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Aims and Methods of Vegetation Ecology

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Community Sampling: The Relevé Method

5

Once the entitation or subdivisioning of the vegetation cover has been clarified, the communities are essentially established. This is the reason why a thorough reconnaissance and familiarization before sampling is so important. Subsequent sampling and data collection will merely derive more detailed information on these communities, irrespective of one's choice for semiquantitative or quantitative methods for description.

However, certain changes in entitation may become necessary with increasing knowledge during the investigation. The approach should be flexible enough to allow for such changes.

5.1 THREE REQUIREMENTS OF A SAMPLE STAND—PARTICULARLY THE HOMOGENEITY REQUIREMENT

Regardless of the method used for field analysis, a sample stand (relevé) should fulfill the following requirements.

1. It should be large enough to contain all species belonging to the plant community.
2. The habitat should be uniform within the stand area, as far as one can determine this.
3. The plant cover should be as homogeneous as possible. For example, it should not show large openings or should not be dominated by one species in one half of the sample area and by a second species in the other half.

This requirement of relative homogeneity throughout the sample stand area rests on the premise that the vegetation parameters or statistics recorded for the stand should result in a meaningful average. An average obtained from a sample area reaching partly into an opening or across an obvious community boundary is an artifact. However, if openings are a characteristic feature of a community, they must be sampled as well.

Depending on the degree of segmentation and geographic scale desired, openings may be recognized as separate entities, or they may be included in larger samples. Where stand openings are stratified as separate entities, they may either be ignored or sampled as separate communities.

An important difference in the homogeneity concept has been practiced in the European relevé analysis as opposed to the American continuum analysis.

In the relevé analysis of a forest stand the requirement for homogeneity applies to both the tree layer and the undergrowth vegetation. DAUBENMIRE (1968) has used the same concept in Western North America. In the continuum analysis of eastern American forests the homogeneity requirement so far has primarily been applied to the tree layer only. In this homogeneity concept, therefore, the undergrowth vegetation and habitat can be quite heterogeneous.

CURTIS (1959) devised a test of homogeneity by quartering a sample stand and by comparing the variation in tree composition among the four quarters in a chi-square test. However, it was found that homogeneity could easily be judged subjectively. Many other attempts have been made to quantify homogeneity (RAABE 1952, DAHL 1960, MORAVEC 1971) of the plant cover. However, there is no satisfactory objective method, and the degree of plant-cover variation one considers integratable into a meaningful expression of average is still a matter of judgment.

At first one is guided by physiognomy and structure of the vegetation, and then by the prevalence or dominance of certain species that must be relatively uniformly present across the sample stand. Less obvious or rarer species may occur dispersed among the more obvious or dominant ones, and the dispersal pattern of these less obvious species may be considered of secondary importance. But as a major qualitative difference in the homogeneity concept we may reemphasize the European tradition as considering the field or herb and low-shrub layer as the guide while the eastern North American tradition pays less attention to the undergrowth in forests and considers the cover composition of the uppermost layer as the guide to homogeneity. These important qualitative differences result in much larger sample stands to be recognized for traditional North American vegetation studies as compared to the traditional European ones.

5.2 MINIMAL SAMPLE AREA—THE SIZE REQUIREMENT

In all within-segment or community sampling it is important that the species are as fully represented as possible.

Where the emphasis is on sampling for recurring plant assemblages, it is common practice to determine the so-called "minimal area" of the community. This is defined as the smallest area on which the species composition of the community in question is adequately represented. This smallest area gives an indication of the relevé or quadrat size that should be used.

In contrast, where the emphasis is on sampling the quantitative variation of species within large communities defined only by dominant species, the idea of representative species composition is commonly reduced to certain quantitative measures of the more abundant species only. Instead of using a few large "minimal area" quadrats or plots, the sample is spread over each vegetation segment as much as possible in the form of small quadrats or point samples. Individual quadrat sizes are adjusted primarily to the convenience of assessing the quantitative parameters selected. The size of the sample as a whole is either determined arbitrarily or adjusted to the quantitative variation of the vegetation segment.

A selection prior to sampling of the "more important" (dominant) from the "less important" (quantitatively less well represented) species is considered inadequate by many ecologists (e.g., FLAHAULT and

SCHRÖTER 1910, BRAUN-BLANQUET 1928, KRAJINA 1960, HANSON and CHURCHILL 1961, DAUBENMIRE 1968, among others).

However, both viewpoints can be combined and the number of small quadrats can be determined to include the minimal area of the community (CAIN 1938, OOSTING 1956, DAUBENMIRE 1968).

The minimal area depends on the kind of community and varies within wide limits. For temperate-zone vegetations, the following empirical values can be given:

Forests (including tree stratum)	**200–500 m^2**
(undergrowth vegetation only)	**50–200 m^2**
Dry-grassland	**50–100 m^2**
Dwarf-shrub heath	**10– 25 m^2**
Hay meadow	**10– 25 m^2**
Fertilized pasture	**5– 10 m^2**
Agricultural weed communities	**25–100 m^2**
Moss communities	**1– 4 m^2**
Lichen communities	**0.1– 1 m^2**

5.21 The Nested Plot Technique. The minimal area can only be determined in a community that is relatively homogeneous and not fragmentary. A community can be called fragmentary if it lacks species that are usually present in the recurring plant assemblages of this kind. Such fragmentation may be caused by selective destruction of certain species, for example through grazing, or simply through fragmentation of the surface area into too small segments. The total number of species (richness) is in itself an important characteristic of a community type (McINTOSH 1967*b*).

The minimal area is determined by initially lining out a small area, for example 0.5×0.5 m (0.25 m^2) and by recording all species that occur within this small area. Then the sample area is enlarged to twice the size, then to four and eight times the size, etc. The additionally occurring species are listed separately for each enlarged area (TABLE 5.1). The sample area is increased until the species added to the list become very few. FIGURE 5.1 shows the arrangement of the sample quadrats in the form of nested plots.

5.22 Criteria for Size of Releve. The species number is then plotted over size of sample area. This results in a species/area curve (FIG. 5.2). The minimal area is the sample area at which the initially steeply increasing curve becomes almost horizontal. This is not an exact definition. It is, therefore, advisable to decide on a somewhat larger area

TABLE 5.1. Example Data for Determining the Minimal Area of a Pasture (Lolieto–Cynosuretum typicum *in Northwest Germany*)

SUBPLOT NUMBER	SIZE (m^2)	SPECIES	CUMULATIVE TOTAL NUMBER OF SPECIES
1	0.25	*Lolium perenne* *Poa pratensis* *Poa trivialis* *Festuca pratensis* *Trifolium repens* *Crysanthemum leucanthemum* *Rumex acetosella* *Plantago lanceolata* *Bellis perennis* *Cirsium arvense*	10
2	0.5	*Cynosurus cristatus* *Trifolium pratense* *Cerastium fontanum* *Centaurea jacea*	14
3	1	*Leontodon autumnalis* *Achillea millefolium*	16
4	2	*Holcus lanatus* *Vicia cracca* *Prunella vulgaris*	19
5	4	*Plantago major* *Festuca rubra* var. *genuina*	21
6	8	*Anthoxanthum odoratum*	22
7	16	*Trifolium dubium* *Taraxacum officinale*	24
8	32	*Rumex crispus*	25
9	64	*Lathyrus pratensis*	26

for an adequate size of sample plot or quadrat. This was done in the empirical values cited in SECTION 5.2.

CAIN (1938) pointed out that the minimal area in such a graphical presentation is influenced by the ratio of the ordinate (y) to the abscissa (x). A contraction of the ordinate in proportion to the abscissa results in a decrease also of the apparent minimal area, since the curve flattens at a faster rate. To overcome this deficiency, he developed a criterion for minimal area delineation that is unaffected by the y/x ratio. He suggested using the point along the curve at which an increase in 10 per-

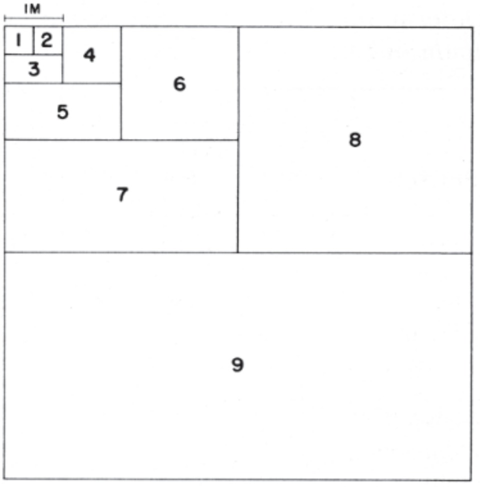

FIGURE 5.1. A system of nested plots for establishing minimal area. Each subplot numbered consecutively to 1 includes the area of the previous subplot. Thus, uneven numbered subplots are square, even numbered ones are rectangular. The plot layout relates to the data shown in TABLE 5.1.

cent of the total sample area yields only 10 percent more species of the total number recorded.

The example in TABLE 5.1 shows that 10 percent of the total area equals 6.4 m^2. Ten percent of the total species number is 2.6. This point ($x = 6.4$ and $y = 2.6$) is plotted on the graph. Then a line is drawn through this point and the intersection of the y and x axes (the origin). However, the same line can be drawn more accurately from the origin through a point defined by the 100 percent values of x and y (see FIG. 5.2, line a_1). Next, a line parallel to the first is drawn that touches the species/area curve tangentially (FIG. 5.2, line a_2). The tangential intersection point on the curve is then protracted to the x axis (FIG. 5.2, line a_3), on which the minimal area is indicated.

A more conservative estimate of minimal area is obtained where a 10 percent increase in area yields only 5 percent more species. This point is found by drawing a line through the origin and a point defined by 50 percent of the total species count and 100 percent of the area sampled (FIG. 5.2, line b_1).

In the two examples shown on FIG. 5.2, the minimal areas defined in this way are:

Pasture at 10 percent species increase	**5 m^2**
at 5 percent species increase	**12 m^2**
Hay meadow at 10 percent species increase	**8 m^2**
at 5 percent species increase	**10 m^2**

The minimal area values are still only approximations and are therefore rounded off to the nearest square meter.

However, CAIN's method is not an absolute guide, because it can be

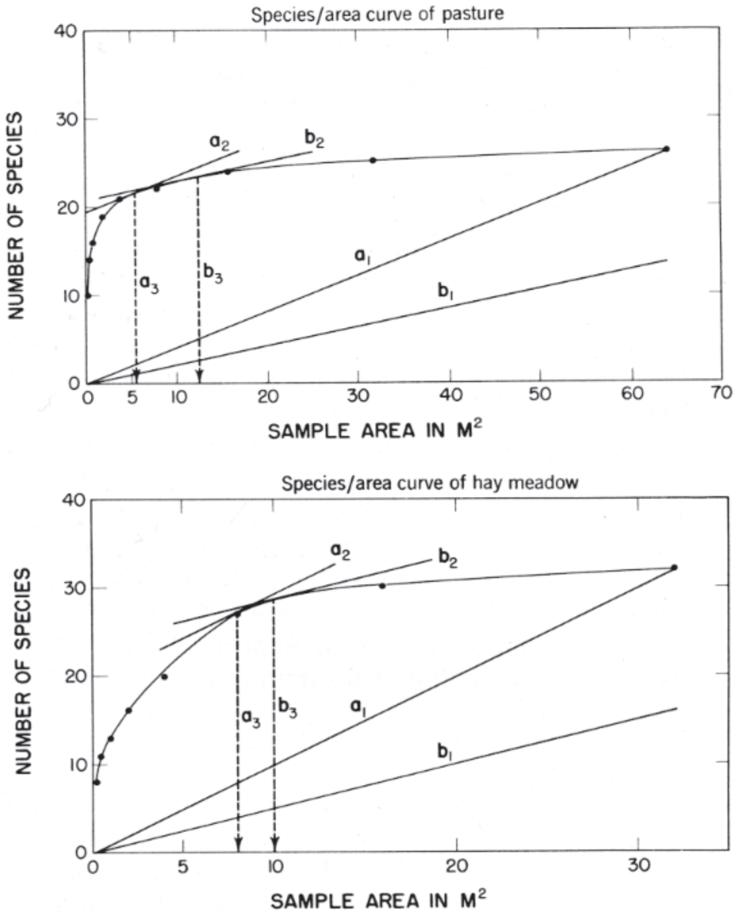

FIGURE 5.2. Species/area curves of a pasture (see TABLE 5.1) and hay meadow. Legend: a_1=10 percent line; a_2=tangent parallel to 10 percent line; a_3= protraction to minimal area based on 10 percent species increase; b_1=5 percent line; b_2=tangent parallel to 5 percent line; b_3=protraction to minimal area based on 5 percent species increase. Further explanation in text.

applied to any shape of curve, whether levelling off or not. Yet, only curves that level off can be used for determining minimal areas. RICE and KELTING (1955) have drawn attention to the fact that the 10 percent point shifts to the right on the species/area curve with any increase in size of sample area. This is so even if the curve remains horizontal.

However, for a relevé analysis there is no advantage in increasing the sample size if it yields no further species.

The objection of RICE and KELTING can be overcome by setting an objective standard through the total number of species sampled. For example, one may require that the sample plot contain at least 90 or 95 percent of the maximum number of species encountered in the largest sample unit of the nested plot.

Applied to the two curves, the minimum relevé sizes containing at least 95 percent of the species are determined as follows:

1. Pasture; total number of species is 26. Subtract 5 percent from total number (1.3) and read off the area from the curve at 24.7 number of species. The minimum plot size is about 25 m^2.

2. Hay meadow; total number of species is 32. Read off the area from the curve at 30.4 number of species. The minimum plot size is about 20 m^2.

Unlike CAIN's criterion, the 95 percent species requirement is affected by the y/x ratio. But since the 95 percent point lies to the right of the levelling-off point, as determined through CAIN's criterion, the effect of the curve shape becomes insignificant. The plot size should always be larger than the minimal area obtained through CAIN's criterion.

In spite of the lack of an absolute criterion for the minimal area, the species/area curve remains an important practical guide to stand or plot size in studies aiming at portraying a representative species composition.

Ideally, the minimal area should be established for the community type and not only for one community member of a type. This means that minimal areas should be determined in several recurring plant assemblages of the same kind. The one that indicates the largest minimal area should be used as a guide to the minimum size of a vegetation sample or relevé. MORAVEC (1973) suggested another method for determining the minimal area, which involves enlarging separate (in contrast to nested) plots in a vegetation segment until the floristic similarity (CHAP. 10) between the plots reaches a maximum value. This method appears sound theoretically but it requires much more time in field sampling and subsequent computation, so that its practicability seems rather doubtful.

5.23 Evaluation of the Minimal Area Concept. The species/area curve is clearly quantitative in terms of species number, but it gives little information on the number of individuals per species.

For example, the pasture showed 24 species in an area of 16 m^2, the hay meadow 30 species on the same unit area. The greater number of species in the hay meadow for the same unit area may indicate a smaller size of individuals, or a smaller number of individuals per species, or a combination of these parameters. Therefore, the species/area curve is often considered less consequential in quantitative studies (McINTOSH 1967*b*). But the problem of counting individuals per species is an entirely different one that requires usually smaller sizes of quadrats or plots. The number of small quadrats depends on the variability or homogeneity of the vegetation segments caused by the more dominant or abundant species in the community. Yet, there is no absolutely objective guide either for determining the sample size or number of small quadrats for quantitative analyses. The problem involves the same sort of judgment as is required for deciding the minimal area from a species/area curve (see discussion under sample size, SECTION 6.4).

The species/area curve has its application also to quantitative community analyses. A quantitative vegetation sample, to be representative of the species composition of a community, should never be smaller than the minimal area.

A species/area curve is of interest also for its own information value, because it indicates an important community property, namely, species diversity in relation to increasing size of area. Any community can be compared on that basis. FIGURE 5.3 shows six species/area curves from tropical rain forests in Borneo that were assembled by ASHTON (1965). Only the lowest curve from Belalong shows a clear trend of levelling-off. In this community a 0.5 acre relevé could be considered satisfactory. In the other communities, even a 5 acre (or 2 hectare)

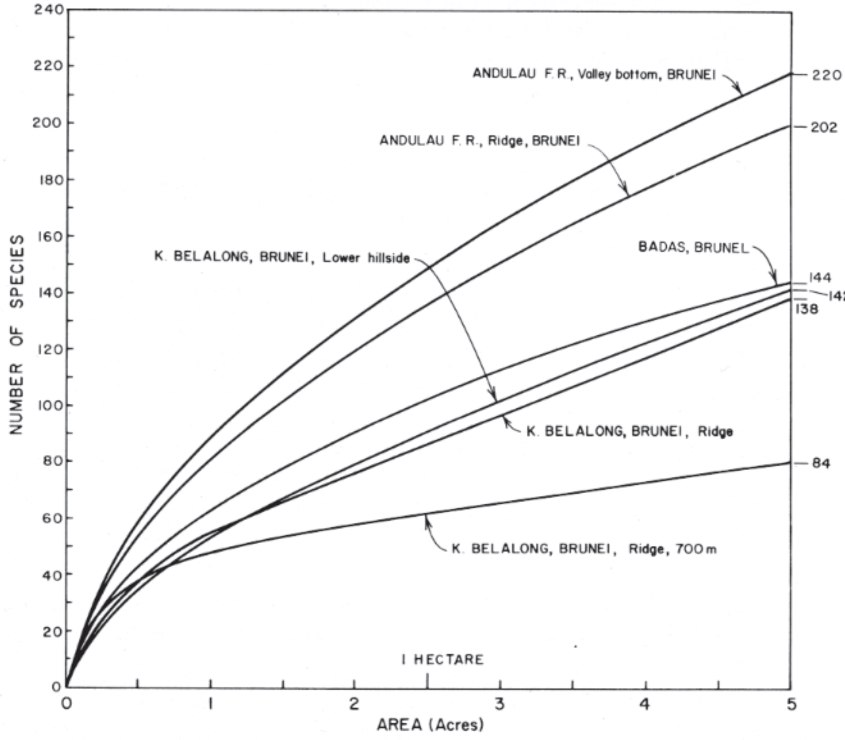

FIGURE 5.3. Species/area curves for sites in Brunei. (Redrafted with modifications from ASHTON 1965:236.)

relevé seems too small. The minimal area of these communities is probably around 5 hectares. In these communities a compromise has to be made. Instead of one large relevé with a near-complete species assemblage, one must choose to work with a relevé size that is practical and manageable, even if it contains only a fraction of the number of species of the community type. But then, several such relevés should be used in place of one to recompose a near-complete species composition of the whole community. Of course, in such rain forest stands, this is a formidable task.

5.3 EXAMPLE OF A RELEVÉ ANALYSIS

After establishing how large a relevé or vegetation sample should be, we then list all species present. A good floristic knowledge and careful collection of all plant species (that cannot be identified immediately) is a necessary prerequisite for such investigations. Depending on the purpose of the study and the questions asked, the species list can be completed by more or less accurate information on the quantitative relations, the current status of development, or other species properties that are readily determinable in the field.

Furthermore, a description of the habitat and the soil profile can be added. The date of analysis and an accurate description of the location should not be missing. A sketch map will facilitate relocation of the sample plot if one intends repeated analyses.

As an example, we will describe the analysis of a forest stand (TABLE 5.2).

The analysis begins with noting down the relevé number (which is used also for marking the relevé location on a map; scale 1:24,000 or similar), the date, a record of the geographic area, general location, detailed location, etc., size, and position of the sample area. The community should be given a structural name and a tentative floristic name describing the most obvious species composition. A few general remarks on the condition of the plant cover, particularly on its vertical stratification into layers of different heights or into life form groups and their percent cover should be recorded in the introductory part of the field note sheet.

5.31 Species Quantities and Stratification. A species list alone is usually not satisfactory for portraying the special characteristics of a plant cover segment. Therefore, the list should be augmented with notes on the quantity of each species. Other aspects often worth recording are certain characteristics of species dispersion and morphological structure. Also, phenological information may be noted with relative ease (see CHAP. 8). In all cases the community structure should be described with respect to its layering into height strata (if evident) and the cover extent of each layer should be estimated in percent of the sample area. Preferably the species should be recorded in height strata right away. This allows for a simple order of recording. Any further preordering of the species list is likely to complicate the analysis.

No definite height limits can be set in advance for any community layer, because this depends on the community structure itself. Nevertheless, certain height limits that are commonly found convenient in forest communities are:

1. *T* = Tree layer, any plant taller than 5 m. In taller forests, this layer is usually subdivided into 2, 3, or even 4 layers of decreasing heights (*T*1, *T*2, etc.).
2. *S* = Shrub layer, plants between 50 cm and 5 m tall, or 30 cm and 5 m tall. A subdivision is commonly indicated at 2 or 3 m height. For example, an *S*1 layer may be indicated from 2 to 5 m, and an *S*2 layer from 30 (or 50) cm to 2 m height.
3. *H* = Herb layer, from < 30 cm (or 50 cm) to 1 m height. Subdivisions analogous to the *T* and *S* layers are often useful. For example, *H*1 as tall herb layer > 30 cm height, *H*2, as medium-tall herb layer from 10 to 30 cm height, *H*3 as low herb layer < 10 cm height.
4. *M* = Moss and lichen layer. This refers usually to a ground-appressed low carpet of less than 5 or 10 cm height. Where necessary it should be subdivided into an *M* layer on bare mineral soil, an *M* layer on humus, an *M* layer on decaying wood, an *M* layer on stones or exposed rocks. This leads over also to a recognition of one or several epiphyte layers (*E*), the plants that occur attached (but not parasitically) to other plants, for example, mosses on tree stumps or trunks.

A compromise must often be made between emphasizing height stratification or life form. For example, a decision is required in certain stands with a distinct moss layer (*M*) whether to record small herbs and seedlings in the same layer (*M*) or to recognize a separate low vascular plant layer (*H*) of < 10 cm or so in height. This may initially cause some difficulties. But the problem can always be solved by a decision that, of course, should be closely adapted to the prevailing conditions.

The species are recorded within these height strata or in life form groups in the order as they are noticed. It is possible also to record the

TABLE 5.2. Example of a Relevé Analysis in a Tropical Insular Rain Forest Near Honolulu, Hawaii.

Relevé #11 March 4, 1972

LOCATION:	Tantalus Mountain in the rain forest, Honolulu, Hawaii. Along trail leading to Pauoa Flats at 450 m (1480 feet) elevation, 160 m before planted *Eucalyptus* stand on Pauoa Flats.
	Below the trail on a gently (21 percent) sloping convex ridge, where *Acacia koa* is present as an emergent tree. Location mapped on 1:24,000 topographic sheet of Honolulu area.
COMMUNITY:	A low-stature submontane rain forest with scattered emergent *Acacia koa* trees up to 10 m tall.
	Acacia koa–Metrosideros–Psidium guajava forest with few tree ferns (*Cibotium splendens*) and *Oplismenus* grass undergrowth.
POSITION	Aspect N 50 W, slope 21 percent, elevation 420 m (1380 feet)
SIZE OF RELEVE:	10 × 20 m (200 m^2); the 20 m part upslope
STRATIFICATION:	*T* Scattered *Acacia koa* 5–10 m tall, 40 percent cover
	S1 Woody plants 2–5 m tall, 80 percent cover
	S2 Woody plants 0.3–2 m tall, 10 percent cover
	H Herbaceous plants, most of them up to 30 cm tall, 95 percent cover
REMARKS:	This stand is composed of native trees (*Acacia, Metrosideros*) and partly of nonwillfully introduced, exotic trees (*Psidium, Citharexylum*). All *Metrosideros* and *Psidium* trees are multistem trees, forked or branched near the base. *Psidium* regeneration is entirely vegetative from root sprouts near the base of the older trees. *Citharexylum* regeneration is from seed.

species right away in a certain order, for example, in order of decreasing abundance. However, this usually takes more time and increases the danger of overlooking certain species. It must be emphasized that the primary requirement in the relevé method is a list of all species present. The consideration of species quantity takes a secondary rank.

It is useful to leave some space on the list in front of the species names for notes on their abundance. By listing each species on a separate line, the names are easily spotted afterwards. The methods for estimating their quantities will be discussed in SECTIONS 5.4–5.43.

Notes on the habitat and the description of the soil profile are often conveniently written on the backside of the note sheet. This is practical, if one uses a loose-leaf data-holder. Loose-leaves facilitate subsequent sorting of field notes.

Other plant communities, such as heath, grassland, bogs, etc. are analyzed in a similar way. However, the general remarks and notes on

TABLE 5.2 (Continued) LIST OF PLANTS BY STRATA WITH BRAUN-BLANQUET RATINGS IN FRONT OF NAME:

Stratum Symbol	BRAUN-BLANQUET Rating Symbol[a]	Plant Species
T	3	*Acacia koa*[b]
	1	*Metrosideros collina* subsp. *polymorpha*[b]
	+	*Psidium guajava*
	1	*Metrosideros tremuloides*[b]
S1	+	*Metrosideros collina* subsp. *polymorpha*[b]
	+	*Citharexylum caudatum*
	4	*Psidium guajava*
S2	+	*Cordyline terminalis*
	1	*Cibotium splendens*[b]
	1	*Citharexylum caudatum*
	+	*Psidium guajava*
	r	*Sadleria* sp.[b]
	1	*Rubus rosaefolius*
H	4	*Oplismenus hirtellus*
	1	*Commelina diffusa*
	1	*Setaria palmifolia*
	+	*Nephrolepis hirsutula*
	1	*Microlepia setosa*[b]
	+	*Athyrium proliferum*
	r	*Asplenium falcatum*

SOIL: Shallow (50–75 cm deep) rain forest soil (Hydrol Humic Latosol or Oxisol) with few rocks outcropping at surface.

[a] For explanation see SECTION 5.42.1.
[b] Native plants.

the habitat features are modified according to the different situation and purposes of the analyses.

5.32 Essential Information Parts. The relevé record may be summarized as having to show always three basic items of information, (*a*) geographic and physiographic, (*b*) the species list with information on the quantity of each species and their membership in different layers, and (*c*) soil information and specific remarks. Of course, the relevé record may be much further extended and systematized. It can go into great detail of quantitative measurements, into an assessment of plant life form and size-structure of populations, and into a study of their functions. Moreover, it may be accompanied or followed by an in-depth analysis of the environment. However, a list of at least all the higher plant species found in the sample stand is mandatory.

CURTIS (1955, CURTIS and GREENE 1949) called this type of analysis the species-presence method but preferred to prepare the species list from random locations of as many sample stands as possible in very broad, at least 6 hectare large forest vegetation segments or in broad landscape segments for prairie vegetation. However, such a large-area sample is necessarily heterogeneous and thus cannot be used for the same purpose as the above described relevé method. Many such relevés (as described in TABLE 5.2) are placed in all the differentiated vegetation segments and repeatedly into recurring plant assemblages of the same kind.

5.33 Further Detail for Complete Investigations. A good example of a systematic extension of important ecological information are the plot or relevé record forms published by KRAJINA, ORLOCI and BROOKE (1962). One plot record form provides space for specific information on geographic and topographic location and space for details on vertical stratification with space for separate percent cover estimates for each layer. Included is an estimate of the ground surface in percent cover of humus, exposed rocks and mineral soil, and decaying wood. A separate form deals with important habitat characteristics, such as position within landform, soil type identification, ground water, and drainage characteristics. Another form provides an outline for a very detailed soil profile description. The plant list form, extending over several sheets with strata subdivisions, provides columns for recording of several phenological, life form, and functional features. Further forms are provided for detailed tree-mensurational data and for subsequent laboratory analyses of the essential physical and chemical soil properties and for micro- or ecoclimatological investigations.

Such an outline suggests a very complete relevé analysis. But this sort of information may be obtained in several stages. The relevé example in TABLE 5.2 is the first completed stage of an investigation that yields a thorough description. Many more such relevés must be obtained to arrive at a well-documented regional classification of vegetation. The relevé method was similarly interpreted by BENNINGHOFF (1966).

5.4 ESTIMATING SPECIES QUANTITIES

A relatively crude estimate of species quantities is satisfactory for many purposes of vegetation description. In earlier times, each plant geographer and ecologist used more or less his own method. Therefore, the results of earlier authors were usually hard to compare (see, for example, the summarized comparisons of DU RIETZ 1921, RÜBEL 1922, CLEMENTS 1928, BRAUN-BLANQUET 1932, and BECKING 1957).

5.41 Relative Magnitude Terms. Relative magnitude terms ascribed to each species are useful on a very general basis. A division into five classes was often applied by earlier ecologists (KERSHAW 1964). These were in order of decreasing magnitude: dominant, abundant, frequent, occasional, and rare. The first three terms have received specified meanings in the course of time. Today, the term dominant is meaningful only if supplied with a definition. It may mean dominant in height (the usual understanding of foresters), dominant in crown cover (the usual understanding in combined estimate scales), dominant in basal area (the usual understanding of the Wisconsin School), or dominant in number. The term abundance implies the same meaning as number of individuals per species or density. But when speaking of abundance, one usually refers to a number estimate; when speaking of density, to an actual count of individuals. Frequency has a special definition. It refers to the number of times a species is found in a given total number of frame placings or quadrats, or at a given total number of sample points.

Now, the magnitude values mentioned above can be replaced by more meaningful terms (e.g., very rare, occasional, abundant, and very abundant) or by code values. But these remain relative as they are only related to each other and not to a specified reference area.

5.42 Absolute Scale Values. BRAUN-BLANQUET made a major contribution in selecting, simplifying, and modifying a system for analysis that is convincingly simple and yet not superficial. It was favorably and rapidly accepted by many investigators and proved to be useful in areas with large numbers of species. The method requires relatively little time per relevé analysis and can be used for all plant communities composed of higher plants and for most moss and lichen communities. Therefore, it is useful not only for monographical work of vegetation zones, but also for a single community type studied throughout its range of distribution.

For reasons of comparability one should not unnecessarily deviate from this method, even if one does not intend to process the data further according to BRAUN-BLANQUET's synthesis table technique. (CHAPTER 9).

5.42.1 The BRAUN-BLANQUET Cover-Abundance Scale. The following scale values of BRAUN-BLANQUET are absolute in so far as the values relate to a reference area, which is fixed by the size of the relevé.

5 Any number, with cover more than ¾ of the reference area (> 75%)

4 Any number, with $\frac{1}{2}$–$\frac{3}{4}$ cover (50–75%)

3 Any number, with $\frac{1}{4}$–$\frac{1}{2}$ cover (25–50%)

2 Any number, with $\frac{1}{20}$–$\frac{1}{4}$ cover (5–25%)

1 Numerous, but less than $\frac{1}{20}$ cover, or scattered, with cover up to $\frac{1}{20}$ (5%)

\+ (Pronounced cross) few, with small cover

r Solitary, with small cover

An idea of the application of the scale values is given in FIGURE 5.4. An estimate is assigned independently to each species.

The upper four scale values (5, 4, 3, 2) refer only to cover, which is understood as the vertical crown or shoot-area projection per species in the plot. The lower three scale values are primarily estimates of abundance, that is, number of individuals per species. Therefore, the scale is often called a combined estimate scale. This combination of the two parameters into one scale was an improvement over a separate estimation of abundance and cover. Abundance can be estimated with some precision only for herb and shrub layer species with little or insignificant crown or shoot cover. Cover can be estimated more accurately only for species that contribute significantly to the biomass of the community. Cover can be expressed in fractions or percentages of the reference area. It is usually less than the total leaf area of a species, since leaves do often overlap each other. Earlier, BRAUN-BLANQUET used only five values. Subsequently the scale was expanded to seven values by extending the scale in the lower classes.

The combined estimate of abundance and cover was later called "species magnitude" (Artmächtigkeit) by BRAUN-BLANQUET (1965) after SCHWICKERATH (1940). KRAJINA (1960) calls it "species significance." The estimating method can be learned quite easily if one recalls and clarifies the range and meaning of each scale value.

The method is often referred to as semiquantitative in the literature, because of the almost qualitative character of the large intervals among the scale values.

One may object that this method is rather crude and does not require measurements. However, estimates cannot be made in many vegetations on a much more refined scale. Measurements always require much more time. Since plant communities vary so much from place to place, it seems more useful for community classification or ordination to analyze several sample stands of the same type of community by estimating species quantities rather than to analyze only one relevé in greater quantitative detail.

During establishment of the plant list, the investigator walks several times through the relevé. The general quantitative relations of the spe-

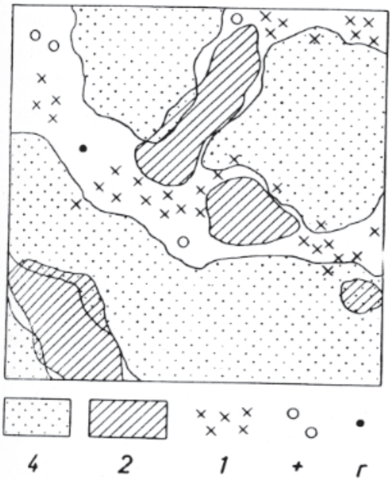

FIGURE 5.4. Schematic presentation of combined estimate values for cover and abundance (4, 2, 1, + and r) after the BRAUN-BLANQUET scale.

cies become apparent during the listing of the species. After all species are recorded, the investigator walks into the middle of the relevé or to a location where he can once more overview the entire plant assemblage of the relevé. From this point he assigns a cover-abundance rating to each species, taking into account his experience during the listing. The rating must apply to the entire area of the relevé. It is convenient to have the scale values on the notebook cover, because it is important to clarify their meaning each time they are used. The procedure for each species on the list is to first ask, does the species cover more than 50 percent of the area or less than 50 percent? If it covers more than 50 percent of the area, the next question is, does it cover more than 75 percent or less than 75 percent? If the latter applies, the rating is 4. Similarly, if a species covers less than 50 percent of the area, the next question is, does it cover more than 25 percent or less than 25 percent? If less than 25 percent, there are again two alternatives, namely, a cover of more than 5 percent or less than 5 percent. This area can be quickly visualized in a 200 m^2 relevé as a 10 m^2 area into which one can mentally contract the species that may be scattered over the 200 m^2 relevé. A species with less than 5 percent cover can either receive the value 1 or + (cross). If the cover seems to be less than 1 percent (or 2 m^2 in a 200 m^2 relevé) the species receives the value of +. If really only seen once in the relevé the species receives an *r* for rare or solitary in the relevé. Species occurring outside the releve but that were not seen inside, should also be recorded if noticed. In that case one assigns a scale value in parentheses.

The rating is quantitatively crude, but if properly applied it is not superficial. At the limit of a range of a scale value, even an experienced investigator may choose a higher or a lower rating symbol. This means, that an error by one rating value can easily occur in border cases. However, since the relevé method aims at describing the spatial floristic variation of a regional vegetation cover, the emphasis is put on more relevés with semiquantitative estimates rather than fewer vegetation samples with exact measurements of species quantities.

Perhaps a more accurate, but also more time-consuming, modification of this method is to estimate the cover of the herbaceous plants in a number of small frames (DAUBENMIRE 1968) and that of shrubs and trees in larger subplots lined out accurately with string. A square meter unit is convenient for many kinds of herbaceous layers. In this case one should estimate the cover directly in percent for each frame placement. This will permit calculation of an average. This method can be used to check the estimate ratings made for the total plot area. Further refinement of this method approaches cover measurement (SECTION 6.5) rather than cover estimation.

5.42.2 *The DOMIN-KRAJINA Cover-Abundance Scale.* KRAJINA (1933) introduced a somewhat more detailed scale (originally developed by DOMIN) that was applied successfully in many studies of forest communities in British Columbia within the last 20 years (KRAJINA 1969), and also, for example, by KERSHAW (1968). It gives an advantage in forest communities where differences in abundance among rarer species are often quite noticeable. The scale values are shown in the table. In species-rich herbaceous communities, estimative errors are

BRAUN-BLANQUET	DOMIN–KRAJINA		COVER %
5	10	any number, with complete cover	≈100
	9	any number, with more than ¾ but less than complete cover	> 75
4	8	any number, with ½–¾ cover	50–75
3	7	any number, with ⅓–½ cover	33–50
	6	any number, with ¼–⅓ cover	25–33
2	5	any number, with 1/10–¼ cover	10–25
	4	any number, with 1/20–1/10 cover	5–10
1	3	scattered, with cover under 1/20	1–5
	2	very scattered, with small cover	< 1
+	1	seldom, with insignificant cover	
r	+	solitary, with insignificant cover	

more likely with the finer scale intervals than with the cruder scale intervals of BRAUN-BLANQUET. The DOMIN-KRAJINA scale can readily be converted to the latter, but the reverse is never possible, as the correspondence of the two scales shows.

5.42.3 The DAUBENMIRE Cover Scale. DAUBENMIRE (1959, 1968) prefers to estimate cover alone according to a similar rating scale as follows:

COVER CLASS	RANGE OF COVER (%)	CLASS MIDPOINTS (%)
6	95–100	97.5
5	75– 95	85
4	50– 75	62.5
3	25– 50	37.5
2	5– 25	15
1	0– 5	2.5

Values 1 to 4 are exactly the same as the BRAUN-BLANQUET values, except that *r* and + species would be included in cover class 1 of DAUBENMIRE. The two upper values in DAUBENMIRE's cover scale are the exact equivalents of the two upper values in the DOMIN-KRAJINA scale.

A recent modification of the DAUBENMIRE scale by BAILEY and POULTON (1968) separates the 0–5 percent cover class into two classes, one for a range of 0–1 percent (midpoint 0.5 percent), a second for 1–5 percent (3 percent). This finer breakdown is analogous to the + and 1 ratings of the BRAUN-BLANQUET scale.

One may wonder why most scales show unequal class intervals. The main reason for this is a practical one. The chosen scale values allow for an easier estimation of species-cover-to-area relationship than do equal intervals of cover. Also, the less abundant species or species with small cover may sometimes have an important diagnostic significance, which requires a finer breakdown in the lower scale values as compared to the larger scale values.

5.43 Estimating Biomass by Partitioning in Grass Communities. The estimate method of KLAPP (1929:714, compare also WACKER 1943) can be applied to grass communities, and it is based on shoot dry weight proportions as estimated from fresh weight proportions under field conditions. The method allows for a more complete quantitative evaluation than is possible with the BRAUN-BLANQUET scale since it is concerned with biomass rather than with cover. It has been applied widely in investigating pastures and tall-grass stands for their feed value. The method is also useful for basic studies, since it provides a good indication of the competitive relations among species. The method is based on an estimate of the weight proportions of each species in percent of total biomass. It replaces an earlier technique of determining the biomass weight for each species separately.

However, a very refined accuracy can never be achieved by mere estimation. One has to allow always for a personal error that may be as high as one fourth of the estimated percentage in this method. But sufficient accuracy for practical purposes can be attained by using the following approach.

One estimates initially the total standing biomass per m² (with weight-checking). Then the two more obvious main groups are partitioned, namely, the grasses (including the grass-like species) and the forbs (including the legumes). These are estimated in relation to one another (also initially by weight-checking). In the example shown in TABLE 9.1 their ratio was probably larger than 75:25, but smaller than 90:10 and is probably quite correctly estimated with 85:15. Next, the two main groups are further subdivided in a similar manner. In this case the legumes are estimated to make up 1/10 at the most of the non-grass species, therefore, only about 1 percent of the total plant material. Sedges form only a small proportion of the graminoids. Their mass appears about double that of the legumes and can be estimated as 2 percent. Therefore, the following percentages can be derived (the extreme values, shown in brackets, were estimates of several unexperienced persons):*

Grasses	**83 (75–90 percent)**
Sedges	**2 (1– 5 percent)**
Legumes	**1 (+– 2 percent)**
Other herbs	**14 (10–22 percent)**

The different species that are always recorded separately on the lists, are then estimated within each group on the basis of the remaining percentages. Here, the "rare" species that probably contribute less than 1 percent are singled out first by designating them with +. The remaining species are then evaluated in order of their magnitude. The begin-

*** A check of air-dry weights resulted in the following values 85.4 : 1.8 : 1.3 : 11.5 percent.**

ner will usually have to change the figures several times before they portray the proper dry weight proportions. Subsequent corrections of initial estimates are sometimes necessary.

Of course, this method requires much more experience than the estimation of species magnitudes after BRAUN-BLANQUET and about four times the time. Moreover, the method can only be learned if the estimates are frequently checked by weighing or by experienced investigators. In spite of this, the method has gained considerable popularity in grassland investigations in Central Europe. We, therefore, discussed it in some detail here.

5.44 Estimating Vitality or Vigor. When estimating cover-abundance or biomass percentages, one sometimes notices species with extremely poor growth or others with extremely good growth. (Poor and good growth, that is, as compared with the growth in the same species on other sites.) Such observations should be recorded, even if one does not wish to assign finer categories of growth-capacities as suggested by ZOLLER (1954) and others. Such a notation may give some information on the competitive status of a species in the plant community. It also may indicate the developmental trend of species in a community in comparison to other communities.

Following a suggestion of BRAUN-BLANQUET, vitality is conveniently shown by adding an index to the magnitude value, provided that the vigor deviates substantially from that normally shown. The following symbols are recommended:

- °° very feeble and never fruiting (e.g., +°° or 2°°)
- ° feeble (e.g., 1°)
- no index: normal
- • exceptionally vigorous (e.g., 3•)

5.45 Estimating Sociability and Dispersion. Two species with the same cover-abundance value may be quite differently distributed. For example, *Crepis biennis* usually grows singly, *Deschampsia caespitosa* in clumps and *Phragmites australis* in large stands. Following BRAUN-BLANQUET, the degrees of dispersion or sociability can be assigned by a scale with five values. These are added to the cover-abundance value (usually separated by a dot, e.g., 3 • 1 meaning species covers 25–50 percent of the area, but plants grow singly or solitarily):

- 5 = growing in large, almost pure population stands
- 4 = growing in small colonies or forming larger carpets

3 = forming small patches or cushions

2 = forming clumps or dense groups

1 = growing solitarily

However, it has been found that sociability is a characteristic property of a species in most instances. Therefore, it does not need to be recorded in normal cases. Sociability ratings have been omitted recently by many authors mainly for this reason, but also to make the tables more easily readable and to save space. We consider it satisfactory to record sociability only in cases of abnormal dispersion of a species. However, even in such cases it is often not necessary, since the species magnitude is then also low. Therefore, species magnitude and sociability are often designated by the same scale value.

Also, the distance between individuals of a species is often a characteristic property of that species. For example, *Androsace helvetica* always forms dense cushions. In contrast, *Phragmites* usually occurs in loose stands, which permit other species to grow between their shoots at least during spring. If one wants to take note of particularly dense growth, one can show this by underlining the sociability value (e.g., 3). Unusually widely spaced distributions can be designated by a dotted line (e.g., 3).