Determining Stocking, Forest Type, and Stand-Size Class From Forest Inventory Data

Mark H. Hansen *and* **Jerold T. Hahn,** *USDA Forest Service, North Central Forest Experiment Station, 1992 Folwell Ave., St. Paul, MN 55108–1099.*

ABSTRACT. This paper describes the procedures used by North Central Forest Experiment Station's Forest Inventory and Analysis Work Unit (NCFIA) in determining stocking, forest type, and stand-size class. The stocking procedure assigns a portion of the stocking to individual trees measured on NCFIA 10-point field plots. Stand size and forest type are determined as functions of the stocking, size, and species of these trees and the physiographic classification of the site. One stand-size classification algorithm used in all states inventoried by NCFIA is described. Three separate forest type classification algorithms used in the Lake States (MI, MN, and WI), Plains States (KS, NE, ND, and SD) and Central States (IA, IL, IN, and MO) are presented.

North. J. Appl. For. 9(3):82–89.

Personnel of the North Central Experiment Station's Forest Inventory and Analysis Work Unit (NCFIA) are frequently asked how stocking, forest type, and stand-size class are determined. This paper presents procedures used in these classifications and describes the concept of stocking as it applies to the work of NCFIA.

Stocking is the basic building block of the other classifications. It should be noted that we refer to stocking as a value rather than a percentage, because we have found the problem of explaining "percentage of what" to be more distracting than helpful. Once the concept of stocking is made clear, the methods used to determine forest type and stand-size class can be described.

PROCEDURE TO DETERMINE STOCKING

NCFIA uses a 10-point cluster design field plot with the points located an equal distance (70 ft) apart (Fig. 1). Points 1, 2, 3, and 7 are on a central north/south axis with points 4, 5, and 6 to the east and points 8, 9, and 10 to the west. Trees are measured on a variable-radius plot (37.5 BAF, standard for FIA in the eastern United States) and on a fixed-area circular 1/300th ac plot (6.8 ft radius) at each point. All trees 5.0 in. diameter breast height (dbh) and larger are tallied on the variable-radius plot. All trees from 1.0 to 4.9 in. dbh are tallied on the fixed-radius plot. Seedlings—i.e., trees less than 1.0 in. dbh and at least 1.0 ft tall (0.5 ft tall for softwoods)—are only tallied if needed to meet stocking requirements. These requirements are explained later in this section.

Stocking is a measure of the extent to which the growth potential of a site is being utilized by trees or other vegetative cover. Stocking is measured by comparing basal area and/or number of trees, by age or size and spacing, with specified standards. Basal area per acre provides a good measure of stocking for stands consisting of trees primarily 5.0 in. dbh and larger, while number of trees per acre provides better stocking estimates for stands consisting of trees less than 5.0 in. dbh.

Two systems for describing stocking are commonly employed, the "167 basis" and the "normalized" basis. Both systems are used across all forest types in various applications. With the 167 basis, which NCFIA uses, a value of 100 represents the minimum basal area and/or number of trees per acre required to make full use of a site. Beyond this density, further increase will not increase the net growth rate. Stands are considered overstocked if the stocking values 133 or more, and maximum stocking is 167 (USDA 1972). Overstocked stands are characterized by reduced growth rates and/or high mortality.

With the normalized system, stocking values range from 0 to 100. A value of 60 is considered the minimum stocking that will make full use of the site, and 100 is the maximum a site can support. Thus, a stocking value of 60 on a normalized scale corresponds to a value of 100 on the 167-basis scale. Many normal yield tables use the normalized system. To convert between these two stocking systems a conversion factor of 1.67 is used—e.g., 60 (normalized) = 60 × 1.67 = 100 (167 basis).

The stocking values used by NCFIA are based solely on sample trees measured on each 10-point field plot. The rules for assigning stocking values are applied to each point of a 10-point field plot, and a point can be given a stocking of no more than 167/number of points per field plot (16.7 in the case of NCFIA where a 10-point field plot is used). In practice this is done by assigning a stocking value to each tree at a point based on tree diameter and occupancy of the point. The total stocking of the 10-point field plot is computed by summing these assigned stocking levels over all the trees measured on the plot. Since stocking is assigned to individual trees it can then be broken down by tree class, tree size, or species. These breakdowns of stocking are the basis for determining forest type, stand-size class, and stocking class.

Live trees measured at each of the 10 points are assigned point occupancy values that rank the trees relative to the portion of the site they use. Rankings are based on the judgment of the field crew. The tree that occupies the largest portion of the site is assigned a point occupancy value of one, the second most dominant tree is assigned a value of two, and so on. Crown class, crown ratio, and dbh are used as guidelines in this determination A large-diameter tree having a full crown that dominates the point yet is shorter than surrounding trees would be assigned a lower point occupancy code (higher rating) than a taller tree that has a smaller, weaker crown. Trees 1.0 in. dbh and larger are always assigned a lower point occupancy than seedlings. At each point the eight most controlling trees are ranked. The individual rankings will not influence the total stocking of a point but they will influence the forest type and stand-size class assignment for 10-point field plots that have overstocked points

After the live trees at a point have been ranked, each ranked tree is assigned a stocking value based on its dbh, as shown in Table 1. To uniformly classify the acre described by the 10-point field plot, a maximum total stocking value of 16.7 is allowed for each point. Thus, the last tree to be assigned stocking may get less than the table value if assigning that value would put the total above the 16 7 maximum. Seedlings are tallied only at points where no trees 5.0 in. dbh or larger were found and they are needed to reach the 16.7 maximum.

The stocking values in Table 1 are based on a full stocking standard of 80 ft^2/ac of live basal area for stands of trees 5.0 in. dbh or larger. Since a 37 5 BAF variable-radius sample is taken at each point, a stand with no trees less

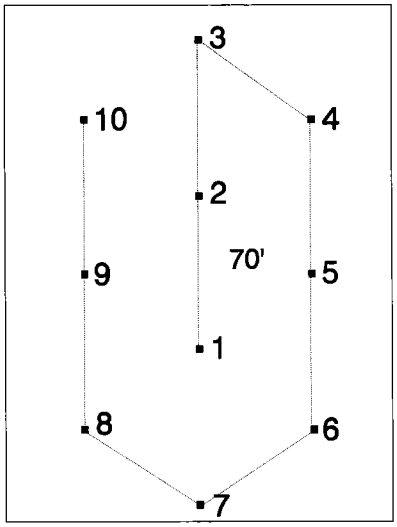

Fig. 1. NCFIA 10-point field plot layout.

than 5.0 in. dbh and a basal area of 80 ft^2/ac would be expected to have a stocking of 100. A stand made up entirely of trees between 4.0 and 4.9 in. dbh would be expected to have a total stocking value of 100 if it has 750 trees/ac A seedling stand would require 1,500 trees/ac to be fully stocked. If no live trees are tallied at a point, the stocking value would be zero, and the point would be classified as nonstocked.

Table 2 summarizes a hypothetical NCFIA 10-point field plot showing the live trees tallied at each point with their dbh, point occupancy, and assigned stocking value. Point 1 has four trees 5.0 in. dbh or larger and four trees less than 5.0 in.; total stocking is 16 7 Trees 1, 3, and 4 were assigned 4.7 each, and tree 2 was assigned a truncated value of 2.6, or the balance of the 16.7 maximum per point. No stocking value was assigned to trees 5 through 8 since the maximum allowed was already achieved by trees 1 through 4.

Points 2 through 5 and 7 show various combinations where at least one tree 5.0 in. plus dbh tree is present and the 16.7 maximum is not reached. At these points no seedlings would be tallied and assigned a stocking value

Table 1. Stocking values assigned to individual trees tallied on the 10-point field plots measured by NCFIA.

	Stocking	
Tree dbh	At least one 5.0 in. dbh tree present	No trees at least 5.0 in. dbh present
5 0+	4.7	—
4 0–4 9	4.0	4.0
3.0–3.9	2.4	3.5
2 0–2 9	1.2	3.0
1 0–1 9	0.4	2.5
Seedlings	0.0	2.0

Table 2. A hypothetical NCFIA 10-point field plot showing live trees tallied at each point and stocking values assigned to these trees.

Point	Tree	Dbh	Point occ.	Stk. value	Point	Tree	Dbh	Point occ.	Stk. value
1	1	5.7	3	4.7	6	1	4.2	1	4.0
	2	5.6	4	2.6		2	1.1	2	2.5
	3	7.9	2	4.7		3	1.5	3	2.5
	4	10.3	1	4.7		4	1.2	4	2.5
	5	3.5	5	0.0		Point 6 stock value			11.5
	6	2.1	6	0.0	7	1	12.7	1	4.7
	7	1.1	7	0.0		2	12.6	2	4.7
	8	1.1	8	0.0		Point 7 stocking value			9.4
	Point 1 stocking value			16.7	8	1	2.2	2	3.0
2	1	10.2	1	4.7		2	3.2	1	3.5
	2	9.5	2	4.7		3	2.1	3	3.0
	3	7.5	3	4.7		4	1.2	5	2.5
	4	3.2	4	2.4		5	0.0	6	2.0
	Point 2 stocking value			16.5		6	1.7	4	2.5
3	1	10.2	1	4.7		7	0.0	7	0.2
	2	5.7	2	4.7		8	0.0	8	0.0
	3	2.1	3	1.2		Point 8 stocking value			16.7
	4	1.9	4	0.4	9	1	4.4	1	4.0
	Point 3 stocking value			11.0		2	4.1	2	4.0
4	1	5.5	1	4.7		Point 9 stocking value			8.0
	2	2.5	2	1.2	10	1	1.5	1	2.5
	Point 4 stocking value			5.9		2	1.7	2	2.5
5	1	10.2	1	4.7		3	1.1	3	2.5
	2	9.7	2	4.7		4	1.5	4	2.5
	Point 5 stocking value			9.4		Point 10 stocking value			10.0

Total plot stocking value = 115.1

even if they were present on the 1/300th ac fixed-radius plot, because these points are presumed to be controlled by the larger trees.

At points 6, 8, 9, and 10 there are no trees with 5.0 in. plus dbh present. Stocking values are assigned to these trees differently than at the other points where trees over 5.0 in. are present. Notice the 3.2-in. tree at point 2 is assigned a stocking value of 2.4, while the same size tree at point 8 is assigned a stocking value of 3.5. At point 8, tally seedlings were available to add to the total stocking. At points 6, 9, and 10, no tally seedlings were present on the 1/300th ac fixed-radius plot. If seedlings had been present on the fixed-radius plot they would have been tallied and each assigned a stocking of 2.0 until the 16.7 maximum was reached.

STAND-SIZE CLASS CLASSIFICATION

Stand-size class is computed by summing the stocking for trees in each size class and applying a classification rule. Trees are classed as seedling-sapling if they are less than 5.0 in. dbh, poletimber if they are 5.0 in.–9.0 in. dbh for softwoods, and 5.0 in.–11.0 in. dbh for hardwoods, and sawtimber if they are larger. The following rules are applied in order until the 10-point field plot is classified:

- *Nonstocked*. Total stocking (all sizes) is less than 16.7.
- *Seedling-sapling*. Total stocking of seedling-sapling trees exceeds the sum of the stocking of poletimber and sawtimber trees.
- *Poletimber*. Total stocking of poletimber trees exceeds the stocking of sawtimber trees.
- *Sawtimber*. Total stocking of sawtimber trees equals or exceeds the stocking of poletimber trees.

If this method is applied to the example shown in Table 2 and it is assumed that all of the trees tallied were softwoods (sawtimber limit 9.0 in. dbh), the total stocking in each size class would be 37.6 in sawtimber, 26.1 in poletimber, and 51.4 in seedling-saplings. The 10-point field plot would be classified as a sawtimber stand-size class [51.4 < (26.1 + 37.6)].

It should be noted that this method of assigning size class is weighted toward the larger (poletimber and sawtimber) size classes. To be classed as seedling-sapling a 10-point field plot must have more than half of its stocking in trees less than 5.0 in. dbh, while a plot can have only one-fourth of its stocking in sawtimber trees and still be classed as a sawtimber stand. This weighting is intentional. Stands are only classed as seedling-sapling if small trees truly dominate the site, not just occur with the larger trees as a two-storied stand.

FOREST TYPE CLASSIFICATION

Forest type is based on definitions published by the Society of American Foresters (SAF) (Eyre 1980). In an effort to standardize the method used to determine forest type we have developed three algorithms, one each for the Lake States (MI, MN, WI), the Central States (MO, IA, IN, IL), and the Plains States (ND, SD, NE, KS).

The three algorithms have some features in common. They start by summing the stocking values of all ranked live trees into type groups based on tree species. These type groups should

not be confused with the forest types, even though in many cases the type group names are similar or identical to the forest type names. These type groups are simply used to aggregate stocking into logical groups for forest typing purposes. For example, in the Lake States a 10-point field plot may have considerable stocking in the aspen type group but the final forest type assigned to the plot may be something other than aspen.

After the type groups have been assigned to all the trees on a 10-point field plot they are combined based on stand conditions, such as physiographic class (moisture regime). Some tree species are common on both wet and dry sites and are associated with different forest types on each of these sites. The forest type is then determined by comparing total stocking in the combined type groups based on specific criteria. The type groups and species assigned to each group are listed in Tables 3–5. The forest typing algorithms are shown in Figures 2–4.

In the typing algorithms there are instances where several type groups are compared, and the predominant group is selected. In these instances the predominant group is determined by plurality, with ties going to the first group listed. In all cases, nonstocked 10-point field plots are initially identified by the stand-size classification algorithm described in the previous section. These nonstocked 10-point field plots are given a forest type of 99 (nonstocked).

Table 6 shows the number of timberland 10-point field plots classified in each forest type obtained by applying these algorithms to data from the most recent forest inventory in each of the states in the North Central Region. It should be noted that the name given a particular forest type in this paper may be somewhat different than the name used for a forest type in a NCFIA report for a specific state or inventory unit. In these reports the names may be modified to match conditions specific to the individual states. For example, in North Dakota, plots that are typed elm-ash-locust are reported under the name elm-ash because locust is not a component of this type in North Dakota. A short summary of each of the three forest typing algorithms is included here.

LAKE STATES FOREST TYPING ALGORITHM

The forest types recognized by FIA in the Lake States (MI, MN, WI) are:

Jack pine	Red pine
White pine	Balsam fir
White spruce	Black spruce
Northern white-cedar	Tamarack

Table 3. Lake States type groups.

No.	Type group name	Species in group
		Initial typing group
1	Jack pine	*Pinus banksiana*
2	Red pine	*P. resinosa*
3	White pine	*P. strobus*
4	Balsam fir	*Abies balsamea*
5	White spruce	*Picea glauca*
6	Black spruce	*P. mariana*
7	Northern white-cedar	*Thuja occidentalis*
8	Tamarack	*Larix laricina*
9	Exotic conifers	*Picea abies, P. engelmannii, P. pungens, Pinus sylvestris, P. ponderosa, Pseudotsuga menziesii*
10	Oak-hickory	*Carya* species, *Quercus* species, *Sassafras albidum, Juniperus virginiana*
11	Soft maple-black ash	*Acer negundo, A. saccharinum, Betula nigra, Celtis laevigata, Celtis occidentalis, Fraxinus nigra, Platanus occidentalis, Populus deltoides, Salix nigra*
12	Maple-beech-birch	*Tsuga canadensis, Acer nigrum, A. saccharum, Betula alleghaniensis, Fagus grandifolia, Fraxinus americana, Juglans cinerea, J. nigra, Prunus serotina, Tilia americana, Tsuga canadensis*
13	Aspen	*Populus grandidentata, P. tremuloides*
14	Paper birch	*Betula papyrifera*
15	Balsam poplar	*Populus balsamifera*
16	Elm-red maple-green ash	*Acer rubrum, Fraxinus pennsylvanica, Ulmus alta, U americana, U. pumila, U. rubra, U. thomasii*
24	Other softwoods	All softwoods not listed above
25	Other hardwoods	All hardwoods not listed above

Combined type groups (not numbered) are aggregations of the initial type groups:
Pines = type groups 1 + 2 + 3
Swamp conifers = type groups 4 + 5 + 6 + 7 + 8
Aspen-birch = type groups 13 + 14 + 15
Softwoods = pines + swamp conifers + type groups 9 + 24
Hardwoods = aspen-birch + type groups 10 + 11 + 12 + 16 + 25
Total = softwoods + hardwoods

Table 4. Plains States type groups.

No.	Type group name	Species in group
		Initial typing groups
1	Jack pine	*Pinus banksiana*
2	Red pine	*P. resinosa*
3	Ponderosa pine	*P. ponderosa*
4	Eastern redcedar	*Juniperus virginiana*
5	Rocky Mt. Juniper	*J. scopulorum*
6	Oak-hickory	*Carya cordiformis, C. illinoensis, C. laciniosa, C. ovata, C. texana, C. tomentosa, Fraxinus americana, Quercus alba, Q. imbricaria, Q. muehlenbergii, Q. palustris, Q. rubra, Q. shumardii, Q. velutina*
7	Bur oak	*Q. macrocarpa*
8	Post-blackjack oak	*Q. marilandica, Q. stellata*
9	Black ash	*Betula nigra, Fraxinus nigra*
10	Cottonwood	*Populus deltoides*
11	Willow	*Salix amygdaloides, S. nigra*
12	Maple-basswood	*Acer saccharum, Prunus serotina, Tilia americana*
13	Locust	*Gleditsia triacanthos, Robinia pseudoacacia*
14	Aspen-birch	*Betula papyrifera, Populus balsamifera, P. tremuloides*
15	Walnut-hackberry	*Celtis occidentalis, Juglans nigra*
16	Silver maple-boxelder	*Acer negundo, A. saccharinum, Platanus occidentalis*
17	Elm-red maple-green ash	*Acer rubrum, Fraxinus pennsylvanica, Ulmus americana, U. pumila, U. rubra, U. thomasii*
24	Other softwoods	All softwoods not listed above
25	Other hardwoods	All hardwoods not listed above

Combined type groups (not numbered) are aggregations of the initial type groups:
Pines = type groups 1 + 2 + 3
Softwoods = pines + type groups 4 + 5 + 24
Oaks = type groups 6 + 7 + 8
Hardwoods = oaks + type groups 9 + 10 + 11 + 12 + 13 + 14 + 15 + 16 + 17 + 25
Total = softwoods + hardwoods

Exotic	Oak-hickory
Elm-ash-cottonwood	Maple-beech-birch
Aspen	Paper birch
Balsam poplar	

The forest typing algorithm used in the Lake States is shown in Figure 2, and the species assigned to each typing group are listed in Table 3. The first step in this procedure compares the total stocking in hardwoods with the total stocking in softwoods. If at least one-half of the total stocking is in softwoods, one of the softwood forest types will be assigned; otherwise, a hardwood type will be assigned. Mixed hardwood-softwood types are not recognized in the Lake States.

If a softwood type is indicated, the forest type is determined by comparing total stocking in the following three combined softwood type groups: pines (jack pine + red pine + white pine), swamp conifers (balsam fir + white spruce + black spruce + northern white-cedar + tamarack), and exotic conifers and other softwoods. If the pine type group is predominant, the algorithm will assign the forest type of the most abundant pine species. If the exotic conifer plus other softwoods group is predominant, the exotic type is assigned. When the swamp conifer type group is predominant, the combined stocking in the two swamp conifer species (balsam fir and white spruce) associated with less hydric sites is compared with the combined stocking in the three species (black spruce, northern white-cedar, and tamarack) usually associated with more hydric sites. If the stocking in balsam fir plus white spruce is greatest, a forest type of balsam fir or white spruce is assigned based on greatest stocking; otherwise, the type is assigned to one of the three more hydric types, again based on greatest stocking

When a hardwood type is indicated, the stocking in white pine is added to the maple-beech-birch type group. On upland sites the stocking in the elm-red maple-green ash type group is also added to the maple-beech-birch type group; otherwise, it is added to the soft maple-black ash type group. After these possible additions to the maple-beech-birch and soft maple-black ash type groups have been made, the forest type is determined by comparing total stocking in the four major hardwood type groups (oak-hickory, soft maple-black ash, maple-beech-birch, and aspen-birch). If the oak-hickory group is the predominant of the four, the algorithm will assign the oak-hickory forest type. If the soft maple-black ash type group (this includes elm-red maple-green ash on lowland sites) is predominant, a type of elm-ash-cottonwood is assigned. When the maple-beech-birch type group (this includes white pine and elm-ash-cottonwood on upland sites) is predominant, a type of maple-beech-birch is assigned. The maple-beech-birch type is referred to as maple-birch in the most recent Michigan and Wisconsin reports, and maple-basswood in the Minnesota publications. Maple-beech-birch is the name used nationally for this type. When the aspen-birch type group is predominant, a forest type of aspen (quaking and/or bigtooth), paper birch, or balsam poplar is assigned depending on which has the greatest stocking. Because balsam poplar is not common in Wisconsin and Michigan, this type was combined with the aspen type in the reports.

Table 5. Plains States type groups.

No.	Type group name	Species in group
		Initial typing groups
1	White-red-jack pine	*Pinus banksiana, P. resinosa, P. strobus*
2	Shortleaf pine	*P. echinata*
3	Virginia pine	*P. virginiana*
4	Eastern redcedar	*Juniperus virginiana*
5	Oak-hickory	*Morus rubra, Robinia pseudoacacia, Sassafras albidum*
6	Post-blackjack oak	*Quercus marilandica, Q. stellata* variant *stellata*
7	Chestnut-black-scarlet oak	*Q. prunus, Q. velutina, Q. coccinea*
8	White oak-red oak-hickory	*Q. ellipsoidalis, Q. imbricaria, Q. nigra, Q. rubra, Q. phellos, Q. muehlenbergii, Q. shumardii, Q. falcata* variant *falcata, Carya glabra, C. cordiformis, C. illinoensis, C. laciniosa, C. ovata, C. tomentosa*
9	White oak	*Quercus alba*
10	Sassafras-persimmon	*Sassafras albidum, Diospyros virginiana*
11	Bur oak	*Quercus macrocarpa*
12	Oak-gum-cypress	*Taxodium* species, *Liquidambar styraciflua, Nyssa sylvatica* variant *biflora*
13	Swamp chestnut oak-cherrybark oak	*Quercus michauxii, Q. palustris, Q. falcata* variant *pagodaefolia, Q. lyrata*
14	Elm-red maple-green ash	*Ulmus americana, U. pumila, U. rubra, U. thomasii, Fraxinus pennsylvanica, Acer rubrum*
15	Soft maple-black ash	*A. negundo, A. saccharinum, Aesculus glabra, Betula nigra, Celtis occidentalis, Fraxinus nigra, Gleditsia triacanthos, Platanus occidentalis*
16	Cottonwood	*Populus deltoides*
17	Willow	*Salix nigra*
18	Maple-beech-birch	*Acer nigrum, A. saccharum, Tilia americana, Betula alleghaniensis, Fagus grandiflora, Juglans cinerea*
19	Cherry-ash-yellow poplar	*Prunus serotina, P. virginiana, Juglans nigra, Fraxinus americana, Liriodendron tulipfera*
20	Aspen-birch	*Populus grandidentata, P. tremuloides, P. balsamifera, Betula papyrifera*
24	Other softwoods	All softwoods not listed above
25	Other hardwoods	All hardwoods not listed above

Combined type groups (not numbered) are aggregations of the initial type groups:
Pines = type groups 1 + 2 + 3
Softwoods = pines + type groups 4 + 24
Lowland Oaks = type groups 12 + 13
Upland Oaks = type groups 5 + 6 + 7 + 8 + 9 + 10 + 11
Hardwoods = type groups 5 + 6 + 7 + 8 + 9 + 10 + 11 + 12 + 13 + 14 + 15 + 16 + 17 + 18 + 19 + 20 + 25
Upland hardwoods = type groups 18 + 19
Elm-ash-cottonwood = type groups 15 + 16 + 17
Total = hardwoods + softwoods

PLAINS STATES FOREST TYPING ALGORITHM

The forest types recognized by NC-FIA in the Plains States (NS, NE, ND, SD) are:

Jack pine	Red pine
Ponderosa pine	Eastern redcedar
Rocky Mt. juniper	Exotic
Eastern redcedar-hardwood	Bur oak
Cottonwood	Willow
Red oak-white oak-hickory	Post-blackjack oak
Elm-ash-soft maple (lowland)	Maple-basswood
Elm-ash-locust (upland)	Aspen-birch

The forest typing algorithm used in the Plains States is shown in Figure 3, and the species assigned to each typing group are listed in Table 4. The first step in this procedure involves comparing the total stocking in hardwoods to that in softwoods. If at least one-half of the total stocking is in softwoods, one of the softwood forest types will be assigned; otherwise, a hardwood or mixed hardwood-softwood type will be assigned.

If a softwood type is indicated, the

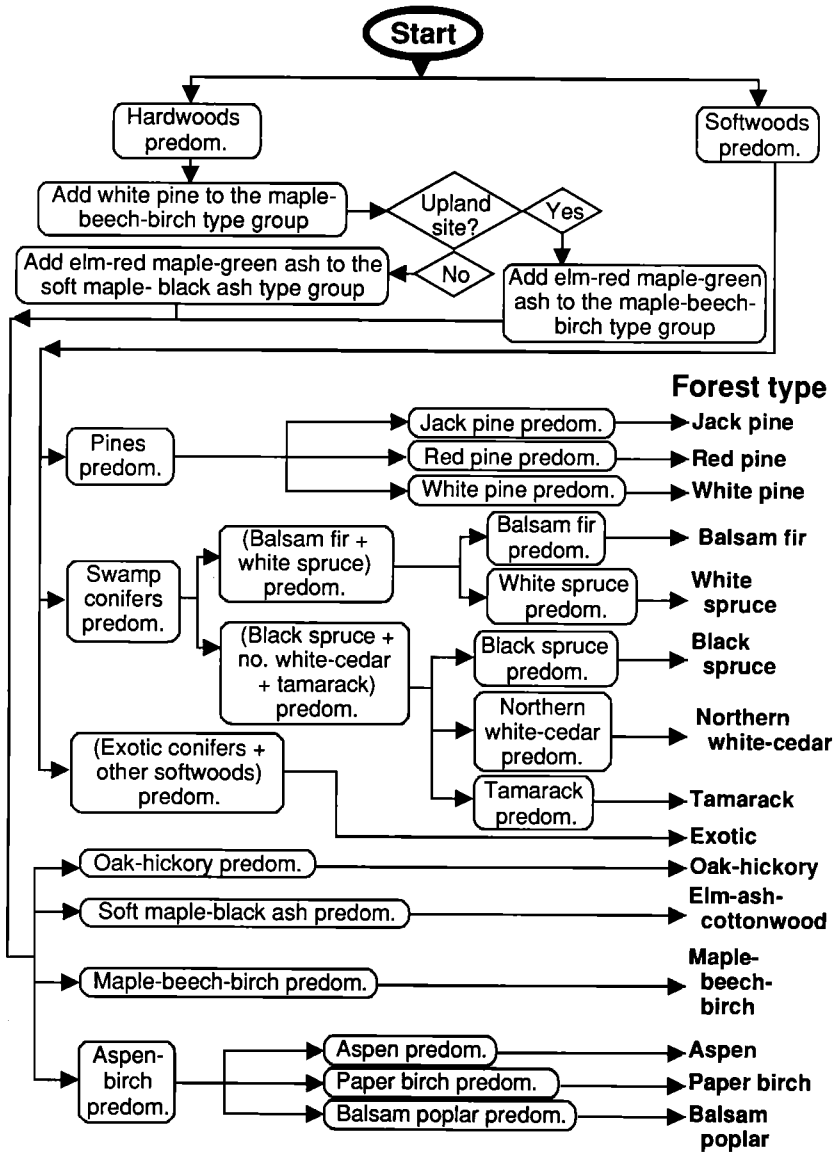

Fig. 2. Lake States typing algorithm.

forest type is determined by comparing total stocking in the following four combined type groups: pines (jack pine + red pine + ponderosa pine), eastern redcedar, Rocky Mt. juniper, and other softwoods. If the pine group is predominant, the algorithm will assign the forest type of the most abundant pine species. If eastern redcedar is predominant, the eastern redcedar type is assigned. If Rocky Mt. juniper is predominant, the Rocky Mt. juniper type is assigned. If the other softwood type group is predominant, the exotic type is assigned.

If a softwood type is not indicated but at least 25% of the total stocking is in eastern redcedar, the eastern redcedar-hardwood type is assigned. In the Plains States, three single-species hardwood types (bur oak, cottonwood, and willow) are recognized. These types are assigned only if 50% of the total stocking comes from that single species.

If a 10-point field plot does not meet the criteria for eastern redcedar-hardwood or one of the softwood or single-species hardwood types, the forest type is determined by comparing total stocking in the four major hardwood type groups (oaks, lowland hardwoods, upland hardwoods, and aspen-birch). On all sites the lowland hardwoods type group includes the black ash, cottonwood, and willow type groups; the upland hardwoods type group includes the maple-basswood and locust type groups. If the site is upland, the walnut-hackberry, silver maple-boxelder, and elm-red maple-green ash type groups are added to the upland hardwoods type group; otherwise, the stocking in these three type groups is added to the lowland hardwoods type group. If the oak group predominates among the four major hardwood type groups, the algorithm compares the total stocking in post-blackjack oak to that in all other oaks. If the post-blackjack oak stocking is greatest, the post-blackjack oak type is assigned, otherwise, the red oak-white oak-hickory type is assigned. If the lowland hardwoods type group is predominant, a type of elm-ash-soft maple (lowland) is assigned If the upland hardwood group is predominant, a forest type of either maple-basswood or elm-ash-locust (upland) is assigned. The maple-basswood type is assigned when the stocking in maple-basswood plus walnut-hackberry is greater than or equal to the combined stocking in locust, silver maple-boxelder, and elm-red maple-green ash. When the aspen-birch type group is predominant, a forest type of aspen-birch is assigned.

CENTRAL STATES FOREST TYPING ALGORITHM

The forest types recognized by NC-FIA in the Plains States (IL, IN, IA, MO) are:

White pine	Shortleaf pine
Virginia pine	Eastern redcedar
Eastern redcedar-hardwood	Shortleaf pine-oak
Other pine-oak	Post-blackjack oak
Chestnut-black-scarlet oak	White oak
Sassafras-persimmon	Bur oak
White oak-red oak-hickory	Oak-gum-cypress
Swamp chestnut oak-cherrybark oak	Cottonwood
Elm-ash-soft maple (lowland)	Willow
Maple-basswood	Cherry-ash-yellow poplar
Aspen-birch	

The forest typing algorithm used in the Central States is shown in Figure 4, and the species assigned to each typing group are listed in Table 5 The first step in this procedure involves looking at the total stocking in softwoods. If at least 25% of the total stocking is in softwoods, one of the softwood or mixed softwood-hardwood forest types will be assigned; otherwise, a hardwood type will be assigned.

If a softwood or mixed type is indicated, the next step in the algorithm looks at the total combined stocking in the three pine type groups (white-red-jack pine, shortleaf pine, and Virginia pine). If the combined stocking in pine is at least 50% of the total stocking, then one of the three pine forest types is assigned based on the predominant type group. If the total stocking in eastern redcedar is at least 50% of the total stocking, the eastern redcedar type is assigned. If the stocking in

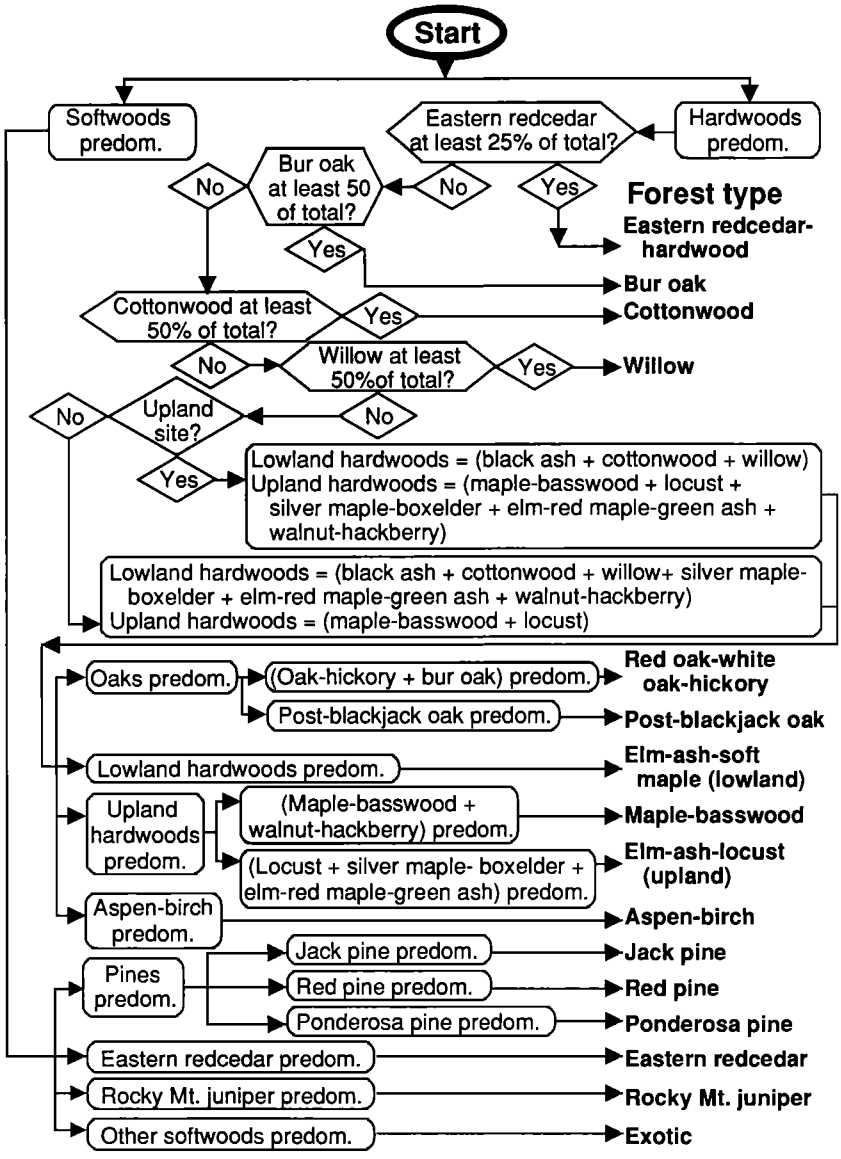

Fig. 3. Plains States typing algorithm.

eastern redcedar is less than 50% but at least 25% of the total, the eastern redcedar-hardwood forest type is assigned. The algorithm then looks at the combined stocking in the shortleaf pine and upland oak type groups. If this combined stocking is at least 50% of the total stocking, the shortleaf pine-oak type is assigned; otherwise, the other pine-oak type is assigned.

If softwoods make up less than 25% of the total stocking, a hardwood forest type will be assigned. Initially, the forest type is determined by comparing total stocking in the five major hardwood type groups (upland oaks, lowland oaks, elm-ash-cottonwood, upland hardwoods, and aspen-birch). On lowland sites, the stocking in the elm-red maple-green ash type group is included in the elm-ash-cottonwood major hardwood type group; on upland sites, however, it is added into the major group for upland hardwoods. The algorithm compares these five major hardwood type groups and selects the predominant one. If the aspen-birch group is predominant, a forest type of aspen-birch is assigned. If, however, one of the other four major hardwood type groups is predominant, the selection of a forest type requires additional stocking comparisons among the individual types within the major group. In all of these additional comparisons, some specific forest types will be assigned only if at least 50% of the total stocking is in an individual type group. For example, if the major group upland oaks is predominant, there are five forest types (post-blackjack oak, chestnut-black-scarlet oak, white oak, sassafras-

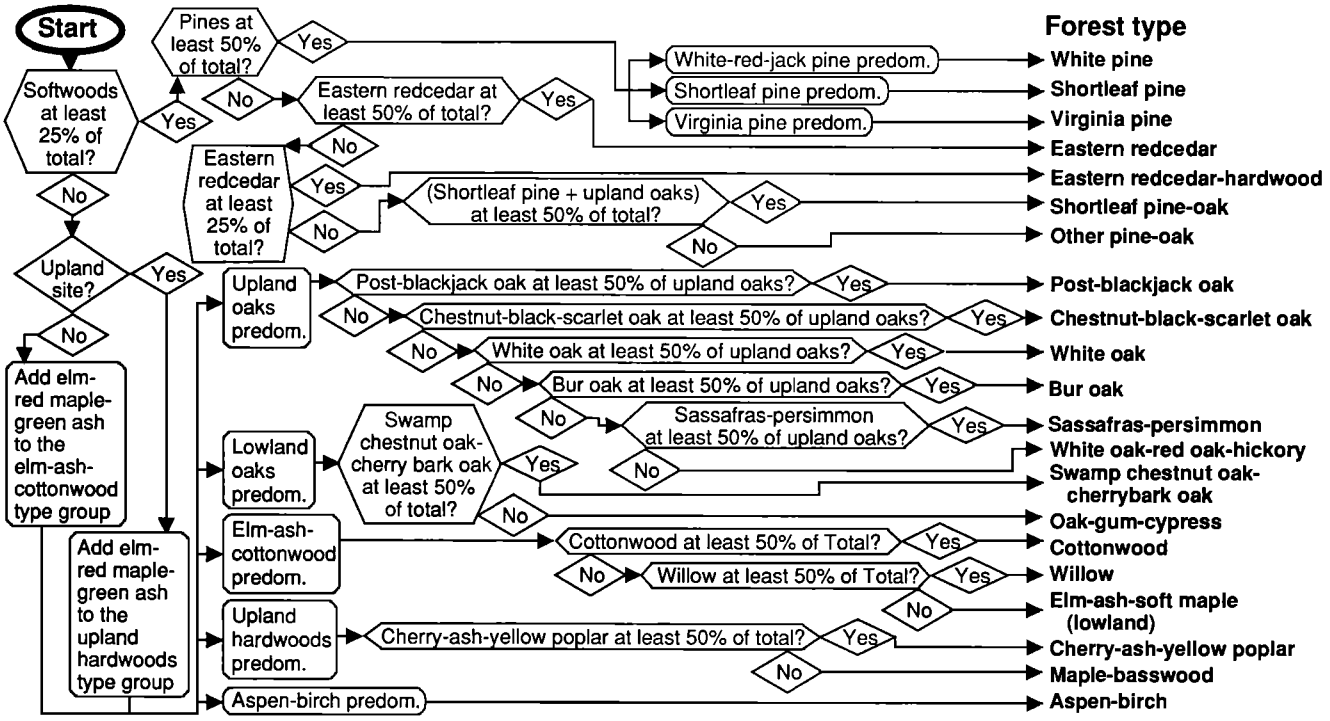

Fig. 4. Central States typing algorithm.

Table 6. Number of 10-point field plots in most recent NCFIA forest inventory by forest type and state.

	State										
	Lake States			Plains States				Central States			
Forest type	MI	MN	WI	KS	NE	ND	SD	IL	IN	IA	MO
Jack pine	351	351	256	0	0	0	0	a	a	a	a
Red pine	220	236	184	0	0	0	0	a	a	a	a
White pine	94	50	108	a	a	a	a	5	16	1	1
Exotic	43	7	0	0	0	0	0	a	a	a	a
Ponderosa pine	a	a	a	0	42	1	11	a	a	a	a
Balsam fir	331	565	208	a	a	a	a	a	a	a	a
Black spruce	232	1,058	143	a	a	a	a	a	a	a	a
Northern white-cedar	667	549	177	a	a	a	a	a	a	a	a
Tamarack	67	555	115	a	a	a	a	a	a	a	a
White spruce	53	73	20	a	a	a	a	a	a	a	a
Rocky Mt. juniper	a	a	a	0	0	0	1	a	a	a	a
Shortleaf pine	a	a	a	a	a	a	a	7	8	0	48
Virginia pine	a	a	a	a	a	a	a	0	9	0	0
Eastern redcedar	a	a	a	5	6	0	0	0	8	7	70
Eastern redcedar-hardwood	a	a	a	16	7	0	1	5	38	11	165
Shortleaf pine-oak	a	a	a	a	a	a	a	6	9	7	141
Other oak-pine	a	a	a	a	a	a	a	3	34	0	2
Oak-hickory	627	899	1,213	a	a	a	a	a	a	a	a
Post-black-jack oak	a	a	a	42	0	0	0	16	3	0	562
Chestnut-black-scarlet oak	a	a	a	a	a	a	a	48	98	13	569
White oak-red oak-hickory	a	a	a	246	10	1	5	383	473	146	1,861
White oak	a	a	a	a	a	a	a	84	93	65	507
Sassafras-persimmon	a	a	a	a	a	a	a	22	48	0	28
Bur oak	a	a	a	19	11	17	1	15	3	51	13
Oak-gum-cypress	a	a	a	a	a	a	a	15	37	2	26
Swamp chestnut oak-cherry-bark oak	a	a	a	a	a	a	a	11	4	1	20
Elm-ash-cottonwood	575	915	614	a	a	a	a	a	a	a	a
Elm-ash-soft maple (lowland)	a	a	a	148	25	27	17	193	221	106	249
Cottonwood	a	a	a	36	26	8	10	5	7	7	12
Willow	a	a	a	3	2	0	0	4	4	8	17
Maple-beech-birch	2,961	1,088	1,902	a	a	a	a	a	a	a	a
Maple-basswood	a	a	a	171	12	4	1	260	776	200	349
Cherry-ash-yellow poplar	a	a	a	a	a	a	a	13	105	4	22
Elm-ash-locust	a	a	a	234	18	29	25	a	a	a	a
Aspen-birch	a	a	a	0	0	54	0	0	1	3	0
Aspen	1,375	4,480	1,578	a	a	a	a	a	a	a	a
Paper birch	201	730	325	a	a	a	a	a	a	a	a
Balsam poplar	117	428	16	a	a	a	a	a	a	a	a
Nonstocked	59	132	28	17	0	4	2	0	3	1	11

[a] This type is not recognized in this state.

persimmon, and bur oak) that require at least 50% of total stocking to be in the type group that corresponds to the forest type; otherwise, the more general white oak-red oak-hickory forest type will be assigned. If the major group lowland oaks is predominant there is only one forest type (swamp chestnut oak-cherrybark oak) that requires at least 50% of total stocking to be in the type group; otherwise, the oak-gum-cypress forest type will be assigned. If the major group upland hardwoods is predominant there is also only one forest type (cherry-ash-poplar) that requires at least 50% of total stocking; otherwise, the maple-basswood forest type will be assigned. When the elm-ash-cottonwood type group is the predominant major hardwood group there are two forest types (cottonwood and willow) that require at least 50% of the total stocking within the corresponding type group; otherwise, the forest type assigned is elm-ash-soft maple (lowland).

INCONSISTENCIES BETWEEN TYPE AND SIZE CLASSIFICATION

Using this system of assigning both forest type and stand-size class based on the trees tallied on the 10-point field plot can lead to some classification inconsistencies between forest type and stand-size class. It is possible for a plot to be assigned a specific forest type/stand-size class combination that does not match any of the trees classified on the plot. For example, a plot may be classified aspen sawtimber and not contain a single sawtimber-size aspen tree. In the Lake States this could occur if the plot's stocking consisted of, say, 35 in white pine sawtimber, 25 in aspen poletimber, and 50 in aspen seedling-saplings The plot would be given a forest type of aspen based on having over half of the total stocking in aspen, but the plot would also be classified as sawtimber based on the stocking value of the white pine sawtimber. Sampling problems can occur when a plot straddles a stand boundary. A plot that has four of its ten points in a shortleaf pine stand and the other six in an oak stand could easily be assigned a forest type of shortleaf pine-oak by the Central States typing algorithm. These examples point out how the system now being used to assign forest type and stand-size class may be inadequate to give a realistic assessment of the situation on the ground. For these reasons NCFIA is currently investigating improved methods for the classification of 10-point field plots. These investigations are being carried out in coordination with FIA units throughout the country in an effort to develop systems of classification that are consistent across regional boundaries. □

LITERATURE CITED

EYRE, F.H., ed. 1980. Forest cover types of the United States and Canada. Soc. Am. For , Bethesda, MD. 148 p.

USDA. 1972. Forest survey handbook. USDA For. Serv. FSH 4809.11. 172 p.

APPENDIX

Forest types recognized by NCFIA

00 White-red-jack pine type group
01 Jack pine
02 Red pine
03 White pine
06 Exotic (generally Scotch pine)
07 Ponderosa pine

10 Spruce-fir type group
11 Balsam fir
12 Black spruce
14 Northern white-cedar
15 Tamarack
16 White spruce
19 Rocky Mt. juniper

30 Loblolly-shortleaf pine type group
32 Shortleaf pine
33 Virginia pine
35 Eastern redcedar

40 Oak-pine type group
42 Eastern redcedar-hardwood
44 Shortleaf pine-oak
49 Other oak-pine

50 Oak-hickory type group
51 Post-blackjack oak
52 Chestnut-black-scarlet oak

53 White oak-red oak-hickory
54 White oak
57 Sassafras-persimmon
59 Bur oak

60 Oak-gum-cypress type group
61 Swamp chestnut oak-cherrybark oak

70 Elm-ash-cottonwood type group
71 Elm-ash-soft maple (lowland)
73 Cottonwood
74 Willow

80 Maple-beech-birch type group
82 Maple-basswood
83 Cherry-ash-yellow poplar

87 Elm-ash-locust (upland)

90 Aspen-birch type group
91 Aspen
92 Paper birch
94 Balsam poplar

99 Nonstocked

Impact of Deer Browsing on Regeneration of Balsam Fir in Canaan Valley, West Virginia

Edwin D. Michael, *Division of Forestry, West Virginia University, Morgantown, WV 26506.*

ABSTRACT. I determined composition and regeneration of balsam fir stands during June 1991 at four sites in Canaan Valley, West Virginia. White-tailed deer had heavily browsed balsam fir, and regeneration did not appear adequate to replace the stands. There was an apparent correlation between relative deer abundance, as measured by numbers of pellet groups, and balsam fir regeneration. The site with the most deer had the fewest balsam fir seedlings (5/ac), and the site with the fewest deer had the most balsam fir seedlings (1040/ac). Balsam fir will probably be replaced by red spruce, one of the few tree species not commonly browsed by deer.

North. J. Appl. For. 9(3):89–90.

Balsam fir is restricted to damp woods and wetlands at elevations above 3,000 ft in West Virginia. Strausbaugh and Core (1964) wrote that it occurred at only four sites in West Virginia Isolated stands scattered widely over an 18,000 ac area are located in Tucker County. Present-day balsam fir stands in West Virginia developed following extensive logging and subsequent forest fires in the early 1900s. Although not commercially important as a timber tree, balsam fir does have a high aesthetic and scientific value.

Balsam fir regeneration is usually associated with a disturbance such as avalanche, fire, or hurricane (Reiners and Lang 1979), or more commonly with fir-waves, repeated patterns of dieback and regeneration which occur in wavelike patterns up or across slopes (Sprugel 1976). Effects of white-tailed deer on forest regeneration, and especially oaks, in the Appalachians have been well documented (Marquis 1981, Horsley and Marquis 1983, Gottschalk 1987). Impacts of deer on balsam fir regeneration have not been documented, even though balsam fir is a preferred food of deer. The purpose of this study was to examine the stems per acre of balsam fir stands in Canaan Valley and evaluate the impact of deer on regeneration of this relatively short-lived tree.

METHODS

This study was conducted in Canaan Valley, which contains one of the largest shrub-swamp forests in the eastern United States. These wetlands (6,000–10,000 ac) are located at an elevation of 3,200 ft and are comprised of interspersed communities of alder, aspen, and meadow-sweet, stands of balsam fir, hemlock, and red spruce, wet meadows, bogs of sphagnum moss and polytrichum moss, and beaver pond complexes. Canaan Valley supports many northern plant species that migrated southward during glaciation (Fortney 1975).

This mountain valley has a cold and humid climate more representative of Canada than of West Virginia, with a mean annual precipitation of 54 in. and mean annual snowfall of 120 in. The frost-free growing season is approximately 92 days, although frost has been recorded in every month of the year.

Four balsam stands were selected for sampling. The size, general location, and ownership were as follows: (1) 17 ac in northern Canaan Valley owned by a land-holding corporation (Pocahontas), (2) 11 ac in central Canaan Valley owned by the homeowners association of a vacation home development (Timberline), (3) 57 ac in southeastern Canaan Valley owned by an individual (Freeland), and (4) 33 ac in southwestern Canaan Valley within Canaan Valley State Park (Park).

Balsam stands were surveyed in June 1991 by establishing transects 50 yd apart through the stands. Each stand contained 20, 0.01-ac circular plots, which were located 50 yd apart along the transects. I recorded the heights of all individual balsam fir stems present in the plots and numbers of all balsam fir seedlings observed while walking between plots within each site.

Pellet-group surveys along belt transects were used to estimate relative deer abundance (Neff 1968). All pellet groups within a 2-yd-wide belt were recorded and removed by crushing with boots each April during the 12 yr period from 1979 to 1991. Transects used to measure deer abundance passed through or near balsam stands at Pocahontas, Freeland, and Canaan Valley State Park and encompassed a variety of habitat types. No transects were established in or near the Timberline balsam stand, thus no deer abundance data are available for this site. Lengths of transects used to determine deer abundance were: 1500 yards at Canaan Valley State Park (4 transects), 2200 yards at Freeland (2 transects), and 16900 yards at Pocahontas (6 transects). All 100 yd segments of each transect were delineated with flagging and numbered tags and identified as to dominant vegetative cover. The equation used to determine relative deer abundance was: number of pellet groups per acre/25 (pellet groups per day per deer)/150 (days pellet groups accumulated since leaf fall) (Neff 1968, Sawyer et al. 1990).

Several factors may affect the results of this deer abundance formula: durability of fecal pellets, efficiency of observers, density of ground cover, and deer behavior. Estimates of deer abundance in this study are given only for comparisons among stands and not to represent actual densities. Survey conditions were similar at all balsam fir stands; thus, the numbers of pellet groups detected were representative of relative deer abundance.

Analysis-of-variance (ANOVA) (Conover 1980) was used to test for differences in deer abundance and balsam fir seedling abundance. Fishers Protected Least Significant Difference test (Dowdy and Wearden 1983) was used to distinguish between site means, if the ANOVA F-test was sig-