Table 5B.--The last three steps in calculating synecological coordinates are: (4) grouping each species according to its original assigned value, (5) averaging community values of each of the species in the group to get a mean average community value for each of those groups, and (6) regrouping each species by matching their average community values to the closest mean average community value. The new relative values designation is found by reading back across the table to the left from each species. This example is a section from the New England calculations for moisture.

Relative values	Preliminary index groups (species average community value)	Mean avg. community values	Reassign according to new values
1	RO (1.83), PP (1.5), RP (1.35)	1.56	RO, PP, RP, BO, WP
2	GB (2.37), Asp (2.83), BC (2.60), RM (2.21), BO (1.73), WO (1.98), WP (1.79)	2.22	RM, SM, WO
3	WB (2.51), SM (2.13), RS (2.64)	2.43	GB, WB, H
4	YB (3.00), BF (2.84), H (2.40)	2.75	RS, Asp, BC, YB, BF
5	none		
	Step 4	**Step 5**	**Step 6**

The method was first tested using only a portion of the field analysis data to investigate some of the possible parameters, such as whether to include intermediate and understory species in the calculations, or how much difference using different original values made. Nineteen species from 37 stands were involved. Only the values for moisture were calculated, but that was considered enough to evaluate the tendencies. In the first test, some difference in relative values was evident between the calculations using only canopy species and those including the understory and intermediate species. However, although some values were noticeably different in mid-calculation, the difference in final values was not substantial. The biggest difference occurred in beech, which showed up in the understory of many stands in which it was not present in the canopy. This tended to decrease the moisture values for beech dramatically and increase moisture values for those stands in which it was found in the understory. In the final calculation, only canopy species were used.

One important assumption in this method is that the stands sampled and used in the adjustment of environmental indices include the maximum diversity of stands in the region--coming from the entire range of possible communities. The test run, in which this assumption was not met, clearly illustrated this effect. In the test primarily pine, oak, and beech-birch-maple stands were used. These stands included hemlock, and it was thus included in the calculations, but the sample only captured the more xeric side of hemlock's range. As a result, the final synecological value for moisture for hemlock was skewed in the drier direction. In the final calculations, however, the condition of maximum diversity should be amply filled by the data collected during the field analysis for this guide, as the emphasis of the guide has been to represent all of the forest cover types of New England.

It is difficult to calculate synecological coordinates for those species that handle a wide range of conditions. If a species is frequently encountered on two different types of sites, such as wet and dry, and with correspondingly different associate species, the resulting synecological value will be a moderation of both extremes--often around the value 3--even if that species is rarely found on moderate sites. A similar problem occurs if a shade-intolerant species persists in stands after other shade-tolerant species have grown in, as often occurs with birch. In this situation, the light values for that shade intolerant species will be averaged with both its light and dark associates, resulting again in a single moderate value that does not tell the entire story. In these and similar situations, the final ecological values were adjusted to better reflect that species' establishment preferences.

Table 6 lists field adjusted values for New England, along with the relative values used as the original in calculating the New England coordinates, and the number of plots in which it occurred in the field data.

Table 6.--Relative values for moisture (M), nutrients (N), heat (H), and light (L) used in the ecological relations section of the guide. Values of 1 for M, N, H, and L represent dry, poor, cool, and dark, respectively.

Original values M	N	H	L	No. of stands	Adjusted New England[a] values M	N	H	L	No. of stands	Common name	Scientific name
4	2	1	2	163	3	2	1	3	82	Balsam fir	*Abies balsamea*
3	4	4	2	est[b]	4	5	4	1	14	Striped maple	*Acer pensylvanicum*
2	2	3	3	70	2	2	2	3	215	Red maple	*Acer rubrum*
3	5	3	1	46	3	5	4	1	73	Sugar maple	*Acer saccharum*
4	5	2	2	13	4	4	3	1	86	Yellow birch	*Betula alleghaniensis*
3	2	2	2	new[c]	2	3	3	3	16	Black birch	*Betula lenta*
3	2	2	5	149	3	3	3	3	140	White birch	*Betula papyrifera*
2	2	3	5	new	2	2	2	5	43	Grey birch	*Betula populifolia*
4	2	2	1	new	4	2	1	1	11	Atlantic white-cedar	*Chameacyparis thyoides*
3	4	4	1	est	3	5	4	1	69	Beech	*Fagus grandifolia*
3	4	5	3	est	3	5	5	2	51	White ash	*Fraxinus americana*
5	1	1	5	33	5	1	1	5	8	Tamarack	*Larix laricina*
4	1	1	3	86	4	1	1	4	13	Black spruce	*Picea mariana*
3	2	1	2	new	3	2	1	2	106	Red spruce	*Picea rubens*
1	2	2	4	70	1	2	2	5	35	Red pine	*Pinus resinosa*
1	2	2	4	new	1	2	2	5	32	Pitch pine	*Pinus rigida*
2	2	2	3	106	2	2	2	3	139	Eastern white pine	*Pinus strobus*
2	2	2	4	129	3	2	2	4	59	Quaking aspen	*Populus tremuloides*
1	2	3	5	23	2	2	3	5	12	Pin cherry	*Prunus pensylvanica*
2	3	4	3	<5	2	3	3	3	36	Black cherry	*Prunus serotina*
2	5	5	2	8	1	4	5	3	43	White oak	*Quercus alba*
1	4	3	3	70	1	3	4	3	85	Northern red oak	*Quercus rubra*
2	3	4	4	est	1	3	5	4	25	Black oak	*Quercus velutina*
4	3	1	1	<5	3	3	2	1	62	Eastern hemlock	*Tsuga canadensis*

[a] When a species' value was thought to be unduly influenced in one direction or another by the associate species captured in the sample, adjustment of those values by one place was considered allowable. There were two exceptions: WB and YB were considered to be dramatically affected by their shade-tolerant associates and their light values were correspondingly adjusted by 2. The following values were shifted up (+) or down (-) on the key pages as a result of corrections that were deemed necessary to better reflect that species' establishment preferences in New England.

Species	Factor	From	To
Yellow birch	light	1	3
White birch	light	3	5
Beech	nutrients	5	4
Red spruce	light	2	1
Red pine	light	5	4
Pitch pine	nutrients	2	1
Aspen	light	4	5
White oak	nutrients	4	3
Red oak	moisture	1	2
Red oak	nutrients	3	4

[b] Estimated by Bakuzis and Kurmis (1978)

[c] New for New England

Appendix II

Development of the Composition Diagrams

Any cover type label necessarily includes a certain range of species composition. To properly apply the type classification, an interpreter should know the limits of this range. The example photos in a photographic key can represent only a fraction of the possible variation. To give the interpreter some perspective, a diagram has been included for each type in the guide to describe the range in species composition possible under its definition, and to depict where within that range the example stand occurs. Superimposed on the range of composition diagrams is an 'X' to demonstrate where within that range the example stand in the CIR stereogram occurs.

Ideally, the categories in any classification system should be distinct, mutually exclusive, and as exhaustive as possible, and to be depicted graphically, they must be. To do so, the inherently vague definitions presented in the SAF guide (Eyre 1980) were simply formalized. Using any and all of the cues given in the SAF guide, we established several rules to remain consistent across the types and to ensure that they are mutually exclusive.

First, the simple majority rule given in the SAF guide ("x/x/x comprise the majority") was applied to situations in which both a single species **and** a recognized combination of species compose a majority of the stocking. For example, a stand of 55 percent WP, 20 percent RO, and 25 percent RM would represent a majority of both WP and WP/RO/RM, each of which are recognized as forest cover types. In this instance of deciding between the single-species and the three-species type, a 30 percent cutoff was used. In other words, where that single species composed 50 percent or more of the stand (basal area), that stand was classified as the single-species type *unless* 30 percent or more of the remaining composition was made up of those associate species characteristic of the combination type (in this example, red oak and red maple). In such a situation, it could be argued that even though one species did compose a majority, it was probably just a result of chance or stand history and the stand "really" represented an example of the combination type. Similar rules were developed for all possible combinations. If a species combination composes a majority, while one or two of the title species also composes a majority (>50 percent) of the basal area, then:

when considering:
two-species types (for example, RS/BF)

- 25 percent is the lower limit for the other title species

with three-species types (for example, WB/RS/BF)

- 30 percent is the lower limit for both other title species combined
- 20 percent is the lower limit for a single species

These figures were chosen from clues given in *The forest cover types of the United States and Canada.* For example, "an added requirement was that a species must comprise at least 20 percent of the total basal area to be used in the type name" (Eyre 1980, p. 2). In the first situation, if red spruce (RS) represents 50 percent or more of the stocking and balsam fir (BF) makes up less than 25 percent, then it is not RS/BF. In the second situation, if red spruce (RS) represents 50 percent or more of the stocking and BF and WB together make up less than 30 percent of the stocking, then it is not WB/RS/BF. In the third situation, if RS/BF represents 50 percent or more of the stocking and white birch (WB) makes up less than 20 percent of the stocking, then it is not WB/RS/BF. The diagrams that were developed to depict these definitions were kept as simple as possible. Applying the above rules results in a general graphic format for each single-species, two-species, and three-species type. These are illustrated in Figure 4.

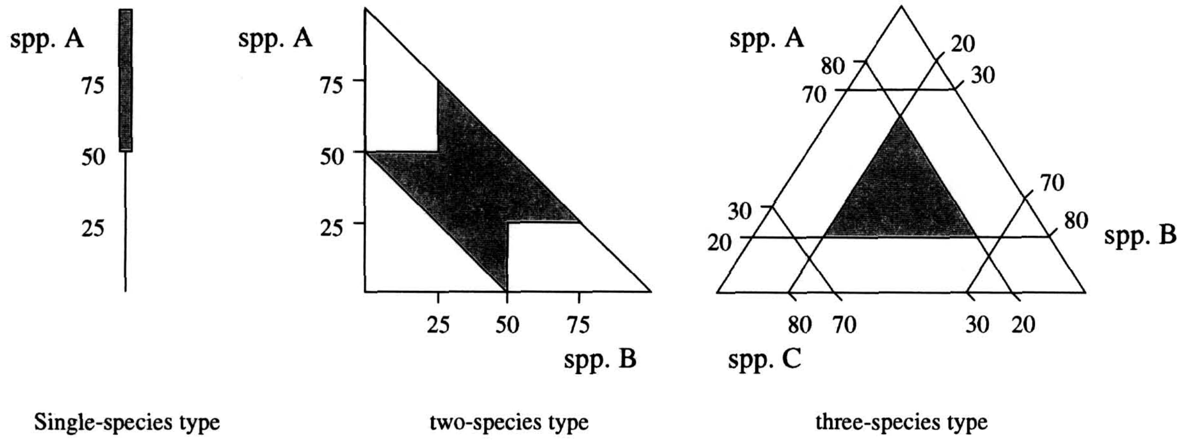


Figure 4.--The general format of composition diagrams for single-species, two-species, and three-species types when all the rules have been applied. The shading identifies that area considered to be the possible range of composition, in percent, for that type. Note the removal of the upper-left and lower-right corners of the two-species diagram. This indicates that composition is > 50 percent of one species and < 25 percent of the other. Stands falling in either of those areas would instead be classified as the corresponding single-species type. Note also the similar removal of the three corners of the three-species diagram by the 30 percent line, and the removal of the three edges by the 20 percent line.

Once the types had been made mutually exclusive, the next step was to ensure that the type definitions were exhaustive. This is necessary to avoid too many unclassified stands and to meet the assumptions of the accuracy analysis statistics. If

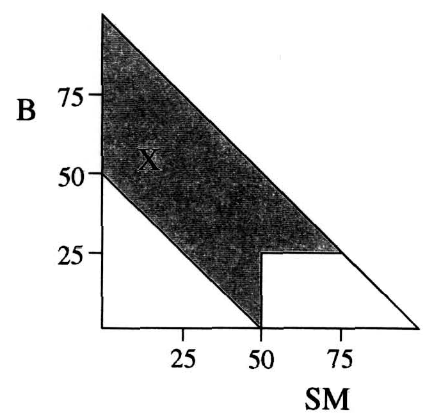


Figure 5.--This diagram is similar to that displayed in figure 4, but altered to include compositions of >50 percent B and < 25 percent SM in the Beech-Sugar Maple type because no Beech type is currently recognized in the guide.

only the types listed in the key are considered the universe of possible categories, using only the above rules allows many "holes", or possibilities that stand composition will not fit a definition and thus will not fit a type. To solve this, the constraints imposed on the range of composition were removed where the single-species (or two-species) types are not recognized as a type category in their own right. The range of composition diagram for the SM/B type provides a simple example. In this guide, sugar maple (SM) is recognized as a single-species type, but beech (B) is not. Because a B type is not recognized, the resulting range of composition diagram for SM/B looks like Figure 5. Thus, a stand with 55 percent B and 20 percent SM would be categorized (the 'x' in Figure 5) as SM/B. This removal of constraints was similarly applied to each type contained in this guide to create the range of compositions presently found on each key page.

Even after this adjustment, some exceptions remain and there are species combinations that still remain unclassified. The two problems that persist are:

(1) The diagrams do not take into consideration any species other than those mentioned

somewhere in a type in the key. In general, if the "other" species (for example, pin cherry, white spruce, black ash, black cherry and yellow-poplar) add up to more than 50 percent of the basal area in a stand, that stand could not be classified anywhere in this key. For example, a stand of 100 percent pin cherry could not be classified anywhere, and neither could a stand of 20 percent black cherry , 25 percent black ash, 10 percent yellow-poplar, and 45 percent sugar maple.

(2) A stand could not be classified even if it did contain greater than 50 percent of combined recognized species if those species combinations were not recognized as a type. An example of this would be 40 percent red maple, 20 percent yellow birch, and 40 percent hemlock, where no single species meets the 50 percent-or-more requirement, and neither RM/YB/H, RM/YB, RM/H, or YB/H are recognized types.

The advantage of an exhaustive system of type categories is that almost all of the stands found in New England would fall into some type classification. The disadvantage is that the range diagrams created are sometimes alarmingly broad, especially if no similar types are recognized. This stretches the imagination as to whether an extreme stand can still be considered that type, and probably decreases the chance that a stand at the extremes of the definitions will be classified correctly.

As already mentioned, the "holes" in the definitions were evaluated on the basis of how often such "deviant" stands occurred. The type combinations being used in this guide were chosen because they represented the majority of what can be found in New England, so the occurrence of unclassified stands should theoretically be low. If this is ever found not to be true, then perhaps a new type needs to be recognized and added to the key, and the user should feel free to do so.

Notes on Diagram Layout

The first two (single- and two-species) diagrams allow for "other" species to exist. Correspondingly, the requirement for the component species to compose 50 percent or more of a stand is shown as a boundary line in both diagrams (see Figure 6).

Such a line does not exist in the triangular three-species diagrams in this guide -- there is no space in the two-dimensional graph for the "other" species. A three-dimensional representation of the diagram, complete with the 50 percent-or-greater line, is illustrated in Figure 7.

The triangle face of the diagram in the guide thus does not represent 100 percent of the composition of the stand. Rather, it represents 100 percent of the "non-other" component of the stand (the "title" species concerned in that particular type), or the proportions of WP, RO, and RM to each other. For example, a stand of 50 percent WP, 20 percent RM, 15 percent RO and 15 percent RP would find its position in the WP/RO/RM diagram as 50/85 = 59

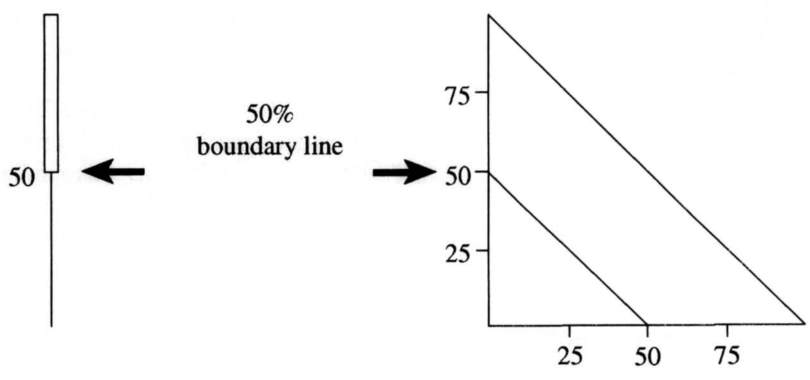


Figure 6.--All the definitions require that the species combination compose at least 50 percent of the stand. The single- and two-species diagrams illustrate the 50 percent bounding line.

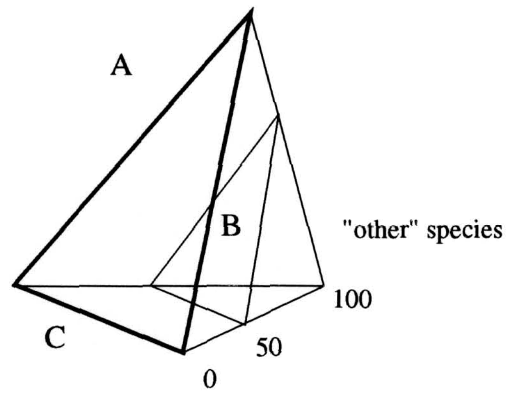


Figure 7.--A three-dimensional version of the diagram for a three-species type. The triangle face in **bold** is the part of this diagram that is presented in the guide. The smaller triangle parallel to the first represents the 50 percent minimum boundary line.

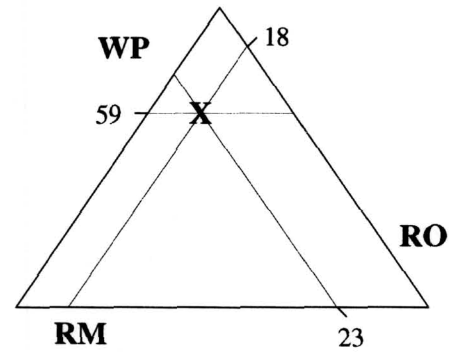


Figure 8.--To present a species composition of 50 percent WP, 20 percent RM and 15 percent RO on the three-species diagram in the guide, it is necessary to convert the values such that the component species total 100%. For example, 50+20+15=85, thus 50/85=59 percent, 20/85=23 percent and 15/85=18 percent. It is these converted species percentages that are depicted on the three-species diagrams in the guide.

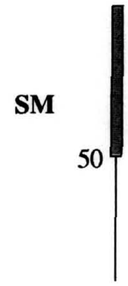
percent WP, 20/85 = 23 percent RM, and 15/85 = 18 percent RO (85 = 50+20+15 = total component or "title" species) (see Figure 8). The actual percentage of composition of the component species as well as the percentage of "other" species in the example photo does not appear in the range of composition diagram, but is given in the caption under the CIR stereogram. To remain consistent with the one- and two-species diagrams, the lines representing the range of composition are with respect to all the trees in the stand, not just those of the major component species. In other words, if White Pine equals 70 percent or greater of the total species composition, it no longer fits into this type. This is a potentially confusing element, but one which is maintained for ease of use.

Figure 9 shows examples of each type of diagram and provides explanations of the boundary lines where they occur. To the left of each diagram is a written version of the composition as it is depicted in the diagram. Anything preceded by "unless" is necessary to make the compositions mutually exclusive. Such rules are incorporated into the composition diagrams of the multi-species types, but cannot appear in single-species and occasionally two-species diagrams. This information is not included on the key pages as it is in Figure 9, because it would give the range of composition diagram the appearance of being a more precise definition than it is.

Variations within a single type will always occur among stands, and the range of composition diagram gives some sense of the range of possibilities a photointerpeter may encounter.

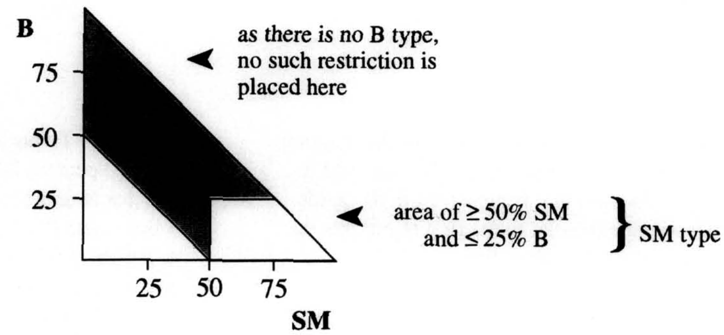
SM

if ≥ 50%
unless ≥ 25% B
unless ≥ 30% B/YB



B/SM

if ≥ 50%
unless ≥ 20% YB
unless ≥ 50% SM
unless < 25% B



SM/B/YB

if ≥ 50%
unless ≥ 25% B
unless ≥ 30% B/YB

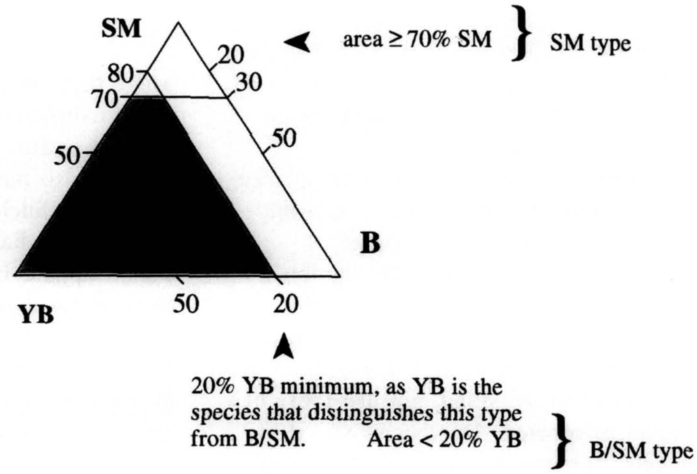


Figure 9--Development of the type definitions requires a comparison between related types. The "if" statements describe the conditions in the diagram immediately to the right. The "unless" statements, when true, direct the user to another type diagram.