in ft.^{2}) is determined for stems over 15 cm. (6 in.) tall by multiplying the total number of stems in each diameter class (01, 02, 03, etc.) by the appropriate area value for a stem of the class. The area values presented below are based on the midpoint of the class; thus, the value for the 01 diameter class is based on a diameter of 0.5 cm.

Diameter class (cm.)	*Basis of area value (cm.)*	*Area per stem (cm.^{2})*	*Area per stem (ft.^{2})*
01 (0-1)	0.5	0.19636	0.00021135
02 (1-2)	1.5	1.76721	.00190220
03 (2-3)	2.5	4.90891	.00528390
04 (3-4)	3.5	9.62146	.01035644

Table 4. – Tall shrub summary sheet for Stand No. 01, Uniform Area No. 01

Species	Plots occurred in	Stems	Basal area	Frequency	Density	Basal area	Relative frequency	Relative density	Relative dominance	Importance value
	Number	Number	Ft.^{2}/acre	Percent	Stems/acre	Ft.^{2}/acre	Percent	Percent	Percent	Percent
Beaked hazel	11	102	0.0710	55	5,100	3.53	21.6	26.4	33.0	27.0
Bush honeysuckle	13	145	.0301	65	7,250	1.53	25.5	37.5	14.2	25.8
Green alder	6	78	.0839	30	3,900	4.20	11.8	20.2	39.4	23.8
Juneberry	6	19	.0172	30	950	.88	11.8	4.9	8.2	8.3
Mountain maple	8	23	.0064	40	1,150	.33	15.7	5.9	3.1	8.2
Hairy-climbing honeysuckle	3	8	.0021	15	400	.08	5.8	2.1	.8	2.9
Fly honeysuckle	2	3	.0010	10	150	.04	3.8	.8	.3	1.7
Round-leaf dogwood	1	7	.0010	5	350	.07	2.0	1.7	.7	1.4
Red osier dogwood	1	2	.0005	5	100	.02	2.0	.5	.2	.9
Total		387	.2132	255	19,350	10.68	100.0	100.0	100.0	100.0

In computing this value, be sure to recognize that it is derived from the class midpoint and is not an absolutely accurate estimate of basal area. The total number of stems and total basal area can be used to estimate density and basal area for all stems just as in the tree stratum. Here too, it can serve as a cross-check on species computations.

Relative values for each characteristic can be computed using the formulae as for the tree stratum. When all summary calculations are completed, the stand summary sheet will contain sections headed tree seedlings and tall shrubs (table 3).

Basal area values could also be carried forward to the summary sheet as cm.^{2} per m. or ha. Divide cm.^{2} per acre values by 929.034 to convert them to ft.^{2} per acre.

8c. Summarize low shrub, forbs, etc. data ( ).

Because the raw data for the low shrub, forbs, ferns, and the ground surface characteristics were collected in the same manner on the same sample plots, we can discuss data reduction procedures for all simultaneously. Although the data may be collected at the same time, they should be recorded either on separate forms or at least separated to facilitate computation (fig. 9).

The measurement recorded in the field is the estimated percent of plot covered by projection of foliage onto the ground. The percent cover of a species can also be used to indicate the species presence in the plot for frequency computation. Occasionally a species may cover part of a plot and yet not be rooted in the plot. The data sheet, therefore, must contain some method for indicating when this occurs so that all recorded values are used for average percent cover computation but not for frequency computation. Note that in fig. 9 this situation was indicated by recording in columns at the far right of the data sheet the plots where only cover and not frequency is to be included for the species.

A worksheet is not needed to derive the totals for the summary sheet for these two strata. Sum the values for cover in the 20 plots across the data sheet for each species and bring this total forward to the summary sheet. Count the number of plots where cover was recorded, subtract those which were noted as not to be included for frequency purposes, and bring this total forward to the summary sheet. Summarize data separately for (1) the low shrubs, (2) the forbs, ferns, and fern allies, and (3) the ground surface characteristics. Because computations are the same for all three groups, only a few examples from the low shrub group will be used.

The species name, frequency, and total estimated percent cover are represented in the first three columns of the summary sheet (table 5). Frequency is computed as it was for the other strata; i.e., the percent of the plots in which a species occurred. Thus, late sweet blueberry (*Vaccinium angustifolium*) was present in 20 plots out of a possible 20 plots for 100 percent frequency. The average percent cover is used as the characterization of dominance for these strata. Average percent cover is the total estimated cover averaged over the number of plots; thus, the cover of wintergreen (*Gaultheria procumbens*) was estimated at 153 percent in the 20 plots (153/20), o

Table 5. – Low shrub, herb, and moss-lichen strata summary sheet for Stand No. 01, Uniform Area No. 01

Species or characteristic	Plots occurred in	Total cover	Species frequency	Average cover	Relative frequency	Relative dominance	Importance value
	Number	Percent	Percent	Percent	Percent	Percent	Percent
Low shrubs:							
Late sweet blueberry	20	272	100	13.60	47.6	55.7	51.7
Wintergreen	18	153	90	7.65	42.9	31.4	37.1
Velvet-leaf blueberry	3	57	15	2.85	7.1	11.7	9.4
Wild rose	1	6	5	.30	2.4	1.2	1.8
Total		488	210	24.40	100.0	100.0	100.0
Herbs:							
Bracken fern	10	470	50	23.50	14.7	48.9	31.8
Large-leaf northern aster	17	327	85	16.35	25.0	34.0	29.5
Grasses	15	48	75	2.40	22.1	5.0	13.5
Clinton's lily	1	5	5	.25	1.5	.5	1.0
Total[1/]		962	340	48.10	100.0	100.0	100.0
Mosses-lichens:							
Litter	20	1,732	100	86.60	29.4	86.6	58.0
Dicranum spp.	12	83	60	4.15	17.6	4.2	10.9
Other mosses	11	48	55	2.40	16.2	2.4	9.3
Total[1/]		2,000	340	100.00	100.0	100.0	100.0

1/ For brevity, totals include species not listed.

an average of 7.65 percent projected ground cover. Relative frequency and relative dominance (percent cover), as in the other strata, are computed as the percent of each species contribution to the total for these values. The importance value is computed as the average of these two relative values.

Note that cover values for the low shrub and forb, fern, and fern allies groups can average more or less than 100 percent cover due to overlap or openings in the foliage, but the total for ground surface characteristics cover will usually average 100 percent. The reason is that the latter includes all ground surface characteristics and there is normally no overlap.

The data derived from this summary will be reported in the last three parts of the stand summary (table 3).

If cover estimates are assigned by classes, the data must be summarized differently than in our example. A frequency chart will show the number of times each species was assigned to each cover-class value. One can also use the cover-class identification numbers to derive an index value for the species. For example, assume that a species was assigned the following cover-class values:

(1) Class identification number	*(2) Number of times assigned*	*(1) x (2)*
1 (less than 1%)	0	0
2 (1 to 5%)	1	2
3 (6 to 25%)	4	12
4 (26 to 50%)	10	40
5 (51 to 100%)	5	25
Total	20	79

Summing the products of the class identification numbers (1) and the number of assignments for the species (2) and dividing by the total number of assignments (79/20 = 3.95) provides an index of the class-cover assignments. This could be done for each species and reported as a part of the stand summary.

An additional useful summary for tree species is a chart or table indicating the number of stems of each diameter encountered in the sample.

8d. Summarize stand characteristics (   ).

Values for the characteristics computed from the raw data comprise four major parts of the stand summary. Copies of this summary sheet (table 3) should be placed in several files.

PART II – DISCUSSION

This section explains in greater detail the steps involved in collecting information on natural areas. Hopefully, it will benefit nonprofessionals who are not familiar with vegetation sampling techniques. Those who wish more information than is provided here are invited to consult the literature references cited. Some general reading of ecology texts would be particularly helpful, especially Cain and Castro (1959), Greig-Smith (1964), and Kershaw (1966).

What is a Research Natural Area?

According to the statement on policy and standards by the Federal Committee on Research Natural Areas, such an area may be defined as ". . .a physical or biological unit where natural conditions are maintained insofar as possible. These conditions are achieved by allowing ordinary physical and biological processes to operate without intervention, but on certain Areas, by deliberate manipulation intended to maintain the unique features that the Research Natural Area was established to protect."

What is the Value of Such an Area?

Many views have been stated on the value of natural area preservation (Shanklin 1951, Shanklin *et al.* 1952, American Association for the Advancement of Science 1963, Lawrence 1963, Spurr 1963, Cowan 1968, Darnell 1968, Franklin and Trappe 1968, Wellner 1969). Buchinger (1969) stressed six values of such areas – patriotic, scientific, economic, educational, recreational, and moral. Nicholson (1968) listed the following reasons why natural areas will be important to both biological and human welfare:

1. The maintenance of large, heterogeneous gene pools.
2. The perpetuation of samples of the full diversity of the world's plant and animal communities in outdoor laboratories.
3. Opportunity for comparison with managed, utilized, and artificial ecosystems.
4. Outdoor museums for study, especially in ecology.
5. Education in the understanding and enjoyment of the natural environment and for the intellectual and esthetic satisfaction of mankind.

Background Information

The first step in characterizing a natural area might best be to collect information already available about the area. Some of these data may have been gathered in conjunction with the reservation procedures for the area. Additional information may have been gathered during completion of IBP checklists. But for most areas, previous data collection will not be as complete as it can or should be. Therefore, a thorough search for background materials is needed. Background information is useful in at least three ways: (1) It sets the stage for selecting a sampling scheme that will adequately describe the vegetation. It may dictate sample stratification. (2) It will aid in interpretation of study data. (3) It may foster further research within the natural area – a major goal in the establishment of these areas. Unique conditions may be brought to light, and future researchers may want to examine these conditions in relation to the biotic communities. Researchers are more willing to work in areas where the historical and environmental aspects are well documented.

Listed below are some kinds of general information that might be sought. We cannot predict which types of information will be most important; any data that add knowledge and promote greater insight will be valuable.

Maps

The landscape features of a natural area are important to its description and study. Most topographic features are the result of the interraction between the erosion and the underlying bedrock. The main forces of erosion are wind (atmospheric), water (fluvial), and ice (glacial). Topographic features are basically the product of four factors: the agent of erosion and its mode of operation (e.g., a river cutting into its valley); the degree to which an agent has completed its work (stage); the physical and chemical character of the rock being eroded (determining those physiographic features that are due to differential erosion); and length of time that an agent has been operative (as well as interruptions to its normal activity).

Landscape features are represented on two types of maps:

(1) *Flat (planimetric).* – A two-dimensional projection of an area that shows only positions of and distances between objects.

(2) *Relief.* – A three-dimensional depiction of the topography as well as the details included in flat maps. Topography may be shown in a variety of ways, including shading, color, hachures (lines drawn in the direction of slope of mountains, hills, and valleys), and most commonly by contours (lines through points of equal elevation).

The existing file for a natural area will usually have a flat map available, and it may also have a relief map. However, the scale may not be well suited for fieldwork. A scale of 1:250,000 (4 mm. per km. (0.25 in. per mile)) may be adequate for general location purposes, but 6.4 cm.^{2} (1 in.^{2}) at this scale will cover almost 4,032 ha. (10,000 acres). A scale of 1:24,000 (4.2 cm. per km. (2.64 in. per mile)) is much more useful because 6.4 cm.^{2} (1 in.^{2}) on this scale will cover only about 37 ha. (90 acres). U.S. Geological Survey quadrangle topographic maps are available at this scale. Surface topography is often shown by 3.04-m. (10-ft.) contour intervals. Another useful scale, if maps are available, is 1:7,920 (12.7 cm. per km. (8 in. per mile)). One in.^{2} (6.4 cm.^{2}) will cover an area of about 4 ha. (10 acres) and thus the map is useful for detailed work on the ground.

In addition to those showing land surface features, there are maps and diagrams (or reports) that deal with the underlying mineral material. Unfortunately, these maps are often unavailable or are too small in scale to be of much help. However, the following related types of maps can be useful.

Bedrock geology. – Maps showing the consolidated materials underlying the area (which may protrude above the surface in places). At least small-scale maps of this type have often been produced (many bedrock geology maps for States are available). Some areas have been mapped in great detail, especially where economically important minerals may be present. Bedrock geology maps may also include topographical and cultural features of the area.

Block diagram. – Illustrations of the geology and physiography of an area. They are especially useful in demonstrating the relationship between geological structure and topography. Such diagrams are usually found in geological reports for an area.

Surface geology. – Maps of the unconsolidated materials above the bedrock. These materials may be derived from the bedrock below or may have been transported into the area by wind, water, or ice. These maps may conform to the bedrock geology maps only where bedrock reaches the surface.

Soil. – Maps of unconsolidated surface materials that have undergone differential weathering and organic matter incorporation. There may be several soil types mapped on the same unconsolidated surface material. Most agricultural soils have been mapped in the United States, but few forest soils have been mapped. If soil maps are available, they represent an especially useful aid to vegetation interpretation.

Glacial geology. – Maps or diagrams showing the extent of the various ice advances and retreats and the resulting landforms, such as moraines, eskers, etc. These are only available where glaciation has been important.

Bathometric. – Lake bottom contour maps. Where lakes are an important part of the natural area, these maps are useful. They are sometimes available in areas where commercial or sport fishing, navigation, or hydroelectric power development has been important.

Vegetation. – Maps of the vegetation of an area. In recent years such maps have become important and are now available for all parts of the world (Kuchler 1967). Most are on a very small scale; for example Kuchler's (1964) map of the United States (1:3,168,000). These maps are useful for showing the relationship of the natural area vegetation to that of the surrounding region, but larger-scale maps are better for fieldwork. The California vegetation-soil survey maps are a good example of such large-scale maps. These maps are based on a minimum mapping area of 4 ha. (10 acres). They are available on a scale of 1:31,680 (3.2 cm. per km. (2 in. per mile)), which is about the same scale as the 7-1/2-minute quadrangle topographic maps of the U.S. Geological Survey. Forest land management agencies (e.g., USDA Forest Service) frequently have timber-type maps available. They are relatively large-scale maps generated by interpretation of aerial photographs and based on commercial important tree species. A common scale is 1:31,680.

Photographs

Aerial. – Photographs taken from above the vegetation by aircraft. One of the most productive sources of information is the aerial photograph. Although few airphotos were taken prior to the 1920's, many areas have been photographed about once per decade since then, providing good visual evidence of major land use and vegetation changes over time. Most natural areas on federal lands have been photographed from the air one or more times. These photos are available in stereographic pairs and will provide a three-dimensional view of the area. Natural areas located in the vicinity of agricultural land may have been photographed from the air frequently in recent years by governmental agencies in their administration of land bank and crop production programs.

Ground. – Photographs taken of the vegetation from ground level. Useful photos from the past that were taken from an established point are difficult to find. Such things as historical documents and land survey party notes occasionally contain photos. If found, they are especially useful to document general plant cover changes that have occurred.

Historical Documents

A part of "analyzing" vegetational data and other observed phenomena is simply relating them to past history. Biotic communities are greatly influenced by what has happened to them in the past. What can one look for to help determine past influences on the area?

Official land surveys. – Land survey records are available for most of the continental United States, and they may be available for other areas, too. The metes and bounds surveys of the colonial States can provide some insight to vegetation changes, but the rectangular surveys of the General Land Office include definitive observations of the vegetation at the time of survey. Thus, they are usable for quantitative as well as qualitative analyses (Bourdo 1956). These surveys have been used to construct maps of forest type distributions, or to determine structure and composition of forests at the time of survey (Davis 1907, Marschner 1946, Cottam 1949, Brown 1950, Bourdo 1956, Lindsey *et al.* 1965, Ward 1956).

Geomorphology. – Geomorphic processes leave their distinct imprint on the land and each develops its characteristic assemblage of landforms. In some regions these processes have been studied and published as reports of the State geologist or in scientific journals. Any literature of this type should be included in the natural area file. This information is best located through contact with local college or university geology or geography departments, or through government agencies that deal with geology, minerals, or land planning.

Climate. – A knowledge of past and present climatic conditions prevalent in the region of the natural area is important in understanding both vegetation and flora. The annual precipitation pattern, seasons of adequate moisture, direction of prevailing winds, frost-free season, and length of growing season are all important and have been documented for most areas through official weather station data (U.S. Weather Bureau Climatological Data – National Summary and also monthly State Reports). Some of these data have been included in the IBP checksheet. Long-term climatic history can be deduced by observation of vegetation change through fossil pollen analysis. A history of the regional vegetation from pollen analysis may be available, especially if the region has been glaciated. Some information may also be available on the historical aspects of the flora in plant geography books. Any such information will help future workers to understand how the present vegetation developed, and it may help to predict what the future vegetation will be. Literature pertinent to the natural area should be added to the file.

Disturbance Records

Natural disturbance. – A record of severe regional disturbances caused by natural agents such as fire, wind, disease, and insects may exist. This kind of information is best sought from area colleges, universities, and land management agencies. Wildfire history, at least for recent periods, can be obtained from the records of the agency that is responsible for protecting the area from fire. Evidence of fire may be found in charcoal presence at the surface of the mineral soil, but will not provide a date for the fire. More exact dates for some vegetation may be obtained by looking for fire-resistant trees with scars on their bases from past fires – these trees can be bored into with an increment borer to obtain an annual ring core showing years of past fires (Heinselman 1969).

Information on wind damage by hurricane or tornado may be obtained through interview of nearby residents, or the former owners of the natural area, if any. Stump evidence of salvaged dead and down trees may be traced to severe wind damage.

History of disease and insect epidemics can probably best be obtained from land management agencies near the natural area. Both of these influences are usually regional in character and thus well known. They can have an important influence on the vegetation present at any given time through setting back succession; for instance, oak wilt (*Ceratocystis fagacearum*) can have a major influence on components of oak forest communities of eastern North America, and the spruce budworm (*Choristoneura fumiferana* Clem.) has drastically altered fir-spruce communities in the northern United States and Canada. Although set back, the plant communities recover in time. Apparently such epidemics have recurred periodically through time.

Human disturbance. – This influence may operate either directly on the natural area (usually not extensive or it probably would not have qualified as a natural area), or indirectly (most natural areas have been affected to some degree). In either case these conditions should be documented so that they are considered in analysis of present or future vegetation studies.

Some of man's direct influences are roads, agriculture, drainage, salvage logging, or other obvious disturbances not present when the area was reserved. Some other direct disturbances such as removal of dead or blown-down trees, trapping, hunting of animals, recreational harvest of forest products (berries, mushrooms, seed cones), plant collecting, and pesticide or herbicide application (as part of a larger regional program) are hard to detect, and may be discovered only through interviews of nearby residents or former owners of the area, if any.

Indirect influences may be more insidious and difficult to document. These are activities that occur on lands surrounding the natural area. Industrial, mining, or agricultural practices may produce materials that find their way into the natural area or utilize substances that would normally move through the natural area. Included in this category are pollutants, both atmospheric and waterborne; dams that influence water levels or flow patterns; irrigation practices; and horticultural or agricultural activities that introduce exotic plant species or diseases, such as the chestnut blight (*Endothea parasitica*), white pine blister rust (*Cronartium ribicola*), and Dutch elm disease (*Ceratocystis ulmi*).

Vegetation Description

In the early years of ecology, subjective observations by trained personnel were considered adequate for describing the characteristics of a plant community (Oosting 1956). Time has shown that few observers view things alike. It became apparent that ecological description would have to become more precise through accurate measurement and detailed records. This has led to the predominant use of quantitative methods of sampling and describing vegetation.

Qualitative Techniques

Floristics. – The flora is the total of all the kinds of plants that exist within an area. The identification and collection of voucher specimens of the flora in a natural area is a useful contribution. This will require some taxonomic ability. Identification "keys" for most areas are available. A hand lens and a dissecting microscope are useful tools to aid in identification. Specimens (including the root system if possible) should be collected, dried in a plant press, mounted on herbarium paper, and properly identified. Collections should be made throughout the growing season. Some natural areas are set aside for the protection of rare or unusual species. If the area being described is one of these, workers should be aware of the rare species and refrain from collecting them without permission of the managing agency. Some plants are also protected by government statute; these too should not be collected without a permit. Rare or unusual plants within natural areas may be indicated on IBP checksheets that have been filled out for most areas. If a copy of the completed checksheet is not in the natural area file, one can be obtained from the Biological Records Centre, The Nature Conservancy, Monks Wood Experiment Station, Abbots Ripton, Huntingdon, England.

Most potential investigators toward whom this manual is directed will have had some experience in collecting and preserving plant specimens. A recent book by Klein and Klein (1970) contains an up-to-date description of the procedures and equipment required.

The problem of where to deposit voucher specimens is still unresolved – it is hoped that eventually some central location will serve as a data bank for all natural areas and that voucher collections will be deposited in an herbarium within this data bank. Meanwhile, the best solution is to house the collection at a nearby educational institution with herbarium facilities. Be sure a list of the plant collection with the collector's identification number is maintained in the natural area file of the managing agency. Duplicate lists should be filed wherever data from the area are deposited as well as with the herbarium where the specimens are deposited. These collections require a great deal of work, but they are necessary. As the vegetation of a natural area matures, certain abundant species may become rare and even disappear, while others may invade and change from rare to abundant. Proper identification through voucher specimens is necessary to prove that a species is present now, even though it may not be found when the area is surveyed again at some future time.

Permanent Photographic Points

Gross changes in vegetation can be recorded by photographic evidence. Photos should be taken from permanently marked locations along recorded compass bearings. Appropriate information as to season, location of permanent points, and compass bearing needs to be recorded for each photo. Marking and describing permanent photo points must be as accurate as marking and describing permanent vegetation sampling plots.

Mapping

Vegetation, at least dominant forest cover types, can be mapped on a qualitative basis by running lines (transects) and recording obvious changes in cover or vegetation characteristics. Vegetation can also be mapped through airphoto interpretation with ground spot-checking. Detailed vegetation mapping is usually best done after one is familiar with the vegetation or after the various plant communities have been distinguished through objective quantitative techniques.

Individual species distributions may also be mapped; this will require an intensive search of the natural area. For certain very rare or unusual species this might be a useful contribution, but often natural areas will be small enough so that most species will be found throughout. Both kinds of mapping are time consuming if done properly and are probably best done after the area's vegetation has been well described.

Physiognomy

Vegetation can be described qualitatively in terms of its physiognomy, or general outward appearance. Dansereau (1958) presented such a method that does not require detailed knowledge of the species present. It involves using symbols as a pictorial representation of the vegetation. The procedure includes five steps, which have been presented in detail by Phillips (1959): *Step 1.* The number of different life forms present is ascertained, and the various symbols necessary to separate these life forms are devised. *Step 2.* The size of the different plants of each life form is estimated or measured. *Step 3.* Leaf shape, size, and texture is recorded for each life form. *Step 4.* Percent coverage is estimated for each life form. *Step 5.* A diagram of the vegetation is prepared on graph paper using the appropriate symbols.

Quantitative Techniques

Time, money, and manpower availability are important considerations in sampling and description. They have a direct bearing on the considerations of what, and how, to sample. Ideally a natural area's plant and animal populations, and the environmental factors that influence them, will be simultaneously described so that future changes can be monitored. The eventual goal, however, should be to describe the processes governing production of organic matter, the flow of energy, and the cycling of nutrient resources. The assumption of this manual is that most potential users will, as a minimum, be interested in sampling to provide a quantitative description of the major plant communities in a natural area. Along with quantitative vegetation data, sufficient environmental information should be collected so that the vegetation can be related to its surroundings.

Obviously, the most accurate way to quantitatively describe the vegetation of an area is to document every plant. However, this is only feasible for very small areas, and is probably unnecessary even there. The customary method of describing vegetation is by sampling – that is, by selecting parts of an area for data collection and then extrapolating for the whole area.

The most critical aspect of sampling is the design – the subsequent data collection is mostly hard work. The sample design for quantitative description is best derived through consultation with statisticians, biometricians, professional botanists, or ecologists. This should be done after the background information is as complete as possible, and after the natural area has been examined by a thorough field reconnaissance. The vegetation should be sampled in such a way that the results can be projected as accurately as possible for a specific part of the whole natural area. A series of samples that properly represent the vegetation of the area under consideration must be obtained. This should be done efficiently to result in as accurate a description as possible for the time, money, and effort expended.

Most ecology textbooks contain a section on sample design and sampling. Some books that deal entirely with vegetation sampling are: Brown (1954), Phillips (1959), Cain and Castro (1959), and Greig-Smith (1957, 1964). Most natural areas will already have had some aspects of what Cain and Castro (1959) refer to as a "primary survey" completed through the checksheet filled out for IBP in accordance with Handbook No. 4 (Peterken 1967). This information, along with other background information, described in the previous sections, should serve as the basis for what Cain and Castro (1959) refer to as the "intensive survey" of the area. This survey can deal with all the communities in an area, or it can treat a particular community. The major problem with this approach is that it assumes one already has knowledge of the communities.

Sample Design

What is the procedure for setting up the sample design? From the preceding paragraphs you have probably surmised that there is no pat answer. This section details some ideas and practices that should help make the sample design as valid as possible.

Stand Selection

On the basis of background information and reconnaissance, the design should treat as separate units those parts of the area that are similar in history, geology, topography, or other features that strongly affect the vegetation (e.g., forest versus nonforest, upland versus lowland, etc.). Within each uniform area (only rarely will the entire natural area be uniform) a random procedure should be used to select stands to be sampled. Perhaps the best method is to sketch on a topographic map or aerial photograph of workable scale the uniform areas from which the sample stands will be drawn. Then establish a grid by drawing baselines at right angles to each other on two sides of each uniform area. Finally, by drawing numbers from a random numbers table, a hat, or a deck of cards, establish the distance along the baselines for each stand to be sampled. Plot the coordinates of the two distances as a point on the map or photo to represent the center of areas (stands) to be sampled (fig. 12).

Each stand is then a random sample of the vegetation within the uniform area. How many such stands are required to adequately describe the vegetation of each

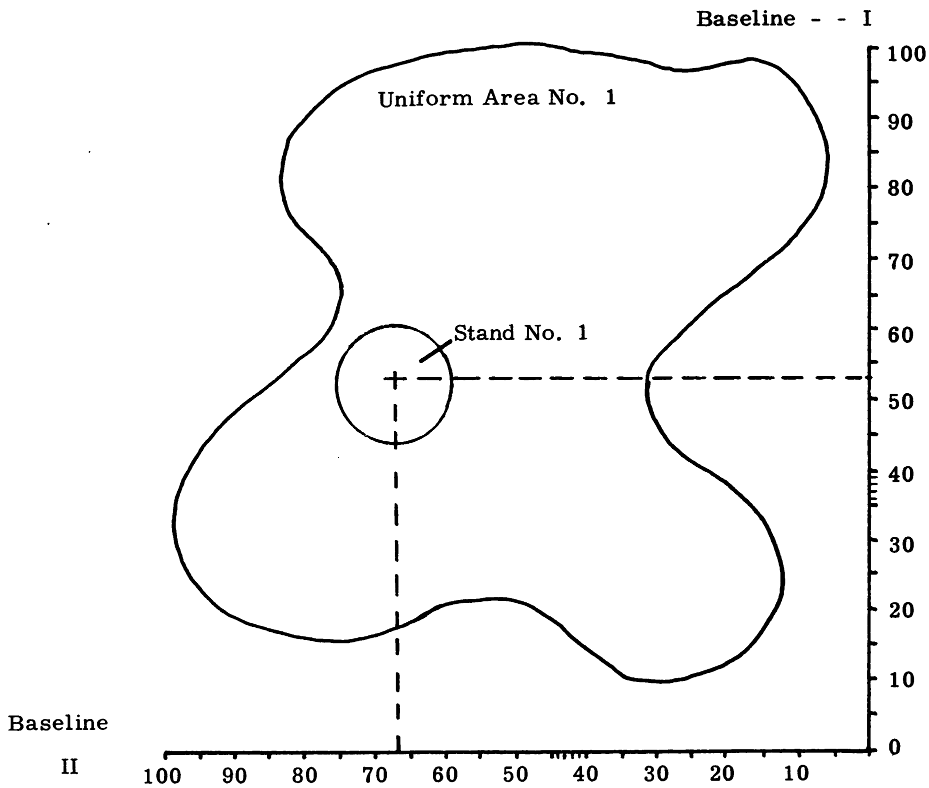


Figure 12. – Random selection of sample stands in Uniform Area No. 1. Number from table of random numbers was 5,367.

uniform area? How many plots need to be sampled to adequately describe the vegetation of each stand? These two questions are related and discussed below.

Number of Samples

The basic objective of sampling is to obtain data for comparison with future data. To do this one can treat each stand (even each plot) as a discrete unit. This is a valuable approach, but another useful approach is to combine data from all sampled stands within a uniform area to describe similar stands; that is, to summarize the stand data to describe the naturally occurring plant communities. For example, of 20 stands sampled on a uniform area, objective methods of comparison may show that they segregate into three groups of 10, four, and six stands. If we have selected enough random samples from the uniform area, we can assume with some degree of confidence that we are describing the three major plant communities in the area. The cause of the differences must be determined. Much of the background information may be of value here.

In other cases, primary interest may be in obtaining baseline data to monitor change and not in summarizing stand data. The baseline data obtained, however, should be such that others can later synthesize them, and use them to describe and analyze the plant communities. Thus, the number of plots should be sufficient to completely describe each stand, and the number of stands sampled within a uniform area should be sufficient to provide information on all the major plant communities present and to allow meaningful summaries of each community type.

How many samples are sufficient depends partly on the nature of the vegetation to be sampled, on its complexity, and on the number of community types present. In the past many authorities recommended using the "species-area curve" as an estimate of the number of samples to take. The general philosophy behind this idea was that when additional samples do not add new species or do not greatly refine the information already obtained, the effort required to obtain further samples is better spent elsewhere. Another method is to compute the standard error of the mean for the plots or stands sampled, and when this error is within the limits of accuracy you wish to obtain in your survey, the sampling is terminated. Methods like these suffer from the fact that they cannot be determined prior to sampling and they cannot be used to determine sample numbers for the next unit to be sampled. A further drawback is that while the error might be low for some species (perhaps the most common), it would not be for other species in the sample. One might use some composite characteristic such as tree density for all species, and by a running computation of the mean and its standard error, terminate sampling when this parameter is at acceptable limits. This is not a useful technique to determine the number of stands to sample until the community types have been defined, and the accuracy of their definition depends on the number of sample stands used. There thus appears to be no good objective way to determine how many samples are sufficient, and the methods proposed in the literature do not go beyond a rough guide as to whether most of the species present have been recorded or not. Greig-Smith (1964) summarizes the problem this way: "The validity of determining, other than empirically, any precise area to be used in describing vegetation depends on whether or not there is at some point, a sudden decrease in the amount of additional information obtained."

Distribution of Samples

Selection (by random means) of areas (stands) to be sampled has already been discussed. Distribution of the sample plots within the stand needs also to be considered.

Within a stand, plots might be distributed in three ways: (1) by arbitrarily selecting plots considered typical of the stand as a whole, (2) by selecting plots randomly, or (3) by selecting plots on some regular pattern. Selection of "typical" sites is generally not the approach used in vegetation description unless the objective is to describe "typical" stands – i.e., the modal characteristics of a predetermined community – through use of a limited number of plots.

If the plots are selected randomly, one can calculate the mean for any characteristic measured, and also measure the precision of this mean through the standard error. This is desirable in comparing sampled stands because unless we know the accuracy of estimated values for vegetation characteristics, it is impossible to assess the likelihood of their differences arising from chance.

Random selection of sample plots is time consuming in the field and many workers prefer to use some systematic method of selection. Systematic sampling is also thought to be more representative of variation over the sample area and thus likely to give better estimates of vegetation values than will random sampling. Some studies have shown little difference in data when both of these methods were used on the same area (Cain and Castro 1959).

The most workable method for randomizing sample plots, like selecting sample stands, is to lay down two perpendicular lines as axes at the edges of the stand, and by using a pair of random numbers as coordinates, position each sample plot along the two axes. Measurement of distances from the axes to the sample plots need not be exact (Greig-Smith 1964); pacing will be adequate and more efficient. However, the plots must be easily relocated in future years.

If systematic location of sample plots is used, it is important that the distribution pattern give a uniform representation of the area. Other considerations must also be met – for example, in some sampling techniques the points must be far enough apart so that individual trees are not sampled from two different points.

For intensive studies of a few stands on small natural areas where extra time and effort are worthwhile, a random location of stands and sample plots within the stands is recommended. On more extensive surveys of many stands, random location of stands and systematic plot distribution after randomly locating the first plot within the stand are desirable.

Sampling Units

Beyond the problem of location and distribution of sample units, a further consideration is the sampling units themselves. Some possible units are plots, plotless units, transects, or some combination of these techniques.

Plots

A plot is an areal sampling unit, traditionally square in shape. Rectangular plots have been found to be statistically more efficient than other shapes, while circular plots are more efficient in terms of measurement time. This is especially true if the outer limits of the plot are established with a rangefinder, thus eliminating the need for establishing plot boundaries.

Rectangular plots are statistically superior for sampling species showing a clumped distribution; the plot intercepts more clumps, thereby reducing the variability of the data. This advantage must be weighed against the advantages of square and circular plots, which are ease and speed of establishing and measuring and having to make fewer decisions on whether a stem is inside or outside the relatively shorter perimeter. Therefore, where time is critical, circular plots might be preferred, and where reduction in data variability is of primary concern, rectangular-shaped plots might be preferred.

Plot size is related to the size of the plants to be sampled and thus should be fitted to the various vegetational strata in the stand. In the section on components I have suggested some plot sizes that might be appropriate for the various strata of a forest stand. Curtis and McIntosh (1950) recommend that plot size be four times the mean area occupied by the most abundant species.

Plant density, frequency, and dominance (basal area or cover) can all be determined through use of plots. Frequency varies with the size of the plot and thus can be compared only for plots of the same size. If large plots are used, percent frequency values for the less numerous species will be inflated. Density and dominance are independent of plot size except in terms of efficiency of sampling.

Plotless Techniques

Some of the newer plotless sampling techniques are generally more efficient than using plots for sampling large woody plants. In forest communities it is often best to use a plotless technique for sampling trees and saplings, and plots for the other strata (Ohmann and Ream 1971a).

In plot sampling, density is determined by counting the number of stems in the plots and expanding this value to a larger area. Another way of characterizing density is to determine the reciprocal of the number of plants per unit area – that is, to determine the mean area each stem occupies within the stand. This value, the mean area, can be computed by assuming that trees are spaced so that the distance between them is equal to the square root of the mean area. In the field, measurements are taken at established points instead of plots within a stand. The points are regularly spaced (the first point may be randomly selected), and the distance between the trees is measured by one of several methods. The point-centered quarter method for measuring density is presented below; other methods of plotless sampling are detailed by Cottam and Curtis (1956).

Although the point-centered quarter method has been applied to sampling shrubs and grasses, it is probably most applicable to the tree stratum. The direction of movement from point to point within the stand constitutes one line, and a hypothetical line is drawn perpendicular to the line of movement (fig. 13). These two lines drawn through the point define four quadrants (note that this term differs from the quadrat). The distance to the nearest tree stem, its species name, and its d.b.h. are recorded in each quadrant at each point. When working with two size classes, trees and saplings, the nearest stem in each class is measured and recorded in each quadrant. The distances are usually measured to the nearest 30 cm. (1 ft.) or 15 cm. (1/2 ft.), and the d.b.h. to the nearest 0.25 cm. (1/10 in.), as in the areal plot methods.

The same information collected on areal plots can be determined by use of the plotless technique. In fact, relative values for frequency, density, dominance, and their summation, the importance value, originated with the plotless techniques. Thus, density, basal area (as a measure of dominance), and frequency (although different from plot-derived frequency) can all be determined through use of the point-centered quarter method.

If basal area is the primary concern, the variable radius sampling method introduced by Bitterlich (Grosenbaugh 1952) is a useful technique. A sighting gage is used to count trees that are within a distance of not more than 33 times their stem diameter from the sampling point. This tally multiplied by 10 results in a direct conversion to $ft.^2$ of basal area per acre. More recently (Bruce 1955), prisms have been used in place of the sighting angle gage, but the theory remains the same.

Lindsey *et al.* (1958) have assessed the efficiency of several plot and plotless techniques for sampling density and basal area in forest stands. The time required to reduce the standard error of the estimate to 15 percent was the basis of comparison. They concluded that variable radius sampling is superior for basal area estimation and that a 400 $m.^2$ (1/10 acre) circular plot defined by a rangefinder is more efficient for density determination.

Stand Vegetation Characterization

What parameters will provide useful information about the composition and structure of forest stands? How does one characterize vegetation? This section will

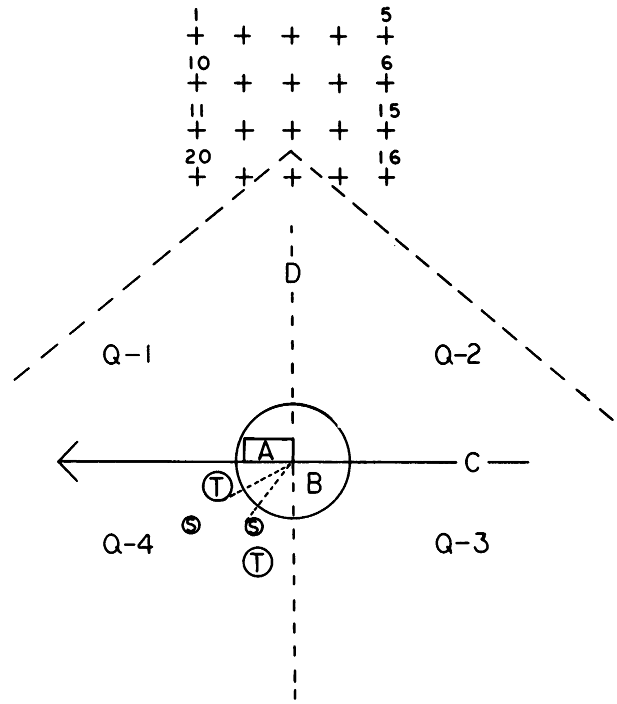


Figure 13. — The upper portion of the figure shows the distribution of sample points within a stand. The lower portion is a diagrammatic representation of the sampling system at one sample point. A is a 1- by 2-ft. plot for sampling herbs and low shrubs. B is a milacre plot for sampling tall shrubs and tree seedlings. C is the line of travel and D is an imaginary line perpendicular to it, forming the four quadrants (Q) of the point-centered quarter method. S is a sapling. T is a tree.

describe some types of quantitative information often collected to describe vegetation.

Density

The number of individuals of each species present in the stand is an important way to characterize vegetation. Density is determined by counting the number of individuals of each species growing on each sample plot, and then estimating the average number of stems of each species per unit area sampled. Density is usually expressed as the number of stems per acre, square meter, hectare, or some other convenient unit.

When number of stems is based on estimation rather than counting, the characterization is referred to as abundance and is expressed by assigning each species to an abundance class. The concepts of density and abundance have been discussed in detail by Cain and Castro (1959).

Density can also be expressed on a relative basis as the percentage that a species makes up of all species. In general, relative density should be used only in conjunction with absolute density or other absolute measures of the species importance because relative density alone may overemphasize the importance of a species. For example, seedlings of prolific seed-producing trees may be very numerous following a good seed crop, but most of these individuals may not survive the first growing season. These may not be as important to the community as another species whose relative density is smaller but which is represented by older individuals.

Density is usually expressed in stems per unit area rather than in individual plants. It is often restricted to woody plants (usually tree and shrub species). With non-woody plants (and some woody plants, too) there is often a problem of determining what constitutes an individual. Even if all species could be adequately separated as individuals, counting small herbaceous plants would be very time consuming. Some tree species exhibit a clonal nature whereby the individuals are connected through underground root sprouts or other species by above-ground runners, and one cannot distinguish (in the normal sense of the term) an individual plant. One can, however, usually distinguish individual stems above the ground although sometimes stems are fused for some distance above the ground. Where does the fusion represent a stem and its branch and where does it represent two separate stems? This should be decided in advance; then the situation should be consistently treated each time it occurs. A convenient way to treat these cases is to consider any fused trees that separate below breast height (1.4 m. (4.5 ft.)) as individual stems, and to consider any shrubs that separate below 15 cm. (6 in.) as individual stems. The procedure used should be recorded in the description of methods that will accompany the data for the natural area.

Density of tree seedlings (stems per unit area) might best be categorized by height class. This is because certain species produce many small seedlings that may live for only one or two growing seasons. These seedlings quickly pass out of the picture in terms of stand succession. Other tree species may not produce many individuals, but more of the seedlings survive and are able to replace canopy trees as they die. Thus, a species with a rather low density but with individuals in several height classes might be ecologically more important than a species that has a high density but individuals only in the smallest height class.

Cain and Castro (1959) warn against obtaining density data as an arbitrary or standard procedure. I agree with their recommendation in part. I would advise density determination only for the tree (all size classes) and tall shrub species.

Frequency

Another method of characterizing the composition and structure of vegetation is to describe how widely each species is distributed within a stand. Frequency is expressed as the percent of sample plots in which a species is represented by at least one stem. The concept of species distribution patterns is discussed in detail by Greig-Smith (1957, 1964), Cain and Castro (1959), and Pielou (1969). Frequency is a measure of the homogeneity of the species distribution when used in conjunction with density and dominance (basal area or cover). Frequency values alone are somewhat unsatisfactory because they may not reflect numerical importance. There are, for instance, plant communities that have the same overall species density but when sampled with equal area, plot size, and plot number, will yield frequencies that vary 25-fold due to differing types of plant distribution (Greig-Smith 1957). To be recorded for frequency, a species needs only be present in a plot; one stem counts the same as many.

Most American ecologists require a stem to be rooted in the plot to count as present. Frequency in this case is technically called rooted frequency. A plant could project over a plot, or because of growth form (such as a trailing stem) be physically present but not rooted. However, these cases do not constitute presence for frequency computation if no other stems of the species are rooted in the plot.

Frequency values cannot be directly compared unless they are determined from plots of equal size and shape because the probability of a given species being present in the plot is dependent on the relationship between the plot area and the plant size. Thus, a plot size appropriate for determining frequency of large trees is not appropriate for small herbs, etc. This in itself is an argument for using different plot sizes to sample the various plant components of a stand. Even within a particular component stratum, frequency will depend on plot size. McGinnies (1934) concluded that larger plots give a better determination of frequency for the less abundant species and smaller plots give a better determination for the more abundant species.

Like density, relative frequency can be expressed as the percent a species makes up of all species.

Dominance

As Cain and Castro (1959) have pointed out, dominance is a term that is used in many contexts. As used here, it refers to the mass that a species contributes to stand structure. Through density and frequency characterization we derive knowledge of species numbers and distributions within a stand. Through dominance we add another dimension—the volume of space occupied or area of ground covered or shaded. Because volume is difficult to measure or even estimate for most species (Cain and Castro 1959), projected coverage of the foliage onto the ground surface or basal area are the measures most often used.

Cover is expressed as a percent. Obviously plants overlap each other in space within a stand; cover therefore may total more than 100 percent. An exception is the lowest stand layer (see section on components) which will normally have a total cover of 100 percent.

A limited number of cover classes are often used to assign cover percentages. Cover can also be estimated to the nearest 10 percent or even to the nearest percent. The smaller the estimated interval of cover, the poorer is the reproducibility of the measurement. The final estimate may not be any more crude, however, than is an estimate made by broad classification.

Cover is most easily estimated for low-growing vegetation because one can project foliage to the ground easily when standing above. It is also easier to estimate projected cover over smaller plots or over a tape laid on the ground than over large plots. For these reasons, cover characterization is often restricted to stand components that are low growing and sampled on small plots. When cover estimates for larger components are desired, some type of sighting device and a combination of mirrors is used to read percent cover projected over a tape laid on the ground. For cover estimates over small plots a piece of material of known area can be used as a standard to aid in estimation.

A more readily obtainable measure of dominance for the larger components of a stand is basal area. Basal area is the cross sectional area occupied by the stems of a species. For trees this is typically measured at breast height (1.4 m. (4.5 ft.)) above the ground surface. For tall shrubs and tree seedlings basal area has been reported at 15 cm. (6 in.) above ground. Tree seedling and tall shrub diameter measurements have also been made in the field by 1-cm. size classes to facilitate sampling. Tree estimates are usually based on diameter measurements using tapes that measure diameter equivalent of tree circumference. The diameter is recorded in the field and the data are converted to area by reference to a table. In the past, diameter has also been measured by use of a caliper. Measuring tapes are also available that measure area equivalent of circumference directly.

Basal area can also be characterized by a plotless technique in which trees surrounding a sampling point are counted by sighting over an angle gage (Grosenbaugh 1952) or through a calibrated prism (Bruce 1955).

Basal area is expressed as ft.^{2} per acre, cm.^{2} per m., or m.^{2} per ha. Diameter in the field is usually measured to the nearest 0.25 cm. (1/10 in.) at the same time the stem is counted for density characterization.

Both relative cover and basal area can also be expressed as the percentage that each species contributes to the total cover of basal area for all species.

Determining the volume occupied by a species, though difficult, can be done. A method for shrub species, which involves removing shrubs from sample plots and immersing them in water to calculate volume by the amount of water displaced, has been described by Buckman (1966). Volume estimates of standing usable timber are made by foresters interested in the amount of merchantable wood available in a stand. The d.b.h. and the height of the usable part of the stem are measured. By reference to appropriate tables the cubic- or board-ft. estimates of wood are determined.

Productivity

Another method of characterizing the stand vegetation is to estimate the standing crop or biomass yield on an annual basis. This is a destructive sampling method because it requires the clipping and removal of the vegetation from the sample plot (ideally including the root system) and thus may not be permitted in some natural areas. The procedure involves drying and weighing the material either by species, groups of species, or other category. The details of this method of vegetation sampling have been described in IBP Handbook No. 2 (Newbould 1967) entitled "Methods for Estimating the Primary Production of Forests."

Age

In temperate climates trees lay down increments of wood that can be differentiated as annual rings when the stem is observed in cross section. The rings can be counted from the center of the tree (pith) to the outermost ring to determine the age of the tree at the height of the cross section. Rather than cutting the stem to count these rings, a core of wood can be taken from the tree with an instrument called an increment borer. As the borer moves into the tree it cuts a small core. The core is removed and the rings are counted. Additional years can be added to the ring count to allow for the time required for the tree to grow to the height at which the core was removed. This addition is only important if one is seeking an absolute age for the tree. By comparing the ages of trees forming the canopy, one should be able to determine if the stand is even-aged (all the canopy trees started growing at about the same time following some past disturbance such as wildfire), or if it is all-aged (suggesting that the forest is mature and has undergone some period of canopy replacement). An all-aged canopy implies that the site has been forested for some time and that there has been replacement of trees that have died. This information can provide an indication of successional trends and capabilities of various species.

Increment borers are available in various lengths from science equipment and forestry suppliers. Most tree species can be aged; however, some species when mature have rotten centers, making accurate ring counts impossible. With a little practice one should be able to remove a core that will include the pith of the tree. Certain hardwood species are difficult to bore, and it is even more difficult to extract the borer after a core has been removed. Applying soap to the outside of the borer when working with difficult species may help. Some species have annual rings that are difficult to distinguish. Smoothing the core on one surface by shaving or sandpapering, and then wetting it with water or kerosene may make the rings appear more pronounced. Cores of nonporous woods are best counted by cutting a thin slice of core and projecting light through the wood so the rings composed of larger, thinner-walled cells laid down in spring are more visible.

Canopy Height

When tree age in a stand is combined with tree height, one can make deductions regarding the site quality. Canopy height can be measured by use of a clinometer or abney level. The directions for doing this are included with the instrument. In general the procedure involves walking a measured distance from the tree and determining the angle, or percent, from your eye to the top and bottom of the tree. Simple tabular or computational conversions then express the tree height as a percent of distance the observer stands from the tree. General canopy or supercanopy height can be estimated by doing this for several trees in a stand.

Vegetation Strata

It is efficient to reduce the stand into components for sampling. Consideration should be given to sampling the various components with different methods and/or with different-sized plots. The data collected for the various components are often reduced to an equivalent base for quantitative description even though they have been collected differently. This section describes a forest stand consisting of four components: the tree, shrub, herb, and ground surface strata. Other stands may not contain all of these strata.

Tree Stratum (Supercanopy, Canopy, and Subcanopy)

This category includes woody stems capable of becoming canopy, supercanopy, or subcanopy trees, which at the time of sampling are at least 2.5 cm. (1 in.) in diameter at breast height (d.b.h.).

Many ecologists use some arbitrary rule to separate "saplings" from "trees"—thus one might consider individuals between 2.5 and 10 cm. (1 and 4 in.) d.b.h. as saplings and all stems over 10 cm. (4 in.) d.b.h. as trees. Separate estimates of density and other parameters would would be made for saplings and trees of each species.

If the vegetation consists of many large and few small trees, and if sampling is by plots, plot size should be rather large—up to 400 m.^{2} (1/10 acre) or 800 m.^{2} (1/5 acre). However, if there are many smaller trees, plots of 40 m.^{2} (1/100 acre) may suffice. Often 100-m.^{2} (1/40-acre) plots are a useful compromise for forest stands. The number of plots may vary with both the size of the plot and the complexity of the vegetation. As few as ten 400-m.^{2} plots or as many as forty 40-m^2 plots may be necessary. Twenty 100-m.^{2} plots may be adequate for some forest types.

Shrub Stratum

Individuals in the seedling size class (under 2.5-cm. (1-in.) d.b.h.) of trees and tall shrub species are included in this component. Tall shrub species, in contrast to low shrubs, are those capable of growing above the surrounding forbs. They may even attain more than 2.5-cm. d.b.h. and enter the subcanopy. This breakdown of the shrubs is an arbitrary procedure that allows more efficient sampling. It is not equivalent to the half-shrub/shrub differentiation of other workers based on dormant season stem dieback.

Where tall shrubs and tree seedlings are numerous, sample plots might be as small as 2 $m.^2$ (1/2 milacre). Where these plants are not especially numerous, or numerous in only some stands, the plot should be at least 4 $m.^2$ (1 milacre). An adequate sample may require as few as 15 plots or as many as 30 plots (or more) per stand.

Herb Stratum

Low shrubs, forbs, ferns, and fern allies are considered to be members of this component. A convenient plot size for this stratum is a quarter-milacre (1 $m.^2$). This plot, however, may range from 0.25 $m.^2$ (2 $ft.^2$). to 4 $m.^2$ (1 milacre). The objective should be to have a plot size such that the most widely distributed species has a frequency of about 90 percent. Ohmann and Ream (1971b), working in a wilderness area, used a 0.25-$m.^2$ (2-$ft.^2$) plot with fair success. At least one herb-stratum plot per tall-shrub plot should be used.

Ground Surface Stratum

Information on the characteristics of the ground surface within a stand is valuable. The area of mosses, lichens, litter, bare rock, dead wood, and bare soil is an easily measured aspect of stand structure. Since mosses and lichens are difficult to identify to the species level, they can be treated as groups and will still provide valuable information. A 0.25-$m.^2$ (2-$ft.^2$) plot will work well for obtaining this information, and will also allow accurate ocular estimates of percent cover. If the plot used to sample the herb stratum is not too large, the ground-cover stratum can also be sampled in that plot.

Data Evaluation and Analysis

Units

Although the examples used in this manual are in English units, one should consider the possibility of using metric units or at least reporting the metric equivalents. Most countries use the metric system. These data may eventually be part of a world data bank that would likely operate under the metric system. Any procedure that will make the natural area data more compatible with other data available in a data bank system is worthwhile.

Errors

Discussion of statistical error has been included throughout the manual. Wherever possible one should use random-sampling procedures. This allows estimates of the standard error of the mean (average) to be made, as well as statements that (within a selected probability) the true value of the mean lies within a certain range on either side of the computed value (Greig-Smith 1964). Because generation of baseline data from individual stands is the primary objective of this manual, statistical tests are not presented. Look to any basic statistical textbook for the necessary statistical treatment, or for more specific examples regarding testing of vegetation data, see Greig-Smith (1964) or Freese (1967). The point to remember is that someone will want to apply statistical treatment to the baseline data for future comparisons. Thus, the nature of the data collection should allow valid comparisons to be made.

Errors in recording data and in computations are also important areas of concern. Review data forms in the field for obvious errors of omission or commission. Set up computing procedures that provide cross-checks on value totals. Retain all field data forms and computation worksheets (properly identified) as part of the natural area files.

Computations

In reporting the data use reasonable numbers of significant figures. Since many of the measurements are made in whole numbers, the resulting values from the computations should also be presented rounded off to the nearest whole number. Mean values are often presented to one or more decimal places, variability measures to two places (Sokal and Rohlf 1969). If summary data are presented to many decimal places for some reason, detail the units of original measurement in the report so that the proper importance may be attached to the reported values.

Analysis and Syntheses of Data

The stand summary data can be used as a baseline for later comparison of vegetation changes. It can also be used to describe the plant communities of the natural area through classification procedures. Finally, the data can be used in other ways, such as examining environment-vegetation relationships, or aiding in mapping vegetation of the area through airphoto interpretation and ground checks. Description of these and other techniques of analysis and synthesis is beyond the scope of this manual, but one should be aware of the possibility that others will become interested in carrying the baseline work forward to a complete description of the natural area.

Data Storage and Use

Be sure to record a complete, detailed description of the methods used to sample the natural area. An accurate description of the location of each stand and the location and marking of each sample plot within the stand should be included.

Devise and use a systematic method of identifying field data forms, worksheets, and summary sheets. The collection of papers mounts quickly and if each sheet is not properly identified, some may be lost or misfiled. Data that cannot be identified as to origin have no scientific value.

Several copies of data and natural area reports should be stored. The original reports should remain in the natural area file deposited with the managing agency. Perhaps one copy should be filed with a local or regional educational institution. Hopefully, there will soon be a national depository for these data where one or more copies of the report should be placed.

In addition to providing baseline data for future comparisons, natural area studies should make data available for use by other scientists. Such data provide a base for studies of productivity, species autecology, and influence of environmental factors on flora or vegetation. One way to make others aware that these basic data are available is to publish (with approval of the managing agency and perhaps with their help) a summarized version of the natural area report.

LITERATURE CITED

American Association for the Advancement of Science. 1963. Natural areas as research facilities. Am. Assoc. Adv. Sci. Counc. Study Comm. on Natural Areas as Res. Facil. Rep., 193 p.

Bormann, F. H. 1953. The statistical efficiency of sample plot size and shape in forest ecology. Ecology 34(3): 474-487.

Burdo, E. A. 1956. A review of the General Land Office survey and of its use in quantitative studies of former forests. Ecology 37: 754-768.

Brown, D. 1954. Methods of surveying and measuring vegetation. Commonw. Agric. Bur. 223 p. Farnham Royal, Bucks, England.

Brown, R. T. 1950. Forests of the central Wisconsin sand plains. Ecol. Soc. Am. Bull. 31: 56.

Bruce, D. 1955. A new way to look at trees. J. For. 53: 163-167.

Buchinger, M. 1969. Saving natural areas. Lat. Am. Nat. Area Programs of Foresta Inst. Publ. 1, Washington, D.C.

Buckman, R. E. 1966. Estimation of cubic volume of Shrubs (*Corylus* spp.). Ecology 47(5): 858-860.

Cain, S. A., and G. M. Castro. 1959. Manual of vegetation analysis. 325 p. New York: Harper and Brothers.

Cottam, G. 1949 The phytosociology of an oak woods in Southwestern Wisconsin. Ecology 30: 271-287.

Cottam, G., and J. T. Curtis. 1956. The use of distance measures in phytosociological sampling. Ecology 37: 451-460.

Cowan, I. 1968. Wilderness-concept, function, and management. VIII. The Horace M. Albright Conservation lectureship. 36 p. Univ. Calif. School For. & Conserv., Berkely.

Curtis, J. T. and R. P. McIntosh. 1950. The interrelation of certain analytic and synthetic phytosiological characters. Ecology 31: 434-445.

Dansereau, P. 1958. A universal system for recording vegetation. Contributions de l'institut botanique de l' Universite de Montreal 72: 1-58.

Darnell, R. 1968. Symposium on the role of the biologist in preservation of the biotic environment. Bioscience 18(5): 383-406, 415-424.

Davis, C. A. 1907. Peat, essays on its origin, uses and distribution in Michigan. Mich. Geol. Surv. Annu. Rep. for 1906.

Franklin, J. F., and J. M. Trappe. 1968. Natural areas: needs, concepts, and criteria. J. For. 66(6): 456-461.

Freese, F. 1967. Elementary statistical methods for foresters. U.S. Dep. Agric., Agric. Handb. 317, 87 p.

Greig-Smith, P. 1957. Quantitative plant ecology. 256 p. Washington, D.C.: Butterworths.

Greig-Smith, P. 1964. Quantitative plant ecology. Ed. 2, 256 p. Washington, D.C.: Butterworths.

Grosenbaugh, L. R. 1952. Plot-less timber estimates—new, fast, easy. J. For. 50: 32-37.

Heinselman, M. L. 1969. Diary of the canoe country's landscape. Naturalist 20(1): 2-14.

Kershaw, K. A. 1966. Quantitative and dynamic ecology. 183 p. New York: American Elsévier Publishing Co., Inc.

Klein, R. M., and D. T. Klein. 1970. Research methods in plant science. 756 p. New York: Natural History Press.

Kuchler, A. W. 1964. Potential natural vegetation of the conterminous United States. Am. Geogr. Soc. Spec. Publ. 36, 116 p.

Kuchler, A. W. 1967. Vegetation mapping. 472 p. New York: The Ronald Press Co.

Lawrence, D. B. 1963. Natural areas primarily for research. College Natural Areas Res. and Teaching Facil. Res. Publ. 1. The Nature Conservancy, p. 3-6.

Lindsey, A. A., J. D. Barton, Jr., and S. R. Miles. 1958. Field efficiencies of forest sampling methods. Ecology 39: 428-444.

Lindsey, A. A., W. B. Crankshaw, and S. A. Qadir. 1965. Soil relations and distribution map of the vegetation of presettlement Indiana. Bot. Gaz. 126: 155-163.

McGinnies, W. G. 1934. The relation between frequency index and abundance as applied to plant populations in a semi-arid region. Ecology 15: 263-282.

Marschner, F. J. 1946. Map of the original forests of Minnesota 1: 500,000. Grand Rapid Res. Center, Lake States For. Exp. Stn.

Newbould, P. J. 1967. Methods for estimating the primary production of forests. Int. Biol. Program Handb. 2. 62 p. Oxford and Edinburgh: Blackwell Scientific Publishers.

Nicholson, E. M. 1968. Handbook to the conservation section of the Int. Biol. Program. 84 p. Oxford and Edinburgh: Blackwell Scientific Publishers.

Ohmann, L. F., and R. R. Ream. 1971a. Wilderness ecology: a method of sampling and summarizing data for plant community classification. USDA For. Serv. Res. Pap. NC-49, 14 p., illus. North Cent. For. Exp. Stn., St. Paul, Minn.

Ohmann, L. F., and R. R. Ream. 1971b. Wilderness ecology; virgin plant communities of the Boundary Waters Canoe Area. USDA For. Serv. Res. Pap. NC-63, 55 p., illus. North Cent. For. Exp. Stn., St. Paul, Minn.

Oosting, H. J. 1956. Study of plant communities. 440 p. San Francisco: W. H. Freeman and Co.

Peterken, G. F. 1967. Guide to the check sheet for IBP areas. Int. Biol. Program Handb. 4. 133 p. Oxford and Edinburgh, Blackwell Scientific Publishers.

Phillips, E. A. 1959. Methods of vegetation study. 55 p. New York: Henry Holt and Co.

Pielou, E. C. 1969. An introduction to mathematical ecology. 286 p. New York: Wiley-Interscience.

Shanklin, J. F. 1951. Scientific use of natural areas. J. For. 49(11): 793-794.

Shanklin, J. F., R. E. Griffith, and J. H. Buell. 1952. Are natural areas essential? J. For 50(3): 237-239.

Sokal, R. R., and R. J. Rohlf. 1969. Biometry. The principles and practice of statistics in biological research. 776 p. San Francisco: W. H. Freeman and Co.

Spurr, S. H. 1963. The value of wilderness to science. *In* Tomorrow's Wilderness. F. Leydet, ed. 262 p. San Francisco: Sierra Club.

U. S. Federal Committee on Research Natural Areas. 1968. A directory of research natural areas on federal land of the USA. 129 p. Washington, D.C.

Ward, R.T. 1956. The beech forests of Wisconsin—changes in forest composition and the nature of the beech border. Ecology 37: 407-419.

Wellner, C. A. 1969. Progress in the development and maintenance of representative natural coniferous forest ecosystems in the northern Rocky Mountains. 1968 Symp. on Coniferous Forests of the Northern Rocky Mountains Proc., Univ. Mont. Foundation, Missoula, p. 131-150.

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