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Description of the Stand-Damage Model: Part of the Gypsy Moth Life System Model

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Abstract

This document describes the structure, organization, and mathematical formulations for the Stand-Damage Model (a component of the Gypsy Moth Life System Model) and the biological basis for these formulations. The model follows the life of a forest stand as represented by tree species and diameter classes. The user supplies the initial state by describing the trees that make up the stand by species and diameter class, and the defoliation history by species and canopy strata. Growth, mortality, and regeneration are modeled along with the effects of user-prescribed defoliation and stand-management actions. The appendices provide a full description of the logic and mathematics in the form of code listings, structure charts, and files.

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Introduction

The Gypsy Moth Life System Model (GMLSM) comprises three components: the stand model simulates tree growth and mortality; the gypsy moth model simulates gypsy moth population dynamics and the feeding and destruction of foliage, and a gypsy moth population's interactions with its natural enemies; the natural enemy component consists of several less complex models that describe the dynamics of individual natural enemy species or guilds. Here we describe the stand model in detail. This model simulates the growth of a single forest stand over time. It treats the stand as a single homogeneous spatial unit. It predicts the number and size of trees in a stand and, within the GMLSM, summarizes stand and tree information for use by other submodels. A separate version of the stand model, the Stand-Damage Model, is available as an independent program that is separate from the rest of the GMLSM. The Stand-Damage Model allows users to examine the effects of a specified defoliation pattern on stand growth and yield; the user can describe particular gypsy moth defoliation episodes or the implementation of particular stand cultural practices.

This document describes the stand model formulations, the basis and background for these formulations, and the code and data for implementing them. The companion User's Guide (Colbert and Racin 1995) provides instructions for installation and use of the model in a tutorial and reference format. The guide to the model's interface management system (Racin and Colbert 1995) provides details of software design and implementation used in the development of the user-interface for the model and the installation program.

Tree growth and mortality functions are based largely on JABOWA (Botkin et al. 1972), a distance-independent, individual-tree model that simulates a single stand. Botkin et al. (1972) presented parameters for several northeastern species; parameters for additional tree species are from Shugart and West (1977). JABOWA predicts annual diameter growth as a function of the optimal growth rate and indices that reflect crowding, shading, and suboptimal temperatures. For the Stand-Damage Model, the effects of defoliation on diameter growth also have been incorporated. Here, diameter growth is calculated not for individual sample trees but for all trees within a species-diameter class. From this growth increment, the number of stems that will be reassigned to the next larger diameter class within the species is calculated. Tree mortality in JABOWA is predicted using a base or background mortality rate plus additional mortality that is simulated when diameter growth is incremented. These mortality sources plus additional mortality that occurs during periods of defoliation (especially if other stresses such as drought occur concurrently with defoliation) are included in the Stand-Damage Model.

The model has been developed over the past several years. It was initially designed as a component of the GMLSM. Following a series of development workshops in 1984, the model was turned over to the USDA Forest Service for additional work. The final report of this initial development is available.[1] This initial model lacked many of the current details and was modified extensively (Sheehan 1989; Colbert 1991). The completion of the model in its current form has proceeded under the direction of Forest Service scientists and cooperators.

Parameter values are taken from the literature as cited or set arbitrarily (and noted as such) in accordance with the best estimates of numerous experts who took part in one or more of the series of workshops and meetings held to design the model. Default values are given in parentheses following single-parameter definitions or in tabular form for arrays or matrices of subscripted parameters. Code listings are provided for review of organization and structural details and the order and method of computations. When questions arise as to particular auxiliary or intermediate values or how variables change within a year, the DEBUG option selected from the output options section of the user interface (see the User's Guide for details) allows the user to produce output of intermediate calculations.

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[1]McNamee, Peter J.; Bunnell, Pille; Jones, Michael L.; Marmorek, David R. 1983. Final report of a project to identify and evaluate important research questions for the gypsy moth life system. Environmental and Social Systems Analysts Ltd. for Adaptive Environmental Assessments, Inc. On file at USDA Forest Service, Northeastern Forest Experiment Station, RWU-4557, 180 Canfield St., Morgantown, WV 26505-3101.

Structure and Organization

Spatial and Temporal Resolution and Scope

The Stand-Damage Model simulates the annual establishment, growth, and mortality of trees by species and diameter class within a single forest stand. Variables are updated annually. Growth of a stand for up to 100 years can be projected. The stand is assumed to be spatially homogeneous with regard to density, species composition, and site conditions. The spatial distribution of trees within a stand is not modeled explicitly. Simulating a stand containing spatially aggregated clusters of preferred species would be identical to that for a stand containing randomly scattered preferred species so long as the number of trees in each diameter class by species remained the same (other factors being equal). Spatially inhomogeneous units should be subdivided so that each unit is relatively homogeneous. Each unit should then be treated as a separate stand.

All calculations are performed on a per-unit-area basis. The user is asked to supply the area sampled so that the initial numbers of trees can be converted to number of trees per unit area. Stand area is carried only for reporting purposes and does not affect calculations. Metric or English units can be specified for input and output. We have chosen English units as the default; these are used in the transfer from the user interface to the model proper. Units are converted automatically to the appropriate form for calculations during the simulation and then back to English units for output. If metric units are selected, all output is converted to metric before it is written to disk.

Representing Trees

Trees within a stand are grouped by species and diameter class; these groups are treated as individual cells. Up to 12 tree species or species groups can be included in a simulation. Parameters for 21 tree species and a user-defined (UD) group are provided in the user interface (Tables 1-5). Users also can supply values for other species or species groups or redefine a species by changing the defaults. For each tree species, up to 20 diameter classes can be simulated. By default, 2-inch-diameter classes are used; all classes start at 0.0, so the first diameter class has midpoint equal to half the class width. Tree growth and mortality are predicted separately for each diameter class of each species. Within a given species and diameter class, all trees are assumed to be identical.

Table 1.–Twenty-two tree species that can be included in a stand for simulation

Species code	Survey code	Common name	Scientific name
WO	802	White oak	*Quercus alba* L.
SO	806	Scarlet oak	*Quercus coccinea* Muenchh.
CO	832	Chestnut oak	*Quercus prinus* L.
RO	833	Northern red oak	*Quercus rubra* L.
BO	837	Black oak	*Quercus velutina* Lam.
RM	316	Red maple	*Acer rubrum* L.
SM	318	Sugar maple	*Acer saccharum* Marsh.
ST	315	Striped maple	*Acer pensylvanicum* L.
YB	371	Yellow birch	*Betula alleghaniensis* Britton
PB	375	Paper birch	*Betula papyrifera* Marsh.
SB	372	Sweet birch	*Betula lenta* L.
AB	531	American beech	*Fagus grandifolia* Ehrh.
BW	951	American basswood	*Tilia americana* L.
YP	621	Yellow-poplar	*Liriodendon tulipifera* L.
FD	491	Flowering dogwood	*Cornus florida* L.
AS	746	Quaking aspen	*Populus tremuloides* Michx.
BC	762	Black cherry	*Prunus serotina* Ehrh.
WA	541	White ash	*Fraxinus americana* L.
HI	400	Hickory spp.	*Carya* spp.
WP	129	Eastern white pine	*Pinus strobus* L.
BG	693	Blackgum (black tupelo)	*Nyssa sylvatica* Marsh.
UD[a]	000	User defined	

[a]Modal values provided for all parameters of user-defined species; range-checking values are similar for all parameters of all tree species.

Weather

The stand model uses annual degree-days to modify annual diameter growth for each tree species (Everson et al. 1976). When using the Stand-Damage Model, users can supply the annual total degree-days for each year. By default, a constant value is supplied for each year. When the length of a simulation or the starting year is changed, the sequence of annual degree-day totals are not resequenced automatically and may need to be adjusted. If the GMLSM is used, the Gypsy Moth Model requires daily weather data or parameters for stochastically generated weather; in this situation, the annual summary datum is calculated from these daily data for each year.

Communication with Gypsy Moth Model

The stand model summarizes stand information by species and strata for other submodels of the GMLSM. These stand attributes, such as potential foliage biomass and the number of resting sites, are updated annually for each species and stratum. Five strata are recognized for each species:

- Foliage from overstory trees,
- Foliage from understory trees,
- Foliage from shrubs and ground cover,
- Lower boles of overstory trees,
- Upper boles and branches of overstory trees together with boles and branches of understory trees.

Overstory and understory trees can be categorized on the basis of diameter or height. By default, trees larger than 6 inches in diameter at breast height (d.b.h.) are considered overstory trees. Both the breakpoint and method can be changed by the user.

The Gypsy Moth Model returns the defoliation each year, using this same stratification. No adjustments are made within the stand model for timing of foliage consumption or the fact that foliage growth and consumption have taken place simultaneously.

Management Actions

Annual silvicultural treatments can be scheduled by the user prior to executing a simulation. For each stand-management entry, the user specifies the year that an action is to take place and the method to be used. With these options, the user can specify standard treatments such as thinning from below or above, and can explore alternatives for reducing gypsy moth damage, for example, reducing the proportion of preferred host tree species in the stand.

When using the proportional cut method, one provides separately for each species a proportion to be removed as well as the diameter limits within which to operate. The proportion of the stem count within each diameter class that falls between the specified diameter limits is removed.

When the target method is specified, the user supplies diameter limits and a target number of stems for each species to remain following the removal. In this instance, the total count for all diameter classes and the total count for the diameter classes that fall within the diameter limits are accumulated for each species. The target count is first reduced by the count outside the diameter limits. Then an equal proportion of the stems from each diameter class that falls within the cut limits provided is removed. Thus, the total stem count outside the limiting diameters added to the remainder inside equals the specified target. In some instances, there may be sufficient stem counts to reach the prescribed targets outside the diameter limits provided. Should this occur, all diameter classes within the limits will be emptied yet still leave more than the prescribed residual outside the limits. At the opposite extreme, if the residual prescribed is above the current stocking for a species, no trees are removed for that species.

Using the Stand-Damage Model, the effects of direct control of gypsy moth populations can be simulated by assigning defoliation rates that reflect the assumed effectiveness of the control efforts. For example, to compare the effectiveness of controlling gypsy moth at different years during an outbreak, the user would supply different defoliation scenarios that are assumed to result from the different control strategies. The full GMLSM allows the user to examine, in much greater detail, the results of spray suppression on gypsy moth, its natural enemies, and consequential foliage dynamics, as well as the tree growth and mortality effects that are simulated in the Stand-Damage Model. Using the GMLSM, the user would supply suppression timing and insecticide mortality rate data. The models would then project the effects of those suppression tactics, carrying the results through to altered defoliation scenarios.

Information Required

The information needed to use the Stand-Damage Model is summarized in Table 2. The initial number of stems by species and diameter, total area of sample plots, and site moisture (wet, moderate, or dry) are required to describe a stand. Other information is optional. Default values are supplied for initial conditions and parameters (Tables 3-6); these will be used if specific values are not supplied. Data on average annual temperature (degree-day total for years) can greatly affect tree dynamics. All information can be accessed through the user-friendly access and control portion of the program that provides a means to input or modify initial conditions and parameters, and to select desired output tables and graphs. There is a full default stand provided when the access and control section is initiated, and an additional complete example stand. See the User's Guide (Colbert and Racin 1995) for instructions. If you are interested in the program that generated the access facility, see the guide to the interface management system (Racin and Colbert 1995).

Table 2.--Required and optional information used by Stand-Damage Model (all data have initial default values supplied by user-interface software)

Required	
Initial Stand Conditions	
	Number of trees in stand, by species and diameter class
	Prior defoliation (4 percentage classes) by species and canopy strata
Stand Data	
	Sample plot area
	Stand area
	Soil-moisture category (mesic, intermediate, or xeric)
Number of years to be simulated	
Optional	
Weather Data (either a or b):	
	a. Total annual degree-days
	b. When used as part of the GMLSM, daily maximum and minimum temperatures (for at least 1 year)
Output Options	
	Format
	Intervals at which output is to be produced
Units (metric or English)	
Stand Structure	
	Number of diameter classes
	Length (and midpoint) of diameter classes
	Boundary that separates overstory and understory canopy strata
Defoliation (percent by species and crown position for each year)	
Tree Attributes	
	Maximum diameter, height, and age
	Height parameters
	Foliage parameters
	Shade-tolerance class (for diameter growth and recruitment)
Diameter-Growth Modifiers	
	Shading parameters
	Temperature parameters
	Relative stand-density parameters
	Defoliation parameters
	Base growth-rate parameter
Tree-Mortality Parameters	
	Background mortality rates
	Effects of defoliation
	Effects of other stress agents
Stem Recruitment	
	Maximum recruitment
	Shading parameters

Information Produced

There are a number of output files that the user can view and, if desired, permanently archive to disk. The summary table is the only output file that is produced by default. It contains information provided by the user relating the source data to the output, a full listing of the parameters and initial conditions for the simulation, and summary output by year. The user can schedule the years for which output should be produced. Detailed descriptions of the output file formats follow the description of the model formulation.

Overview: Sequence of Steps

Figure 1 shows the sequence of steps performed by the Stand-Damage Model during a simulation. As soon as parameters and initial conditions are read into the program, the information header and all initial output are written to temporary disk files. These include a complete description of the data used in the simulation.

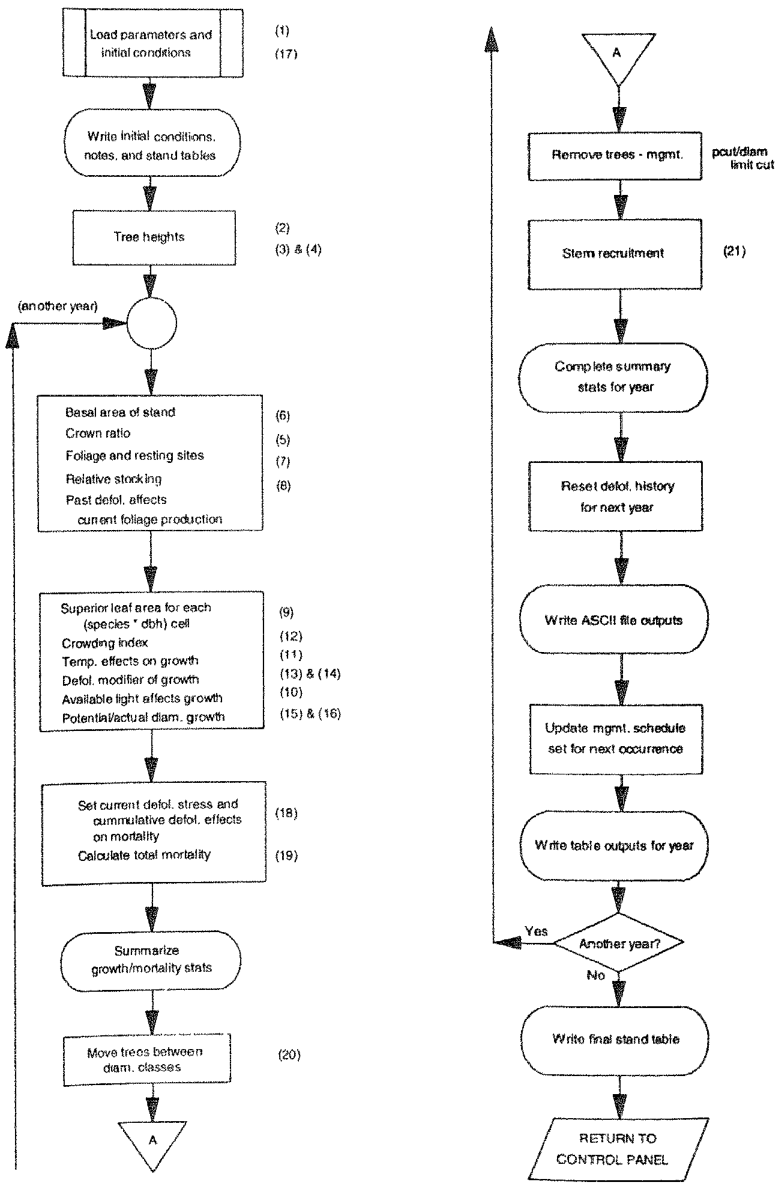

Figure 1.--Flowchart for Stand-Damage Model. Equation numbers are given in parentheses at places where they are calculated.

Because Equations 1-4 and 17 are not dependent on time-varying parameters or variables, for numerical efficiency these values are calculated once at the start of the simulation. Tree height is dependent on diameter, but diameter for each species-diameter cell is known at the start, and the height is calculated once for each cell using the cell midpoint diameter, regardless of the number of trees occupying that cell.

At the start of each year, two items are calculated for each diameter class of each species: the amount of foliage that would be produced per tree if no defoliation were to occur, and the number of resting sites available to gypsy moths per tree. As part of the GMLSM, these data are passed to the gypsy moth model. Defoliation estimates are retrieved, either from the gypsy moth model or, in the case of the Stand-Damage Model, from a file created by the program to store information provided by the user. Next, intermediate variables used to estimate tree growth are calculated. These equations use the variable values for the previous year along with associated parameters to develop the precursors to and components of diameter growth and tree mortality. Tree growth, mortality, and stem recruitment are then simulated. Next, growth increments are translated to changes in the number of stems in each diameter class, followed by removals from prescribed stand-management entries.

Stand-Damage Model Calculations Prior to Defoliation

Several stand variables are calculated each year before defoliation by gypsy moth is simulated. These variables are used by the gypsy moth model. Some of these variables also are used later by the stand model for predictions of tree growth, mortality, and recruitment.

Annual Degree-Days

The total annual heat input (degree-days) experienced by trees is estimated for each year as the sum of the daily degree-days that occurred during that year. Daily degree-days are calculated from maximum and minimum temperatures as shown in Equation 1 (from Arnold 1959):

$$DDAYS_j = \max[\frac{TMAX_j + TMIN_j}{2.0} - TREMIN, 0] \quad \textbf{(1a)}$$

$$ANNDD = \sum_{j=1}^{365} DDAYS_j \quad \textbf{(1b)}$$

where:

$DDAYS_j$	=	degree-days (°F) experienced by trees on day j,
$TMAX_j$	=	maximum temperature (°F) on day j,
$TMIN_j$	=	minimum temperature (°F) on day j,
TREMIN	=	threshold temperature for tree development (42°F),
ANNDD	=	accumulated degree-days for the year.

All tree species have the same default threshold temperature but the user can adjust these values for any tree species. In the gypsy moth model, species-specific thresholds also are used when simulating the timing of budbreak and leaf expansion and gypsy moth development. If the user has provided temperatures in metric units, the temperatures and the development threshold will be converted to degrees Fahrenheit for use within the model, then converted back to metric units for output. When the stand model is accessed as a stand-alone system, daily temperature details are not required and only the annual sums are used. These annual totals are used to modify annual diameter-growth rates and defaults are accessible for user modification.

Tree Heights

The heights of trees are calculated using species-specific parameters and the midpoint of each of the diameter class (Ker and Smith 1955):

$$HEIGHT_{h,d} = DBHHT + B1_h \times DIAM_d - B2_h \times DIAM_d^2 \quad \textbf{(2)}$$

where:

$HEIGHT_{h,d}$	=	height (cm) of diameter class d of species h,
DBHHT	=	breast height (137 cm),
$DIAM_d$	=	mean diameter (cm) of diameter class d,
$B1_h$, $B2_h$	=	height growth parameters for species h.

DBHHT is fixed at the mensuration standard and not available for redefinition by users. Following Botkin et al. (1972), $B1_h$ and $B2_h$ values were chosen so that when the maximum diameter ($DMAX_h$) has been reached, tree height equals the maximum tree height ($HMAX_h$) and height growth ceases. These conditions are met when:

$$B1_h = 2 \times \frac{HMAX_h - DBHHT}{DMAX_h} \quad (3)$$

$$B2_h = \frac{HMAX_h - DBHHT}{DMAX_h^2} \quad (4)$$

where:

$HMAX_h$	=	maximum height (cm) for species h,
$DMAX_h$	=	maximum diameter (cm) at breast height for species h,
DBHHT	=	breast height (cm).

Default values for $HMAX_h$ and $DMAX_h$ were taken from Harlow et al. (1979), and were used with Equations 3 and 4 to calculate the values for $B1_h$ and $B2_h$ (Table 3). If the diameter is above $DMAX_h$, tree height is modified from the value given by Equation 2; in this case, the height is reset to $HMAX_h$.

Table 3.--Parameters for maximum diameter, height, and age along with associated parameters for height equation

Species code $TNAME_h$	Maximum diameter[a] $DMAX_h$	Maximum height $HMAX_h$	Height parameters[b] $B1_h$	$B2_h$	Maximum age[c] $AGEMAX_h$
	Inches	*Feet*			*Years*
WO	48	100	47.76	0.196	450
SO	36	80	50.35	0.275	400
CO	24	60	55.48	0.455	250
RO	36	80	50.35	0.275	250
BO	36	60	37.02	0.203	200
RM	24	70	65.48	0.537	150
SM	24	80	75.44	0.618	350
ST	18	40	47.35	0.518	30
YB	30	70	54.42	0.344	300
PB	24	70	65.48	0.537	140
SB	24	60	55.48	0.455	300
AB	36	70	43.70	0.239	350
BW	36	80	50.35	0.275	200
YP	24	120	115.44	0.946	300
FD	18	40	47.35	0.518	100
AS	24	60	55.48	0.455	150
BC	36	80	50.35	0.275	200
WA	36	80	50.35	0.275	300
HI	24	70	65.48	0.537	300
WP	42	100	54.56	0.256	450
BG	48	120	57.75	0.237	200
UD	36	100	63.67	0.348	250

[a]Heights and diameters reported by Harlow et al. (1979) for mature trees except ST was assigned values for FD; when a range was given for heights or diameters, the upper boundary was used.
[b]Calculated using maximum height and diameter (listed in this table) in Equations 3 and 4.
[c]Maximum ages reported by Harlow et al. (1979) except CO (assigned values of RO) and BW (assigned values of BC).

Overstory Versus Understory Trees

Individual-tree characteristics such as basal area, foliage biomass, and number of resting sites are summarized across diameter classes into overstory and understory totals by species for use by the gypsy moth model. Height or diameter can be used to separate overstory from understory trees, and the user can specify the boundary height or diameter. By default, trees less than 6 inches in d.b.h are classified as understory. This point of division is chosen before initiating a simulation and is used throughout the simulation. As a fixed parameter, it does not reflect the dynamic of this break point as is sometimes assumed. Non-tree understory vegetation is not considered in the Stand-Damage Model, but will be described in the gypsy moth model as it only affects and is affected by gypsy moth larval feeding.

Foliage Biomass

Foliage biomass is calculated for each diameter class and species using the allometric function:

$$FOLIAG_{h,d} = F1_h \times DIAM_d^{F2_h} \times STEMS_{h,d} \qquad \textbf{(5)}$$

where:

$FOLIAG_{h,d}$	=	foliage biomass (kg/ha dry weight) in diameter class d for species h,
$F1_h$, $F2_h$	=	foliage biomass parameters for species h,
$STEMS_{h,d}$	=	number of trees per hectare (ha) in diameter class d of species h.

Default values for $F1_h$ and $F2_h$, shown in Table 4 were derived from the literature. Each published curve was used to generate five data points spanning the range of the data that originally were used to generate the curve. The newly generated data were then combined to form a set used to fit the allometric relationship of Equation 5. For each species, foliage biomass also is summed for overstory and understory crown classes and converted to grams for use by the gypsy moth model. Foliage is summed in overstory ($FOL_{h,1}$) and understory ($FOL_{h,2}$) variables for each tree species (h). Adjustments are then made for the effect of prior defoliation on current production. The defoliation in this cell last year ($DEFL_{h,s}$), expressed as a proportion, times a rate constant (DFOLDE = 0.15) is used to reduce this maximum: [1.0-DFOLDE(DEFL/100.0)]. This adjusted value is then used by the gypsy moth model as the asymptotic maximum foliage produced that year. In that model $FOL_{h,s}$ is used as the base to estimate foliage growth, consumption, and defoliation, while in the Stand-Damage Model, it is used as the base for estimating the effects of user-supplied defoliation.

Live Crown Ratio

The live crown ratio (live crown to total tree height) is calculated using a model developed by Holdaway (1986) that uses four species-specific parameters (Table 5) and has two main components--the effect of competition for light within the stand, represented by stand basal area, and the effect of an individual tree's competitive position, as indicated by diameter:

$$CROWNR_{h,d} = \left[CR\frac{1_h}{1.0 + CR2_h \times BA} + CR3_h \times (1.0 - e^{-CR4_h \times DIAM_d}) \right] \qquad \textbf{(6)}$$

where:

$CROWNR_{h,d}$	=	live crown ratio for diameter class d of species h,
$CR1_h$-$CR4_h$	=	crown-ratio parameters (Table 5),
BA	=	total stand basal area (ft^2 per acre),
$DIAM_d$	=	d.b.h. (inches) for diameter class d.

Using the live crown ratio, each overstory tree is separated into components of two strata--boles and live crowns--for use by the gypsy moth model. Live crown ratio will also be used to calculate the total number of larval resting sites (Equation 7); the number of resting sites in each strata is calculated separately.

Table 4.--Shade-tolerance classes, stocking group, and foliage and resting-site parameters for each tree species

Species code	Tolerance class[a]		Stocking group[b]	Foliage parameter[c]		No. of resting sites/m² of bark surface area[d]	
	Recruit-ment	Diam. growth				Boles	Crown
$TNAME_h$	$ISHADE_{h,1}$	$ISHADE_{h,2}$	$ISTOKG_h$	$F1_h$	$F2_h$	$RESTIN_{h,1}$	$RESTIN_{h,2}$
WO	3	3	3	0.04049	1.72844	0.10	1.00
SO	2	2	3	0.07925	1.60213	0.05	0.50
CO	2	2	3	0.02622	1.77519	0.10	1.00
RO	2	6	2	0.02622	1.77519	0.05	0.50
BO	2	2	3	0.01571	2.00000	0.05	0.50
RM	5	5	2	0.00812	2.01495	0.01	0.10
SM	4	4	3	0.00699	2.06012	0.01	0.10
ST	3	4	3	0.00812	2.01495	0.01	0.10
YB	2	3	2	0.01992	1.71179	0.05	0.50
PB	1	1	2	0.00629	2.09544	0.10	1.00
SB	1	1	2	0.00453	2.42000	0.05	0.50
AB	4	4	3	0.01470	1.83296	0.01	0.10
BW	2	2	2	0.04656	0.71011	0.01	0.10
YP	2	2	1	0.05589	1.39263	0.01	0.10
FD	4	4	2	0.00812	2.01495	0.01	0.10
AS	1	1	2	0.02591	1.87187	0.01	0.10
BC	2	2	1	0.02622	1.77519	0.10	1.00
WA	3	2	1	0.00681	1.79510	0.01	0.10
HI	2	2	2	0.02010	1.96005	0.05	0.50
WP	3	2	2	0.00880	2.04480	0.01	0.10
BG	2	2	1	0.02622	1.77519	0.10	1.00
UD	2	2	2	0.01000	1.50000	0.10	1.00

[a]1 = intolerant, 2 = intolerant-intermediate, 3 = tolerant intermediate, 4 = tolerant, 5 = red maple (growth loss: like tolerant class at low light availability, like intolerant class at high light; recruitment: like intolerant at low relative stocking, like tolerant at high relative stocking), 6 = red oak (growth loss: like intermediate-intolerant at low light availability, like intolerant at high light; recruitment: same as intolerant-intermediate).
[b]From Stout et al. (1987).
[c]Foliage parameters for Equation 5, summarized from published literature with the following exceptions: CO and BC (both assigned values for RO), and ST and FD (assigned values for RM).
[d]Assigned arbitrarily.

Table 5.--Parameter[a] values for calculating live crown ratio (Equation 6)

Species code	$CR1_h$	$CR2_h$	$CR3_h$	$CR4_h$
WO	4.49	0.0029	1.21	0.065
SO	4.20	0.0016	2.76	0.025
CO	4.49	0.0029	1.21	0.065
RO	4.20	0.0016	2.76	0.025
BO	4.20	0.0016	2.76	0.025
RM	4.35	0.0046	1.82	0.274
SM	3.40	0.0066	2.87	0.434
ST	4.35	0.0046	1.82	0.274
YB	4.18	0.0025	1.41	0.512
PB	5.00	0.0066	4.92	0.026
SB	5.00	0.0066	4.92	0.026
AB	3.40	0.0066	2.87	0.434
BW	4.44	0.0037	2.09	0.065
YP	4.49	0.0029	1.21	0.065
FD	4.35	0.0046	1.82	0.274
AS	3.83	0.0024	9.99	0.009
BC	4.49	0.0029	1.21	0.065
WA	4.49	0.0029	1.21	0.065
HI	6.21	0.0073	9.99	0.010
WP	6.79	0.0058	7.59	0.010
BG	3.83	0.0024	9.99	0.009
UD	4.00	0.0040	2.50	0.025

[a]Source: Holdaway (1986), with the following exceptions (for species not included in Holdaway 1986): CO is assigned the values of WO; SO and BO are assigned the values of RO; ST and FD are assigned the values of RM; AB is assigned the values of SM, BG is assigned the values of AS; SB is assigned the values of PB; and BC and YP are assigned the values of WA.

Resting Sites

The number of resting sites present--bark flaps or crevices and other locations where gypsy moth might avoid predators or parasites while in a larval resting phase or as pupae--is estimated for each diameter class by species. The total represents the number of resting sites that could be occupied by first-instar larvae, and will be adjusted later by the gypsy moth model to account for the effect of larval size on resting-site suitability. The number of resting sites is assumed to be a function of bark surface area and tree species:

$$RSITES_{h,s} = \sum_{d \in s} STEMS_{h,d} \times \frac{RESTIN_{h,c}}{10{,}000} \times \frac{\pi \times DIAM_d}{2.0} \times \sqrt{\frac{DIAM_d^2 + HEIGHT_{h,d}^2}{4.0}} \qquad \textbf{(7)}$$

where:

$RSITES_{h,s}$	=	maximum number of resting sites found on a tree of species hand canopy strata s,
$RESTIN_{h,c}$	=	resting-site index: number of resting sites per m² of bark surface area (c = 1 for boles, c = 2 for crowns, see Table 2),
10,000 cm²	=	1 m²,
π	=	Pi, ≈ 3.14159,
$DIAM_d$	=	d.b.h. (cm) of diameter class d,
$HEIGHT_{h,d}$	=	height (cm) of diameter class d of species h (Equation 1).

The first summation in Equation 7 is over all diameter classes (d) that fall within the crown strata (s). The number of resting sites is summed separately for overstory and understory (canopy strata s = 2) trees for each species for use by the gypsy moth model. Resting sites on overstory trees are further partitioned to crown (s = 1) and bole (s = 4) according to the live crown ratio. For overstory trees, $HEIGHT_{h,d}$ ′ $CROWNR_{h,d}$ is substituted for $HEIGHT_{h,d}$ in Equation 7 to calculate the number of resting sites in the crowns. In calculating resting sites for the boles of overstory trees, it is assumed that bole is a right circular cylinder. Resting sites play no role in the dynamics of trees and are used only when the stand submodel is linked to the gypsy moth submodel in the full GMLSM. The final strata considered (s = 3) is the ground and non-tree understory vegetation which, again, is relevant only to the linked model.

Relative Stocking

Relative stocking is an indicator of stand density (Stout et al. 1987). Tree species are assigned to one of three categories according to their influence on stand density (Table 4), and the total number of stems in each stocking class is used to calculate relative stocking for the stand:

$$RSTOCK = \sum_{d=1}^{NDIAM} \sum_{s=1}^{3} TOT_{d,s} \times \left[S_{s,1} + S_{s,2} \times DIAM_d + S_{s,3} \times DIAM_d^2 \right] \qquad \textbf{(8)}$$

where:

RSTOCK	=	relative-stocking index for the stand,
$TOT_{d,s}$	=	total number of stems per acre in diameter class d and stocking class s,
$S_{s,1}$, $S_{s,2}$, $S_{s,3}$	=	relative-stocking parameters for species group s,
$DIAM_d$	=	d.b.h. (inches) for diameter class d,
NDIAM	=	number of diameter classes.

The stocking parameters reported by Stout et al. (1987), shown in Figure 2, are used by default. Relative stocking is used later in the Stand-Damage Model to calculate both annual diameter growth and recruitment of new trees to the smallest diameter class. Parameters $S_{s,i}$ are implemented in the code as STOCKS(s,i).

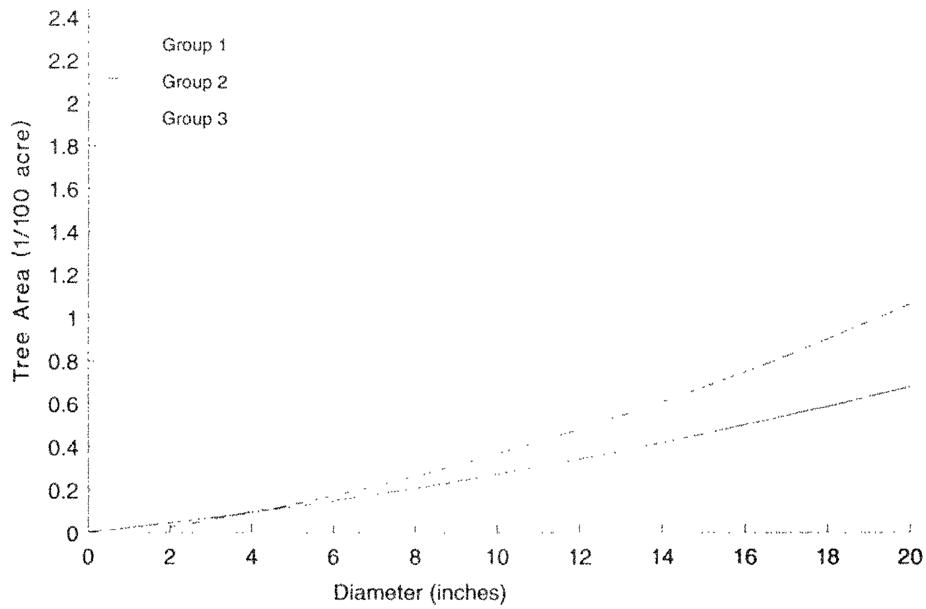

Figure 2.--Tree Area (TA) of stand in centacres as functions of diameter (D) by species group (1, 2, or 3). TA = TA1 + TA2 + TA3, where:

Group 1: $TA1 = 0.0033033\, n_1 + 0.020426\, (\Sigma\, D_1) + 0.0006776\, (\Sigma\, D_1^2)$;
Group 2: $TA2 = -0.027142\, n_2 + 0.024257\, (\Sigma\, D_2) + 0.0015225\, (\Sigma\, D_2^2)$;
Group 3: $TA3 = -0.0027935\, n_3 + 0.0058959\, (\Sigma\, D_3) + 0.0047289\, (\Sigma\, D_3^2)$.

Defoliation

Annual defoliation estimates for both overstory and understory trees of each species can be supplied by the user. As part of the full GMLSM, they are generated by and passed from the gypsy moth submodel each year, depending on species-specific feeding preference (Mosher 1915). In this case, the stand submodel passes the potential foliage biomass to the gypsy moth submodel at the start of each year. Both diameter growth and tree mortality are affected by multiyear defoliation histories. Three years' (current and past two) defoliation are combined to determine current effects.

The defoliation history by strata for the 2 years prior to the first year of the simulation is a user-definable initial condition that is set to zero by default. For each tree species, the amount of foliage present in each canopy strata (and hence all associated diameter classes) is reduced in proportion to the defoliation percentage that was supplied for that canopy strata. The resulting changes in foliage distribution in the stand indirectly affect diameter growth by influencing the shading index. Defoliation also affects diameter growth directly through the defoliation index; both indices are described in the next section. A 2-year defoliation scenario is provided as part of the defaults for the Stand-Damage Model.

Diameter Growth

Annual diameter growth in the JABOWA model is assumed to be a function of the maximum growth rate as modified by crowding, temperatures, and shading factors (Botkin et al. 1972). For the Stand-Damage Model, the functions that describe the three growth modifiers have been revised, and a fourth factor has been added that accounts for the direct effect of defoliation on growth.

Shading

Following Botkin et al. (1972), the effect of shading on tree growth is assumed to be a function of the amount of light available to the tree and the tree's degree of shade tolerance. For each diameter class of each species, the total amount of foliage biomass per hectare for all taller trees is summed and then adjusted to reflect the assumed area of influence for each tree:

$$SUMFOL_{h',d'} = PLOTSZ \times \sum_{h=1}^{NHOSTS} \sum_{d=d_t}^{NDIAM} STEMS_{h,d} \times FOLIAG_{h,d} \quad \textbf{(9)}$$

where:

$SUMFOL_{h',d'}$	=	amount of foliage (kg) assumed to influence diameter class d' of species h' through shading,
PLOTSZ	=	total area surrounding a tree that is assumed to affect the shading of that tree (0.833 ha),
d_t	=	smallest diameter class that is taller than diameter class d' of host h',
$FOLIAG_{h,d}$	=	foliage biomass (kg dry weight) on a tree of diameter class d and species h (Equation 5), adjusted for defoliation if appropriate,
$STEMS_{h,d}$	=	number of stems per ha for diameter class d and species h.

PLOTSZ has been set in accordance with the procedure described by Botkin (1993); shading leaf area of surrounding trees (implemented as SUMLFA in the code) must be rescaled from the standard units of biomass on a trees/ha basis. The amount of foliage influencing a given tree is then used to calculate the amount of light available to that tree:

$$ALIGHT_{h,d} = TLIGHT \times e^{-TKL \times SUMFOL_{h,d} \times SURFAR_h} \quad \textbf{(10)}$$

where:

$ALIGHT_{h,d}$	=	available light for diameter class d of species h,
TLIGHT	=	annual insolation factor (1.0),
TKL	=	a shading coefficient (0.0002),
$SUMFOL_{h,d}$	=	amount of foliage biomass that is influencing a tree in diameter class d of species h (Equation 11),
$SURFAR_h$	=	ratio of leaf surface area to biomass (cm^2 per kg dry weight) for species h.

Local geography and topographic position could be used to improve this relationship using latitude, slope, and aspect to adjust TLIGHT (Botkin et al. 1972). TKL has been set arbitrarily in accordance with the assumed area of influence (PLOTSZ, viz. Botkin et al. 1972). Calculations of ALIGHT using this default value for TLIGHT and three values of TKL are shown in Figure 3 for a range of values of total Shading Leaf Area, SLA = $SUMFOL_{h,d} \times SURFAR_h$. Default values for $SURFAR_h$ are listed in Table 6.

Table 6.--Parameters for diameter growth, heat range, leaf area, and recruitment

Species code	Max. diameter growth rate[a]	Diam. growth parameter[b] GROWR$_h$	Range in annual degree-days[c] Minimum COLD$_h$	Range in annual degree-days[c] Maximum HOT$_h$	Leaf area to biomass ratio[d] SURFAR$_h$	Max. number of stems recruited per year[e] RECRUT$_h$
	Inches/yr				*in²/oz*	
WO	0.262	83.3	2,966	10,204	597.6	30
SO	--	82.0	4,105	8,499	457.0	30
CO	--	83.3	3,686	7,756	628.4	30
RO	0.359	21.5	731	8,499	457.0	30
BO	0.323	82.0	3,313	9,461	593.2	30
RM	0.437	194.4	1,810	13,395	900.8	50
SM	0.323	164.1	1,522	7,366	900.8	50
ST	--	164.1	1,522	7,366	900.8	50
YB	0.179	63.7	731	7,366	1010.6	50
PB	0.333	148.0	731	6,391	1010.6	50
SB	0.250	95.2	3,686	7,366	1010.6	50
AB	0.238	70.5	2,097	10,204	1111.7	30
BW	0.125	42.3	5,526	8,499	1111.7	30
YP	0.444	338.1	3,686	10,947	799.7	50
FD	0.569	192.6	3,686	10,947	1005.2	30
AS	--	94.4	731	6,391	465.8	50
BC	0.350	118.5	3,899	10,947	1037.0	80
WA	0.313	105.9	2,414	10,947	606.4	50
HI	0.193	85.7	3,791	11,428	606.4	30
WP	1.250	453.5	731	6,391	650.3	30
BG	--	118.5	3,800	12,000	1037.0	80
UD	--	120.0	4,000	10,000	1000.0	100

[a]Values shown are largest values reported by Fowells (1965), increased arbitrarily by 25 percent, and then converted to metric units.
[b]As suggested by Botkin et al. (1972), these values were calculated from maximum annual diameter-growth rates (this table) and maximum heights and diameters (Table 3) so that trees reach two thirds of maximum diameter at half their maximum age.
[c]Values taken from Shugart and West (1977) except ST (assigned values of SM) and PB and AS (both assigned minimum values of RO and maximum values of WP, YB (assigned minimum values of RO and maximum values of SM), and SB (assigned minimum values of *Carya ovata* and maximum values of SM). Values used for HI are the average of values for *C. cordiformis*, *C. glabra*, *C. ovata*, and *C. tomentosa* reported by Shugart and West (1972).
[d]Sources: Monk et al. (1970), Pollard (1972), Rothacher et al. (1954), Whittaker et al. (1974), and Whittaker and Woodwell (1968) except RM and ST (assigned values of SM), PB and SB (YB), WA (HI), BW (AB), and WP (shortleaf pine).
[e]Assigned using the seedling development data from Burns and Honkala (1990) where available; otherwise, assigned arbitrarily.

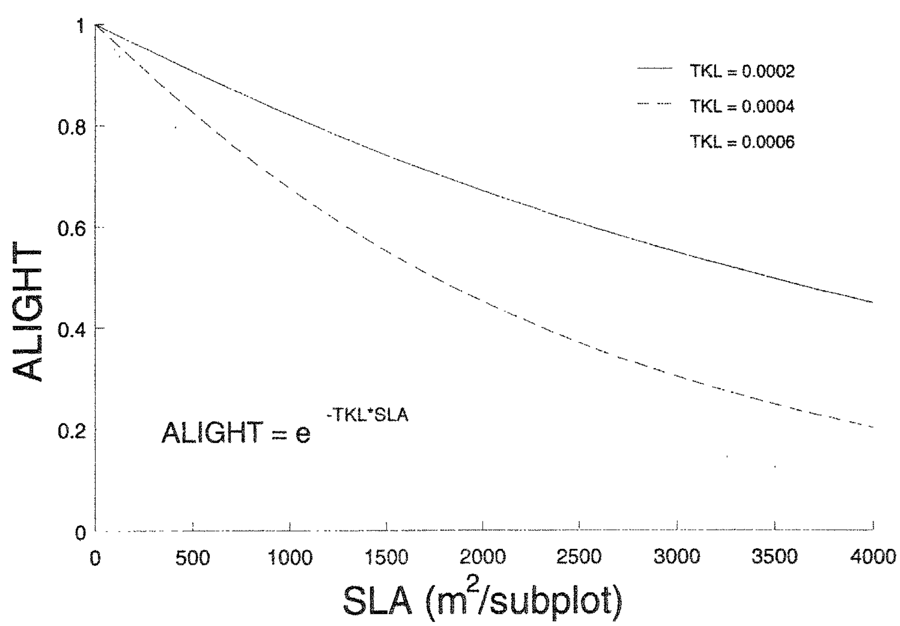

Figure 3.--Effect of superior leaf area (SLA) on available light (ALIGHT) reaching a particular tree crown.

For a given tree, available light ($ALIGHT_{h,d}$) and shade-tolerance class (ISHADE) determine the shading index ($SHADE_{h,d}$), which is used to modify diameter growth. By default, six tolerance classes are used: intolerant, intolerant-intermediate, tolerant-intermediate, tolerant, red maple, and red oak (Fig. 4). Red maple is assumed to behave like tolerant species at low light availability and like intolerant species at high light; red oak is assumed to behave like intolerant-intermediate species at low light availability and intolerant species at high light. The shade index is used as a diameter-growth multiplier.

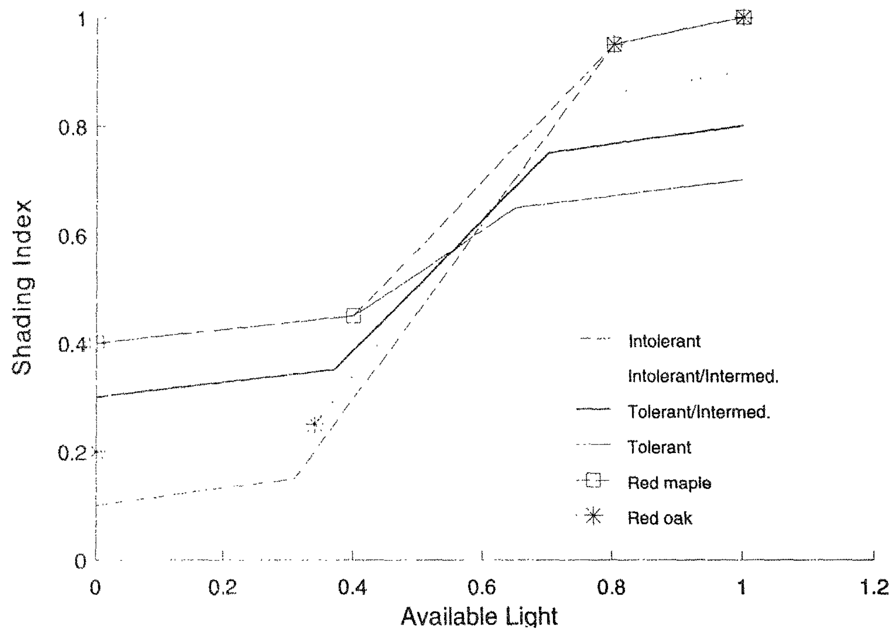

Figure 4.--Effect of available light on diameter growth by four tolerance classes; red oak and red maple have distinct light-effect characteristics.

Temperature

The JABOWA model assumes that temperature affects growth rates by changing photosynthesis rates (Botkin et al. 1972). Each species is assumed to have an optimum temperature for photosynthesis, and with photosynthesis rates declining symmetrically above and below this optimum temperature. For each species, the minimum and maximum annual degree-days that occur within the species' geographic range (default values shown in Table 4, from Botkin et al. 1972 and Shugart and West 1977) are used as the limits to photosynthesis and, therefore, growth. The temperature-growth modifier is calculated as:

$$DEGDT = ANNDD \times TFAC \tag{11a}$$

$$TEMP_h = \frac{4.0 \times (DEGDT - COLD_h) \times (HOT_h - DEGDT)}{(HOT_h - COLD_h)^2} \tag{11b}$$

where:

$TEMP_h$	=	temperature index for species h,
DEGDT	=	daily degree-days for trees (Equation 1) summed for the entire year,
TFAC	=	temperature effect adjustment factor (1.0),
$COLD_h$	=	minimum total degree-days per year that occur within the range of species h (Table 4),
HOT_h	=	maximum total degree-days per year that occur within the range of species h (Table 4).

The calculated value of $TEMP_h$ has been constrained arbitrarily to be at least 0.05. The relation between temperature index and annual degree-days is shown in Figure 5 using the maximum and minimum degree-day range for several species. TFAC is provided to allow uniform variation in heat accumulation across simulation years. Note that this is equivalent to changing both the daily temperatures and the threshold(s) by the same proportion.

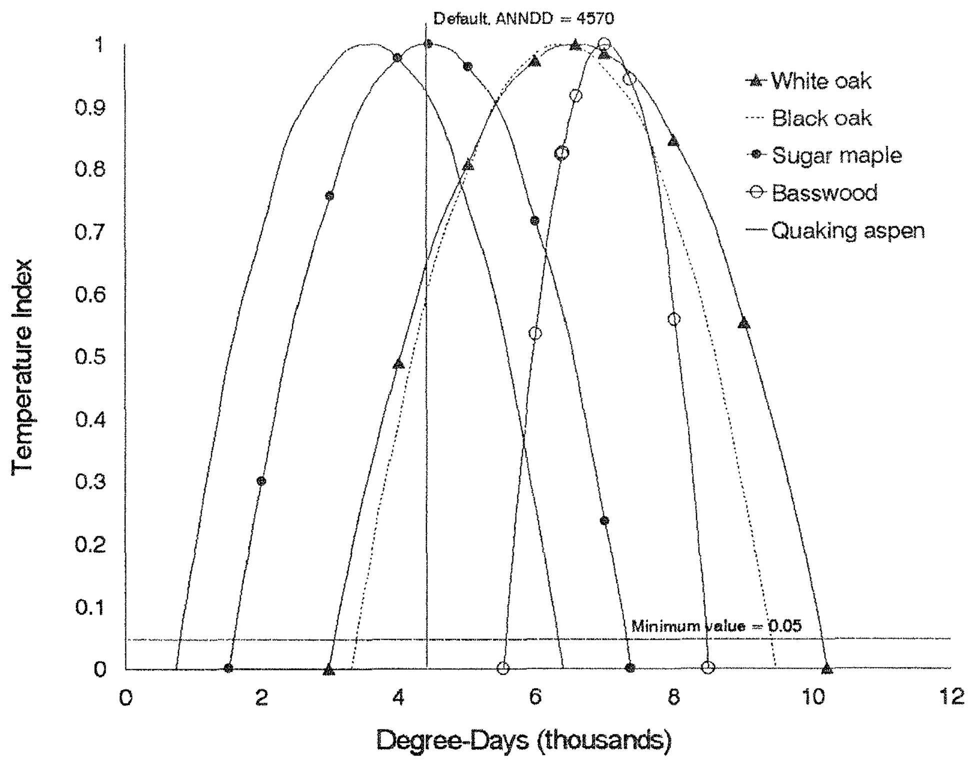

Figure 5.--Effect of total annual accumulated heat measured in degree-days, on temperature index for five tree species.

Crowding

Diameter growth is assumed to decrease as relative stocking increases (Fig. 6):

$$CROWD = 1.0 - (RSMULT \times RSTOCK) \qquad (12)$$

where:

CROWD	=	crowding index,
RSTOCK	=	relative stocking (Equation 8),
RSMULT	=	crowding parameter (0.0025).

CROWD is further constrained by a lower limit (0.75), the value that CROWD reaches when RSTOCK reaches 100. Thus, overstocking has no additional effect. In the model, all trees in the stand are affected equally by crowding, regardless of species or diameter class.

Defoliation

Both current defoliation and defoliation history for the past 2 years are used to account for direct effects of defoliation on annual diameter growth. Percent defoliation for the previous 2 years is categorized as light (0 to 34 percent), medium (35 to 65 percent), or heavy (> 65 percent). The possible combinations of defoliation patterns have been assigned arbitrarily to

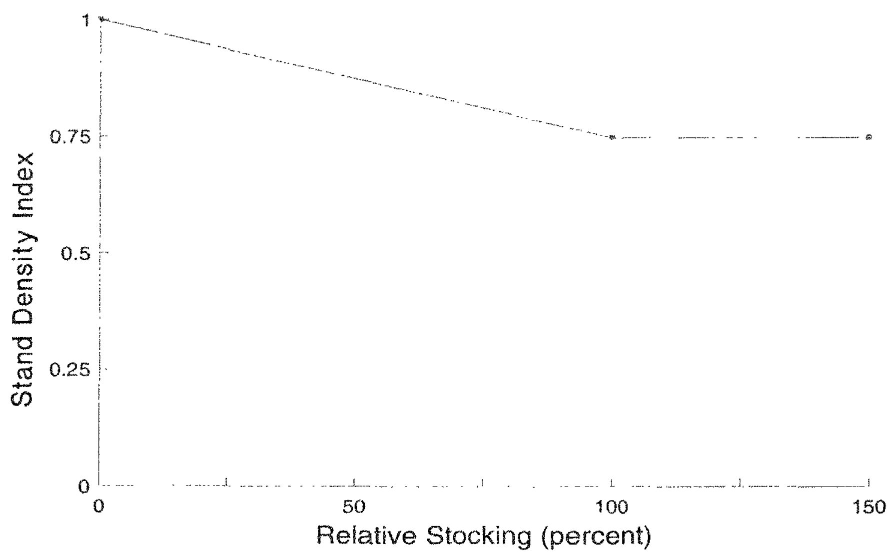

Figure 6.--Effect of relative stocking on stand density. As stocking increases, the stand density index (CROWD in equation 12) decreases to minimum of 0.75 at fully stocked.

one of two history categories, light or heavy (Table 7). Current defoliation is then used to determine the effect on diameter growth (when prior defoliation is light, use Equation 13; heavy, use Equation 14):

$$DEFIND_{h,d} = 0.9689 - 0.00405 \times DEFOL_{h,s} \quad (13)$$

$$DEFIND_{h,d} = \frac{1.0}{1.3418 + 0.00540 \times DEFOL_{h,s}} \quad (14)$$

where:

$DEFIND_{h,d}$ = defoliation index for diameter class d of species h,
$DEFOL_{h,s}$ = percentage of foliage of species h in the strata s that corresponds to diameter class d that has been destroyed by gypsy moth.

$DEFOL_{h,s}$ is calculated by the gypsy moth model or supplied by the user. The parameters in Equations 13 and 14 were fit to data reported by Campbell and Garlo (1982) and Baker (1941) (Fig. 7).

Table 7.--Defoliation history categories used to calculate effect of defoliation[a] on annual diameter increment

Defoliation history		Overall
2 years ago	1 year ago	category
Light	Light	Light
Light	Medium	Light
Light	Heavy	Heavy
Medium	Light	Light
Medium	Medium	Heavy
Medium	Heavy	Heavy
Heavy	Light	Heavy
Heavy	Medium	Heavy
Heavy	Heavy	Heavy

[a]None = 0 percent; light = 1 to 30 percent; medium = 31 to 65 percent; heavy = 65+ percent.

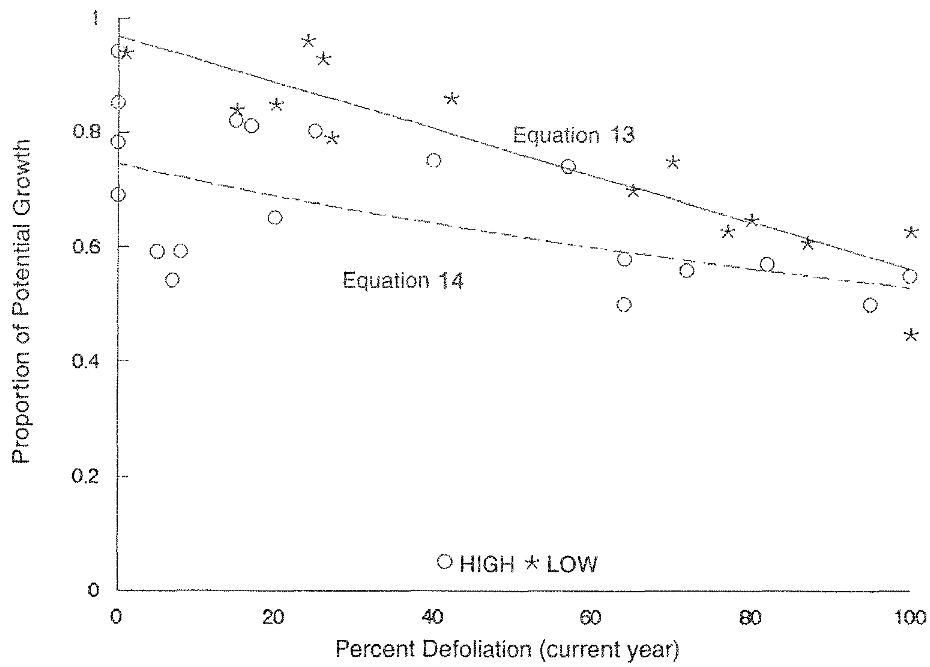

Figure 7.--Effect of defoliation on diameter growth. Low (*) and high (O) previous defoliation were used to fit equations (13) and (14), respectively.

Predicted Diameter Growth

Annual diameter growth is calculated as a function of the base-growth amount and the four indices described. The base growth that would occur in the absence of crowding, shading, non-optimal temperatures, or defoliation is calculated as follows (from Botkin et al. 1972):

$$GROWMX_{h,d} = \frac{GROWR_h \times DIAM_d \times \left[1.0 - \frac{DIAM_d \times HEIGHT_{h,d}}{DMAX_h \times HMAX_h}\right]}{2.0 \times DBHHT + DIAM_d \times \left[3.0 \times B1_h - 4.0 \times B2_h \times DIAM_d\right]} \qquad (15)$$

where:

$GROWMX_{h,d}$	=	maximum diameter growth (cm/year) that can be attained by a tree in diameter class d of species h,
$GROWR_h$	=	growth rate parameter for species h,
$DIAM_d$	=	mean d.b.h. (cm) for diameter class d,
$HEIGHT_{h,d}$	=	height (cm) of trees of species h in diameter class d (Equation 1),
DBHHT	=	breast height (cm),
$DMAX_h$	=	maximum d.b.h. (cm) for species h,
$HMAX_h$	=	maximum height (cm) for species h,
$B1_h$ & $B2_h$	=	height-growth coefficients for species h.

Table 3 lists default values for $DMAX_h$, $HMAX_h$, $B1_h$, and $B2_h$ while Table 4 lists those for $GROWR_h$. Following Botkin et al. (1972), values for $GROWR_h$ are set so that a tree that is half the maximum age will be two-thirds of the maximum diameter. Figure 8 shows the relation among diameter growth, maximum age, and maximum diameter. Negative calculated values of $GROWMX_{h,d}$ are reset to zero.

Equation 16 is then used to predict annual diameter growth:

$$GROW_{h,d} = GROWMX_{h,d} \times SHADE_{h,d} \times TEMP_h \times CROWD \times DEFIND_{h,d} \qquad (16)$$

where:

$GROW_{h,d}$	=	actual diameter growth (cm/year) for trees of species h in diameter class d,
$GROWMX_{h,d}$	=	maximum possible annual diameter growth for trees of species h in diameter class d (Equation 15),
$SHADE_{h,d}$	=	shading factor for diameter class d of species h (Fig. 9),
$TEMP_h$	=	temperature index for species h (Equation 11),
CROWD	=	crowding index for the stand (Equation 12),
$DEFIND_{h,d}$	=	defoliation index for diameter class d of species h (Equation 13 or 14, depending on defoliation history).

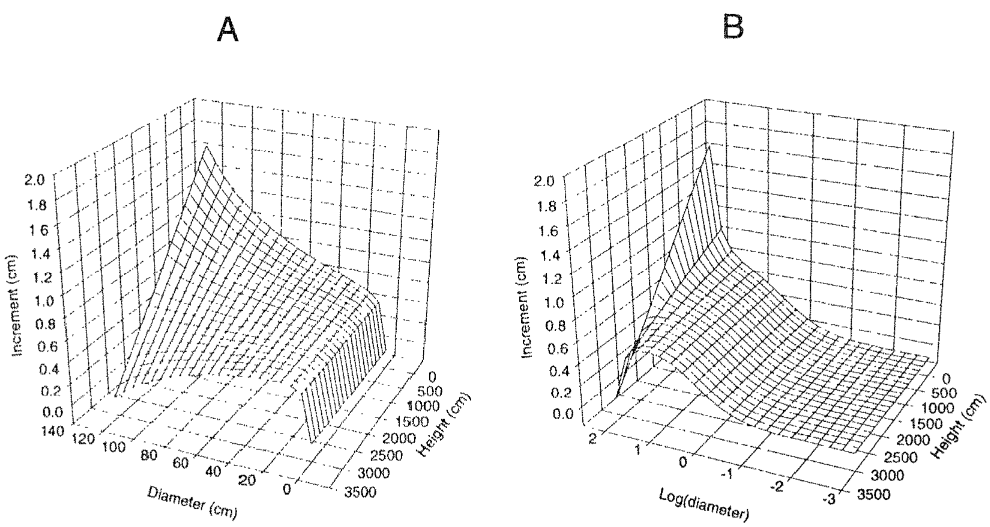

Figure 8.--Effect of current diameter and height on diameter increment. The abrupt increase as diameter increases (A) can be seen more clearly when diameter is presented in log scale (B). These graphs are for white oak (DMAX = 48 inches; HMAX = 100 feet = 3,050cm). For other species, similar graphs are scaled in proportion to DMAX, HMAX, and AGEMAX.

Tree Mortality

The proportion of trees of a given diameter class and species that die each year is assumed to be a function of the base mortality rate and additional mortality that may occur during periods of reduced growth and/or defoliation.

Base Mortality Rates

The base or background mortality rate is calculated following Botkin et al. (1972). By assuming that base mortality rates are age-independent and that no more than 2 percent of saplings of a given species will reach the maximum age for that species, Botkin et al. estimated the probability that a tree will die in any given year:

$$BDIE_h = \frac{4.0}{AGEMAX_h} \quad \textbf{(17)}$$

where:

$BDIE_h$	=	background annual mortality rate for species h,
$AGEMAX_h$	=	maximum age (years) for species h.

Default values used in the model for $AGEMAX_h$ are shown in Table 3.

Mortality During Periods of Reduced Growth

Trees with annual diameter-growth rates that are less than a specified threshold (set to 0.05 cm/year by default) are assumed to be subject to additional mortality (following Botkin et al. 1972). Further, the probability of additional mortality is assumed to increase as the number of consecutive years with growth reduced below the threshold increases:

$$GDIE_{h,d} = 1.0 - e^{SGMORT \times NSLOW_{h,d}} \quad \textbf{(18)}$$

where:

$GDIE_{h,d}$	=	additional proportion of trees of species h in diameter class d that will die in a given year,
SGMORT	=	rate parameter for effect of slow growth on mortality (-0.84),
$NSLOW_{h,d}$	=	number of consecutive years of slow growth for species h in diameter class d.

Figure 9 shows the relation between number of years with reduced growth (NSLOW) and additional mortality (GDIE). Diameter growth for each cell is compared to $SLOWD_h$; if less, $NSLOW_{h,d}$ is incremented by 1.0. Otherwise, $NSLOW_{h,d}$ is reset to zero. Users have access to both $SLOWD_h$ in the species-specific data-management screens and SGMORT as a standwide parameter, permitting local recalibrations.

Mortality During Periods of Defoliation

Defoliation of northeastern forests by gypsy moth often has been followed by increased tree mortality due to secondary agents, primarily *Armillaria mellea*, a root disease, or *Agrilis bilineatus*, the twolined chestnut borer, an insect (Baker 1941; Dunbar and Stephens 1976; Kegg 1971, 1973; Parker and Houston 1971; Wargo 1977). Reported mortality rates following gypsy moth defoliation (in percent) include 3 to 11 (Baker 1941), 1 to 50 (Brown et al. 1979), 25 to 58 (Campbell and Valentine 1972), 1 to 28 (Kegg 1971), 0 to 84 (Kegg 1973), and 0 to 42 (Stalter and Serrao 1983). Differences in tree species, stand species composition, duration and severity of outbreaks, length of observation periods, and other factors contribute to the variability in reported mortality rates. When other stresses such as droughts or late frosts occur concurrently with defoliation, effects on trees may be exacerbated (Baker 1941; Crossman 1948; Nichols 1968; Stephens and Hill 1971). The effect of gypsy moth defoliation on tree mortality also is influenced by site and stand conditions (Kegg 1973; Stalter and Serrao 1983; Stephens 1971; Stephens and Hill 1971), and by individual-tree conditions (Campbell and Sloan 1977; Campbell and Valentine 1972; Gansner and Herrick 1984).

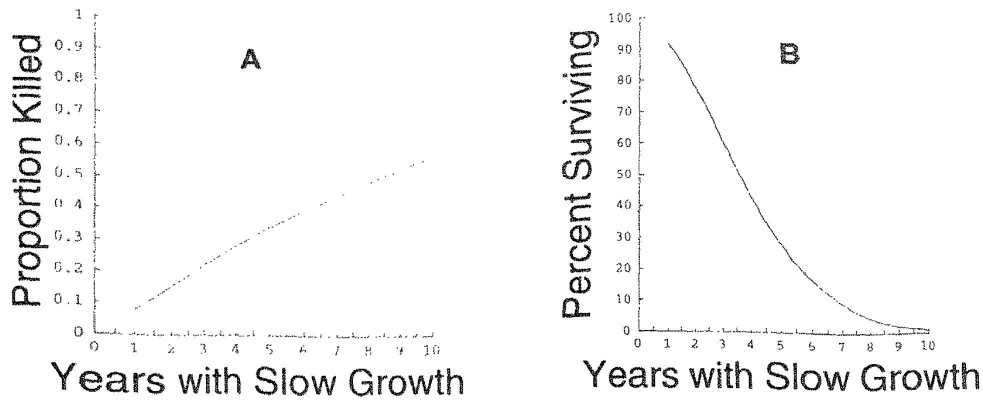

Figure 9.--Additional tree mortality resulting from reduced diameter growth (less than 0.01 cm/yr) (A) proportion killed each year; (B) total cumulative percent surviving following years of slow growth.

The Stand-Damage Model uses defoliation as an indicator of subsequent mortality caused by gypsy moth. Additional mortality for a given species and diameter class following defoliation is assumed to be a function of the number of consecutive years of defoliation, soil-moisture category, and other stresses that may occur during the same year as the defoliation.

For years without other stress, the probability of mortality induced by gypsy moth defoliation is assumed to vary with the number of consecutive years of heavy defoliation (> 65 percent) and soil-moisture category, as shown in Table 8. By default, all species are assumed to have the same probabilities of defoliation-induced mortality (given the same defoliation history and soil-moisture index), but these values are species specific and can be reset for any species (the table look-up function $FDIE_{h,m,n}$ where *h* is the tree species, *m* is the site index, and *n* is the number of years of heavy defoliation). The tree mortality used at any specific instance (DDIE) is the current value of this function (FDIE). Note that mortality due to stresses is in addition to defoliation and is assumed to occur only for trees that are heavily defoliated (> 65 percent).

Table 8.--Proportion of trees that die each year due to gypsy moth defoliation assuming no additional stress

No. consecutive years with defoliation greater than 65%	Soil-moisture category		
	Mesic	Intermediate	Xeric
0	0.0	0.0	0.0
1	0.1	0.1	0.1
2	0.2	0.2	0.2
3+	0.35	0.35	0.35

By default, no stress mortality will be scheduled (ISOPT = 0); users can choose either of two scheduling options. One selects the proportion of years that stress should occur (ISOPT = 1); the other allows the user to identify specific years when stress occurs (ISOPT = 2). For the former option, stress years will be scheduled at random such that the proportion of stress years matches the proportion selected by the user ($STRESS_m$) for the particular site moisture index (m). Users can alter the probability of high stress-induced mortality (STRFAC[2]) as well as mortality when stress is low (STRFAC[1]) but defoliation is heavy.

Total Annual Mortality

The annual mortality rate for a given species and diameter class is set to the sum of the mortality rates due to background mortality, reduced growth, defoliation, and additional stress:

$$TDIE_{h,d} = BDIE_h + GDIE_{h,d} + DDIE_{h,m,n} + SDIE \quad \textbf{(19)}$$

where:

$TDIE_{h,d}$	=	proportion of trees of species h in diameter class d that die at the end of the current year,
$BDIE_h$	=	background annual mortality rate for species h (Equation 17),
$GDIE_{h,d}$	=	mortality induced by reduced growth for trees of species h and diameter class d (Equation 18),
$DDIE_{h,m,n}$	=	defoliation-induced mortality for species h in a stand with soil-moisture index m that has had defoliation greater than 65 percent for n consecutive years (Table 8),
SDIE	=	additional mortality caused by other stresses in years with heavy defoliation (SDIE = STRFAC[ISTRES]).

By default, SDIE is set to 0.15 for years with high stress and 0.0 for low-stress years. For each species and diameter class, the number of live trees per ha ($STEM_{h,d}$) is multiplied by the total annual mortality rate ($TDIE_{h,d}$) to determine the number of trees that will die during the current year. This number of dying trees is subtracted from the number of live trees at the end of each year.

Applying Growth Calculations

After mortality has been applied, the number of trees in each diameter class and species ($STEMS_{h,d}$) is adjusted to account for trees that grew from one diameter class to the next. For each species, all trees within any individual diameter class are assumed to be equally likely to grow into the next larger class. Each year, the number of trees that grow into the next diameter class is calculated as a function of the increase in diameter that year relative to the diameter range for that class:

$$TREEN_{h,d} = \frac{GROW_{h,d}}{DLEN} \times STEMS_{h,d} \quad \textbf{(20)}$$

where:

$TREEN_{h,d}$	=	number of trees of species h that will move from diameter class d to diameter class d+1 at the end of the current year,
$GROW_{h,d}$	=	growth in diameter (cm/year) for species h and diameter class d (Equation 16),
DLEN	=	width (cm) of diameter classes,
$STEMS_{h,d}$	=	number of stems of species h in diameter class d at the start of the year.

Beginning with the second largest diameter class and continuing to the smallest, the number of trees growing into the next larger diameter class is calculated using Equation 20; this number is added to the number of stems in the next larger diameter class and subtracted from the original diameter class.

Stem Recruitment

The net effects of seedling establishment and early regeneration growth are simulated by calculating the number of stems that are recruited each year to the smallest diameter class of each tree species; that is, trees entering the first diameter class have an associated d.b.h. The Stand-Damage Model assumes that for each species there is a maximum number of new stems that can be added per year (see Table 6 for default values). Under this assumption, seedling establishment (seed generation, viability, and germination) and growth of trees until they have reached the diameter of the smallest class (class midpoint), are not modeled explicitly. Rather, only the number of stems entering that smallest class is simulated.

The maximum possible stem recruitment is adjusted to account for shading and random variation. Relative stocking (Equation 8) is used to determine the effect of shading on recruitment for five shade-tolerance classes. Figure 10 shows the relationships between relative stocking and recruitment that are used by default. Red maple, assigned to the fifth tolerance class, is assumed to behave like intolerant species at low stocking levels and tolerant species at high stocking levels. Random variation is simulated by selecting a number from a uniform distribution between 0 and 1 (inclusive) and using that number to further adjust the number of stems recruited:

$$NEWST_h = RECRUT_h \times RSHADE_h \times RANDRC_h \qquad (21)$$

where:

$NEWST_h$	=	number of new stems recruited to the smallest diameter class for host h,
$RECRUT_h$	=	maximum number of stems that can be recruited in 1 year,
$RSHADE_h$	=	index for the effect of relative stand density as measured by RSTOCK (Equation 8) on stem recruitment for host h (Fig. 12),
$RANDRC_h$	=	random number from a uniform distribution between 0 and 1 that has been selected for host h.

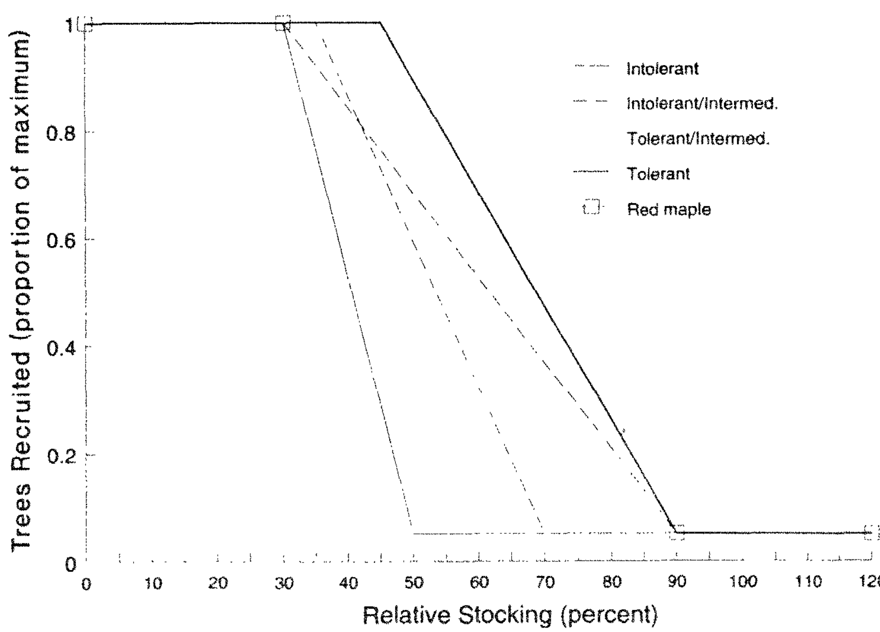

Figure 10.--Effect of relative stocking (RSTOCK) on maximum recruitment (RSHADE). As stocking increases, recruitment decreases for four tolerance classes except that red maple is intolerant at high light and tolerant at low light.

Users can alter the piecewise linear relationship between stocking level, RSTOCK, and shading, RSHADE. There are four shade-tolerance classes to which species are assigned. Red maple has been assigned separately to the fifth class, because it behaves like tolerant species at low stocking levels and intolerant species at high stocking levels.

Output

Output is produced in tabular formats and in ASCII files is suitable for statistical or graphics software packages. Users determine which files are created and which are permanently archived to disk. For each species and crown class (overstory or understory), the stand table summarizes basal area, number of stems, volume, average diameter, total foliage biomass, diameter growth, growth modifiers, tree mortality, and sources of mortality. The stand table can be printed at intervals selected by the user (such as every 5 years) or for specific years. An example of the stand table output is shown on pages 23 and 24 as Figure 11.

Users control ASCII files content, which can represent only overstory trees, understory trees, or both understory and overstory trees by species. Separate files are produced for basal area, number of stems, tree volume, and average (quadratic mean) diameter. In Figures 12-15, using the example stand, ASCII files have been plotted in a format similar to that produced by the model software. The format of each of these files is described in detail in the User's Guide (Colbert and Racin 1994) and in the on-line help system under the output selection windows.

*** User supplied input/output information ***

Input Data File Name: EXAMPLE.INP
User Name: Peicht & Fosbroke
Job Name: Block 41 Stand 123
Site Name: Mifflin Co. PA, USA
Date: September 2, 1978

User notes supplied through the Setup-Edit Job Description

Stand Output Table: EXAMPLE.TBL; printed every other year.
Other outputs: printed every year for all trees (category 3), Stem count, Basal area, & Volume; these output files not saved
Parameter changes: Sample Plot area = 0.3 ac.; Stand area = 2.4 ac.
Start year: 1978, Duration = 13 years.
Sampled Basal area: approximately 60% oak and 20% red maple
Defoliation years: 1981, 1986

DAMAGE MODEL VERSION 1.1: PARAMETER VALUES

No. of Years to be Simulated: 13
First Year of Simulation: 1978
Output to be produced Every 2 Years

UNITS: ENGLISH
Stand Area: 2.4 AC
Total Sample Plot area: .3 AC
Site moisture Index: 3

RANDOM NUMBER SEEDS --
Stem Recruitment: 2653
Add. Tree Mort. due to Stress: 3745

Defoliation data will be read from file: DEFOLDAT.D1S

OVERSTORY / UNDERSTORY BOUNDARY (BASED ON DIAMETER): 5.00 (IN)

SHADING PARAMETERS: TLIGHT= 1.0 TKL= .00020 SHADMN= .05 PLOT SIZE FOR SHADING= .0200 AC

EFFECT OF AVAIL. LIGHT ON DIAM. GROWTH, BY TOLERANCE CLASSES (PROP. AVAIL. LIGHT, PROP. OF POT. GROWTH):

TOL. CLASS:	1	2	3	4	5	6
	.00, .10	.00, .20	.00, .30	.00, .40	.00, .40	.00, .20
	.31, .15	.34, .25	.37, .35	.40, .45	.40, .45	.34, .25
	.80, .95	.75, .85	.70, .75	.65, .65	.80, .95	.80, .95
	1.00, 1.00	1.00, .90	1.00, .80	1.00, .70	1.00, 1.00	1.00, 1.00

MULTIPLIER FOR EFFECT OF RELATIVE STOCKING ON DIAMETER GROWTH: .0025
EFFECT OF REL. STOCKING ON RECRUITMENT, BY TOLERANCE CLASSES (REL. STOCKING, PROP. OF POT. RECRUIT.):

TOL. CLASS:	1	2	3	4	5	6
	0., 1.00	0., 1.00	0., 1.00	0., 1.00	0., 1.00	0., .00
	30., 1.00	35., 1.00	40., 1.00	45., 1.00	30., 1.00	0., .00
	50., .05	70., .05	80., .05	90., .05	90., .05	0., .00
	120., .05	120., .05	120., .05	120., .05	120., .05	0., .00

No additional stress included (ISOPT = 0).

ADDITIONAL MORTALITY IN YEARS WITH NO STRESS: .00, IN YEARS WITH STRESS: .15

13 Years of weather summary data, accumulated degree-days for each year in data file: ANNDDSUM.D1S
Tree Threshold Temperature: 42.0 Temperature Multiplier: 1.0 Minimum Value for variable TEMP: .05

PARAMETERS THAT VARY WITH TREE SPECIES --

SPECIES CODE:	RM	RO	CO
Relative Stocking Class	2	2	3
Recruitment Tolerance Class	5	2	2
Diam. Growth Tolerance Class	5	6	2
Maximum Diam. (IN)	24.	36.	24.
Maximum Height (FT)	70.	80.	60.
Maximum Age (Years)	250.	250.	250.
Minimum Annual Day-Deg.s	1810.	731.	3686.
Maximum Annual Day-Deg.s	13195.	8499.	7756.
Diam. Growth Parameter	194.4	121.5	83.3
Height Parameter B1	65.51	50.62	55.51
Height Parameter B2	.5373	.2783	.4553
Foliage Biomass Param. F1	.00812	.02622	.02622
Foliage Biomass Param. F2	2.0150	1.7752	1.7752
Surface Area::Biomass Ratio	205.0	104.0	143.0
Max. Annual Tree Recruitment	50.	30.	30.
Bole Resting Sites / sq. ft.	.0929	.4645	.0929
Crown Resting Sites / sq. ft.	.9290	4.6450	9.2900
Live Crown Ratio Parameters 1:	4.35	4.20	4.49
2:	.0046	.0010	.0020
3:	1.82	2.76	1.21
4:	.274	.025	.065
Add. Mort. When Growth Slowed	.010	.010	.010
Base mortality rate	.01600	.01600	.01600

Tree Mortality Rates Following Heavy Defoliation:

	YEARS OF HEAVY DEFOL.		
SPECIES	1	2	3
RM	.10	.20	.35
RO	.10	.20	.35
CO	.10	.20	.35

No Stand Treatments Scheduled

DAMAGE MODEL VERSION 1.1: INITIAL CONDITIONS

NUMBER OF STEMS PER AC:

	DIAMETER CLASS (IN)																			
SPECIES	1.0	3.0	5.0	7.0	9.0	11.0	13.0	15.0	17.0	19.0	21.0	23.0	25.0	27.0	29.0	31.0	33.0	35.0	37.0	39.0
RM	.00	76.67	10.00	6.67	3.33	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
RO	.00	3.33	6.67	10.00	13.33	13.33	3.33	6.67	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
CO	.00	6.67	10.00	20.00	16.67	3.33	6.67	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

DEFOLIATION HISTORY:	RM		RO		CO	
	OVER	UNDER	OVER	UNDER	OVER	UNDER
% Defol. 1 Year Ago:	0	0	0	0	0	0
% Defol. 2 Years Ago:	0	0	0	0	0	0

											MODIFIERS OF GROWTH					SOURCES OF MORTALITY			
SPEC	STRAT	% DEFOL	BASAL AREA (FT2/AC)	NUMBER STEMS (AC)	MEAN DBH (IN)	VOLUME (FT3/AC)	YIELD (FT3/AC)	FOLIAGE (LB/AC)	ACTUAL GROWTH (IN)	POTEN. GROWTH (IN)	GYPSY MOTH	TEMP	STAND DENS.	SHADE	TOTAL % MORT.	BASE % MORT.	SLOW GR. MORT.	RAND. STRESS MORT.	GYPSY MOTH MORT.
End of Year: 1978								Accumulated day-degrees for year: 4570.0											
RM	OVER	0.	6.0	27.8	7.5	73.3	.0	252.2	.232	.368	1.000	.726	.874	.992	1.6	1.6	.0	.0	.0
RM	UNDER	0.	3.4	83.7	2.9	22.2	.0	203.0	.215	.342	1.000	.726	.874	.990	1.6	1.6	.0	.0	.0
RO	OVER	0.	30.7	52.9	10.4	462.2	.0	2365.2	.261	.300	1.000	1.000	.874	.995	1.6	1.6	.0	.0	.0
RO	UNDER	0.	.2	6.4	3.0	.8	.0	17.5	.227	.262	1.000	1.000	.874	.989	1.6	1.6	.0	.0	.0
CO	OVER	0.	22.6	56.1	8.6	298.8	.0	1867.4	.096	.180	1.000	.680	.874	.895	1.6	1.6	.0	.0	.0
CO	UNDER	0.	.4	14.9	3.1	1.9	.0	35.0	.089	.168	1.000	.680	.874	.891	1.6	1.6	.0	.0	.0
End of Year: 1980								Accumulated day-degrees for year: 4570.0											
RM	OVER	0.	8.7	40.2	6.9	107.2	.0	402.5	.229	.367	1.000	.726	.868	.991	1.6	1.6	.0	.0	.0
RM	UNDER	0.	2.8	78.3	2.5	18.3	.0	167.2	.197	.316	1.000	.726	.868	.989	1.6	1.6	.0	.0	.0
RO	OVER	0.	33.0	51.8	10.8	513.9	.0	2523.2	.258	.300	1.000	1.000	.868	.994	1.6	1.6	.0	.0	.0
RO	UNDER	0.	.3	33.0	1.8	1.5	.0	27.2	.169	.197	1.000	1.000	.868	.988	1.6	1.6	.0	.0	.0
CO	OVER	0.	23.0	54.8	8.8	308.3	.0	1892.5	.095	.180	1.000	.680	.868	.894	1.6	1.6	.0	.0	.0
CO	UNDER	0.	.4	23.8	1.9	2.1	.0	43.9	.071	.134	1.000	.680	.868	.891	1.6	1.6	.0	.0	.0
End of Year: 1982								Accumulated day-degrees for year: 4570.0											
RM	OVER	0.	9.4	41.9	6.7	118.4	.0	411.8	.173	.367	.745	.726	.876	.992	1.6	1.6	.0	.0	.0
RM	UNDER	0.	2.4	81.5	2.3	15.0	.0	117.5	.142	.303	.745	.726	.876	.989	1.6	1.6	.0	.0	.0
RO	OVER	0.	30.8	45.7	11.2	490.3	.0	2083.2	.194	.299	.745	1.000	.876	.995	1.6	1.6	.0	.0	.0
RO	UNDER	0.	.5	42.2	1.5	2.2	.0	44.5	.125	.194	.745	1.000	.876	.989	1.6	1.6	.0	.0	.0
CO	OVER	0.	20.7	48.0	8.9	280.0	.0	1502.3	.071	.179	.745	.680	.876	.895	1.6	1.6	.0	.0	.0
CO	UNDER	0.	.5	38.5	1.7	2.3	.0	43.0	.051	.129	.745	.680	.876	.891	1.6	1.6	.0	.0	.0
End of Year: 1984								Accumulated day-degrees for year: 4570.0											
RM	OVER	0.	11.6	48.4	6.9	148.8	.0	563.9	.230	.367	1.000	.726	.871	.991	1.6	1.6	.0	.0	.0
RM	UNDER	0.	2.2	87.1	2.3	13.9	.0	123.1	.187	.300	1.000	.726	.871	.989	1.6	1.6	.0	.0	.0
RO	OVER	0.	32.6	45.6	11.6	531.1	.0	2455.3	.259	.298	1.000	1.000	.871	.995	1.6	1.6	.0	.0	.0
RO	UNDER	0.	.7	52.0	1.8	3.2	.0	65.4	.172	.200	1.000	1.000	.871	.988	1.6	1.6	.0	.0	.0

											MODIFIERS OF GROWTH					SOURCES OF MORTALITY			
SPEC	STRAT	% DEFOL	BASAL AREA (FT2/AC)	NUMBER STEMS (AC)	MEAN DBH (IN)	VOLUME (FT3/AC)	YIELD (FT3/AC)	FOLIAGE (LB/AC)	ACTUAL GROWTH (IN)	POTEN. GROWTH (IN)	GYPSY MOTH	TEMP	STAND DENS.	SHADE	TOTAL % MORT.	BASE % MORT.	SLOW GR. MORT.	RAND. STRESS MORT.	GYPSY MOTH MORT.
CO	OVER	0.	20.9	47.0	9.1	285.9	.0	1708.0	.095	.179	1.000	.680	.871	.894	1.6	1.6	.0	.0	.0
CO	UNDER	0.	.6	54.6	1.6	2.9	.0	64.9	.067	.127	1.000	.680	.871	.891	1.6	1.6	.0	.0	.0
End of Year: 1986								Accumulated day-degrees for year: 4570.0											
RM	OVER	80.	12.2	48.2	7.0	161.1	.0	71.3	.148	.367	.645	.726	.862	.998	11.6	1.6	.0	.0	10.0
RM	UNDER	80.	2.1	111.5	2.1	12.6	.0	12.2	.117	.290	.645	.726	.862	.998	11.6	1.6	.0	.0	10.0
RO	OVER	80.	30.7	41.3	11.8	511.4	.0	264.9	.165	.297	.645	1.000	.862	.999	11.6	1.6	.0	.0	10.0
RO	UNDER	80.	.7	46.6	1.7	3.6	.0	9.1	.113	.203	.645	1.000	.862	.997	11.6	1.6	.0	.0	10.0
CO	OVER	80.	18.9	41.4	9.2	261.1	.0	175.6	.061	.178	.645	.680	.862	.899	11.6	1.6	.0	.0	10.0
CO	UNDER	80.	.8	73.3	1.5	3.5	.0	9.1	.043	.127	.645	.680	.862	.898	11.6	1.6	.0	.0	10.0
End of Year: 1988								Accumulated day-degrees for year: 4570.0											
RM	OVER	0.	13.9	52.2	7.2	187.9	.0	713.7	.171	.366	.745	.726	.872	.992	1.6	1.6	.0	.0	.0
RM	UNDER	0.	2.4	138.5	1.9	14.0	.0	119.5	.131	.280	.745	.726	.872	.988	1.6	1.6	.0	.0	.0
RO	OVER	0.	32.1	41.9	12.0	542.0	.0	2417.6	.191	.296	.745	1.000	.872	.994	1.6	1.6	.0	.0	.0
RO	UNDER	0.	.8	51.0	1.9	4.1	.0	88.4	.132	.206	.745	1.000	.872	.988	1.6	1.6	.0	.0	.0
CO	OVER	0.	19.0	40.6	9.3	264.3	.0	1549.2	.070	.178	.745	.680	.872	.894	1.6	1.6	.0	.0	.0
CO	UNDER	0.	.9	78.0	1.5	4.1	.0	101.3	.050	.126	.745	.680	.872	.891	1.6	1.6	.0	.0	.0
End of Year: 1990								Accumulated day-degrees for year: 4570.0											
RM	OVER	0.	16.6	58.6	7.5	229.7	.0	832.5	.227	.366	1.000	.726	.864	.991	1.6	1.6	.0	.0	.0
RM	UNDER	0.	2.8	160.5	1.9	16.4	.0	138.8	.173	.279	1.000	.726	.864	.988	1.6	1.6	.0	.0	.0
RO	OVER	0.	34.2	43.5	12.2	589.6	.0	2537.6	.253	.295	1.000	1.000	.864	.994	1.6	1.6	.0	.0	.0
RO	UNDER	0.	1.1	70.6	1.8	5.2	.0	108.7	.174	.204	1.000	1.000	.864	.987	1.6	1.6	.0	.0	.0
CO	OVER	0.	19.3	40.3	9.4	271.3	.0	1560.0	.093	.177	1.000	.680	.864	.894	1.6	1.6	.0	.0	.0
CO	UNDER	0.	1.1	92.1	1.5	5.2	.0	119.6	.067	.127	1.000	.680	.864	.890	1.6	1.6	.0	.0	.0

NUMBER OF STEMS PER AC:

	DIAMETER CLASS (IN)																			
SPECIES	1.0	3.0	5.0	7.0	9.0	11.0	13.0	15.0	17.0	19.0	21.0	23.0	25.0	27.0	29.0	31.0	33.0	35.0	37.0	39.0
RM	116.33	44.14	27.21	16.78	8.83	3.94	1.42	.38	.07	.01	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
RO	54.62	15.98	7.02	4.85	5.71	7.19	6.87	5.51	3.69	1.85	.66	.16	.03	.00	.00	.00	.00	.00	.00	.00
CO	78.38	13.71	6.45	10.03	11.19	6.11	4.47	1.69	.32	.03	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

Figure 11.--Output table generated by the model: this copy was generated using the file EXAMPLE.INP that is bundled as part of the installation package.

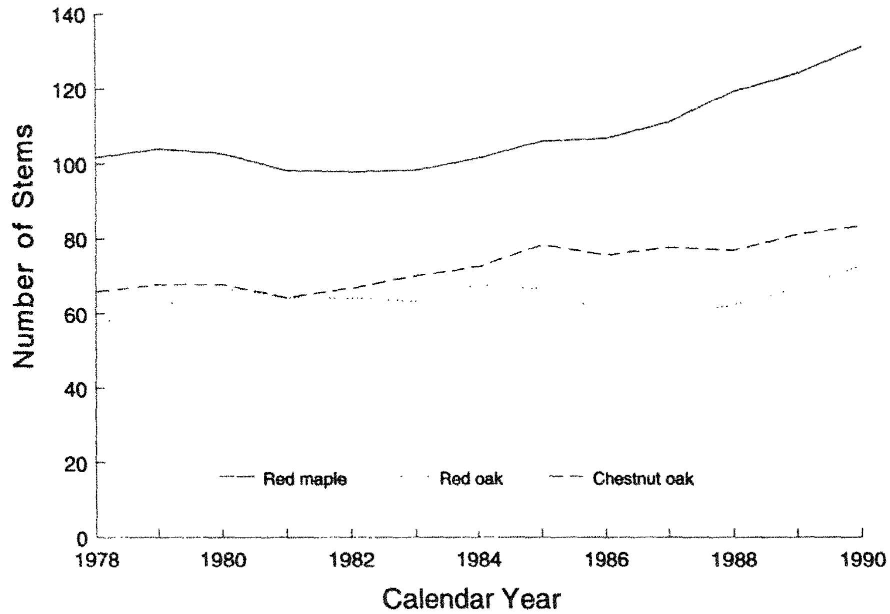

Figure 12.--Number of stems of each species over time (all trees) using the example stand. The user can select output for all trees, only overstory trees, or only understory trees.

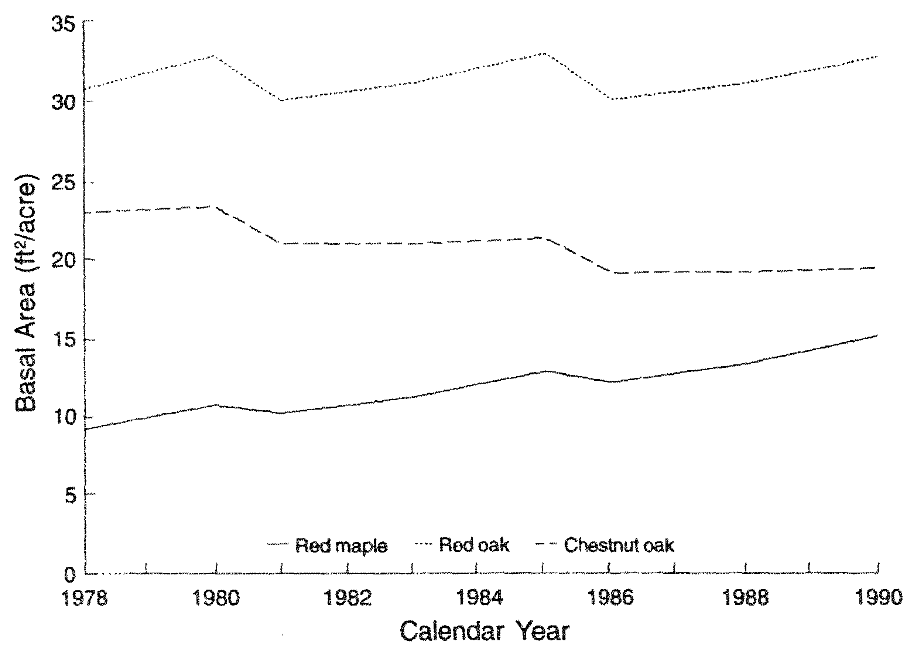

Figure 13.--Basal area over time (all trees) using the example stand. If the user changes units from English to metric, the output graphs are rescaled automatically and the axis labels are reset accordingly.

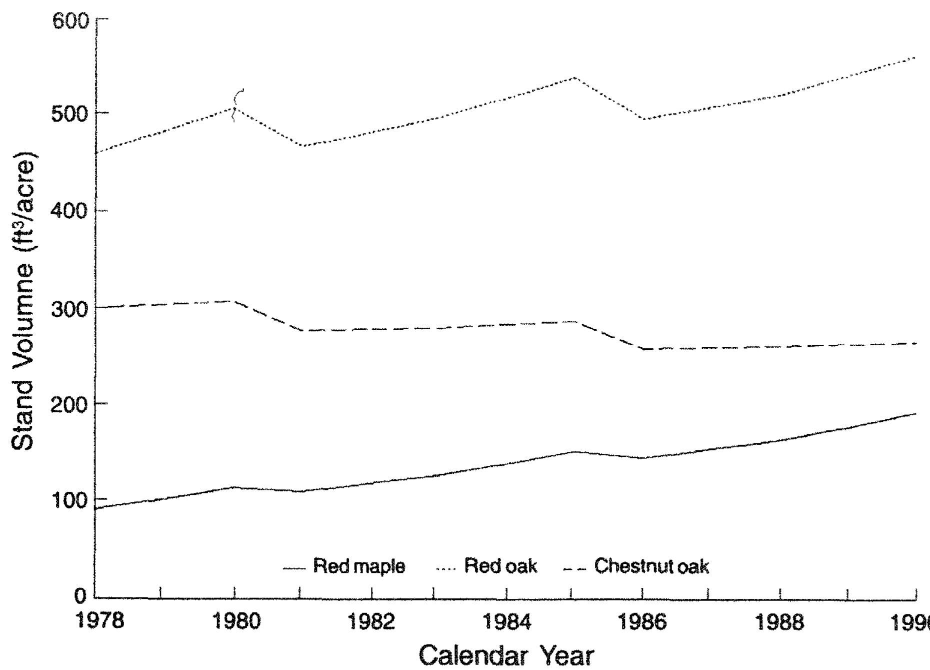

Figure 14.--Stand volume by species over time (all trees) using the example stand.

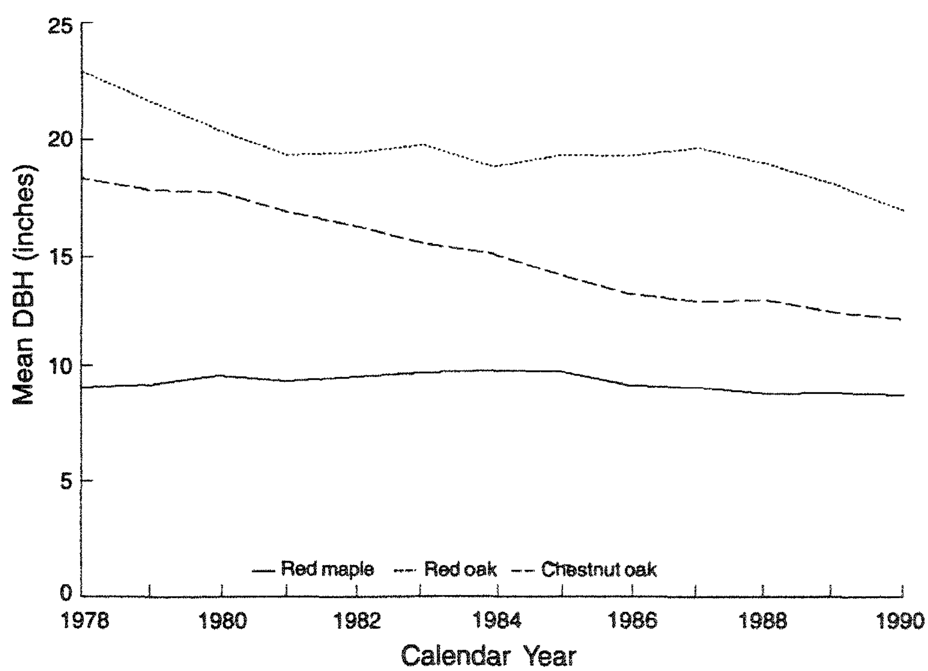

Figure 15.--Quadratic mean diameter by species over time (all trees) using the example stand.

Acknowledgments

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Appendix A Structure of the Stand-Damage Model Code: Call Sequencing

Parenthetic listings are line numbers of the calls within the routine at the prior level.

Damage(Main)		
	INITW (L229)	
	TINIT (L231)	
	PINIT (L232)	
		PRNOTE (L260)
		PTSTBL (L406)
	THGHTS (L234)	
	start primary loop -- years	
	TREE1 (L262)	
	RELSTK (L266)	
	FLUPDT (L271)	
	DEFOL (L285)	
	TREE21 (L298)	
		GTCRWD (L218)
		RANDS (L234)
		PTSTBL (L255)
		PRTMGT (L270)
	TREE22 (L299)	
		SLIP (L336)
		PTSTBL (L516)
		SLIP (L534)
		RANDS (L535)
		PTSTBL (L543)
	WASCII (L300)	
	GNXTMG (L301)	
	TPRINT (L307)	
	TPRINT (L311)	
	end primary loop - years	
	PTSTBL (L329)	
	CLEAN (L333)	

Appendix B Description of Stand-Damage Model Routines

BLOCK DATA	Describes fixed values used for common block parameters.
CLEAN	The cleanup routine that closes all disk files.
DAMAGE	Main routine that controls the Stand-Damage Model; after initializing and setting up the system, it runs through the main loop once for each year to be simulated; then it does the final writing of summary data and cleanup before returning control to the user interface.
DEFOL	Used with the Stand-Damage Model to read defoliation estimates provided by the user and uses those rates to adjust the amounts of foliage present. This routine is not used when the stand model is linked to the gypsy moth model.
FLUPDT	This subroutine calculates the function that accounts for the effects of last year's defoliation on this year's foliage production. DEFL = percent defoliation last year.
GNXTMG	This section brings in the next management year and action type.
GTCRWD	Calculates the stand competition factor ("CROWD") as a function of the relative-stocking index (RSTOCK) and RSMULT (set arbitrarily). CROWD is constrained and has a minimum value of 0.75, the user-accessible value of the parameter CRWDMN.
INITW	Reads parameter values and initial conditions from file with handle JWIN.
PINIT	Writes (prints) parameter values and initial conditions for the stand model.
PRNOTE	Produces copy of user's input notes as part of output table header information; writes them to Stand Table file.
PRTMGT	Writes stand management treatments that have been scheduled to Stand Table file.
PTSTBL	Writes (PrinTs) the Stand TaBLe (stem counts by species and diameter class).
RANDS	Pseudo-random number generator.
RELSTK	Calculates relative stocking (RSTOCK) based on SILVAH (Marquis et al. 1992); sums total number of stems by diameter class in three stocking groups identified in SILVAH as TOT1, TOT2, and TOT3.
SLIP	Linear-interpolation function. Input is XX; find YY(XX) by linear interpolation; (X(I),Y(I)) pairs are used for XX greater than X(1) and less than X(N); otherwise, end value Y(1) or Y(N) is used.
THGHTS	Calculates heights (cm) for each host-diameter class (HEIGHT). See Equation 2. If the diameter is greater than the maximum diameter for species (ih), sets height equal to maximum height for species ih.
TINIT	Reads parameter values and initial conditions for stand model.
TPRINT	Writes Stand Table Output summary for 1 year.
TREE1	Calculates foliage amounts, crown ratios, number of resting sites, and stem counts and basal area in the under and overstory strata by tree species. Called from the main program DAMAGE or DAMSR. No calls are made by this routine.
TREE21	This routine (1) calculates superior leaf area for each tree class, (2) sets crowding factor for this year, (3) sets stress option ISTRES for this year, (4) reads management prescription data for this year (if any), and (5) sets up DEBUG output printing.

TREE22 — Calculates diameter-growth and mortality rates for each tree species and diameter class, followed by recruitment of new stems and management entries. First the temperature modifier of growth is calculated for each species; then for each diameter class and host, the defoliation modifier, shading modifier, and potential and actual growth are calculated. Then the mortality factors are calculated and accumulated (past and current defoliation, stress, slow growth, and background rates). Growth and mortality effects are summarized for tabular and ASCII file output. Growth is simulated by moving stem counts between diameter classes. Management entries (tree removals) are simulated followed by further summarizing of the stand for output. Finally, defoliation histories (by tree species and crown strata) for the year are updated.

WASCII — Writes output data as flat ASCII formatted files to disk for use in plotting or permanent archiving for other uses. There are four separate files, one each for stem counts, basal area, volume, and quadratic mean diameter by species for specified strata (overstory trees only, understory trees only, or all trees).

Appendix C Code Listings

```
c        *****   BLOCK DATA, file: BLKDATA.FOR   *****
c A portion of the:
c Stand-Damage Model - a portion of the Gypsy Moth Life System Model
c       (the stand submodel) converted to a stand-alone model.  Last
c       revised by K.Sheehan January 1988; revised starting in 1989
c       by Colbert and Racin.
c
c              J. Colbert, Northeastern Forest Experiment Station
c            180 Canfield St., Morgantown, WV  26505  (304)-285-1600

c  **  Local variables, parameters, and inputs required
c  '                                 by BLKDATA.FOR  **
c  The following designations for LOCATIONs apply:
c        (1) - l := local variable
c        (2) - n := new parameter; not yet assigned to a common block
c        (3) - cp:= call parameter of this subroutine
c        (4) - s := subroutine called from within this code
c        (5) -XXN:= CAPS or CAPS+digit indicate a common block name
c----------------------------------------------------------------
c NAME - LOCATION - DESCRIPTION
c----------------------------------------------------------------
c NDIAM     S4    - Number of diameter classes to be simulated
c STRATA    CHAR1 - The 4 strata names to be simulated for each host
c----------------------------------------------------------------

        BLOCK DATA


c  **** Include common blocks  ****

        INCLUDE 'CHAR1.CMB'
        INCLUDE 'S4.CMB'

        DATA STRATA / 'OVER ', 'UNDER', 'SHRUB', 'BOLE ' /
        DATA NDIAM /20/

        END
```

```
c       *****   Subroutine CLEAN, file: CLEANUP.FOR   *****
c A portion of the:
c Stand-Damage Model - a portion of the Gypsy Moth Life System Model
c       (the stand submodel) converted to a stand-alone model.  Last
c       revised by K.Sheehan January 1988; revised starting in 1989
c       by Colbert and Racin.
c
c              J. Colbert, Northeastern Forest Experiment Station
c            180 Canfield St., Morgantown, WV  26505  (304)-285-1600

c Called from main program DAMSR.
c No subroutines are called by this routine.
c  **  Local variables, parameters, and inputs required
c                                  by Subroutine CLEAN(IOPT)  **
c  The following designations for LOCATIONs apply:
c        (1) - l := local variable
c        (2) - n := new parameter; not yet assigned to a common block
c        (3) - cp:= call parameter of this subroutine
c        (4) - s := subroutine called from within this code
c        (5) -XXN:= CAPS or CAPS+digit indicate a common block name
c  ---------------------------------------------------------------
c NAME - LOCATION - DESCRIPTION
c  ---------------------------------------------------------------
c DEBUG     LOG1  - Logical variable, true to produce Debug output
c IOPT       cp   - Means to pass ISOPT, Stress option indicating
c                   additional tree stress has been designated in
c                   specific years.
c LDEFOL    LOG2  - Logical variable, true if defoliation data is
c                   to be obtained from external file.
c STABLE    LOG2  - Logical variable, true to produce tabular output.
c TGBA      LOG2  - Logical variable, true to produce ASCII data file
c                   of basal area by species each year.
c TGDBH     LOG2  - Logical variable, true to produce ASCII data file
c                   of mean DBH for each species each year.
c TGSTEM    LOG2  - Logical variable, true to produce ASCII data file
c                   of total stem count for each species each year.
c TGVOL     LOG2  - Logical variable, true to produce ASCII data file
c                   of total stem volume across each species each year.
c  ---------------------------------------------------------------

        SUBROUTINE CLEAN (IOPT)

c  **** Include common blocks ****

        INCLUDE 'LOG1.CMB'
        INCLUDE 'LOG2.CMB'

        CLOSE (9)
        CLOSE (10)
        CLOSE (20)
        IF (IOPT .EQ. 2) CLOSE (11)
        IF (DEBUG) CLOSE (12)
      +--IF (STABLE) THEN
      |    ENDFILE (UNIT = 13)
      |    REWIND (13)
```

```
      |    CLOSE (13)
      +--ENDIF
         IF (LDEFOL) CLOSE (14)
         IF (TGSTEM) CLOSE (15)
         IF (TGBA) CLOSE (16)
         IF (TGVOL) CLOSE (17)
         IF (TGDBH) CLOSE (18)

c end of cleanup operations...
         RETURN
         END

c ***  End of subroutine CLEAN; file name CLEANUP.FOR  ***
```

```
      INTERFACE TO INTEGER*2 FUNCTION PGAUGE[C](IY)
      INTEGER IY
      END

c    *****  Main Program, called from the c interface code,
c                  as the Subroutine, DAMAGE, file: DAMSR.FOR  *****
c A portion of the:
c Stand-Damage Model - a portion of the Gypsy Moth Life System Model
c       (the stand submodel) converted to a stand-alone model.  Last
c       revised by K.Sheehan January 1988; revised starting in 1989
c       by Colbert and Racin.
c
c              J. Colbert, Northeastern Forest Experiment Station
c            180 Canfield St., Morgantown, WV  26505  (304)-285-1600

c  Called by the user interface (C-code).
c  Calls made to: DEFOL, FLUPDT, GNXTMG, PINIT, PTSTBL, RELSTK, THGHTS,
c                  TINIT, TREE1, TREE21, TREE22, and WASCII.
c  **  Local variables, parameters, and inputs required
c                                             by Subroutine DAMSR()   **
c                                          or by Main Program DAMAGE. **
c  The following designations for LOCATIONs apply:
c        (1) - 1 := local variable
c        (2) - n := new parameter; not yet assigned to a common block
c        (3) - cp:= call parameter of this subroutine
c        (4) - s := subroutine called from within this code
c        (5) -XXN:= CAPS or CAPS+digit indicate a common block name
c-----------------------------------------------------------------
c NAME - LOCATION - DESCRIPTION
c-----------------------------------------------------------------
c DEBUG    LOG1   - True if debug output is desired
c DEFOL     s
c FLUPDT    s
c FOL      S3     - Potential foliage biomass (g/ha) by host & strata.
c GMSUBM    1     - True if gypsy moth submodel is to be used; included
c                   for compatibility when linked to gypsy moth model.
c GNXTMG    s
c I         1     - Used in system call to clear screen
c IGYEAR   S4     - Index for printing graphic output to files.  KGYEAR,
c                   initialized to 0, is incremented in the main (DO 20)
c                  loop and compared to IGYEAR for decision criteria for
c                   data output.  At that point KGYEAR is reset to 0.
c IH        1     - Host species index
c INITW     s
c IPYEAR   GEN1   - Output interval for stand submodel (Stand table); if
c                   set to 0, then print output in years listed in
c                   IVIEW(iy)
c IS        1     - Strata index
c ISEED(i) GEN1   - Seeds for random number generator (1=establishment
c                   of new trees, 2= not used at this time, 3=additional
c                   tree mortality due to stress, 4=additional gypsy
c                   moth mort. due to winter temperatures, 5 = weather
c                   data generation, 6 = gypsy moth L1 dispersal.
c ISOPT    S4     - Tree species option: 1= stress occurs in random yrs
c                   2= user specifies stress yrs
```

```
c ISYEAR    GEN1   - Initially, calendar year to start simulation; then
c                    calendar year counter during simulation.
c IVIEW(iy) S4     - Years that  stand submodel output is desired; used
c                    only if IPYEAR = 0
c IWFORM    GEN1   - Format # for weather data
c IWOPT     GEN1   - Weather option: 1= 1 year, 2= more than 1 year, 3=
c                    generate weather data, 4= use annual degree-days)
c IYEAR     GEN1   - Current year of simulation
c JDB       GEN1   - DEBUG output file handle.
c JGEN      GEN1   - General data file (always req.; sets no. of
c                    years to be simulated, etc.)
c JTIN      GEN1   - Tree data file (req. if stand submodel is used)
c JWIN      GEN1   - Weather data file (always req.) - annual degree-day
c                    totals.  For the stand model only!
c KGYEAR    S4     - Counter for number of years since last writing of
c                    ASCII data for file(s)
c KYEAR     l      - No. of yrs since output was last printed
c LDEFOL    LOG2   - True if defoliation to be simulated
c LRAIN     LOG1   - True if user wants to use rain data (may slow
C                    development of larvae.)
c MV        l      - Index for IVIEW
c NHOSTS    GEN1   - Number of host tree species
c NLINES    GEN1   - Number of lines of text in the user notes file.
c                    for printing as part of the tabular output.
c NUMLIN    GEN1   - Line counter for tabular output.
c NWEAYR    GEN1   - Number of years of weather data
c NYEARS    GEN1   - Number of years simulation is to run
c OVERBA    S3     - Overstory basal area, by host
c OVERS     S3     - Overstory number of stems, by host
c PGAUGE    s      - Call to C-function to run the pop-gauge during
c                    the simulation, the current year counter is passed.
c PINIT     s
c PTSTBL    s
c RELSTK    s
c RNSPCn    CHAR1  - Five lines, each is a 20 character string passed to
c                    the model for inclusion as banner information in the
c                    stand output table. (n = 1,2,3,4, or 5)
c RSITES    S3     - Number of resting sites, by host and strata
c STABLE    LOG2   - True if stand table output is desired
c STSUBM    GEN1   - True if stand submodel is to be used
c TEMPC     LOG2   - True if temps are metric
c TFAC      WTHR1  - Temperature multiplier
c TGBA      LOG2   - True if ASCII output files (basal area) are to be
c                    produced.
c TGDBH     LOG2   - True if ASCII output files (mean d.b.h.) are to be
c                    produced.
c TGSTEM    LOG2   - True if ASCII output files (no. stems) are to be
c                    produced.
c TGVOL     LOG2   - True if ASCII output files (volume) are to be
c                    produced.
c THGHTS    s
c TINIT     s
c TNAME(ih)CHAR1   - 2 Char. code for tree species.
c TPRINT    s
c TREE1     s
```

```
c TREE21   s
c TREE22   s
c TRETHR   WTHR1  - Lower threshold for trees (used in stand submodel
c                   only).
c UNDBA    S3     - Understory basal area, by host
c UNDERS   S3     - Understory number of stems, by host
c WASCII   s
c ------------------------------------------------------------

      SUBROUTINE DAMAGE

10010 FORMAT (1X, I2, 1X, I2)
10020 FORMAT (1X, L1, 1X, L1, 1X, L1)
10030 FORMAT ('  YOU ARE TRYING TO RUN THE DAMAGE MODEL EITHER', /
     *  '  WITHOUT THE STAND SUBMODEL OR WITH THE GM SUBMODEL.', /
     *  '  PLEASE CHECK THE GENDATA.X FILE')
10040 FORMAT (1X, I3, 1X, I4/2(1X, I2, 1X, L1), 3(1X, L1)/, 2(10(1X,
     *  I4)/)6(1X, I7))
10050 FORMAT (1X, F5.2, 1X, I3, 1X, F6.2, 2(1X, I1), 2(1X, L1))
10060 FORMAT ('  The stand model will not use rain data.')
10070 FORMAT (' MAIN 3006: TINIT DONE ')
10090 FORMAT (' MAIN 3040: TREE1 DONE ')
10100 FORMAT (' MAIN 3042: ', 2F8.2)
10110 FORMAT ('    DATA: OVERBA(IH),UNDBA(IH),FOL(IH,1),',
     *  'FOL(IH,2),(RSITES(IH,IS),IS=1,4)', /2F9.0, 2F11.0/4F6.0)
10120 FORMAT (' MAIN 3060: DEFOLIATION DONE ')
10130 FORMAT (' MAIN 3070: TREE2x, WASCII, and GNXTMG done.')
10140 FORMAT (1X,I2,/ 12(1X,A2))

c *** INCLUDE common blocks... ***

      INCLUDE 'CHAR1.CMB'
      INCLUDE 'GEN1.CMB'
      INCLUDE 'LOG1.CMB'
      INCLUDE 'LOG2.CMB'
      INCLUDE 'S2.CMB'
      INCLUDE 'S3.CMB'
      INCLUDE 'S4.CMB'
      INCLUDE 'WTHR1.CMB'

c *** End of Common blocks ***

      LOGICAL STSUBM, GMSUBM

c  Clear the screen for the start of simulation.

      INTEGER*2 PGAUGE


c  Set the page length counter for initial page eject and line banner in
c  TPRINT routine.

      NUMLIN = 80

c Open the general data file: GENDATA.
```

```

          OPEN (9, FILE = 'GENDATA.D1S', STATUS = 'OLD')
          JGEN = 9

c   Read general information

          READ (JGEN, 10010) NHOSTS, NLINES
          READ (JGEN, '(A)') RNSPC1, RNSPC2, RNSPC3, RNSPC4, RNSPC5
          READ (JGEN, 10020) STSUBM, GMSUBM, DEBUG

c Open the stand data file: treedata.

          IF (STSUBM) OPEN (10, FILE = 'TREEDATA.D1S', STATUS = 'OLD')
          JTIN = 10

       +--IF (.NOT. STSUBM .OR. GMSUBM) THEN
       |    WRITE (*, 10030)
       |    STOP
       +--ELSE
       |
       |    IF (DEBUG) OPEN (12, FILE ='DBUGDAMG.D1S', STATUS = 'UNKNOWN'
      *|     )
       |    JDB = 12
       |    READ (JGEN, 10040) NYEARS, ISYEAR, IPYEAR, STABLE, IGYEAR,
      *|          TGSTEM, TGBA, TGVOL, TGDBH, (IVIEW(I), I = 1, 20),
      *|           (ISEED(I), I = 1, 6)
       |    INITYR = ISYEAR
       |
c      | --> Read weather info. <--
       |
       |    READ(JGEN, 10050) TFAC, NWEAYR, TRETHR, IWFORM, IWOPT, TEMPC,
      *|     LRAIN
       |
c Assure that proper weather option is used in the stand model.
c this|is only used in the stand alone version of the stand model.
       |
       | +--IF (IWOPT .NE. 4) THEN
       | |    WRITE (*, *) '   IWOPT not properly set to 4; will reset!'
       | |    IWOPT = 4
       | |    PAUSE
       | +--ENDIF
       |
c End of addition for iwopt under stand damage model.
       |
c Open|the weather data file:
       |
       |    OPEN (20, FILE = 'ANNDDSUM.D1S', STATUS = 'OLD')
       |    JWIN = 20
       |
c No longer open the rain data file: RAINDATA, if logical variable calls
c for it, write an error message.  Rain is only used by Gypsy Moth
c submodel.
       |
       |    IF (LRAIN) WRITE (*, 10060)
       |
```

```
        |
c Call|subroutine INITW to initialize weather variables.
c Call|subroutine TINIT to initialize stand & tree variables & parameters
c Call|subroutine PINIT to print initial stand conditions and parameter
c     |                     settings.
c Call|subroutine THGHTS to calculate tree heights for each species and
c     |                      diameter class.
      |
      |    CALL INITW()
      |
      |    CALL TINIT()
      |    CALL PINIT()
      |
      |    CALL THGHTS()
      |
      |    IF (DEBUG) WRITE (JDB, 10070)
      |
c Do the following for each year in the simulation.
c Set output counters.  IPYEAR = the interval (in years) that
c stand output is to be printed (default = every year).  KYEAR = no.
c of years since output was last printed.  IYEAR = number of
c current year.  Ensure that output is printed after the 1st year.
c If IPYEAR=0, then output will be printed only in years specified
c by IVIEW; MV=counter that points to next year to be printed.
c ISYEAR = current year (ex: 1980).
      |
      |    MV = 1
      |    KYEAR = IPYEAR - 1
      |    KGYEAR = 0
      |    ISYEAR = ISYEAR - 1
      | +--DO IYEAR = 1, NYEARS
      | |    KYEAR = KYEAR + 1
      | |    KGYEAR = KGYEAR + 1
      | |    ISYEAR = ISYEAR + 1
      | |
c The Stand submodel is running alone and total annual
c degree-days have been provided for each year (IWOPT = 4).
      | |
c Estimate foliage present by calling TREE1 (part of the
c Stand submodel)
      | |
      | |    CALL TREE1()
      | |
c Call|RELSTK to compute relative stocking
      | |
      | |    CALL RELSTK()
      | |
c Call|FLUPDT to estimate last year's defoliation effect on this year's
c foliage production.
      | |
      | |    CALL FLUPDT()
      | |
      | | +--IF (DEBUG) THEN
      | | |    WRITE (JDB, 10090)
      | | |    WRITE (JDB, 10100) UNDERS(1), OVERS(1)
```

```
      | | | +--DO IH = 1, NHOSTS
      | | | |     WRITE (JDB, 10110) OVERBA(IH), UNDBA(IH), FOL(IH, 1),
     *| | | |       FOL(IH, 2), (RSITES(IH, IS), IS = 1, 4)
      | | | +--ENDDO
      | | +--ENDIF
      | |
      | |
c  Simulate GM defoliation by calling Subroutine DEFOL
      | |
      | |     CALL DEFOL()
      | |     IF (DEBUG) WRITE (JDB, 10120)
      | |
      | |
c   Call TREE21, TREE22, WASCII, and GNXTMG;
c then|check to see if it's time to print a stand table
      | |
c TREE21 - The initial portion of old TREE2.
c TREE22 - The big "by host" loop of TREE2.
c      |The above two routines will be further subdivided.
c WASCII - write the ASCII data to files as requested.
c GNXTMG - Get the NeXT ManaGement date and type.
      | |
      | |     CALL TREE21()
      | |     CALL TREE22()
      | |     CALL WASCII()
      | |     CALL GNXTMG()
      | |
C     | |     IF (DEBUG) WRITE (JDB, 10130)
      | | +--IF (STABLE) THEN
      | | | +--IF (IPYEAR .EQ. 0) THEN
      | | | | +--IF (ISYEAR .EQ. IVIEW(MV)) THEN
      | | | | | |     CALL TPRINT()
      | | | | | |     MV = MV + 1
      | | | | +--ENDIF
      | | | +--ELSEIF (KYEAR .EQ. IPYEAR) THEN
      | | | |     CALL TPRINT()
      | | | |     KYEAR = 0
      | | | +--ENDIF
      | | +--ENDIF
      | |
c End of primary do loop for simulating each year.
c Check to see if the no. of years to be simulated (NYEARS)
c has been reached.  If not, go on to the next year.
      | |
      | |     I = PGAUGE(IYEAR)
      | |
      | +--ENDDO
      |
c Otherwise, end of simulation, do house cleaning.
      |
      |
c Print final Stand table.
      |
      |     IF (STABLE .OR. DEBUG) CALL PTSTBL()
      |
```

```
c Call|clean for following:
      |
      |     CALL CLEAN (ISOPT)
      |     OPEN (8, FILE = 'GRAFHOST.DIS', STATUS = 'UNKNOWN')
      |     JGRAPH = 8
      |     WRITE(JGRAPH, 10140) NHOSTS,(TNAME(IH),IH=1,NHOSTS)
      |     CLOSE (8)
      |     RETURN
      +--ENDIF
         END

c *** END of subroutine DAMAGE -- file name: DAMSR.FOR  ***
```

```
c       *****   Subroutine DEFOL, file: DEFOL.FOR   *****
c A portion of the:
c Stand-Damage Model - a portion of the Gypsy Moth Life System Model
c       (the stand submodel) converted to a stand-alone model. Last
c       revised by K.Sheehan January 1988; revised starting in 1989
c       by Colbert and Racin.
c
c              J. Colbert, Northeastern Forest Experiment Station
c            180 Canfield St., Morgantown, WV  26505 (304)-285-1600

c Used when the stand submodel is used without the gypsy moth
c submodel.  This section reads defoliation estimates provided by the
c user and uses those rates to adjust the amounts of foliage present.
c      Called by the main program DAMSR.
c      No calls to other routines.

c  **  Local variables, parameters, and inputs required
c                                  by Subroutine DEFOL **
c  The following designations for LOCATIONs apply:
c        (1) - l := local variable
c        (2) - n := new parameter; not yet assigned to a common block
c        (3) - cp:= call parameter of this subroutine
c        (4) - s := subroutine called from within this code
c        (5) -XXN:= CAPS or CAPS+digit indicate a common block name
c-------------------------------------------------------------
c NAME - LOCATION - DESCRIPTION
c-------------------------------------------------------------
c ACTFOL      S3  - Actual foliage present.
c (ih,is)
c DEFL        S3  - Defoliation this year.
c (ih,is)
c DEFOL      <Subroutine>
c FOL         S3  - Foliage produced, before defoliation.
c (ih,is)
c IDFOLY      S3  - Year next defoliation will take place.
c IFS0         l  - IOSTAT return variable.
c IH           l  - Host index
c IS           l  - Strata index
c ISYEAR     GEN1 - Current calendar year.
c JDEF       GEN1 - Defoliation data file handle.
c LDEFOL     LOG1 - Logical variable, true if defoliation trace
c                   activated.
c METRIC     LOG2 - True if output is to be presented in metric
c                   units.
c NHOSTS     GEN1 - Number of (host) tree species used this sim.
c-------------------------------------------------------------

         SUBROUTINE DEFOL
         INTEGER IFS0
10000    FORMAT (12(1X, F3.0))
10010    FORMAT (1X, I4)

c  ****  Include blocks  ****

         INCLUDE 'GEN1.CMB'
```

```
          INCLUDE 'LOG2.CMB'
          INCLUDE 'S3.CMB'

c If defoliation has been scheduled and the year is correct, then get
c the defoliation data.

      +--IF (LDEFOL .AND. (ISYEAR .EQ. IDFOLY)) THEN
      |
c The |% defoliation for the current year is read into the model
c and used to reduce actual foliage present (ACTFOL).
      |
      |     READ (JDEF, 10000) (DEFL(IH, 1), IH = 1, NHOSTS)
      |     READ (JDEF, 10000) (DEFL(IH, 2), IH = 1, NHOSTS)
      |
c get IDFOLY = the next year that has defoliation scheduled.
      |
      |     READ (JDEF, 10010, IOSTAT = IFS0) IDFOLY
      |
c If EOF, another year (IDFOLY) not present so quit trying to read data.
      | +--IF (IFS0 .LT. 0) THEN
      | |     IDFOLY = 0
      | +--ENDIF
      | +--DO IH = 1, NHOSTS
      | | +--DO IS = 1, 2
      | | | +--IF (METRIC) THEN
      | | | |     ACTFOL(IH, IS) =
     *| | | |      FOL(IH, IS) * (1.0 - (DEFL(IH, IS)/100.0))
      | | | +--ELSE
c Conversion of kilograms per hectare to pounds per acre:
      | | | |     ACTFOL(IH, IS) =
     *| | | |      FOL(IH, IS) * (1.0 - (DEFL(IH, IS)/100.0))*
     *| | | |      1.12086
      | | | +--ENDIF
      | | +--ENDDO
      | +--ENDDO
      |
c  If IDEFOL is false or defoliation has not been scheduled for
c  this year then no defoliation will occur - set all
c  values of DEFL to zero and ACTFOL to FOL.
      |
      +--ELSE
      | +--DO IH = 1, NHOSTS
      | | +--DO IS = 1, 2
      | | |     DEFL(IH, IS) = 0.0
      | | | +--IF (METRIC) THEN
      | | | |     ACTFOL(IH, IS) = FOL(IH, IS)
      | | | +--ELSE
      | | | |     ACTFOL(IH, IS) = FOL(IH, IS) * 2.2046
      | | | +--ENDIF
      | | +--ENDDO
      | +--ENDDO
      +--ENDIF
         RETURN
         END
c *****  END of subroutine DEFOL, file name: DEFOL.FOR  *****
```

```
c       *****   Subroutine FLUPDT, file: FOLUPDTE.FOR   *****
c A portion of the:
c Stand-Damage Model - a portion of the Gypsy Moth Life System Model
c       (the stand submodel) converted to a stand-alone model.  Last
c       revised by K.Sheehan January 1988; revised starting in 1989
c       by Colbert and Racin.
c
c              J. Colbert, Northeastern Forest Experiment Station
c            180 Canfield St., Morgantown, WV  26505  (304)-285-1600

c This is a part of the Stand-Damage Model, part of the Gypsy Moth
c Life System Model.  This subroutine calculates the function that
c accounts for the effects of last year's defoliation on this
c year's foliage production.  DEFL= % defoliation last year.
c This simple linear function was arbitrarily selected by K.SHEEHAN.
c Called by the main program DAMSR.
c No calls made to other routines.

c  **  Local variables, parameters, and inputs required
c                               by Subroutine FLUPDT **
c  The following designations for LOCATIONs apply:
c        (1) - l := local variable
c        (2) - n := new parameter; not yet assigned to a common block
c        (3) - cp:= call parameter of this subroutine
c        (4) - s := subroutine called from within this code
c        (5) -XXN:= CAPS or CAPS+digit indicate a common block name
c-------------------------------------------------------------
c NAME - LOCATION - DESCRIPTION
c-------------------------------------------------------------
c DEFL       S3   - Percent defoliation, by host and strata
c DFOLDE     S3   - Slope of defoliation curve
c FOL        S3   - Potential foliage biomass by host and strata
c IH         l    - Host index
c IS         l    - Index for overstory and understory
c IYEAR      GEN1 - Current year in the simulation
c LYEAR      l    - "Last year"
c NHOSTS     GEN1 - Number of hosts to be simulated
c-------------------------------------------------------------

       SUBROUTINE FLUPDT

c  **** Include blocks  ****
       INCLUDE 'GEN1.CMB'
       INCLUDE 'S3.CMB'

       LYEAR = IYEAR - 1
     +--DO IH = 1, NHOSTS
     | +--DO IS = 1, 2
     | |     IF (LYEAR .NE. 0) FOL(IH, IS) = FOL(IH, IS) * (1.0 -
    *| |      (DEFL(IH, IS)/100.0) * DFOLDE)
     | +--ENDDO
     +--ENDDO
       RETURN
       END
C ***  End of Subroutine FLUPDT -- File name: FOLUPDTE.FOR  ***
```

```
c        ******   Subroutine GNXTMG, file: GETNXTMG.FOR   *****
c A portion of the:
c Stand-Damage Model - a portion of the Gypsy Moth Life System Model
c        (the stand submodel) converted to a stand-alone model.  Last
c        revised by K.Sheehan January 1988; revised starting in 1989
c        by Colbert and Racin.
c
c               J. Colbert, Northeastern Forest Experiment Station
c             180 Canfield St., Morgantown, WV  26505  (304)-285-1600
c    This section brings in the next management year and action type.
c Called from main program DAMSR.
c No subroutines are called by this routine.
c  **  local variables, parameters, and inputs required
c                                  by subroutine GNXTMG   **
c  the following designations for locations apply:
c         (1) - l := local variable
c         (2) - n := new parameter; not yet assigned to a common block
c         (3) - cp:= call parameter of this subroutine
c         (4) - s := subroutine called from within this code
c         (5) -XXN:= caps or caps+digit indicate a common block name
c  ---------------------------------------------------------------
c Name - Location - Description
c  ---------------------------------------------------------------
c ISYEAR      GEN1  - Current calendar year
c JTIN        GEN1  - Input handle for file TREEDATA.D1S: stand & tree--
c                     data and parameters.
c MANAGE      S4    - Management type code: 1 or 2 only.
c MTOTAL      S4    - Total number of management entries for this
c                     simulation.
c MYEARS      S4    - Management year of next scheduled entry.
c  ---------------------------------------------------------------
         SUBROUTINE GNXTMG
10000    FORMAT (1X, I4, 1X, I1)
c ****  Include blocks  ****
         INCLUDE 'GEN1.CMB'
         INCLUDE 'S4.CMB'
c If stand management has taken place this year, MYEARS is equal to
c ISYEAR, and if there is additional management to follow, MTOTAL is
c greater than 0, so get the next year in which management will take
c place, MYEARS, and the management type, MANAGE, after decrementing
c by 1, the number of management years remaining.
      +--IF (MTOTAL .GT. 0 .AND. MYEARS .EQ. ISYEAR) THEN
```

```
        |     MTOTAL = MTOTAL - 1
        |     READ (JTIN, 10000) MYEARS, MANAGE
        |
        +--ENDIF
           RETURN
           END

c  End of subroutine GNXTMG  --  file name GETNXTMG.FOR
```

```
c       *****   Subroutine GTCRWD, file: GETCROWD.FOR   *****
c A portion of the:
c Stand-Damage Model - a portion of the Gypsy Moth Life System Model
c       (the stand submodel) converted to a stand-alone model.  Last
c       revised by K.Sheehan January 1988; revised starting in 1989
c       by Colbert and Racin.
c
c              J. Colbert, Northeastern Forest Experiment Station
c            180 Canfield St., Morgantown, WV  26505  (304)-285-1600

c Called by TREE21.
c No subroutines are called by this routine.
c  **  Local variables, parameters, and inputs required
c                                      by Subroutine GTCRWD **
c  The following designations for LOCATIONs apply:
c        (1) - l := local variable
c        (2) - n := new parameter; not yet assigned to a common block
c        (3) - cp:= call parameter of this subroutine
c        (4) - s := subroutine called from within this code
c        (5) -XXN:= CAPS or CAPS+digit indicate a common block name
c  ---------------------------------------------------------------
c NAME - LOCATION - DESCRIPTION
c  ---------------------------------------------------------------
c CROWD      S2    - Crowding index (a tree growth modifier)
c CRWDMN     S2    - Minimum crowding index value; parameter available
c                    to user.
c RSMULT     S2    - Relative stocking multiplier, used to account for
c                    the effects of relative stocking on tree growth
c RSTOCK     S3    - Relative stocking index for the stand
c  ---------------------------------------------------------------

        SUBROUTINE GTCRWD

c  ****  Include blocks  ****
        INCLUDE 'S2.CMB'
        INCLUDE 'S3.CMB'


c Calculate the stand competition factor ("CROWD") as a function of the
c relative stocking index (RSTOCK, calc. a la Silvah) and RSMULT
c (arbitrarily set by K.Sheehan). CROWD is constrained and has a minimum
c value of 0.75, the user accessible value of the parameter CRWDMN.

        CROWD = 1.0 - (RSTOCK*RSMULT)
        IF (CROWD .LT. CRWDMN) CROWD = CRWDMN


        RETURN
        END

C  End of subroutine GTCRWD  --  file name GETCROWD.FOR
```

```

c       *****    Subroutine INITW, file: INITW.FOR   *****
c A portion of the:
c Stand-Damage Model - a portion of the Gypsy Moth Life System Model
c       (the stand submodel) converted to a stand-alone model.  Last
c       revised by K.Sheehan January 1988; revised starting in 1989
c       by Colbert and Racin.
c
c              J. Colbert, Northeastern Forest Experiment Station
c            180 Canfield St., Morgantown, WV  26505  (304)-285-1600

c Read parameter values & initial conditions from file with handle JWIN
c Called by the main program DAMSR.
c No calls made to other routines.

c  **  Local variables, parameters, and inputs required
c                                   by Subroutine INITW **
c  The following designations for LOCATIONs apply:
c        (1) - l := local variable
c        (2) - n := new parameter; not yet assigned to a common block
c        (3) - cp:= call parameter of this subroutine
c        (4) - s := subroutine called from within this code
c        (5) -XXN:= CAPS or CAPS+digit indicate a common block name
C        (6) - G := GLOBAL Microsoft parameter.
c  ---------------------------------------------------------------
c NAME - LOCATION - DESCRIPTION
c  ---------------------------------------------------------------
c ANNDD   WTHR1   - Total annual degree days for each year of simulation
c     (100)         up to 100 years possible.
c DEBUG    LOG1   - Logical variable, true for DEBUG output generation
c IFS0       l    - Local variable holding READ error return code.
c IOSTAT     g    - FORTRAN I/O status parameter.
c IY         l    - Year index for reading annual totals of degree-days
c                   for each year (IY = 1, ..., NYEARS).
c JDB       GEN1  - Logical unit number for DEBUG output writing.
c JWIN      GEN1  - Logical unit number for weather data input.
c NYEARS    GEN1  - Number of years to simulate; less than or equal to
c                   100.
c  ---------------------------------------------------------------

        SUBROUTINE INITW

        INTEGER IFS0

10000   FORMAT (' INITW;1010: NYEARS = ', I3)
10010   FORMAT (F7.1)
10020   FORMAT (' INITW;2000: IY, ANNDD(IY)'/100(11X, I4, 3X, F8.2/))

        INCLUDE 'GEN1.CMB'
        INCLUDE 'WTHR1.CMB'
        INCLUDE 'LOG1.CMB'

c ************************************************************
c   Read weather information.
c ************************************************************
```

```
      REWIND (JWIN)
      IF (DEBUG) WRITE (JDB, 10000) NYEARS
      READ (JWIN, 10010, IOSTAT = IFS0) (ANNDD(IY), IY = 1, NYEARS)
      IF (IFS0 .LT. 0) WRITE(*, *) 'EOF found on file handle JWIN =',
     *  JWIN
      IF (DEBUG) WRITE (JDB, 10020) (IY, ANNDD(IY), IY = 1, NYEARS)
      RETURN
      END

c ***   END of subroutine INITW -- file name: INITW.FOR    ***
```

```
c   *****   Subroutine PINIT, file: PINIT.FOR   *****
c A portion of the:
c Stand-Damage Model - a portion of the Gypsy Moth Life System Model
c       (the stand submodel) converted to a stand-alone model.  Last
c       revised by K.Sheehan January 1988; revised starting in 1989
c       by Colbert and Racin.
c
c              J. Colbert, Northeastern Forest Experiment Station
c            180 Canfield St., Morgantown, WV  26505  (304)-285-1600

c Print parameter values & initial conditions for the STAND submodel.
c Called by the main program DAMSR.
c Calls made by this routine to PRNOTE and PTSTBL.

c  **  Local variables, parameters, and inputs required
c                                 by Subroutine PINIT  **
c  The following designations for LOCATIONs apply:
c         (1) - l := local variable
c         (2) - n := new parameter; not yet assigned to a common block
c         (3) - cp:= call parameter of this subroutine
c         (4) - s := subroutine called from within this code
c         (5) -XXN:= CAPS or CAPS+digit indicate a common block name
c-------------------------------------------------------------------
c   NAME - LOCATION - DESCRIPTION
c-------------------------------------------------------------------
c AGEMAX       S1   - Maximum tree age by host
c BDIE         S1   - Background tree mortality rate, by host
c B1           S1   - For calculating tree height
c B2           S1   - For calculating tree height
c COLD         S1   - Minimum annual degree-days tolerated, by host
c CR1          S1   - CR(1-4): tree species specific parameters for
c CR2          S1     predicting live crown ratio from stand basal area
c CR3          S1     and tree diameter.
c CR4          S1
c DMAX           S1   - Maximum DBH (cm.) by host
c FDIE         S1   - Proportion of trees that die because of defol.,
c                     based on host, no. of years of defol., and site
c F1           S1   - For calculating foliage biomass / tree
c F2           S1   - For calculating foliage biomass / tree
c GROWR        S1   - For calculating potential annual diam. growth
c HMAX         S1   - Max. height (cm), by host
c HOT          S2   - Max. annual degree-days tolerated, by host
c HOVER        S2   - Height or diam. that separates over- & understory
c               trees
c I            l    - Index
c IBOUND       S4   - Overstory/understory boundary type: 1 = height (ft
c               or cm), 2=diam. (in or cm)
c IDHIST       S3   - Defoliation history for past two years: 0 = none,
c               1=light, 2 = medium, 3=heavy; by host and strata
c IH           l    - Host index
c IPYEAR       GEN1 - Interval in years for printing stand output
c IS           l    - Index for overstory and understory
c ISEED        GEN1 - Random number seeds: 1=recruitment of new trees,
c                     2=not used at this time, 3=additional tree
c                     mortality due to stress, 4=add. gypsy moth
```

```
c                         mortality due to winter temp., 5=for weather
c                         generation, 6= GM L1 disp.
c ISHADE      S4    - Shade tolerance class by species (2=diam. growth,
c                         1=recruitment)
c ISITE       S4    - Index for site (1=moist, 2=intermediate, 3=dry)
c ISOPT       S4    - Tree stress option (1=stress occurs in random
c                         years, 2=user specifies stress years
c ISTOKG      S1    - Relative stocking class, by host
c ISTR        S4    - Array to hold the Years that stress will occur
c                         (set by user) -- used for table display only.
c ISTRYR      S4    - Use to decide when to add stress STRFAC(2) as SDIE
c ISYEAR      GEN1 - Starting year; example: 1987
c IWOPT       GEN1 - Weather option(1= 1 yr of data, 2= >1 yr of data
c                         3= generate data with subr. WGEN, 4 = use annual
c                         total degree-days (GMOTH)
c IY          1     - Year index
c J           1     - Index
c JSOUT1      GEN1 - File number: stand output
c JSTRS       GEN1 - File number: stress years
c K           1     - Index
c LDEFOL      LOG2 - True if data to be read in from LUN 14=JDEF
c METRIC      LOG2 - True if input/output units are to be metric
c MTOTAL      S4    - Total management years
c NDEF        1     - Number of years of heavy defoliation (above 65%)
c NHOSTS      GEN1 - Number of hosts to simulate
c NLINES      GEN1 - Number of lines
c NSTRYR      S4    - Number of stress years
c NWEAYR      GEN1 - Number of years of weather data provided by user
c NYEARS      GEN1 - Number of years to be simulated
c NYRS        1     - Set to NSTRYR
c PLOTAR      S3    - Total sample plot area -- used to calculate
c                         number of stems/ha
c PLOTSZ      S2    - Area for calc. influence of surrounding trees on
c                         shading of a given tree
c PRNOTE      s
c PTSTBL      s
c RECRUT      S1    - Maximum number of seedlings that can be recruited
c                  into the smallest diameter class, by host
c RESTIN      S1    - Number of resting sites per 100 sq. cm., by host
c                         and location of tree
c RNSPC1      CHAR1- User supplied char. strings (input data file name)
c RNSPC2      CHAR1- User supplied char. strings (user name)
c RNSPC3      CHAR1- User supplied char. strings (job name)
c RNSPC4      CHAR1- User supplied char. strings (site name)
c RNSPC5      CHAR1- User supplied char. strings (date)
c RSMULT      S2    - Relative stocking index for the stand
c SHADMN      S1    - Minimum value for SHADE in equation 16.  This
c                         minimum value is used for all species & diameters.
c SHX         S1    - Effect of light on diam. growth by shade tolerance
c                         index
c SHY         S1    - Effect of light on diam. growth by shade tolerance
c                         index
c SLOWD       S1    - Minimum annual growth needed to avoid additional
c                         mortality
c STABLE      LOG2 - True if stand submodel output is desired
```

```
c STNDAR        S3    - Area of stand
c STOKX         S1    - For effect of relative stocking on recruitment
c STOKY         S1    - For effect of relative stocking on recruitment
c STRESS        S1    - Probability that stand on site ISITE will not be
c                       subject of additional unspecified stress
c STRFAC        S1    - Proportion of trees that die because of stress
c SURFAR        S1    - Foliage biomass to surface area conversion factor
c TEMPMN        S1    _ Minimum value for variable TEMP in equation 11(b).
c TFAC          WTHR1- Multiplier used to change all temp. values by a
c                       certain proportion
c TKL           S2    - For calculating available light
c TLIGHT        S2    - For calculating available light
c TNAME         CHAR1- Tree code, by host
c TRETHR        WTHR1- Threshold temp. used by stand submodel to
c                       calculate total annual degree-days
c UNITS         CHAR1- 'METRIC' or 'ENGLISH'
c UNITS2        CHAR1- 'HA' or 'AC'
c UNITS3        CHAR1- 'CM' or 'IN'
c UNITS4        CHAR1- 'FT'
c X             1     - Probability that defoliated trees have additional
c                       mortality due to stress
c-------------------------------------------------------------

            SUBROUTINE PINIT
10000       FORMAT (5X, '***  User supplied input/output information ***'/,
     *       10X, 'Input Data File Name: ', A12/, 21X, 'User Name: ', A20/,
     *       22X, 'Job Name: ', A20/, 21X, 'Site Name: ', A20/, 26X,'Date:'
     *       , A20)
10010       FORMAT (16X, 'DAMAGE MODEL VERSION 1.1: ', A20/)
10020       FORMAT (' No. of Years to be Simulated: ', I3, T50, 'UNITS: ',
     *       A7, T80, 'RANDOM NUMBER SEEDS -- '/
     *       '  First Year of Simulation: ', I4, T50, 'Stand Area: ', F7.1,
     *       1X, A2, T90, 'Stem Recruitment: ', I7, /,
     *      ' Output to be produced Every ', I2, ' Years', T50,
     *       'Total Sample Plot area: ', F7.1, 1X, A2,T90,'Add. Tree Mort',
     *       '. due to Stress: ', I7, /, T50, 'Site moisture Index: ', I2)
10030       FORMAT (/, ' No Defoliation prescribed for this simulation.'/)
10040       FORMAT (/, ' Defoliation data will be read from file: ',
     *       'DEFOLDAT.D1S'/)
10050       FORMAT (/'  OVERSTORY / UNDERSTORY BOUNDARY (BASED ON ',
     *       ' HEIGHT): ', F7.2, '  (', A2, ')')
10060       FORMAT (/'  OVERSTORY / UNDERSTORY BOUNDARY (BASED ON ',
     *       ' DIAMETER): ', F7.2, '  (', A2, ')')
10070       FORMAT (/, '  SHADING PARAMETERS: TLIGHT= ', F4.1, 2X, 'TKL= ',
     *       F7.5, 2X, 'SHADMN= ',F4.2, 2X, 'PLOT SIZE FOR SHADING=', F7.4,
     *       1X, A2, //
     *       '  EFFECT OF AVAIL. LIGHT ON DIAM. GROWTH, BY TOLERANCE',
     *       ' CLASSES  (PROP. AVAIL. LIGHT, PROP. OF POT. GROWTH):'/,
     *       ' TOL. CLASS:        1            2             ',
     *       '3            4            5          ', '     6', /, 12X, 6(
     *       ' ----------- ')/4(10X, 6(F7.2, ',', F5.2)/))
10080       FORMAT ('  MULTIPLIER FOR EFFECT OF RELATIVE STOCKING ON ',
     *       'DIAMETER GROWTH: ', F7.4/'  EFFECT OF REL. STOCKING ON ',
     *       'RECRUITMENT, BY TOLERANCE CLASSES (REL. STOCKING, PROP. ',
     *       'OF POT. RECRUIT.):'/' TOL. CLASS:        '
```

```
     *    '1             2               3              4               5',
     *    '              6', /13X, 6(' ---------- ')/, 4(12X, 6(F6.0, ',',
     *    F5.2)/))
10090     FORMAT (' PROBABILITY THAT DEFOLIATED TREES HAVE ',
     *    'ADDITIONAL MORTALITY DUE TO STRESS = ', F7.3)
10100     FORMAT (' DEFOLIATED TREES MAY HAVE ADDITIONAL MORTALITY',
     *    ' DUE TO STRESS IN THE FOLLOWING YEARS: '/)
10110     FORMAT (1X, I4)
10120     FORMAT (10X, 15(I4, 2X))
10130     FORMAT (' No additional stress included (ISOPT = 0).')
10140     FORMAT (' ADDITIONAL MORTALITY IN YEARS WITH NO STRESS: ',F5.2,
     *    ',        IN YEARS WITH STRESS: ', F5.2/)
10150     FORMAT (1X, I5, ' YEARS OF WEATHER DATA READ FROM FILE WDATA.')
10160     FORMAT (3X, I3, ' YEARS OF WEATHER DATA GENERATED FROM ',
     *    'PARAMETERS IN FILE WDATA.')
10170     FORMAT (2X, I3, ' Years of weather summary data, accumulated ',
     *    'degree-days for each year in data file: ANNDDSUM.D1S')
10180     FORMAT (' Tree Threshold Temperature: ', F6.1, 5X,
     *    'Temperature Multiplier: ', F6.1, 5X, 'Minimum Value for '
     *    'variable TEMP: ',1F4.2)
10190     FORMAT (/' PARAMETERS THAT VARY WITH TREE SPECIES --', //
     *    '     SPECIES CODE:', 13X, 12(6X, A3))
10195     FORMAT (34X, 12(A))
10200     FORMAT (' Relative Stocking Class', 7X, 12(8X, I1))
10210     FORMAT (' Recruitment Tolerance Class   ', 12(8X, I1))
10220     FORMAT (' Diam. Growth Tolerance Class  ', 12(8X, I1))
10230     FORMAT (' Maximum Diam. (', A2, ') ', 12X, 12(4X, F5.0))
10240     FORMAT (' Maximum Height (', A2, ')', 12X, 12(2X, F7.0))
10250     FORMAT (' Maximum Age (Years)', 12X, 12(4X, F5.0))
10260     FORMAT (' Minimum Annual Day-Deg.s', 7X, 12(2X, F7.0))
10270     FORMAT (' Maximum Annual Day-Deg.s', 7X, 12(2X, F7.0))
10280     FORMAT (' Diam. Growth Parameter  ', 7X, 12(3X, F6.1))
10290     FORMAT (' Height Parameter B1 ', 11X, 12(2X, F7.2))
10300     FORMAT (' Height Parameter B2  ', 10X, 12(2X, F7.4))
10310     FORMAT (' Foliage Biomass Param. F1 ', 5X, 12(1X, F8.5))
10320     FORMAT (' Foliage Biomass Param. F2 ', 5X, 12(2X, F7.4))
10330     FORMAT (' Surface Area::Biomass Ratio', 4X, 12(4X, F5.1))
10340     FORMAT (' Max. Annual Tree Recruitment   ', 12(3X, F6.0))
10350     FORMAT (' Bole Resting Sites / 100 sq. cm', 12(2X, F7.4))
10355     FORMAT (' Bole Resting Sites / sq. ft.   ', 12(2x, F7.4))
10360     FORMAT (' Crown Resting Sites / 100 sq.cm', 12(2X, F7.4))
10365     FORMAT (' Crown Resting Sites / sq. ft.  ', 12(2X, F7.4))
10370     FORMAT (' Live Crown Ratio Parameters 1: ', 12(3X, F6.2))
10380     FORMAT (29X, ' 2: ', 12(2X, F7.4))
10390     FORMAT (29X, ' 3: ', 12(4X, F5.2))
10400     FORMAT (29X, ' 4: ', 12(3X, F6.3))
10410     FORMAT (' Add. Mort. When Growth Slowed ', 12(3X, F6.3))
10420     FORMAT (' Base mortality rate         ', 5X, 12(1X, F8.5))
10430     FORMAT (/)
10440     FORMAT (/' Tree Mortality Rates Following Heavy Defoliation:',
     *    /14X, 'YEARS OF HEAVY DEFOL.'/, ' SPECIES', 6X, '1', 8X, '2',
     *    8X, '3', /, ' -----', 3(4X, '-----'), 12(/, 4X, A3, 1X, 3F9.2)
     *    , /)
10450     FORMAT (' No Stand Treatments Scheduled'/)
10460     FORMAT (' STAND TREATMENTS SCHEDULED: ', I4, ' years have ',
```

```
     *    'been requested; input parameters'/, 35X, 'and results will '
     *    'be printed at the years requested.'/)
10470    FORMAT (/, '  DEFOLIATION HISTORY:', 1X, 12(6X, A3, 3X))
10480    FORMAT (25X, 12(A))
10490    FORMAT ( '    % Defol. 1 Year Ago:', 12(1X, I5, I6))
10500    FORMAT ('   % Defol. 2 Years Ago:', 12(1X, I5, I6))
10510    FORMAT (//)

c ** Common Blocks included:

         INCLUDE 'CHAR1.CMB'
         INCLUDE 'GEN1.CMB'
         INCLUDE 'LOG1.CMB'
         INCLUDE 'LOG2.CMB'
         INCLUDE 'S1.CMB'
         INCLUDE 'S2.CMB'
         INCLUDE 'S3.CMB'
         INCLUDE 'S4.CMB'
         INCLUDE 'WTHR1.CMB'

c              FILE HANDLES FOR OUTPUTS:
c  File No.                                   Var. Name
c       13 = Stand table                       JSOUT1
c       15 = Stand graph file - No. Stems      JSOUT2
c       16 = Stand graph file - Basal Area     JSOUT3
c       17 = Stand graph file - Volume         JSOUT4
c       18 = Stand graph file - DBH            JSOUT5
c
c              FILE HANDLES FOR INPUTS:
c  File No.                                   Var. Name
c       14 = Defoliation estimates             JDEF

c ************************************************************
c   Print initial conditions
c ************************************************************
      +--IF (STABLE) THEN
      |    WRITE (JSOUT1, 10000) RNSPC1, RNSPC2, RNSPC3, RNSPC4, RNSPC5
      | +--IF (NLINES .GT. 0) THEN
      | |    WRITE (JSOUT1, '(//)')
      | |    CALL PRNOTE(JSOUT1, NLINES)
      | +--ENDIF
      |    WRITE (JSOUT1,'(A1)') '\f'C
      |    WRITE (JSOUT1, 10010) 'PARAMETER VALUES '
      |
      | +--IF (METRIC) THEN
      | |    UNITS = 'METRIC '
      | |    UNITS2 = 'HA'
      | |    UNITS3 = 'CM'
      | |    UNITS4 = 'M.'
      | +--ELSE
      | |    UNITS = 'ENGLISH'
      | |    UNITS2 = 'AC'
      | |    UNITS3 = 'IN'
      | |    UNITS4 = 'FT'
      | +--ENDIF
```

```
     | +--IF (METRIC) THEN
     | |    WRITE (JSOUT1, 10020) NYEARS, UNITS, ISYEAR, STNDAR,
    *| |     UNITS2, ISEED(1), IPYEAR, PLOTAR,
    *| |     UNITS2, ISEED(3), ISITE
     | +--ELSE
     | |    WRITE (JSOUT1, 10020) NYEARS, UNITS, ISYEAR,
    *| |     (STNDAR*2.471044), UNITS2, ISEED(1),
    *| |     IPYEAR, (PLOTAR*2.471044), UNITS2,
    *| |     ISEED(3), ISITE
     | +--ENDIF
     | +--IF (LDEFOL) THEN
     | |    WRITE (JSOUT1, 10040)
     | +--ELSE
     | |    WRITE (JSOUT1, 10030)
     | +--ENDIF
     | +--IF (METRIC) THEN
     | | +--IF (IBOUND .EQ. 1) THEN
     | | |    WRITE (JSOUT1, 10050) HOVER/100.0, UNITS4
     | | +--ELSE
     | | |    WRITE (JSOUT1, 10060) HOVER, UNITS3
     | | +--ENDIF
     | |    WRITE (JSOUT1, 10070) TLIGHT, TKL, SHADMN, PLOTSZ, UNITS2,
    *| |     ((SHX(K, J), SHY(K,J), K = 1, 6), J = 1, 4)
     | +--ELSEIF (IBOUND .EQ. 1) THEN
     | |    WRITE (JSOUT1, 10050) (HOVER/30.48), UNITS4
     | |    WRITE (JSOUT1, 10070) TLIGHT, TKL, SHADMN, PLOTSZ*2.471044,
    *| |     UNITS2, ((SHX(K, J), SHY(K,J), K = 1, 6), J = 1, 4)
     | +--ELSE
     | |    WRITE (JSOUT1, 10060) (HOVER/2.54), UNITS3
     | |    WRITE (JSOUT1, 10070) TLIGHT, TKL, SHADMN, PLOTSZ*2.471044,
    *| |     UNITS2, ((SHX(K, J), SHY(K,J), K = 1, 6), J = 1, 4)
     | +--ENDIF
     |    WRITE (JSOUT1, 10080) RSMULT, ((STOKX(I, J), STOKY(I, J), I =
    *|     1, 6), J = 1, 4)
     |
     |
     | +--IF (ISOPT .EQ. 1) THEN
     | |    X = 1 - STRESS(ISITE)
     | |    WRITE (JSOUT1, 10090) X
     | +--ELSEIF (ISOPT .EQ. 2) THEN
     | |    WRITE (JSOUT1, 10100)
c  ISTR(IYEAR) = Years that users specifies are stress years.
c    | | This array is used only for the display of data that is read
c    | | into this routine for inclusion in the output table.  The file
c    | | that contains the years that stress will occur is then re-
c    | | wound and the first value is placed in variable ISTRYR for use
c    | | in TREE21 to decide when to add the stress STRFAC(2) as SDIE.
     | |    OPEN (11, FILE = 'STRESYRS.DlS', STATUS = 'OLD')
     | |    JSTRS = 11
     | |    NYRS = NSTRYR
     | | +--DO WHILE (NYRS .GT. 15)
     | | |    READ (JSTRS, 10110) (ISTR(IY), IY = 1, 15)
     | | |    WRITE (JSOUT1, 10120) (ISTR(IY), IY = 1, 15)
     | | |    NYRS = NYRS - 15
     | | +--ENDDO
```

```
| |     READ (JSTRS, 10110) (ISTR(IY), IY = 1, NYRS)
| |     WRITE (JSOUT1, 10120) (ISTR(IY), IY = 1, NYRS)
| |     REWIND (JSTRS)
| |     READ (JSTRS, 10110) ISTRYR
| |     NSTRYR = NSTRYR - 1
| +--ELSE
| |     WRITE (JSOUT1, 10130)
| +--ENDIF
|       WRITE (JSOUT1, 10140) STRFAC(1), STRFAC(2)
| +--IF (IWOPT .LT. 3) THEN
| |     WRITE (JSOUT1, 10150) NWEAYR
| +--ELSEIF (IWOPT .EQ. 3) THEN
| |     WRITE (JSOUT1, 10160) NWEAYR
| +--ELSE
| |     WRITE (JSOUT1, 10170) NYEARS
| +--ENDIF
|       WRITE (JSOUT1, 10180) TRETHR, TFAC, TEMPMN
|       WRITE (JSOUT1, 10190) (TNAME(I), I = 1, NHOSTS)
|       WRITE (JSOUT1, 10195) (' ------- ', I = 1, NHOSTS)
|       WRITE (JSOUT1, 10200) (ISTOKG(I), I = 1, NHOSTS)
|       WRITE (JSOUT1, 10210) (ISHADE(I, 1), I = 1, NHOSTS)
|       WRITE (JSOUT1, 10220) (ISHADE(I, 2), I = 1, NHOSTS)
| +--IF (METRIC) THEN
| |     WRITE (JSOUT1, 10230) UNITS3, (DMAX(I), I = 1, NHOSTS)
| |     WRITE (JSOUT1, 10240) UNITS4, (HMAX(I)/100.0, I=1, NHOSTS)
| +--ELSE
| |     WRITE (JSOUT1, 10230) UNITS3,(DMAX(I)/2.54001, I=1,NHOSTS)
| |     WRITE (JSOUT1, 10240) UNITS4,(HMAX(I)/30.48012, I=1,NHOSTS)
| +--ENDIF
|       WRITE (JSOUT1, 10250) (AGEMAX(I), I = 1, NHOSTS)
| +--IF (METRIC) THEN
| |     WRITE (JSOUT1, 10260) (COLD(I)/1.8, I = 1, NHOSTS)
| |     WRITE (JSOUT1, 10270) (HOT(I)/1.8, I = 1, NHOSTS)
| +--ELSE
| |     WRITE (JSOUT1, 10260) (COLD(I), I = 1, NHOSTS)
| |     WRITE (JSOUT1, 10270) (HOT(I), I = 1, NHOSTS)
| +--ENDIF
|       WRITE (JSOUT1, 10280) (GROWR(I), I = 1, NHOSTS)
|       WRITE (JSOUT1, 10290) (B1(I), I = 1, NHOSTS)
|       WRITE (JSOUT1, 10300) (B2(I), I = 1, NHOSTS)
|       WRITE (JSOUT1, 10310) (F1(I), I = 1, NHOSTS)
|       WRITE (JSOUT1, 10320) (F2(I), I = 1, NHOSTS)
|       WRITE (JSOUT1, 10330) (SURFAR(I), I = 1, NHOSTS)
| +--IF (METRIC) THEN
| |     WRITE (JSOUT1, 10340) (RECRUT(I), I = 1, NHOSTS)
| |     WRITE (JSOUT1, 10350) (RESTIN(I, 1), I = 1, NHOSTS)
| |     WRITE (JSOUT1, 10360) (RESTIN(I, 2), I = 1, NHOSTS)
| +--ELSE
| |     WRITE (JSOUT1, 10340) ((RECRUT(I)*0.404687), I = 1, NHOSTS)
| |     WRITE (JSOUT1, 10355) ((RESTIN(I, 1)*9.29), I = 1, NHOSTS)
| |     WRITE (JSOUT1, 10365) ((RESTIN(I, 2)*9.29), I = 1, NHOSTS)
| +--ENDIF
|       WRITE (JSOUT1, 10370) (CR1(I), I = 1, NHOSTS)
|       WRITE (JSOUT1, 10380) (CR2(I), I = 1, NHOSTS)
|       WRITE (JSOUT1, 10390) (CR3(I), I = 1, NHOSTS)
```

```
        |     WRITE (JSOUT1, 10400) (CR4(I), I = 1, NHOSTS)
        | +--IF (METRIC) THEN
        | |     WRITE (JSOUT1, 10410) (SLOWD(I), I = 1, NHOSTS)
        | +--ELSE
        | |     WRITE (JSOUT1, 10410) ((SLOWD(I)/2.54001), I = 1, NHOSTS)
        | +--ENDIF
        |     WRITE (JSOUT1, 10420) (BDIE(I), I = 1, NHOSTS)
        |     WRITE (JSOUT1, 10430)
        |     WRITE (JSOUT1, 10440) (TNAME(I), (FDIE(I, NDEF, ISITE),
       *|      NDEF = 1, 3), I = 1, NHOSTS)
        |
        |
        | +--IF (MTOTAL .EQ. 0) THEN
        | |     WRITE (JSOUT1, 10450)
        | +--ELSE
        | |     WRITE (JSOUT1, 10460) MTOTAL
        | |     MTOTAL = MTOTAL - 1
        | +--ENDIF
        |     WRITE (JSOUT1,'(A1)') '\f'C
        |     WRITE (JSOUT1, 10010) ' INITIAL CONDITIONS'
        |     CALL PTSTBL()
        |     WRITE (JSOUT1, 10470) (TNAME(I), I = 1, NHOSTS)
        |     WRITE (JSOUT1, 10480) (' OVER UNDER ', I = 1, NHOSTS)
        |     WRITE (JSOUT1, 10480) (' ---- ----- ', I = 1, NHOSTS)
        |     WRITE (JSOUT1, 10490) ((IDHIST(IH, IS, 1), IS = 1, 2),
       *|      IH = 1, NHOSTS)
        |     WRITE (JSOUT1, 10500) ((IDHIST(IH, IS, 2), IS = 1, 2),
       *|      IH = 1, NHOSTS)
        |     WRITE (JSOUT1, 10510)
        |
        +--ENDIF
           RETURN
           END

c *** END of subroutine PINIT -- file PINIT.FOR
```

```
c         ***** Subroutine PRNOTE, file: PRNTNOTE.FOR *******
c A portion of the:
c Stand-Damage Model - a portion of the Gypsy Moth Life System Model
c       (the stand submodel) converted to a stand-alone model.  Last
c       revised by K.Sheehan January 1988; revised starting in 1989
c       by Colbert and Racin.
c
c              J. Colbert, Northeastern Forest Experiment Station
c            180 Canfield St., Morgantown, WV  26505  (304)-285-1600

c Produces a copy of the user's input notes as part of the output
c table header information; writes them to the Stand Table file.
c Called from: subroutine PINIT, at the beginning of the writing of the
c              Stand Table output.
c No calls to other routines.

c  **  Local variables, parameters, and inputs required
c                           by Subroutine PRNTNOTE(OUTHDL, LENGTH) **
c  The following designations for LOCATIONs apply:
c        (1) - l := local variable
c        (2) - n := new parameter; not yet assigned to a common block
c        (3) - cp:= call parameter of this subroutine
c        (4) - s := subroutine called from within this code
c        (5) -XXN:= CAPS or CAPS+digit indicate a common block name
c-------------------------------------------------------------
c NAME - LOCATION - DESCRIPTION
c-------------------------------------------------------------
c BUFFER    l       - Text buffer
c IFILE     l       - File handle for opening input data file.
c J         l      - Index
c LENGTH    cp      - Number of lines in notes file
c OUTHDL    cp      - Output device handle (number).
c-------------------------------------------------------------

          SUBROUTINE PRNOTE(OUTHDL, LENGTH)
10000     FORMAT (//, 5X,
     *    'User notes supplied through the Setup-Edit Job Description',/)


          CHARACTER*75 BUFFER
          INTEGER OUTHDL, LENGTH

          IFILE = 19
          OPEN (IFILE, FILE = 'USERNOTE.D1S', STATUS = 'OLD')
          WRITE (OUTHDL, 10000)
       +--DO J = 1, LENGTH
       |    READ (IFILE, '(A)') BUFFER
       |    WRITE (OUTHDL, '(A)') BUFFER
       +--ENDDO
          CLOSE (IFILE)
          RETURN
          END

c ***** End of subroutine PRNOTE, file: PRNTNOTE.FOR
```

```
c  *****   Subroutine PRTMGT, file: PRNTMGMT.FOR    *****
c A portion of the:
c Stand-Damage Model - a portion of the Gypsy Moth Life System Model
c        (the stand submodel) converted to a stand-alone model.  Last
c        revised by K.Sheehan January 1988; revised starting in 1989
c        by Colbert and Racin.
c
c              J. Colbert, Northeastern Forest Experiment Station
c             180 Canfield St., Morgantown, WV  26505  (304)-285-1600
c Writes the stand management treatments that have been scheduled
c to the Stand Table file.
c Called by subroutine TREE21.
c No calls made.
c  **  Local variables, parameters, and inputs required
c                                          by Subroutine PRTMGT  **
c  The following designations for LOCATIONs apply:
c         (1) - l := local variable
c         (2) - n := new parameter; not yet assigned to a common block
c         (3) - cp:= call parameter of this subroutine
c         (4) - s := subroutine called from within this code
c         (5) -XXN:= CAPS or CAPS+digit indicate a common block name
c  ----------------------------------------------------------------
c NAME - LOCATION - DESCRIPTION
c  ----------------------------------------------------------------
c CUTMAX      S4    - Maximum diam. to be cut, by host and year
c CUTMIN      S4    - Minimum diam. to be cut, by host and year
c IH          l     - Host tree species counter.
c JSOUT1      GEN1  - File number: stand output
c MANAGE      S4    - Stand management option: 0= no actions, 1= user
c                     specifies proportions to be cut, 2= user specifies
c                     target no. of stems
c METRIC      LOG2  - True if input/output units are to be metric
c MYEARS      S4    - Yrs that management actions have been scheduled
c NHOSTS      GEN1  - Number of hosts to be simulated
c NUMLIN      GEN1  - Line counter for setting page eject on stand
c                     table output file.
c PCUT        S4    - Proportion of trees to be cut, by host and yr
c T           l     - Local variable for TARGET
c TARGET      S4    - Target no. of residual stems (if MANAGE=2) for
c                     scheduled harvests, by yr and host
c TNAME       CHAR1- Tree code, by host
c UNITS3      CHAR1- Diameter limit units for treatment (cm).
c X           l     - Local variable for CUTMIN.
c Y           l     - Local variable for CUTMAX.
c  ----------------------------------------------------------------
        SUBROUTINE PRTMGT
 10000  FORMAT (/'  STAND TREATMENTS SCHEDULED: USER HAS SPECIFIED ',
     *   'TREATMENTS BY YEAR & SPECIES'/20X, 'PROPORTION NO.', 'STEMS',
     *   10X, 'DIAMETER LIMITS (', A2, ')', /, 5X,
     *   'YEAR  SPECIES  TO BE CUT  TO REMAIN   MINIMUM   ', 'MAXIMUM '
     *   /, 5X, '----  -------   ---------  ---------  ---------',
```

```
     *     '-  ---------'/)
10010     FORMAT (5X, I4, 3X, A3, 7X, F7.2, 16X, F6.1, 6X, F6.1)
10020     FORMAT (5X, I4, 3X, A3, 17X, F7.2, 6X, F6.1, 6X, F6.1)
10030     FORMAT (1X)


c **** Common Blocks Included:

          INCLUDE 'CHAR1.CMB'
          INCLUDE 'GEN1.CMB'
          INCLUDE 'LOG2.CMB'
          INCLUDE 'S2.CMB'
          INCLUDE 'S4.CMB'


          WRITE (JSOUT1, 10000) UNITS3
          NUMLIN = NUMLIN + 6

       +--DO IH = 1, NHOSTS
       | +--IF (METRIC) THEN
       | |     X = CUTMIN(IH)
       | |     Y = CUTMAX(IH)
       | |     T = TARGET(IH)
       | +--ELSE
c      | |   2.54001 cm/in. and 0.404687 ha/ac.
       | |     X = CUTMIN(IH)/2.54001
       | |     Y = CUTMAX(IH)/2.54001
       | |     T = TARGET(IH)*0.404687
       | +--ENDIF
       | +--IF (MANAGE .EQ. 1) THEN
       | |     WRITE (JSOUT1, 10010) MYEARS, TNAME(IH), PCUT(IH), X, Y
       | |     NUMLIN = NUMLIN + 1
       | +--ELSE
       | |     WRITE (JSOUT1, 10020) MYEARS, TNAME(IH), T, X, Y
       | |     NUMLIN = NUMLIN + 1
       | +--ENDIF
       +--ENDDO
          WRITE (JSOUT1, 10030)
          NUMLIN = NUMLIN + 1

          RETURN
          END

c *****   End of subroutine PRTMGT;  file name: PRNTMGMT.FOR  *****
```

```
c       *****   Subroutine PTSTBL, file: PRNTSTBL.FOR   *****
c A portion of the:
c Stand-Damage Model - a portion of the Gypsy Moth Life System Model
c       (the stand submodel) converted to a stand-alone model.  Last
c       revised by K.Sheehan January 1988; revised starting in 1989
c       by Colbert and Racin.
c
c              J. Colbert, Northeastern Forest Experiment Station
c            180 Canfield St., Morgantown, WV  26505  (304)-285-1600

c Writes (PrinTs) the Stand TaBLe (Stem counts by Species and Diameter
c                               Class).
c Called by the main program DAMSR and the subroutines
c        PINIT, TREE21, and TREE22.
c No calls to other routines.


c  **  Local variables, parameters, and inputs required
c                                by Subroutine PTSTBL **
c  The following designations for LOCATIONs apply:
c        (1) - l := local variable
c        (2) - n := new parameter; not yet assigned to a common block
c        (3) - cp:= call parameter of this subroutine
c        (4) - s := subroutine called from within this code
c        (5) -XXN:= CAPS or CAPS+digit indicate a common block name
c-------------------------------------------------------------------
c NAME - LOCATION - DESCRIPTION
c-------------------------------------------------------------------
c DIAM        S1    - Diameter at mid-point, by diam. class
c ID          l     - Diameter index
c IH          l     - Host index
c JSOUT1      GEN1  - File number; stand output
c METRIC      LOG2  - True if input/output units are to be metric
c NDIAM       S4    - Number of diam. classes to be simulated
c NHOSTS      GEN1  - Number of hosts to simulate
c NUMLIN      GEN1  - Number of lines printed; used for page eject
c STEMS       S1    - Number of stems, by host and diameter class
c TNAME       CHAR1 - Tree code, by host
c UNITS2      CHAR1- 'HA' or 'AC'
c UNITS3      CHAR1- 'CM' or 'IN'
c-------------------------------------------------------------------

      SUBROUTINE PTSTBL
10000 FORMAT (12X, 'NUMBER OF STEMS PER ', A2, ':', /64X,
     *  'DIAMETER CLASS(', A2, ')'/2X, 'SPECIES', 20F6.1/, 2X, 7('-'),
     *  1X, 20(' -----'))
10010 FORMAT (3X, A3, 3X, 20F6.2)

c **** Common blocks included:

      INCLUDE 'CHAR1.CMB'
      INCLUDE 'GEN1.CMB'
      INCLUDE 'LOG2.CMB'
      INCLUDE 'S1.CMB'
      INCLUDE 'S4.CMB'
```

```


      +--IF (METRIC) THEN
      |     WRITE (JSOUT1, 10000) UNITS2, UNITS3, (DIAM(ID), ID = 1,
     *|      NDIAM)
      |     NUMLIN = NUMLIN + 3
      | +--DO IH = 1, NHOSTS
      | |     WRITE (JSOUT1, 10010) TNAME(IH), (STEMS(IH, ID), ID = 1,
     *| |      NDIAM)
      | |     NUMLIN = NUMLIN + 1
      | +--ENDDO
      +--ELSE
      |     WRITE (JSOUT1, 10000) UNITS2, UNITS3, ((DIAM(ID)/2.54001),
     *|      ID = 1, NDIAM)
      | +--DO IH = 1, NHOSTS
      | |     WRITE (JSOUT1, 10010) TNAME(IH), ((STEMS(IH, ID)/2.471044),
     *| |      ID = 1, NDIAM)
      | |     NUMLIN = NUMLIN + 1
      | |
      | +--ENDDO
      +--ENDIF
          RETURN
          END

C *****   End of Subroutine PTSTBL;  File name: PRNTSTBL.FOR  *****
```

```
c       *****  Subroutine RANDS(K, YFLO), file: RANDS.FOR  *****
c A portion of the:
c Stand-Damage Model - a portion of the Gypsy Moth Life System Model
c       (the stand submodel) converted to a stand-alone model.  Last
c       revised by K.Sheehan January 1988; revised starting in 1989
c       by Colbert and Racin.
c
c              J. Colbert, Northeastern Forest Experiment Station
c            180 Canfield St., Morgantown, WV  26505  (304)-285-1600
c Pseudo-random number generator;
c called from subroutines TREE21 and TREE22.
c No calls made to other routines.
c  **  Local variables, parameters, and inputs required
c                                      by Subroutine RANDS(K, YFLO) **
c  The following designations for LOCATIONs apply:
c        (1) - l := local variable
c        (2) - n := new parameter; not yet assigned to a common block
c        (3) - cp:= call parameter of this subroutine
c        (4) - s := subroutine called from within this code
c        (5) -XXN:= CAPS or CAPS+digit indicate a common block name
c-------------------------------------------------------------------
c NAME - LOCATION - DESCRIPTION
c-------------------------------------------------------------------
c FLM          l    - Floating point equivalent of integer seed M.
c I            l    - Index used in modular extraction.
c K            cp   - Random number seed for this iteration.
c M            n    - Random number generator, large base for routine.
c N            n    - Random number generator, small base for routine.
c YFLO         cp   - Real output -- pseudo-random in [0.0,1.0].
c-------------------------------------------------------------------
         SUBROUTINE RANDS(K, YFLO)
         DATA M, N, FLM/8192, 5, 8192./
      +--DO I = 1, 3
      |    K = MOD(N*K, M)
      +--ENDDO
         YFLO = FLOAT(K)/FLM
         RETURN
         END
c *****  End of Subroutine RANDS, file name: RANDS.FOR  *****
```

```
c       *****   Subroutine RELSTK, file: RELSTOCK.FOR   *****
c A portion of the:
c Stand-Damage Model - a portion of the Gypsy Moth Life System Model
c       (the stand submodel) converted to a stand-alone model.  Last
c       revised by K.Sheehan January 1988; revised starting in 1989
c       by Colbert and Racin.
c
c              J. Colbert, Northeastern Forest Experiment Station
c             180 Canfield St., Morgantown, WV  26505  (304)-285-1600

c Calc. relative stocking ('RSTOCK') based on GTR-NE-96 (Silvah);
c sum the total number of stems by diam. class in the three stocking
c groups identified in Silvah as TOT1, TOT2, & TOT3.
c Called from the main program DAMSR.
c No calls made by this routine.


c  **  Local variables, parameters, and inputs required
c                                  by Subroutine RELSTK **
c  The following designations for LOCATIONs apply:
c        (1) - l := local variable
c        (2) - n := new parameter; not yet assigned to a common block
c        (3) - cp:= call parameter of this subroutine
c        (4) - s := subroutine called from within this code
c        (5) -XXN:= CAPS or CAPS+digit indicate a common block name
c  ---------------------------------------------------------------
c NAME    -  LOCATION  - DESCRIPTION
c  ---------------------------------------------------------------
c DIAM(id)       S1      Diameter class midpoint (cm)
c DM             l       Diameter class midpoint (in)
c ID             l       Diameter class index
c IH             l       Host species index
c ISTOKG(ih)     S1      Stocking class for host ih
c NDIAM          S4      Number of diameter classes, constant = 20
c NHOSTS         GEN1    Number of hosts in simulation (less or eq. 6)
c RSTOCK         S3      Relative stocking number for stand
c STEMS(ih,id)   S1      Stems per ha in (host X diam) cell
c STEMT          l       Stems per acre, converted
c STOCKS(sc,cf)  S2      Stocking class (sc) coefficients for quadratic
c                        equations (cf=1,2,3 for constant, linear, or
c                        quadratic term)
c TOT1(id)       l       | Total stem count across species for each
c TOT2(id)       l       | diameter class (id) and stocking class (1, 2,
c TOT3(id)       l       | or 3: as part of the variable name).
c ---------------------------------------------------------------------

        SUBROUTINE RELSTK

c  **** Include blocks ****

        INCLUDE 'GEN1.CMB'
        INCLUDE 'S1.CMB'
        INCLUDE 'S2.CMB'
        INCLUDE 'S3.CMB'
        INCLUDE 'S4.CMB'
```

```


        DIMENSION TOT1(20), TOT2(20), TOT3(20)

     +--DO ID = 1, NDIAM
     |    TOT1(ID) = 0.0
     |    TOT2(ID) = 0.0
     |    TOT3(ID) = 0.0
     +--ENDDO
        RSTOCK = 0.0

     +--DO ID = 1, NDIAM
     | +--DO IH = 1, NHOSTS
     | |
c  Total stem counts for each of the three stocking classes and
c  each diameter class.  Change stems from per HA to per AC
c  ISTOKG(ih)=stocking class for species ih (acc'ding to Silvah)
     | |
     | |    STEMT = STEMS(IH, ID)/2.471044
     | |    IF (ISTOKG(IH) .EQ. 1) TOT1(ID) = TOT1(ID) + STEMT
     | |    IF (ISTOKG(IH) .EQ. 2) TOT2(ID) = TOT2(ID) + STEMT
     | |    IF (ISTOKG(IH) .EQ. 3) TOT3(ID) = TOT3(ID) + STEMT
     | |
     | +--ENDDO
     |
c  Change diameter from cm to in.  Calc. relative stocking based
c  on Silvah's method (Marquis et al. 1984 - GTR-NE-96).
     |
     |    DM = DIAM(ID)/2.54
     |    RSTOCK = RSTOCK + TOT1(ID)*(STOCKS(1, 1) + STOCKS(1, 2)*DM +
    *|     STOCKS(1, 3)*(DM**2)) + TOT2(ID)*(STOCKS(2, 1)+ STOCKS(2, 2)
    *|     *DM + STOCKS(2, 3)*DM**2) + TOT3(ID)*(STOCKS(3, 1) + STOCKS
    *|     (3, 2)*DM + STOCKS(3, 3)*DM**2)
     |
     |
     |
     +--ENDDO
        RETURN
        END

c *** End of Subroutine RELSTK -- file name: RELSTOCK.FOR ***
```

```
c       *****  Function SLIP(XX, X, Y, N), file: SLIP.FOR  *****
c A portion of the:
c Stand-Damage Model - a portion of the Gypsy Moth Life System Model
c       (the stand submodel) converted to a stand-alone model.  Last
c       revised by K.Sheehan January 1988; revised starting in 1989
c       by Colbert and Racin.
c
c              J. Colbert, Northeastern Forest Experiment Station
c            180 Canfield St., Morgantown, WV  26505  (304)-285-1600

c Called two times by TREE22.
c No routines called by this function.
c Linear-interpolation function, created by
c Jim Colbert, USDA-FS, Morgantown, WV 26505 USA
c Input is XX; find YY(XX) by linear interpolation; (X(I),Y(I))
c pairs are used for XX greater than X(1) and less than X(N);
c otherwise end value Y(1) or Y(N) is used.

c  **  Local variables, parameters, and inputs required
c                                     by Subroutine SLIP(XX, X, Y, N) **
c  The following designations for LOCATIONs apply:
c        (1) - l := local variable
c        (2) - n := new parameter; not yet assigned to a common block
c        (3) - cp:= call parameter of this subroutine
c        (4) - s := subroutine called from within this code
c        (5) -XXN:= CAPS or CAPS+digit indicate a common block name
c-------------------------------------------------------------
c NAME - LOCATION - DESCRIPTION
c-------------------------------------------------------------
c I           l   - Index for (X,Y) pairs.
c N           cp  - Dimension of the call parameter arrays.
c SLIP        Function return variable.
c X           cp  - Independent variable array.
c XX          cp  - Independent variable for which dependent is to
c                   be associated [Y = SLIP(X)].
c Y           cp  - Dependent variable array.
c-------------------------------------------------------------

        FUNCTION SLIP(XX, X, Y, N)

        DIMENSION X(N), Y(N)
      +--IF (XX .LE. X(1)) THEN
      |     SLIP = Y(1)
      +--ELSEIF (XX .GE. X(N)) THEN
      |     SLIP = Y(N)
      +--ELSE
      | +--DO I = 1, N-1
      | |     IF (XX .LE. X(I + 1)) GOTO 100
      | +--ENDDO
      |     RETURN
  100 |     SLIP = Y(I) + ((Y(I+1) - Y(I))/(X(I+1) - X(I)))*(XX - X(I))
      +--ENDIF
        RETURN
        END
c *****  End of Function SLIP, file name: SLIP.FOR  *****
```

```
c       *****   Subroutine THGHTS, file: THEIGHTS.FOR   *****
c A portion of the:
c Stand-Damage Model - a portion of the Gypsy Moth Life System Model
c       (the stand submodel) converted to a stand-alone model.  Last
c       revised by K.Sheehan January 1988; revised starting in 1989
c       by Colbert and Racin.
c
c              J. Colbert, Northeastern Forest Experiment Station
c            180 Canfield St., Morgantown, WV  26505  (304)-285-1600

c Calculate heights (cm) for each host-diameter class (height).
c Equation (2) in "A Description of the Stand-Damage Model"
c If the diameter is greater than the max. diam for species (ih),
c then set the height = the max. height for species ih.
c Called by the main program DAMSR.
c No calls made to other routines.

c  **  Local variables, parameters, and inputs required
c                                   by Subroutine THGHTS **
c  The following designations for LOCATIONs apply:
c        (1) - l := local variable
c        (2) - n := new parameter; not yet assigned to a common block
c        (3) - cp:= call parameter of this subroutine
c        (4) - s := subroutine called from within this code
c        (5) -XXN:= CAPS or CAPS+digit indicate a common block name
c-----------------------------------------------------------------
c NAME - LOCATION - DESCRIPTION
c-----------------------------------------------------------------
c B1(ih)        S1 - Linear effect coefficient for diameter-height
c B2(ih)        S1 - Quadratic effect coefficient
c DIAM(ih)      S1 - Current diameter of the tree (by diam. class)
c DMAX(ih)      S1 - Maximum diameter of this species (ih).
c HEIGHT        S1 - Height of tree diameter class (id) for species
c  (ih,id)           ih.
c HMAX(ih)      S1 - Maximum height for a tree of this species (ih).
c ID             l - Diameter index (1, ..., NDIAM)
c IH             l - Species index (1, ..., NHOSTS)
c NDIAM         S4 - Number of diameter classes (20) for each species.
c NHOSTS      GEN1 - Current no. of hosts (max. of 6).
c-----------------------------------------------------------------

        SUBROUTINE THGHTS

c **** Include blocks ****

        INCLUDE 'GEN1.CMB'
        INCLUDE 'S1.CMB'
        INCLUDE 'S4.CMB'

c Calculate height for each tree-class cell by species and diam.

     +--DO IH = 1, NHOSTS
     | +--DO ID = 1, NDIAM
     | |    HEIGHT(IH, ID) = 137.0 + (B1(IH)*DIAM(ID)) - (B2(IH)*DIAM
    *| |     (ID)**2)
```

```
      | |     IF (DIAM(ID) .GE. DMAX(IH)) HEIGHT(IH, ID) = HMAX(IH)
      | +--ENDDO
      +--ENDDO
         RETURN
         END

c  ***  End of Subroutine THGHTS; file name THEIGHTS.FOR  ***
```

```
c     *****   Subroutine TINIT, file: TINIT.FOR   *****
c A portion of the:
c Stand-Damage Model - a portion of the Gypsy Moth Life System Model
c       (the stand submodel) converted to a stand-alone model.  Last
c       revised by K.Sheehan January 1988; revised starting in 1989
c       by Colbert and Racin.
c
c              J. Colbert, Northeastern Forest Experiment Station
c            180 Canfield St., Morgantown, WV  26505  (304)-285-1600

c Read parameter values & initial conditions for the stand submodel.
c Called by the main routine DAMSR.
c No calls made by this routine.

c  **  Local variables, parameters, and inputs required
c                                  by Subroutine TINIT **
c  The following designations for LOCATIONs apply:
c        (1) - l := local variable
c        (2) - n := new parameter; not yet assigned to a common block
c        (3) - cp:= call parameter of this subroutine
c        (4) - s := subroutine called from within this code
c        (5) -XXN:= CAPS or CAPS+digit indicate a common block name
c  ---------------------------------------------------------------
c NAME - LOCATION - DESCRIPTION
c  ---------------------------------------------------------------
c AGEMAX(ih)   S1   - Maximum age (years) for species ih
c BDIE(ih)     S1   - Base tree mortality rate
c B1 & B2(ih)  S1   - Height coefficients for species ih
c COLD(ih)     S2   - Minimum total degree-days per year that occur within
c                     the range of species ih
c CRWDMN       S2   - Minimum value for crowd in equation 12. see TREE21.
c CR1-CR4(ih)  S1   - Live crown ratio parameters for species ih
c DEBUG        LOG1- Logical variable, true for "DEBUG" output
c DFLC(i,j)    S3   - For j=1,2;i=1,2: parameters for equation (13)
c                     (light) and equation (14) (heavy) for predicting
c                     DEFIND (eqn. (16)), the effect of current defolia-
c                     tion on diameter growth.
c DFOLDE       S3   - Slope of the defoliation effect curve; and the
c                     maximum proportional decrease in this year's foliage
c                     production (at 100% defoliation) due to last year's
c                     defoliation (defl(ih,is)) in tree1.
c DIAM(id)     S1   - Midpoint diameter of diameter class id
c DLEN(id)     S1   - Range in diameters of trees in diameter class id
c DLENBASE     1    - The base diameter length for all diameter classes.
c                     note that to assure proper use of mortality and
c                     growth calculations, all diameter classes are now of
c                     equal width.
c DMAX(ih)     S1   - Maximum diameter (cm) for species ih
c EPSIGR       S2   - Decision parameter for including stems(host,diam) in
c                     growth calculations, if >0 then small stem counts
c                     will not enter into these calculations.
c EPSIMG(i)    S4   - Decision parameters for management (tree removals).
c EPSITR       S2   - Decision parameter for including stems(h,d) in
c                     transfer between diameter classes.
c FDIE         S1   - Proportion of trees of species ih growing
```

```
c (ih,nf,isite)      on site isite that die following nf consecutive
c                    years of heavy defoliation.
c F1,F2(ih)    S1  - Parameters used to calculate foliage biomass for
c                    species ih.
c GROWR(ih)    S1  - Base growth rate parameter for species ih
c HMAX(ih)     S1  - Maximum height (cm) for species ih
c HOT(ih)      S2  - Maximum total degree-days per year that occur within
c                    the range of species ih
c HOVER        S2  - Ht. of overstory/understory boundary (cm or ft) if
c                    ibound=1; else = diam. of boundary (cm or in).  will
c                    be converted to metric units if necessary.
c I             1  - Counter for loading (reading in) arrays
c IBOUND       S4  - Overstory/understory boundary type: 1= ht, 2= diam
c ICAT         S4  - Tree graphics category:  1=overstory, 2=understory,
c                    3=total
c ID            1  - Diameter index
c IDEF          1  - Defoliation index for reading/writing FDIE.
c IDFOLY       S3  - Calendar year for defoliation input.
c IDHIST       S3  - Class variable, values 0, 1, 2, or 3 depending
c (ih,is,iy)         on percent defoliation last year (iy=1) and 2 years
c                    ago (iy=2) for a given host and strata.  see TREE22
c                    for defoliation range definitions of this class
c                    variable.  is: the strata, 1 for overstory, 2 for
c                    understory; not defined for other strata (3 or 4).
c IH            1  - Host species index.
c IN            1  - Index for reading in Shade and Stocking effect
c                    values.
c IS            1  - Index for reading in Strata specific values of
c                    defoliation history (IDHIST).
c ISHADE       S4  - Shade tolerance index (it = 1 := recruitment,
c (ih, it)           it = 2 := diam. growth).
c ISIT          1  - Site index for reading data.
c ISITE        S4  - Index to site (1=wet, 2=medium, 3=dry)
c ISOPT        S4  - Stress option: 0 no stress; 1 = stress occurs at
c                    random, 2 = stress occurs only for designated years.
c ISTOKG(ih)   S1  - Rel. stocking index for each tree species (1,2,or 3)
c IY            1  - Year index for reading data.
c J             1  - Index for reading & writing STOCKS and DFLC values.
c JDB        GEN1  - DEBUG file handle reference no.
c JDEF       GEN1  - Defoliation data file handle reference no. (= 14)
c JSOUT1     GEN1  - = 13 = stand table (output) file handle ref. no.
c JSOUT2     GEN1  - = 15 = no. stems file handle reference no.
c JSOUT3     GEN1  - = 16 = basal area file handle reference no.
c JSOUT4     GEN1  - = 17 = volume file handle reference no.
c JSOUT5     GEN1  - = 18 = dbh file handle reference no.
c JTIN       GEN1  - = 10 = tree data file (input) handle reference no.
c LDEFOL     LOG2  - Logical variable - true if defoliation is to be
c                    simulated.
c MANAGE     S4    - Stand management options (0=none, 1=specific harvest
c                    rates, 2=to target no. of stems)
c METRIC     LOG2  - True if metric units are used for stand data (input)
c MTOTAL     S4    - Total number of management actions (also no. of
c                    years that management will take place).
c MYEARS     S4    - Years that management actions have been scheduled.
c NDIAM      S4    - Number of diameter classes (20).
```

```
c NHOSTS     GEN1 - Number of host tree species in the current
c                   simulation, less than or equal to 6.
c NSTRYR     S4   - Number of years with additional stress, under
c                   additional stress option isopt = 2, for defoliation
c                   induced stress mortality.
c PLOTAR     S3   - Sample Plot area (ha if metric = true, otherwise ac)
c PLOTSZ     S2   - The size of the plot to be used when calculating the
c                   shading multiplier for tree growth.
c PRTMIN     S2   - Set smallest residual stem counts to be printed in
c                   the stand table.
c RECRUT(ih) S1   - Max. # of trees recruited to the smallest diameter
c                   class per year for species ih
c RESTIN     S1   - Number of larval resting sites per 100 sq-cm of
c (ih,is)           bole and branch surface area (for lower boles of
c                   overstory trees, is=1; for upper boles and branches
c                   of overstory trees and for all boles and branches of
c                   understory trees, is=2)
c RSMULT     S2   - Parameter for effect of relative stocking on tree
c                   growth.
c SGMORT     S2   - No. of years of slow growth (NSLOW) effect on tree
c                   mortality rate. exponential rate coefficient for
c                   calculating GDIE, eqn. (18).
c SHADMN     S1   - Minimum value for shade in equation 16.
c SHX,SHY    S1   - Parameters for effect of light on diam growth, by
c                   shade tolerance index.
c SLOWD      S1   - Minimum growth (cm/yr) required to avoid add.
c                   mortality.
c STABLE     LOG2 - Logical, true if stand table output has been
c                   requested.
c STEMS(ih,id) S1 - Number of stems of species ih in diameter class id.
c STNDAR     S3   - Stand area (ha if metric = true, otherwise ac)
c STOCKS     S2   - For j=1,2,3;i=1,2,3: stocking class parameters, 3
c (i,j)             per quadratic, 3 stocking classes, species specific
c                   (in istokg(ih)).
c STOKX      S1   - Parameters to adjust effect of relative stocking on
c STOKY      S1     recruitment.  Arrays [5,4].
c (ishade(ih,1),4)
c STRESS     S1   - The probability that a stand on site isite will not
c (isite)           be subject to additional unspecified stress.  Used
c                   in tree mortality calculations.
c STRFAC(i)  S1   - Additional mortality due to stress in years with
c                   heavy defoliation (1 = mort. without stress, 2 =
c                   mort. w/ stress).
c SURFAR(ih) S1   - Biomass/surface area conversion constant for species
c                   ih.
c TEMPMN     S1   - Minimum value for TEMP in equation 11(b).
c TGBA       LOG2 - Logical variable, true to open Basal area data file.
c TGDBH      LOG2 - Logical variable, true to open mean DBH data file.
c TGSTEM     LOG2 - Logical variable, true to open stem count data file.
c TGVOL      LOG2 - Logical variable, true to open volume data file.
c TKL        S2   - Shading coefficient, equation (10).
c TLIGHT     S2   - Multiplier used in calculating the influence of leaf
c                   surface area on available light.  set to 1.0 by
c                   default.
c TNAME(ih)  CHAR1- Tree species code, two characters.
```

```
c ---------------------------------------------------------------

      SUBROUTINE TINIT

10000 FORMAT (/1X, I1, 1X, L1, 1X, L1)
10010 FORMAT (1X, I4)
10020 FORMAT (2(1X, F6.2), 1X, I1, 1X, F7.1)
10030 FORMAT (' PLOTAR = ', F7.3)
10040 FORMAT (' STNDAR = ', F7.3)
10050 FORMAT (/, 1X, F4.1, 1X, F7.5/8(6(1X, F6.2)/), 2(1X, F5.2), 1X,
     *  F7.4,1X, /, 1X, I2, 3(1X, F4.1), /1X, F7.4, 4(/, 6(1X, F4.0)),
     *  4(/, 6(1X, F5.2)))
10060 FORMAT (3(3(1X, F10.7), /), 4(1X, F4.2), 1X, F6.3, /, 4(1X,
     *  F11.8))
10070 FORMAT (5X, 'STOCKS(I,J) array', /' J=', 3(5X, I1, 6X)/, 'I=1',
     *  3(F10.7, 1X), /, ' I=2', 3(F10.7, 1X), /, ' I=3', 3(F10.7,1X),
     *  /, ' DFOLDE  CRWDMN  SHADMN  TEMPMN  SGMORT', /,4(2X,F4.2,2X),
     *  2X, F6.3, /, 5X, 'DFLC(I,J) array'/, ' J=', 6X,I1, 11X, I1, /,
     *  ' I=1', 2(1X, F10.8), /, ' I=2', 2(1X, F10.8))
10080 FORMAT (1X, I3, 1X, F6.2, 1X, I1, /, 6(1X, F8.6))
10090 FORMAT ('  TINIT, @READ 1240: NSTRYR=', I3,', DLENBASE=', F6.2,
     *  ', ICAT=', I1, ', EPSIGR=', F8.6, ', EPSITR=',F8.6,', PRTMIN='
     *  , F8.6/, 'EPSIMG(I),I=1,3: ', 3(1X, F8.6))
10100 FORMAT (A2/, 2(1X, I2), 2(1X, F8.4), 1X, F7.1, 2(1X, F6.0), 1X,
     *  F6.3, /, 1X, F6.2, 1X, F7.4, 1X, F6.2, 1X, F6.3, /, 1X, F7.1,
     *  1X, F7.0, 1X, F4.0, 2(1X, F8.5), 1X, F6.1, 1X, I2, 1X, F6.0,/,
     *  9(1X, F4.2), /, 4(1X, I4))
10110 FORMAT (10(1X, F6.1), /, 10(1X, F6.1))
10120 FORMAT (/, I2)
10130 FORMAT (1X, I4, 1X, I1)

c Include the common blocks:

      INCLUDE 'CHAR1.CMB'
      INCLUDE 'GEN1.CMB'
      INCLUDE 'LOG1.CMB'
      INCLUDE 'LOG2.CMB'
      INCLUDE 'S1.CMB'
      INCLUDE 'S2.CMB'
      INCLUDE 'S3.CMB'
      INCLUDE 'S4.CMB'
      INCLUDE 'WTHR1.CMB'

c End of common block includes

c ****************************************************************
c     Read Stand Submodel information
c ****************************************************************

      READ (JTIN, 10000) ISITE, METRIC, LDEFOL
      IF (DEBUG) WRITE (JDB, 10000) ISITE, METRIC, LDEFOL

c  If requested or if debug trace is on, open Stand Table Output file.

      IF (STABLE .OR. DEBUG) OPEN(13, FILE = 'STANDTBL.D1S', STATUS =
```

```
     *    'UNKNOWN')
        JSOUT1 = 13
      +--IF (LDEFOL) THEN
      |    OPEN (14, FILE = 'DEFOLDAT.D1S', STATUS = 'OLD')
      |    JDEF = 14
      |    READ (JDEF, 10010) IDFOLY
      +--ENDIF
         IF (TGSTEM) OPEN(15, FILE = 'GSTEMNUM.D1S', STATUS = 'UNKNOWN')
         JSOUT2 = 15
         IF (TGBA) OPEN (16, FILE = 'GBASALAR.D1S', STATUS = 'UNKNOWN')
         JSOUT3 = 16
         IF (TGVOL) OPEN (17, FILE = 'GVOLUME.D1S', STATUS = 'UNKNOWN')
         JSOUT4 = 17
         IF (TGDBH) OPEN (18, FILE = 'GDBH.D1S', STATUS = 'UNKNOWN')
         JSOUT5 = 18


         READ (JTIN, 10020) PLOTAR, STNDAR, IBOUND, HOVER

c Check to see that plot and stand areas are big enough.

      +--IF ((PLOTAR .LT. 0.01) .OR. (STNDAR .LT. 0.01)) THEN
      |    WRITE (*, *) ' Error, plot or stand area too small.'
      |    WRITE (*, 10030) PLOTAR
      |    WRITE (*, 10040) STNDAR
      +--ENDIF


c Read miscellaneous parameters for stand model.

         READ (JTIN, 10050) TLIGHT, TKL, ((SHX(I, IN), I = 1, 6), IN= 1,
     *    4), ((SHY(I, IN), I = 1, 6), IN = 1, 4), STRFAC(1), STRFAC(2),
     *    PLOTSZ, ISOPT, (STRESS(ISIT), ISIT = 1, 3), RSMULT, ((STOKX(I,
     *    IN), I = 1, 6), IN = 1, 4), ((STOKY(I, IN), I = 1, 6), IN = 1,
     *    4)

c Within the interface, units are English for all variables with units,
c convert to metric for use within the model.

         PLOTAR = PLOTAR * 0.404687
         STNDAR = STNDAR * 0.404687
         PLOTSZ = PLOTSZ * 0.404687

c For variable HOVER, convert diameter or height to metric
c 30.48 cm/ft or 2.54 cm/in, depending upon the type boundary
c chosen by user.

         IF (IBOUND .EQ. 1) HOVER = HOVER*30.48012
         IF (IBOUND .EQ. 2) HOVER = HOVER*2.54001


         READ (JTIN, 10060)((STOCKS(I, J), J = 1, 3), I = 1, 3), DFOLDE,
     *    CRWDMN, SHADMN, TEMPMN, SGMORT, ((DFLC(I, J),J = 1, 2), I=1,2)

```

```

        READ (JTIN, 10080) NSTRYR, DLENBASE, ICAT, EPSIGR, EPSITR,
     *    (EPSIMG(I), I = 1, 3), PRTMIN
      +--IF (DEBUG) THEN
      |    WRITE (JDB, 10090) NSTRYR, DLENBASE, ICAT, EPSIGR, EPSITR,
     *|     PRTMIN, (EPSIMG(I), I = 1, 3)
      |    WRITE (JDB, 10070) (J, J = 1, 3), ((STOCKS(I, J), J = 1,3), I
     *|     = 1, 3), DFOLDE, CRWDMN, SHADMN, TEMPMN, SGMORT,(J,J = 1,2),
     *|     ((DFLC(I, J), J = 1, 2), I = 1, 2)
      +--ENDIF

c Convert diameter base to metric units:

        DLENBASE = DLENBASE*2.54001

      +--DO ID = 1, 20
      |    DLEN(ID) = DLENBASE
      |    DIAM(ID) = DLENBASE*FLOAT(ID) - DLENBASE/2.0
      +--ENDDO

c ********************************
c Read info. for each tree species.
c ********************************

      +--DO IH = 1, NHOSTS
      |
      |    READ (JTIN, 10100) TNAME(IH), ISHADE(IH, 1), ISHADE(IH, 2),
     *|     RESTIN(IH, 1), RESTIN(IH, 2), GROWR(IH), COLD(IH), HOT(IH),
     *|     SLOWD(IH), CR1(IH), CR2(IH), CR3(IH),CR4(IH), DMAX(IH), HMAX
     *|     (IH), AGEMAX(IH), F1(IH), F2(IH), SURFAR(IH), ISTOKG(IH),
     *|     RECRUT(IH), ((FDIE(IH, IDEF, ISIT), IDEF = 1, 3), ISIT = 1,
     *|     3), ((IDHIST(IH, IS, IY), IS = 1, 2), IY = 1, 2)
      |    IF (DEBUG) WRITE(JDB, 10100) TNAME(IH), ISHADE(IH, 1), ISHADE
     *|     (IH, 2), RESTIN(IH, 1), RESTIN(IH, 2), GROWR(IH), COLD(IH),
     *|     HOT(IH), SLOWD(IH), CR1(IH), CR2(IH), CR3(IH), CR4(IH), DMAX
     *|     (IH), HMAX(IH), AGEMAX(IH), F1(IH), F2(IH), SURFAR(IH),
     *|     ISTOKG(IH),RECRUT(IH), ((FDIE(IH, IDEF, ISIT), IDEF = 1, 3),
     *|     ISIT = 1, 3), ((IDHIST(IH, IS, IY), IS = 1, 2), IY = 1, 2)
      |
c  Convert SURFAR, SLOWD, DMAX, HMAX, and RECRUT to metric units:
c     |        1 sq.-in. / oz. == 0.22757 sq.-cm / g.
c     |        1 in. == 2.54001 cm.
c     |        1 ft. == 30.48012 cm.
c     |        1 hectare == 2.471044 acres
      |
      |    SURFAR(IH) = SURFAR(IH)*0.22757
      |    SLOWD(IH) = SLOWD(IH)*2.54001
      |    HMAX(IH) = HMAX(IH)*30.48012
      |    DMAX(IH) = DMAX(IH)*2.54001
      |    RECRUT(IH) = RECRUT(IH)*2.471044
      |
c  Computing the parameters B1(ih) & B2(ih).
      |
      |    B1(IH) = 2.0*(HMAX(IH) - 137.0)/DMAX(IH)
      |    B2(IH) = (HMAX(IH) - 137.0)/(DMAX(IH)*DMAX(IH))
```

```
      |
c Read|the initial stocking levels for the stand.
      |
      |    READ (JTIN, 10110) (STEMS(IH, ID), ID = 1, NDIAM)
      |
      +--ENDDO

c Convert stems from stems/plot-area to stems/ha.  Conversion
c from trees/ac. to trees/ha. is handled along with the plot area
c since plot area has already been converted to hectares.
      +--DO IH = 1, NHOSTS
      | +--DO ID = 1, NDIAM
      | |    STEMS(IH, ID) = (STEMS(IH, ID)/PLOTAR)
      | +--ENDDO
      +--ENDDO


c  Calculate the base mortality rate for each species as a
c  function of the maximum age for that species (from Botkin
c  and others 1972).

      +--DO IH = 1, NHOSTS
      |    BDIE(IH) = 4.0/(AGEMAX(IH) + .000001)
      +--ENDDO


c Note that the variables MYEARS and MANAGE are read once each time
c MTOTAL is decremented; the associated management data are read
c elsewhere.  These reads take place in the subroutine TREE21.  JTIN is
c closed at the end of main routine DAMAGE (or Subroutine DAMSR when run
c under control of the front end).

         READ (JTIN, 10120) MTOTAL
      +--IF (MTOTAL .GT. 0) THEN
      |    READ (JTIN, 10130) MYEARS, MANAGE
      +--ENDIF
         RETURN
         END

c *** End of Subroutine TINIT -- File TINIT.FOR  ***
```

```
c       *****  Subroutine TPRINT, file: TPRINT.FOR  *****
c A portion of the:
c Stand-Damage Model - a portion of the Gypsy Moth Life System Model
c       (the stand submodel) converted to a stand-alone model.  Last
c       revised by K.Sheehan January 1988; revised starting in 1989.
c       by Colbert and Racin.
c
c              J. Colbert, Northeastern Forest Experiment Station
c            180 Canfield St., Morgantown, WV  26505  (304)-285-1600

c Write Stand Table Output summary for one year.
c Called from the main program DAMSR.
c No calls made by this to other routines.

c  **  Local variables, parameters, and inputs required
c                                  by Subroutine TPRINT() **
c  The following designations for LOCATIONs apply:
c        (1) - l := local variable
c        (2) - n := new parameter; not yet assigned to a common block
c        (3) - cp:= call parameter of this subroutine
c        (4) - s := subroutine called from within this code
c        (5) -XXN:= CAPS or CAPS+digit indicate a common block name
c  --------------------------------------------------------------
c NAME - LOCATION - DESCRIPTION
c  --------------------------------------------------------------
c ACTFOL      S3    - Actual foliage present (after defoliation).
c ANNDD(100)  WTHR1 - Annual total day-degrees for year IYEAR.
c CROWD       S2    - Crowding index (a tree growth modifier).
c DEFIND      S2    - Defoliation index (a tree growth modifier).
c DEFL        S3    - Percent defoliation, by host and strata.
c DMEAN       S2    - Mean diameter, by host and strata.
c IH          l     - Host species number.
c IS          l     - Strata number.
c ISYEAR      GEN1  - Starting year; example: 1987.  Then incremented to
c               contain calendar year of simulation.
c IYEAR       GEN1  - Year index, used for array indexing.
c JSOUT1      GEN1  - Number of file: stand output.
c METRIC      LOG2  - Set to true if input/output units are to be metric
c NHOSTS      GEN1  - Number of hosts to be simulated.
c NUMLIN      GEN1  - Line counter for tabular output.
c PRTMIN      S2    - Minimum amount of stems to get output printed.
c RSTRES      S2    - Proportion of mortality due to stress, by host.
c SMFDIE      S2    - Mean tree mortality due to defoliation, by host
c               and strata.
c SMGDIE      S2    - Mean tree mortality due to slow growth.
c SMGROW      S2    - Mean actual diameter growth.
c SMPGRO      S2    - Mean potential diameter growth.
c SMSHAD      S2    - Mean shading growth modifier.
c SMTDIE      S2    - Mean total tree mortality.
c STEM        S2    - Number of stems, by host and strata.
c STRATA      l     - Names of the 4 strata simulated for each host.
c TEMP        S2    - Tree growth modifier for temperature, by host.
c TNAME       l     - Tree code, by host.
c VOL         S2    - Stand volume, by host and strata.
c YLD         S2    - Yield from harvesting, by host and strata.
```

```
c  ----------------------------------------------------------------

          SUBROUTINE TPRINT
10000     FORMAT (108X, 'SOURCES OF MORTALITY'/, 79X, 'MODIFIERS OF ',
     *     'GROWTH', 9X, 23('-')/, 77X, 23('-'), ' TOTAL BASE  SLOW',
     *     '  RAND. GYPSY'/, 14X, '%', 4X, 'BASAL NUMBER  MEAN', 26X,
     *     'ACTUAL POTEN. GYPSY', 7X, 'STAND', 9X, '%', 5X, '%    GR.',
     *     ' STRESS MOTH')
10010     FORMAT (1X, 'SPEC STRAT DEFOL  AREA   STEMS   DBH  VOLUME',
     *     '    YIELD  FOLIAGE GROWTH GROWTH MOTH  TEMP  DENS. SHADE',
     *     ' MORT. MORT. MORT. MORT. MORT.')
10020     FORMAT (17X, '(FT2/AC) (AC)   (IN) (FT3/AC) (FT3/AC) (LB/AC)',
     *     ' (IN)    (IN)'/1X, 130('-'))
10030     FORMAT (17X, ' (M2/HA) (HA)   (CM)   (M3/HA)   (M3/HA) (KG/HA)',
     *     ' (CM)    (CM)'/1X, 130('-'))
10040     FORMAT (1X, 10X, 100('*')//, T20, 'End of Year: ', I4, T60,
     *     'Accumulated day-degrees for year: ', F8.1/)
10050     FORMAT (1X, A4, 1X, A5, 1X, F5.0, 1X, F6.1, 1X, F6.1, 1X, F5.1,
     *     1X, F7.1, 2X,F7.1, F8.1, 1X,F6.3, 1X, F6.3, 4(1X, F5.3), 5(1X,
     *     F5.1))
10060     FORMAT (1X)


          INCLUDE 'CHAR1.CMB'
          INCLUDE 'GEN1.CMB'
          INCLUDE 'LOG2.CMB'
          INCLUDE 'S1.CMB'
          INCLUDE 'S2.CMB'
          INCLUDE 'S3.CMB'
          INCLUDE 'WTHR1.CMB'

c Write header info. if needed.

c Formats for output headers (10030= for metric, 10020= for English).

       +--IF (NUMLIN .GT. 60) THEN
       |
       |   WRITE (JSOUT1,'(A1)') '\f'C
       |
       |   WRITE (JSOUT1, 10000)
       |   WRITE (JSOUT1, 10010)
       | +--IF (METRIC) THEN
       | |   WRITE (JSOUT1, 10030)
       | +--ELSE
       | |   WRITE (JSOUT1, 10020)
       | +--ENDIF
       |   NUMLIN = 10
       +--ENDIF


c Print header for start of year.
       +--IF (METRIC) THEN
       |   WRITE (JSOUT1, 10040) ISYEAR, ANNDD(IYEAR)/1.8
       +--ELSE
       |   WRITE (JSOUT1, 10040) ISYEAR, ANNDD(IYEAR)
```

```
      +--ENDIF
         NUMLIN = NUMLIN + 5

c For each host & strata, print output if there are stems.
c Convert foliage biomass from g to kg & mortality proportions
c to percentages.

      +--DO IH = 1, NHOSTS
      | +--DO IS = 1, 2
      | |    IF ((STEM(IH, IS) .GT. PRTMIN) .OR. (YLD(IH, IS) .GT. 0.0))
     *| |  +--THEN
      | |  |   WRITE (JSOUT1, 10050) TNAME(IH), STRATA(IS), DEFL(IH,
     *| |  |     IS), BA(IH, IS), STEM(IH, IS), DMEAN(IH, IS), VOL(IH,
     *| |  |     IS), YLD(IH, IS), ACTFOL(IH, IS)/1000.0, SMGROW(IH, IS)
     *| |  |     , SMPGRO(IH, IS), DEFIND(IH, IS), TEMP(IH), CROWD,
     *| |  |     SMSHAD(IH, IS), SMTDIE(IH, IS)*100.0, BDIE(IH)*100.0,
     *| |  |     SMGDIE(IH, IS)*100.0, RSTRES(IH, IS)*100.0, SMFDIE(IH,
     *| |  |     IS)*100.0
      | |  |   NUMLIN = NUMLIN + 1
      | |  +-ENDIF
      | +--ENDDO
      |    WRITE (JSOUT1, 10060)
      |    NUMLIN = NUMLIN + 1
      |
c Go to next page & print header if necessary.  NUMLIN = no. of lines
c printed on the page so far; go to a new page when NUMLIN > 60
      |
      | +--IF (NUMLIN .GT. 60 .AND. IH .NE. NHOSTS) THEN
      | |
      | |    WRITE (JSOUT1,'(A1)') '\f'C
      | |
      | |    WRITE (JSOUT1, 10000)
      | |    WRITE (JSOUT1, 10010)
      | | +--IF (METRIC) THEN
      | | |    WRITE (JSOUT1, 10030)
      | | +--ELSE
      | | |    WRITE (JSOUT1, 10020)
      | | +--ENDIF
      | |    NUMLIN = 10
      | +--ENDIF
      |
      +--ENDDO
         RETURN
         END

c   ***** End of subroutine TPRINT,  File name: TPRINT.FOR   *****
```

```
c       *****     Subroutine TREE1, file: TREE1.FOR   *****
c A portion of the:
c Stand-Damage Model - a portion of the Gypsy Moth Life System Model
c       (the stand submodel) converted to a stand-alone model.  Last
c       revised by K.Sheehan January 1988; revised starting in 1989
c       by Colbert and Racin.
c
c              J. Colbert, Northeastern Forest Experiment Station
c            180 Canfield St., Morgantown, WV  26505  (304)-285-1600

c This portion of the Stand-Damage Model calculates: foliage amounts,
c crown ratios, no.s of resting sites, as well as stem counts and basal
c area in the under- and overstory strata by tree species.
c Called form the main program DAMSR.
c No calls made by this routine.

c  **  Local variables, parameters, and inputs required
c                                by Subroutine TREE1()  **
c  The following designations for LOCATIONs apply:
c        (1) - 1 := local variable
c        (2) - n := new parameter; not yet assigned to a common block
c        (3) - cp:= call parameter of this subroutine
c        (4) - s := subroutine called from within this code
c        (5) -XXN:= CAPS or CAPS+digit indicate a common block name
c  ---------------------------------------------------------------
c NAME - LOCATION - DESCRIPTION
c  ---------------------------------------------------------------
c BAR          1    - Basal area of stand.
c CROWNR       1    - Crown ratio for trees of particular species,
c                     diameter, and height.
c CR1         S1    - Crown ratio prediction equation coefficient 1.
c CR2         S1    - Crown ratio prediction equation coefficient 2.
c CR3         S1    - Crown ratio prediction equation coefficient 3.
c CR4         S1    - Crown ratio prediction equation coefficient 4.
c DEBUG     LOG1    - Logical variable, true to produce debug output.
c DIAM        S1    - Midpoint diameter of tree class (20 total).
c DIAMIN       1    - Diameter converted to inches.
c FOL         S3    - Foliage biomass of strata (overstory or understory),
c                     canopy leaf biomass.
c FOLIAG       1    - Intermediate value for individual host and diameter
c                     of foliage in a tree class (species and diameter).
c F1          S1    - allometric foliage biomass parameters from Sheehan
c                     (unpubl.).
c F2          S1    - allometric foliage biomass parameters from Sheehan
c                     (unpubl.).
c HEIGHT      S1    - Height of each diameter class, by species.
c HOVER       S2    - the boundary ht. or diam.
c IBOUND      S4    - If height is to be used to separate over &
c                     understory, or 2 if diameter is to be used.
c ID           1    - diameter index
c IH           1    - host index
c IS           1    - Strata index - 1 = overstory; 2 = understory.
c JDB       GEN1    - file number; debug file
c NDIAM       S4    - number of diameter classes to be simulated
c NHOSTS    GEN1    - number of host species
```

```
c OVERBA      S3  - Basal area for the overstory by species.
c OVERS       S3 - No. of stems in the overstory by species.
c R           1   - tree radius
c RESTIN      S1  - The number of resting sites per square meter
c                   of surface area
c RSITES      S3  - RSITES=number of resting sites.
c STEMS       S1  - number of stems, by host and diameter class
c TOTOVR      1   - Total no. of overstory stems in stand.
c UNDBA       S3  - understory basal area, by host
c UNDERS      S3  - understory number of stems, by host
c WLEAF       1   - Total leaf area for the stand.
c X           1   - portion of equation calculation
c ---------------------------------------------------------------

        SUBROUTINE TREE1
10000   FORMAT ('  In Subroutine TREE1; ',
     *   'Stand basal area calculated, BAR = ', F10.5)
10010   FORMAT ('  For IH = ', I2, ', and ID = ', I2, ', CROWNR = ',
     *   F10.5)

c **** Include blocks *****

        INCLUDE 'GEN1.CMB'
        INCLUDE 'LOG1.CMB'
        INCLUDE 'S1.CMB'
        INCLUDE 'S2.CMB'
        INCLUDE 'S3.CMB'
        INCLUDE 'S4.CMB'


c Set the following variables to zero:
c   FOL=foliage biomass, RSITES=number of resting sites,
c   OVERS & UNDERS = no. of stems in the overstory & understory
c   OVERBA & UNDBA = basal area for the overstory & understory

      +--DO IH = 1, NHOSTS
      |    OVERS(IH) = 0.0
      |    UNDERS(IH) = 0.0
      |    OVERBA(IH) = 0.0
      |    UNDBA(IH) = 0.0
      | +--DO IS = 1, 3
      | |    FOL(IH, IS) = 0.0
      | |    RSITES(IH, IS) = 0.0
      | +--ENDDO
      |    RSITES(IH, 4) = 0.0
      +--ENDDO

c Sum total basal area for the stand (BAR) - used when calc. live
c crown ratio for individual trees.  when finished, convert BAR
c from cm2/ha to ft2/ac

         BAR = 0.0
      +--DO ID = 1, NDIAM
      |    R = DIAM(ID)/2.0
      | +--DO IH = 1, NHOSTS
```

```
      | |    BAR = BAR + STEMS(IH, ID)*3.14159*R*R
      | +--ENDDO
      +--ENDDO

c  convert from sq.-cm/ha to sq.-ft./ac.

         BAR = BAR*0.000435609

         IF (DEBUG) WRITE (JDB, 10000) BAR

c    Calc. crown ratio for each tree based on Holdaway (1986). CR1-
c  CR4 = parameters from Holdaway (1986).  Crown ratio will be used
c  when partitioning the resting sites on overstory trees between
c  boles and crown.  convert diam. from cm to inches.  Holdaway computed
c  CRC (Crown Ration Code) from field data that was coded as 1 for crown
c  ratios between 1 and 10 percent, 2 for ratios between 11 and 20
c  percent, etc.  Thus we multiply by 0.1 and subtract 0.05 to get
c  CROWNR

         TOTOVR = 0.0
         WLEAF = 0.0
      +--DO IH = 1, NHOSTS
      | +--DO ID = 1, NDIAM
      | |    DIAMIN = DIAM(ID)/2.54
      | |    CROWNR = (CR1(IH)/(1.0+CR2(IH)*BAR) + CR3(IH)*(1.0-EXP
     *| |      (-CR4(IH)*DIAMIN)))*0.1-0.05
      | |
      | |    IF (DEBUG) WRITE (JDB, 10010) IH, ID, CROWNR
      | |
c Sum the total foliage in the stand (WLEAF, in kg per ha).
c F1 &|F2 are allometric foliage biomass parameters from
cSheehan (unpubl.).
      | |
      | | +--IF (STEMS(IH, ID) .GT. 0.0) THEN
      | | |    FOLIAG = F1(IH)*DIAM(ID)**(F2(IH))*STEMS(IH, ID)
      | | |    WLEAF = WLEAF + FOLIAG
      | | |
c Separate overstory and understory calculations.
c set IS = to strata (1=overstory, 2=understory)
c IBOUND=1 if height is to be used to separate over & understory,
c or 2|if diameter is to be used.  HOVER = the boundary ht. or diam.
      | | |
      | | |    IS = 1
      | | | +--IF (IBOUND .EQ. 1) THEN
      | | | |    IF (HEIGHT(IH, ID) .LT. HOVER) IS = 2
      | | | +--ELSE
      | | | |    IF (DIAM(ID) .LT. HOVER) IS = 2
      | | | +--ENDIF
      | | |
c  Convert to g/ha & store understory foliage (FOL(ih,2)).
c  sum|the number of understory trees by species in UNDERS(ih).
c sum the basal area of understory trees by species in UNDBA(ih).
c the number of resting sites (RSITES) is assumed to be a function
c of tree surface area and a species-specific index.  Tree surface
c area|is calculated by assuming that the tree is a right circular
```

```
c cone.  RESTIN(ih,ix) is the number of resting sites per square meter
c of surface area; therefore divide by 100**2=10000 to compute the
c number that will rest in location ix (ix = 1 for boles of overstory
c trees, ix = 2 for crowns of over- or understory trees).
       | | |
       | | |
       | | |    R = DIAM(ID)/2.0
       | | | +--IF (IS .EQ. 2) THEN
       | | | |     FOL(IH, 2) = FOL(IH, 2) + FOLIAG*1000.0
       | | | |     X = R*R + (HEIGHT(IH, ID)**2)
       | | | |     RSITES(IH, 2) = RSITES(IH, 2) + (STEMS(IH, ID)
      *| | | |      *3.14159*R*SQRT(X)*RESTIN(IH, 2)/10000.0)
       | | | |     UNDERS(IH) = UNDERS(IH) + STEMS(IH, ID)
       | | | |     UNDBA(IH) = UNDBA(IH) + STEMS(IH, ID)*3.14159*R*R
       | | | +--ELSE
       | | | |
c Next, for overstory trees:  sum foliage biomass in g/ha (FOL),
c no. of overstory stems (OVERS), & overstory basal area (OVERBA)
       | | | |
       | | | |     FOL(IH, 1) = FOL(IH, 1) + FOLIAG*1000.0
       | | | |     OVERS(IH) = OVERS(IH) + STEMS(IH, ID)
       | | | |     OVERBA(IH) = OVERBA(IH) + (STEMS(IH, ID)*R*R*3.14159)
       | | | |     TOTOVR = TOTOVR + STEMS(IH, ID)
       | | | |
c For overstory trees, the lower bole is assumed to have the
c shape of a cylinder, and the upper bole is assumed to have the
c shape of a right circular cone.  CROWNR = crown ratio (proportion
c of total tree height that is covered by live crown), and
c bole|length = 1.0 - CROWNR; RESTIN(ih,1) is for boles of trees;
c RESTIN(ih,2) is for branches within crowns.  These (RESTIN) are
c numbers of resting sites per 100 cm. square area.
       | | | |
       | | | |     RSITES(IH, 4) = RSITES(IH, 4) + STEMS(IH, ID)*3.14159
      *| | | |      *DIAM(ID)*HEIGHT(IH, ID)*(1.0 - CROWNR)*RESTIN(IH,
      *| | | |      1)/10000.0
       | | | |     X = R*R + (HEIGHT(IH, ID)*CROWNR)**2
       | | | |     RSITES(IH, 1) = RSITES(IH, 1) + STEMS(IH, ID)*3.14159
      *| | | |      *R*SQRT(X)*RESTIN(IH, 2)/10000.0
       | | | +--ENDIF
       | | +--ENDIF
       | +--ENDDO
       |
       +--ENDDO
          RETURN
          END

c   ***    End of subroutine TREE1; file name TREE1.FOR     ***
```

```
c       *****   Subroutine TREE21, file: TREE21.FOR   *****
c A portion of the:
c Stand-Damage Model - a portion of the Gypsy Moth Life System Model
c       (the stand submodel) converted to a stand-alone model.  Last
c       revised by K.Sheehan January 1988; revised starting in 1989
c       by Colbert and Racin.
c
c              J. Colbert, Northeastern Forest Experiment Station
c            180 Canfield St., Morgantown, WV  26505  (304)-285-1600

c This routine (1) calculates the superior leaf area for each tree
c class, (2) set crowding factor for this year, (3) sets stress option
c ISTRES for this year, (4) reads the management prescription data for
c this year (if any), and (5) sets up DEBUG output printing.
c
c Called from main program DAMSR.
c Calls subroutines RANDS and PTSTBL if conditions are met.
c  **  Local variables, parameters, and inputs required
c                                    by Subroutine TREE21()  **
c  The following designations for LOCATIONs apply:
c        (1) - l := local variable
c        (2) - n := new parameter; not yet assigned to a common block
c        (3) - cp:= call parameter of this subroutine
c        (4) - s := subroutine called from within this code
c        (5) -XXN:= CAPS or CAPS+digit indicate a common block name
c  ---------------------------------------------------------------
c NAME - LOCATION - DESCRIPTION
c  ---------------------------------------------------------------
c CUTMAX     S4   - Maximum diameter to be cut, by host & year.
c CUTMIN     S4   - Minimum diameter to be cut, by host & year.
c CUTPR      S4   - Proportion to be cut by species.
c DEBUG     LOG1  - True if debug table to be produced.
c DEFL       S3   - Percent defoliation, by host & strata.
c DIAM       S1   - Diameter at mid-point, by diameter class.
c EPSIMG     S4   - Min. no. of stems that must be present for a
c                   particular cell stem count to be accumulated.
c EPSI01      n   - Minimum stem count (STEMS) required for use in calc-
c                   ulation of superior leaf area and foliage biomass.
c FAREA       l   - Accumulates foliage surface area.
c FOLIAG      l   - Amount of foliage biomass for a given tree.
c F1         S1   - Parameter for calculating foliage biomass /tree.
c F2         S1   - Parameter for calculating foliage biomass /tree.
c GTCRWD      s
c HEIGHT     S1   - Tree heights by host and diameter class.
c HOVER      S2   - Height or diameter that separates overstory and
c                   understory trees.
c HTALL       l   - Height of tallest tree.
c IBOUND     S4   - Overstory/understory boundary type: 1 = height (ft
c             or cm), 2=diam. (in or cm).
c ID          l   - Diameter index.
c IH          l   - Host index.
c IHOST       l   - Species of the tallest tree.
c ISEED     GEN1  - Random number seeds: 1=recruitment of new trees,
c             2=not used at this time, 3=additional tree
c             mortality due to stress, 4=add. gypsy moth
```

```
c              mortality due to winter temp., 5=for weather
c              generation, 6= GM L1 disp.
c ISITE       S4   - Index for site (1=moist, 2=intermediate, 3=dry).
c ISOPT       S4   - Tree stress option (1=stress occurs in random
c              years, 2=user specifies stress years.
c ISTRAT      1    - Strata (1=over-, 2=understory).
c ISTRES      1    - Stress index (1 = no stress this year, 2 = stress
c                    will occur this year).
c ISTRYR      S4   - Used to decide when to add stress STRFAC(2) as SDIE
c ISYEAR     GEN1  - Start in year.
c JSOUT1     GEN1  - File number: stand output.
c JSTRS      GEN1  - File number: stress years.
c JTIN       GEN1  - File number.
c MANAGE      S4   - Stand management option: 0= no actions, 1= user
c                    specifies proportions to be cut, 2= user specifies
c                    target no. of stems.
c MYEARS      S4   - Yrs that management actions have been scheduled.
c NDIAM       S4   - Number of diameter classes to be simulated.
c NDTALL      1    - Pointer to tallest diameter class present.
c NHOSTS     GEN1  - Number of hosts to be simulated.
c NSTRYR      S4   - Number of stress years.
c PCUT        S4   - Number of trees to be cut, by host and year.
c PLOTSZ      S2   - Area for calculating influence of surrounding trees
c                    on shading of a given tree.
c PTSTBL      s
c RANDS       s
c STABLE     LOG2  - True if stand submodel output is desired.
c STEMS       S1   - Number of stems, by host and diameter class.
c STRESS      S1   - Probability that a stand on site ISITE will not be
c                    subject to additional unspecified stress.
c SUM         1    - Total stems.
c SUMLFA      S2   - Sum of leaf surface area for all trees taller than
c                    a given tree, by host and diameter class.
c SURFAR      S1   - Foliage biomass to surface area conversion factor.
c TARGET      S4   - Target no. of residual stems (if MANAGE=2) for
c                    scheduled harvests, by yr and host.
c TOBCUT      S4   - Total no. of stems to be harvested.
c TSUMDC      1    - Number of stems in the harvest range.
c X           1    - Value returned from random number generator.
c ----------------------------------------------------------------

          SUBROUTINE TREE21
10000     FORMAT (1X, I4)
10010     FORMAT (2(1X, F6.1), 1X, F6.2)
10020     FORMAT (2X, 'Initial Number of Stems per Hectare:', /64X,
     *     'DIAMETER CLASS  (cm.)'/2X, 'SPECIES', 20F6.2/, 2X, 7('-'),20(
     *     ' -----'))

c ***** Common Blocks Included:

          INCLUDE 'GEN1.CMB'
          INCLUDE 'LOG1.CMB'
          INCLUDE 'LOG2.CMB'
          INCLUDE 'S1.CMB'
          INCLUDE 'S2.CMB'
```

```
         INCLUDE 'S3.CMB'
         INCLUDE 'S4.CMB'
         DIMENSION NDTALL(6)

c For each host species and diameter class, calculate the
c superior leaf area (SUMLFA) -- the surface area of foliage
c on all trees taller than the given tree.  Start with the tallest
c tree in the stand and work towards the shortest, accumulating
c foliage area and storing the superior leaf area for all taller
c trees (= FAREA for a given trees) in SUMLFA.
c            First set NDTALL(ih) to the index of the largest diameter
c class present for each tree species.  Note that this is done for all
c trees with sufficiently positive stem counts.  This assures that
c trees with only roundoff error for input height are ignored.
c Along the way, set SUMLFA and FAREA to zero.
c (1)*********************************************************************

         EPSI01 = 0.0001

         FAREA = 0.0
      +--DO IH = 1, NHOSTS
      |    NDTALL(IH) = 0
      | +--DO ID = 1, NDIAM
      | |    SUMLFA(IH, ID) = 0.0
      | +--ENDDO
      | +--DO ID = NDIAM, 1, -1
      | | +--IF (STEMS(IH, ID) .GT. EPSI01) THEN
      | | |    IF (ID .GT. NDTALL(IH)) NDTALL(IH) = ID
      | | +--ENDIF
      | +--ENDDO
      +--ENDDO

c For each sp., NDTALL now contains the diameter class index of the
c tallest trees.  Compare the heights of the tallest trees for each host
c species.  Set IHOST to the species of the tallest tree.  The DO WHILE
c (.TRUE.) starts of the loop for ordering the trees from tallest to
c smallest.

      +--DO WHILE (.TRUE.)
      |    HTALL = 0.0
      |    IHOST = 0
      | +--DO IH = 1, NHOSTS
      | | +--IF (NDTALL(IH) .GT. 0) THEN
      | | | +--IF (HTALL .LT. HEIGHT(IH, NDTALL(IH))) THEN
      | | | |    HTALL = HEIGHT(IH, NDTALL(IH))
      | | | |    IHOST = IH
      | | | +--ENDIF
      | | +--ENDIF
      | +--ENDDO
      |
c The species & diam. class of the tallest tree remaining
c are IHOST & NDTALL(IHOST).
c Check to see if no more trees are left; if so, then skip to
c next|section of code.  Label "100" is the exit point for this loop.
      |
```

```
      |     IF (IHOST .EQ. 0) GOTO 100
      |
c Store foliage area accumulated so far (FAREA) in SUMLFA for the
c current tree, but adjust the area that the tree effects (PLOTSZ)
c this|assumes that the effected area is similar to the stand at large,
c i.e., the stand is homogeneously stocked.
      |
      |     SUMLFA(IHOST, NDTALL(IHOST)) = FAREA*PLOTSZ
      |
c Calculate the foliage area for the current tree and add the area per
c hectare to variable FAREA.  FOLIAG = foliage surface area of crown for
c tree, given no defoliation.  ISTRAT = strata (1=over-, 2=understory)
c DEFL|= tree's total defoliation by species & strata this year.
c Determine if current tree is over or understory using IBOUND (1 = use
c hts,|2 = use diam.s) and HOVER (boundary ht. or diam.).  F1 & F2 =
c foliage biomass parameters from Sheehan (unpubl.) (for calc. kg).
c SURFAR = leaf surface area to biomass ratio (cm2/g).  SURFAR * .10 =
c m2/kg.
      |     ISTRAT = 1
      | +--IF (IBOUND .EQ. 1) THEN
      | |     IF (HEIGHT(IHOST, NDTALL(IHOST)) .LT. HOVER) ISTRAT = 2
      | +--ELSE
      | |     IF (DIAM(NDTALL(IHOST)) .LT. HOVER) ISTRAT = 2
      | +--ENDIF
      |
      |     FOLIAG = (F1(IHOST)*DIAM(NDTALL(IHOST))**F2(IHOST))*SURFAR
     *|      (IHOST)*0.10
      |     FAREA = FAREA + (FOLIAG*(1.0 - (DEFL(IHOST, ISTRAT)/100.0))
     *|      *STEMS(IHOST, NDTALL(IHOST)))
      |
c For the tree species that was just handled, reset the pointer
c NDTALL to the next smaller diameter class that has trees.
      |
      | +--DO WHILE (.TRUE.)
      | |     NDTALL(IHOST) = NDTALL(IHOST) - 1
      | |     IF (NDTALL(IHOST) .EQ. 0) GOTO 90
      | |     IF (STEMS(IHOST, NDTALL(IHOST)) .GT. EPSI01) GOTO 90
      | |
c Go back and find the next tallest tree.
      | |
      | +--ENDDO
   90 |     CONTINUE
     +--ENDDO
c Exit for the loop that started 60 lines up.
  100     CONTINUE
c (2)*********************************************************************
c Calculate the crowding factor for this stand, a function of the
c relative stocking calculated earlier in subroutine RELSTK.
          CALL GTCRWD()
c (3)*********************************************************************
```

```
c  Determine if additional stress that may affect tree mortality
c  will occur this year.  ISTRES is dependent variable that is used to
c  invoke the stress called for by setting stress option ISOPT to 1 or
c  2.  ISTRES = stress index (1 = no stress this year, 2 = stress will
c  occur this year).  if ISOPT =1, then stress occurs in years when a
c  random number (using ISEED(3)) is less than the threshold value
c  STRESS(ISITE). thus, STRESS(ISITES) is the probability of additional
c  random stress. random.  If ISOPT=2, then the user has identified
c  specific years when stress will occur by providing a list of those
c  years.  RANDS = pseudo-random number generator.  ISEED(3) = seed for
c  random number generator and stress.
            ISTRES = 1
         +--IF (ISOPT .EQ. 1) THEN
         |     CALL RANDS(ISEED(3), X)
         |     IF (X .LT. STRESS(ISITE)) ISTRES = 2
         +--ELSEIF ((ISOPT .EQ. 2) .AND. (ISTRYR .EQ. ISYEAR)) THEN
         |     ISTRES = 2
c If more stress years have been scheduled, get the next one.
         | +--IF (NSTRYR .GT. 0) THEN
         | |     NSTRYR = NSTRYR - 1
         | |     READ (JSTRS, 10000) ISTRYR
         | +--ENDIF
         +--ENDIF

c (4)*******************************************************************
c Handle some management actions.  If MANAGE=0, then no actions are
c scheduled; if MANAGE=1, then proportions to be cut have been
c specified by the user -- they will be applied later.

c See if any actions are scheduled for this year.  ISYEAR=current year,
c MYEARS = year of next management action.


         +--IF (MANAGE .GT. 0 .AND. MYEARS .EQ. ISYEAR) THEN
         |     IF (STABLE .OR. DEBUG) CALL PTSTBL()
         | +--IF (MANAGE .EQ. 1) THEN
         | | +--DO IH = 1, NHOSTS
         | | |     READ (JTIN, 10010) CUTMIN(IH), CUTMAX(IH), PCUT(IH)
         | | |     CUTMIN(IH) = CUTMIN(IH)*2.54001
         | | |     CUTMAX(IH) = CUTMAX(IH)*2.54001
         | | +--ENDDO
         | +--ELSE
         | | +--DO IH = 1, NHOSTS
         | | |     READ (JTIN, 10010) CUTMIN(IH), CUTMAX(IH), TARGET(IH)
         | | |     CUTMIN(IH) = CUTMIN(IH)*2.54001
         | | |     CUTMAX(IH) = CUTMAX(IH)*2.54001
         | | |     TARGET(IH) = TARGET(IH)*2.471044
         | | +--ENDDO
         | +--ENDIF
         |     IF (STABLE .OR. DEBUG) CALL PRTMGT()
         |
c The user has specified the target number of stems (MANAGE=2). Sum
c total stems (SUM) and the number of stems in the harvest range
c (TSUMDC).  Set proportion to be cut by species (CUTPR) to zero.
c STEMS = no. of stems, DIAM = diam class index, EPSIMG(1) = min. no. of
```

```
c stems that must be present for a particular cell stem count to be
c accumulated.  CUTMIN & CUTMAX are minimum & maximum diameters to be
c cut in this treatment (they have been set by the user).
      |
      |
      | +--IF (MANAGE .EQ. 2) THEN
      | | +--DO IH = 1, NHOSTS
      | | |      SUM = 0.0
      | | |      TSUMDC = 0.0
      | | |      CUTPR(IH) = 0.0
      | | | +--DO ID = 1, NDIAM
      | | | | +--IF (STEMS(IH, ID) .GE. EPSIMG(1)) THEN
      | | | | |      IF (DIAM(ID) .GE. CUTMIN(IH) .AND. DIAM(ID) .LT.
     *| | | | |       CUTMAX(IH))    TSUMDC = TSUMDC + STEMS(IH, ID)
      | | | | |      SUM = SUM + STEMS(IH, ID)
      | | | | +--ENDIF
      | | | +--ENDDO
      | | |
c Calc. total no. of stems to be harvested (TOBCUT) based on target
c no. of trees to remain (which has been specified by the user).
c Set the proportion of stems to be cut by species (CUTPR) if there
c are sufficient stems in the species for the specified diameter range.
      | | |
      | | |      TOBCUT(IH) = SUM - TARGET(IH)
      | | |      IF (TOBCUT(IH) .LT. 0.0) TOBCUT(IH) = 0.0
      | | | +--IF (TSUMDC .GT. EPSIMG(2)) THEN
      | | | | +--IF (TOBCUT(IH) .GE. TSUMDC) THEN
      | | | | |      CUTPR(IH) = 1.0
      | | | | +--ELSE
      | | | | |      CUTPR(IH) = TOBCUT(IH)/TSUMDC
      | | | | +--ENDIF
      | | | +--ENDIF
      | | +--ENDDO
      | +--ENDIF
      +--ENDIF

c (5)*********************************************************************
c If DEBUG, write a header line for annual stand data output
      +--IF (DEBUG) THEN
      |     WRITE (JSOUT1, *) 'Debug output from TREE21:10020:'
      |     WRITE (JSOUT1, 10020) (DIAM(ID), ID = 1, 20)
      +--ENDIF

         RETURN
         END

c  End of subroutine TREE21  --  File name TREE21.FOR
```

```
c      *****   Subroutine TREE22, file: TREE22.FOR   *****
c A portion of the:
c Stand-Damage Model - a portion of the Gypsy Moth Life System Model
c       (the stand submodel) converted to a stand-alone model.  Last
c       revised by K.Sheehan January 1988; revised starting in 1989
c       by Colbert and Racin.
c
c             J. Colbert, Northeastern Forest Experiment Station
c           180 Canfield St., Morgantown, WV  26505  (304)-285-1600

c    This section calculates diameter growth and mortality rates
c for each tree species & diameter class, followed by recruitment of
c new stems and management entries.  First the temperature modifier of
c growth is calculated for each species; then for each diameter class
c and host, the defoliation modifier, the shading modifier, the
c potential and actual growth are calculated.  Then the mortality
c factors are calculated and accumulated (past and current defoliation,
c stress, slow growth and background rates).  Growth and mortality
c effects are summarized for tabular and ASCII file output.  Growth is
c simulated by moving the stem counts between diameter classes.
c Management entries (tree removals) are simulated followed by further
c summarizing of the stand for output.  Finally, defoliation histories
c (by tree species and crown strata) for the year is updated.

c Called from main program DAMSR.
c Calls subroutines RANDS, PRTMGT, and PTSTBL if conditions are met.

c  **  Local variables, parameters, and inputs required
c                             by Subroutine TREE22()  **
c  The following designations for LOCATIONs apply:
c        (1) - l := local variable
c        (2) - n := new parameter; not yet assigned to a common block
c        (3) - cp:= call parameter of this subroutine
c        (4) - s := subroutine called from within this code
c        (5) -XXN:= CAPS or CAPS+digit indicate a common block name
c  ---------------------------------------------------------------
c NAME - LOCATION - DESCRIPTION
c  ---------------------------------------------------------------
c ALIGHT      l    - Available light, see equation ().
c ANNDD     WTHR1 - The total number of degree-days for the year above
c                   a 42 degree F. threshold.
c BA          S2  - Basal area (by host & strata).
c BASAL       l   - Basal area.
c BDIE        S1  - Background tree mortality rate, by host.
c B1          S1  - Parameter for calc. tree height.
c B2          S1  - Parameter for calc. tree height.
c COLD        S2  - Minimum annual degree-days tolerated, by host.
c CROWD       S2  - Crowding index (a tree growth modifier).
c CUTMAX      S4  - Maximum diameter to be cut, by host and year.
c CUTMIN      S4  - Minimum diameter to be cut, by host and year.
c CUTNUM      l   - Number of trees to be cut by species.
c CUTPR       S4  - Proportion to be cut by species
c DDIE        l   - Proportion of trees that will die following
c                   defoliation (calc. by host and diam. class).
c DEBUG     LOG1  - Logical variable, true to produce debug output.
```

```
c DEFIND       S2    - Defoliation index (a tree growth modifier).
c DEFL         S3    - Percent defoliation, by host and strata.
c DEGDT      WTHR1   - Total degree-days for the current year.
c DFLC(i,j)    S3    - For j=1,2;i=1,2: parameters for equation (13)
c                      (light) and equation (14) (heavy) for predicting
c                      defind (eqn. (16)), the effect of current defolia-
c                      tion on diameter growth.
c DIAM         S1    - Diameter at mid-point, by diameter class.
c DIAMCL       l     - DBH squared for each diameter class.
c DLEN         S1    - Length of diameter class (cm).
c DMAX         S1    - Maximum diameter at breast height (cm), by host.
c DMEAN        S2    - Quadratic mean dbh by host and strata.
c EPSIGR       S2    - Decision parameter for including stems(host,diam) in
c                      growth calculations, if >0 then small stem counts
c                      will not enter into these calculations.
c EPSIMG       S4    - Min. no. of stems that must be present for a
c                      particular cell stem count to be accumulated
c EPSITR       S2    - Decision parameter for including stems(h,d) in
c                      transfer between diameter classes.
c FDIE         S1    - Proportion of trees that die because of defoliation,
c                      based on host, number of years of defoliation, and
c                      site.
c GDIE         l     - Proportion of trees that die following slow growth.
c GROW         l     - Actual annual diameter tree growth, by host and
c                      diameter class, in cm.
c GROWMX       S2    - Potential diameter growth, by host and diam. class.
c GROWR        S1    - Parameter for calc. potential annual diam. growth.
c HEIGHT       S1    - Tree heights (cm), by host and diameter class.
c HMAX         S1    - Maximum height (cm), by host.
c HOT          S2    - Maximum annual degree-days tolerated, by host.
c HOVER        S2    - Height or diameter (cm) that separates over- and
c                      understory trees.
c IBOUND       S4    - Overstory/understory boundary type: 1=height (ft or
c                      cm), 2=diameter (in or cm).
c ID           l     - Diameter class number.
c IDHIST       S3    - Defoliation history for the past two years: 0=none,
c                      1=light (0.1-29.9%), 2=medium (30-64.9%), 3=heavy
c                      (65+%), by host and strata.
c IH           l     - Host species index.
c IHEAVY       l     - Temporary variable storing heavy defoliation for
c                      past two yrs.
c IN           l     - Index for reading in Shade and Stocking effect
c                      values.
c IS           l     - Strata number.
c ISEED       GEN1   - Random number seeds (1= recruitment of new trees, 2=
c                      not used at this time, 3= additional tree mortality
c                      due to stress, 4= add. gypsy moth mortality due to
c                      winter temperatures, 5= for weather generator, 6=
c                      gypsy moth L1 dispersal.
c ISHADE       S4    - Shade tolerance class by species (1=recruitment, 2=
c                      diameter growth).
c ISITE        S4    - Index for site (1=moist, 2=intermediate, 3=dry).
c ISTRAT       l     - Set to 1 for overstory, 2 for understory.
c ISTRES       S4    - Set to 2 if current year is a stress year.
c ISYEAR      GEN1   - Starting year; example: 1987.  Then incremented to
```

```
c                           contain calendar year of simulation.
c ITEST         1         - Temporary variable storing defoliation history
c                           for past two years.
c IWOPT         GEN1      - Weather option: 1=1 year of data, 2=>1 year of data,
c                           3=generate data with Subr. WGEN, 4=use annual total
c                           degree-days.
c IYEAR         GEN1      - Current year in the simulation.
c JDB           GEN1      - Number of file that contains debug output.
c JSOUT1        GEN1      - Number of file: stand output.
c MANAGE        S4        - Stand management option: 0=no actions, 1=user
c                           specifies proportions to be cut, 2=user specifies
c                           target no. of stems.
c METRIC        LOG2      - Set to true if input/output units are to be metric.
c MYEARS        S4        - Years that management actions have been scheduled
c                           (for example: if MYEARS(1)=1990, then first harvest
c                           occurs in 1990).
c NDEF(ih,id)   1         - Number of years of heavy defoliation (>65%), by host
c                           and diameter class.
c NDIAM         S4        - Number of diameter classes to be simulated.
c NEWST         1         - Indicates first diameter class only.
c NHOSTS        GEN1      - Number of hosts to be simulated.
c NSLOW(ih,id)  1         - Number of years of slow growth (<.01cm/yr), by host
c                           and diameter class.
c OVERS         S3        - Total count of overstory stems, by species.
c PCUT          S4        - Proportion of trees to be cut, by host and year.
c PTSTBL        s
c RANDRC        1         - Random number returned by RANDS.
c RANDS         s
c RECRUT        S1        - Maximum number of seedlings that can be recruited
c                           into the smallest diameter class, by host.
c RSHADE        1         - Local Real variable in TREE22 holds shading
c                           effect on stocking of new recruits.
c RSTOCK        S3        - Relative stocking index for the stand.
c RSTRES        S2        - Proportion of mortality due to stress, by host.
c SDIE          1         - Proportion of trees that will die due to stress in
c                           years of heavy defoliation.
c SGMORT        S2        - No. of years of slow growth (nslow) effect on tree
c                           mortality rate. exponential rate coefficient for
c                           calculating gdie, eqn. (18).
c SHADE         1         - Tree growth modifier for shading for a given tree.
c SHADMN        S1        - Minimum value for shade in equation 16.
c SHX           S1        - Parameter for effect of light on diam. growth by
c                           shade tolerance index.
c SHY           S1        - Parameter for effect of light on diam. growth by
c                           shade tolerance index.
c SLIP          1         - Function that interlopes between data points.
c SLOWD         S1        - Minimum annual growth needed to avoid additional
c                           mortality
c SMFDIE        S2        - Mean tree mortality due to defoliation, by host
c                           and strata.
c SMGDIE        S2        - Mean tree mortality due to slow growth.
c SMGROW        S2        - Mean actual diameter growth.
c SMPGRO        S2        - Mean potential diameter growth.
c SMSHAD        S2        - Mean shading growth modifier.
c SMTDIE        S2        - Mean total tree mortality.
```

```
c STABLE    LOG2  - Set to true if stand submodel output is desired.
c STEM        S2  - Number of stems (by host & strata)
c STEMS       S1  - Number of stems, by host and diameter class.
c STOKX       S1  - Relative stocking parameter for effect of relative
c                   stocking on recruitment.
c STOKY       S1  - Recruitment parameter for effect of relative
c                   stocking on recruitment.
c STRFAC      S1  - Proportion of trees that die because of stress.
c SUMLFA      S2  - Sum of leaf surface area for all trees taller than a
c                   given tree, by host and diameter class.
c TDIE        1   - Total proportion of trees that die.
c TEMP        S2  - Tree growth modifier for temperature, by host.
c TEMPMN      S1  - Minimum value for TEMP in equation 11(b).
c TEMPX(4)    1   - Temporary storage variable for SHX.
c TEMPY(4)    1   - Temporary storage variable for SHY.
c TFAC      WTHR1 - Multiplier used to change all temperature values by
c                   a certain proportion (set to 1.0 by default).
c TKL         S2  - Parameter for calculating available light.
c TLIGHT      S2  - Parameter for calculating available light.
c TNAME     CHAR1 - Tree code, by host.
c TOBCUT      S4  - Total no. of stems to be harvested.
c TOTBA      SUM  - Total basal area (over+understory), by host.
c TOTDBH     SUM  - Quadratic mean diameter for all trees,
c             by host species.
c TOTSTM     SUM  - Total number of trees (over+understory), by host.
c TOTVOL     SUM  - Total volume (over+understory), by host.
c TREEN(id)   1   - Temporary variable storing STEMS times GROW, divided
c                   by DLEN.
c TSTEM       1   - Temporary variable storing STEMS.
c UNDERS(ih)  S3  - Total count of understory stems, by species.
c VOL(ih,is)  S2  - Total live tree volume (by host & strata)
c VOLUME      1   - Volume of right-circular cone, [pi*r**2]*h/3.
c YIELD       1   - Yield accumulator variable, used to calculate and
c                   load the YLD variables.
c YLD(ih,is)  S2  - Yield (volume of harvested trees, by host & strata)
c ----------------------------------------------------------------

          SUBROUTINE TREE22
10000     FORMAT(' TREE22;4765: IYEAR = ',I5, ', ANNDD(IYEAR) = ', F10.2,
     *     ', TFAC = ',F10.5, ', DEGDT = ',F10.5, ', Species Co', 'de = '
     *     , A3, ', TEMP(IH) = ', F10.5)
10010     FORMAT (3X, A3, 3X, 20F6.2)
10020     FORMAT ('POTGROWTH', 20F6.4)
10030     FORMAT ('ACTGROWTH', 20F6.4)
10040     FORMAT (2X, A5, 2X, 20F6.4)
10050     FORMAT ('NEWST = ', F10.4, ', STEMS(IH,1) = ', F10.4,
     *     ', RANDRC = ', F10.6, ', RSHADE = ', F10.4, ', RECRUT(IH) = ',
     *     F10.4)

c *****   Common Blocks Included:

          INCLUDE 'CHAR1.CMB'
          INCLUDE 'GEN1.CMB'
          INCLUDE 'LOG1.CMB'
          INCLUDE 'LOG2.CMB'
```

```
          INCLUDE 'S1.CMB'
          INCLUDE 'S2.CMB'
          INCLUDE 'S3.CMB'
          INCLUDE 'S4.CMB'
          INCLUDE 'SUM.CMB'
          INCLUDE 'WTHR1.CMB'

c ***** Local variable definitions and initialization:

          REAL*8 NEWST

          DIMENSION GROW(20), NSLOW(12, 20), NDEF(12, 20)
          DIMENSION TEMPX(4), TEMPY(4), TREEN(20)

          DATA NSLOW, NDEF/480*0/

c Do the following growth and mortality calculations for each host

       +--DO IH = 1, NHOSTS
       |
c Initialize summary variables to zero.
       |
       |    OVERS(IH) = 0.0
       |    UNDERS(IH) = 0.0
       |    TOTSTM(IH) = 0.0
       |    TOTBA(IH) = 0.0
       |    TOTVOL(IH) = 0.0
       | +--DO ISTRAT = 1, 2
       | |    RSTRES(IH, ISTRAT) = 0.0
       | |    SMGROW(IH, ISTRAT) = 0.0
       | |    SMPGRO(IH, ISTRAT) = 0.0
       | |    SMSHAD(IH, ISTRAT) = 0.0
       | |    SMTDIE(IH, ISTRAT) = 0.0
       | |    SMFDIE(IH, ISTRAT) = 0.0
       | |    SMGDIE(IH, ISTRAT) = 0.0
       | |    DMEAN(IH, ISTRAT) = 0.0
       | |    STEM(IH, ISTRAT) = 0.0
       | |    BA(IH, ISTRAT) = 0.0
       | |    VOL(IH, ISTRAT) = 0.0
       | |    YLD(IH, ISTRAT) = 0.0
       | +--ENDDO
       |
c Compute the growth modifier for temperature (=TEMP(ih)).
c DEGDT = annual degree-days for trees.  If IWOPT=4, annual deg.days
c have|been provided by the user (=ANNDD) & may be modified by a
c temperature multiplier (TFAC, set to 1.0 by default).  Otherwise,
c annual deg-days have been calc. in subr. WEATHER & stored in DEGDT.
c HOT & COLD are the max. and min. deg-days found in a species
c geographic range.  the relation is taken from JABOWA.  The
c minimum value has been arbitrarily set to 0.05, this minimum value is
c now user accessible through parameter TEMPMN.
       |
       |    IF (IWOPT .EQ. 4) DEGDT = ANNDD(IYEAR)*TFAC
       |    TEMP(IH) = 4*(DEGDT - COLD(IH))*(HOT(IH) - DEGDT)/(HOT(IH) -
      *|     COLD(IH))**2
```

```
         |      IF (TEMP(IH) .LT. TEMPMN) TEMP(IH) = TEMPMN
         |      IF (DEBUG) WRITE (JDB, 10000) IYEAR, ANNDD(IYEAR), TFAC,
        *|       DEGDT, TNAME(IH), TEMP(IH)
         |
c Do the following preliminary calculations for each diameter class.
c No changes have been made to the stems per acre STEMS(ih,id) yet!
         |
c ***********************************************************************
         |      IF (DEBUG) WRITE (JSOUT1, 10010) TNAME(IH), (STEMS(IH,ID), ID
        *|       = 1, NDIAM)
c ***********************************************************************
         |
         | +--DO ID = 1, NDIAM
         | |
c  Determine which strata this diameter class belongs to
         | |
         | |     ISTRAT = 1
         | | +--IF (IBOUND .EQ. 1) THEN
         | | |     IF (HEIGHT(IH, ID) .LT. HOVER) ISTRAT = 2
         | | +--ELSE
         | | |     IF (DIAM(ID) .LT. HOVER) ISTRAT = 2
         | | +--ENDIF
         | |
c  Calculate growth modifier due to defoliation (=DEFIND)
c  based on defoliation history for previous 2 years (stored
c  in IDHIST (0=none, 1=light, 2=medium, 3=heavy) and current
c  defoliation (DEFL).
c  (eqns. from Sheehan (unpubl.) interpretation of literature)
         | |
         | |     ITEST = IDHIST(IH, ISTRAT, 1) + IDHIST(IH, ISTRAT, 2)
         | |     IHEAVY = 0
         | |     IF (IDHIST(IH, ISTRAT, 1) .EQ. 3 .OR. IDHIST(IH, ISTRAT, 2)
        *| |      .EQ. 3) IHEAVY = 1
         | | +--IF (ITEST .EQ. 0 .AND. DEFL(IH, ISTRAT) .LE. 0.0) THEN
         | | |     DEFIND(IH, ISTRAT) = 1.0
         | | +--ELSEIF (ITEST .LE. 3 .AND. IHEAVY .EQ. 0) THEN
         | | |     DEFIND(IH, ISTRAT) = DFLC(1, 1) + DFLC(1, 2)*DEFL(IH,
        *| | |      ISTRAT)
         | | +--ELSE
         | | |     DEFIND(IH, ISTRAT) = 1.0/(DFLC(2, 1) + DFLC(2, 2)*DEFL
        *| | |      (IH, ISTRAT))
         | | +--ENDIF
         | |
c    Calc. growth loss due to shading (=SHADE)
c available light (ALIGHT) is calc. based on foliage area above (SUMLFA)
c using exponential approach of JABOWA.  TLIGHT is set to 1.0 by default
c and TKL was arbitrarily set by Sheehan (following the technique
c used|in JABOWA).  ISHADE(ih,2) stores the shade tolerance index for
c use when calc. diam. growth.  SHX and SHY store the coordinates of
c the 4-pt. step functions that describe the relation between avail.
c light and diam. growth for a given shade tolerance index.  These
c coordinates are temporarily stored in TEMPX and TEMPY when using the
c SLIP|function to interpolate between points.  If SHADE is below the
c minimum value (SHADMN = 0.05 by default) then it reset to the min.
         | |
```

```
          | |    ALIGHT = TLIGHT*EXP( - TKL*SUMLFA(IH, ID))
          | | +--DO IN = 1, 4
          | | |    TEMPX(IN) = SHX(ISHADE(IH, 2), IN)
          | | |    TEMPY(IN) = SHY(ISHADE(IH, 2), IN)
          | | +--ENDDO
          | |    SHADE = SLIP(ALIGHT, TEMPX, TEMPY, 4)
          | |    IF (SHADE .LT. SHADMN) SHADE = SHADMN
          | |
c  Calc. potential growth (= GROWMX) using function from JABOWA.
c  also see equations (15) and (16) in the documentation.
c DMAX=maximum diameter, HMAX= maximum height, B1 and B2 = parameters
c used|to calculate tree height, GROWR = optimum growth parameter from
c JABOWA or FORET.  Next, calc. actual growth (=GROW) by applying the
c 4 growth modifiers calc. earlier to the amt. of potential growth.
c GROWMX and grow units = cm per year.  This is calculated only for
c cells where the stem count is above min. count EPSIGR (default 0.0).
          | |
          | |    GROW(ID) = 0.0
          | | +--IF (STEMS(IH, ID) .GE. EPSIGR) THEN
          | | |    GROWMX(IH, ID) = GROWR(IH)*DIAM(ID)*(1. - DIAM(ID)
         *| | |      *HEIGHT(IH, ID)/(DMAX(IH)*HMAX(IH)))/(274. + DIAM(ID)*
         *| | |      (3.*B1(IH) - 4.*B2(IH)*DIAM(ID)))
          | | |    GROW(ID) = GROWMX(IH, ID)*DEFIND(IH, ISTRAT)*SHADE*TEMP
         *| | |      (IH)*CROWD
          | | |    IF (GROW(ID) .LT. 0.) GROW(ID) = 0.0
          | | +--ENDIF
          | |
c  Calculate tree mortality
          | |
c  First, calc. mortality following defoliation.
c  NDEF = number of years with continuous heavy defoliation.
c  DDIE = proportion of trees that will die following defoliation.
c  DEFL = defoliation (host,strata)
c  FDIE = mortality rate for species ih on site type "ISITE" after
c     | | NDEF years of continuous heavy defoliation.
c  SDIE = additional mortality due to stress (can only occur in
c     | | years with heavy defoliation)
c  ISTRES = 1 if no stress occurs this year, = 2 if no stress occurs
c     | | (was set earlier in this subroutine)
c  STRFAC = mortality rate due to stress (value 1 = rate with no stress,
c     | |   value 2 = rate with stress)
          | |
          | |    DDIE = 0.0
          | |    SDIE = 0.0
          | |    NDEF(IH, ID) = NDEF(IH, ID) + 1
          | |    IF (DEFL(IH, ISTRAT) .LE. 65.0) NDEF(IH, ID) = 0
          | |    IF (NDEF(IH, ID) .GT. 3) NDEF(IH, ID) = 3
          | | +--IF (NDEF(IH, ID) .GT. 0) THEN
          | | |    DDIE = FDIE(IH, NDEF(IH, ID), ISITE)
          | | |    SDIE = STRFAC(ISTRES)
          | | +--ENDIF
          | |
c Next, calc. additional mortality following years of slow growth
c (function came from JABOWA).
c  NSLOW = number of years of slow growth (less than SLOWD cm/yr)
```

```
c  SLOWD(ih) = minimum growth (cm/yr) required to avoid add. mortality
c  GDIE = proportion of trees that die following slow growth.
       | |
       | |     NSLOW(IH, ID) = NSLOW(IH, ID) + 1
       | |     IF (GROW(ID) .GT. SLOWD(IH)) NSLOW(IH, ID) = 0
       | |     IF (NSLOW(IH, ID) .GT. 10) NSLOW(IH, ID) = 10
       | |     GDIE = 1. - EXP(SGMORT*FLOAT(NSLOW(IH, ID)))
       | |
c Finally, calc. total mortality rate
c  BDIE = base or background mortality rate
c  TDIE = total proportion of trees that die.
       | |
       | |     TDIE = BDIE(IH) + GDIE + DDIE + SDIE
       | |     IF (TDIE .GT. 1.) TDIE = 1.
       | |     STEMS(IH, ID) = STEMS(IH, ID)*(1 - TDIE)
       | |
c  Causes of growth loss and mortality are summed (for output)
c  by species for overstory and understory trees.  Weighted means
c  will be calc. for pot. growth (SMPGRO), actual growth (SMGROW),
c  shading (SMSHAD), total mortality (SMTDIE), slow growth mortality
c  (SMGDIE), defoliation mortality (SMFDIE), & stress mort. (RSTRES)
       | |
       | | +--IF (ISTRAT .EQ. 1) THEN
       | | |     OVERS(IH) = OVERS(IH) + STEMS(IH, ID)
       | | +--ELSE
       | | |     UNDERS(IH) = UNDERS(IH) + STEMS(IH, ID)
       | | +--ENDIF
       | |     SMPGRO(IH, ISTRAT) = SMPGRO(IH, ISTRAT) + (GROWMX(IH, ID)
      *| |      *STEMS(IH, ID))
       | |     SMGROW(IH, ISTRAT) = SMGROW(IH, ISTRAT) + (GROW(ID)*STEMS
      *| |      (IH, ID))
       | |     SMSHAD(IH, ISTRAT) = SMSHAD(IH, ISTRAT) + (SHADE*STEMS(IH,
      *| |      ID))
       | |     SMTDIE(IH, ISTRAT) = SMTDIE(IH, ISTRAT) + (TDIE*STEMS(IH,
      *| |      ID))
       | |     SMGDIE(IH, ISTRAT) = SMGDIE(IH, ISTRAT) + (GDIE*STEMS(IH,
      *| |      ID))
       | |     SMFDIE(IH, ISTRAT) = SMFDIE(IH, ISTRAT) + (DDIE*STEMS(IH,
      *| |      ID))
       | |     RSTRES(IH, ISTRAT) = RSTRES(IH, ISTRAT) + (SDIE*STEMS(IH,
      *| |      ID))
       | |
       | +--ENDDO
       |
       |
c *********************************************************************
       | +--IF (DEBUG) THEN
       | |     WRITE (JSOUT1, 10010) TNAME(IH), (STEMS(IH, ID), ID = 1,
      *| |      NDIAM)
       | |     WRITE (JSOUT1, 10020) (GROWMX(IH, ID), ID = 1, NDIAM)
       | |     WRITE (JSOUT1, 10030) (GROW(ID), ID = 1, NDIAM)
       | +--ENDIF
c *********************************************************************
       |
c If appropriate, move trees from one diameter class to another,
```

```
c starting with the largest trees.  The proportion that move up =
c ratio of diameter growth for this diam. class (GROW) to the
c width of this diam. class (DLEN).  Only move trees if the
c no. of new trees to be added is greater than the tree transfer epsilon
c value (EPSITR) set by user (default=0.0).  Don't move trees into diam.
c classes that are larger than the maximum diameter (DMAX) for sp. ih.
        |
        | +--DO ID = NDIAM - 1, 1, -1
        | | +--IF ((DIAM(ID) + DLEN(ID)/2.0) .LT. DMAX(IH)) THEN
        | | |    TREEN(ID) = STEMS(IH, ID)*GROW(ID/DLEN(ID)
        | | |    IF (TREEN(ID) .GT. STEMS(IH, ID)) TREEN(ID) = STEMS(IH,
       *| | |     ID)
        | | | +--IF (TREEN(ID) .GE. EPSITR) THEN
        | | | |    STEMS(IH, ID + 1) = STEMS(IH, ID + 1) + TREEN(ID)
        | | | |    STEMS(IH, ID) = STEMS(IH, ID) - TREEN(ID)
        | | | +--ENDIF
        | | +--ENDIF
        | +--ENDDO
        |
c *********************************************************************
        | +--IF (DEBUG) THEN
        | |    WRITE (JSOUT1, 10040) 'TREEN', (TREEN(ID), ID = 1, NDIAM)
        | |    WRITE (JSOUT1, 10010) TNAME(IH), (STEMS(IH, ID), ID = 1,
       *| |     NDIAM)
        | +--ENDIF
c *********************************************************************
        |
        |
        | +--DO ID = 1, NDIAM
        | |
        | |
c  Apply cutting if scheduled.  If manage=0, no cutting is scheduled.
c  If (MYEARS is less than ISYEAR), then cutting is scheduled, but not
c  for|this year.
c  CUTMIN(ih) = minimum diameter class to be cut for species ih,
c  CUTMAX(ih) = maximum diameter class to be cut.
        | |
c  if MANAGE=1, user has specified proportions to be cut.
c    the proportions are applied to all trees with the diameter
c    limits specified by CUTMIN and CUTMAX.
c  If MANAGE=2, the user has chosen target residual stem counts.
c    TARGET residuals are in relation to the total stem counts for
c    each species and not just trees within the cutting diameter limits.
c  Trees will only be cut if their diameter class falls
c  between CUTMIN and CUTMAX.  When a diameter class of a given
c  species is within the "cut range", the proportion of trees in
c  that diameter class that will be cut is set by PCUT(ih).
        | |
      | |    YIELD = 0.0
        | | +--IF (MANAGE .GT. 0 .AND. MYEARS .EQ. ISYEAR) THEN
        | | | +--IF (MANAGE .EQ. 1) THEN
        | | | |    IF (DIAM(ID) .GE. CUTMIN(IH) .AND. DIAM(ID) .LE.
       *| | | |    +--CUTMAX(IH)) THEN
        | | | |    |    YIELD = (STEMS(IH, ID)*DIAM(ID)*DIAM(ID)*
       *| | | |    |     (3.14159/12.)*HEIGHT(IH, ID)*PCUT(IH)/1E6)
```

```
          | | | |   |   STEMS(IH, ID) = STEMS(IH, ID)*(1. - PCUT(IH))
          | | | |   +-ENDIF
          | | | |
  c User|has selected a target number of stems (MANAGE=2).  CUTPR
  c stores the proportion of trees to be cut by species (calc.
  c earlier in this subroutine).  Specified target may leave few trees to
  c be cut (TOBCUT(ih)) and user may specify minimum sufficient for
  c removal as EPSIMG(3) (default 0.0).
          | | | |
          | | | +--ELSEIF (TOBCUT(IH) .GT. EPSIMG(3)) THEN
          | | | |     IF (DIAM(ID) .GE. CUTMIN(IH) .AND. DIAM(ID) .LE.
        * | | | |   +--CUTMAX(IH)) THEN
          | | | |   |   CUTNUM = STEMS(IH, ID)*CUTPR(IH)
          | | | |   |   YIELD = ((CUTNUM*DIAM(ID)*DIAM(ID)*3.14159
        * | | | |   |    /12.0*HEIGHT(IH, ID)/1E6))
          | | | |   |   STEMS(IH, ID) = STEMS(IH, ID) - CUTNUM
          | | | |   +-ENDIF
          | | | +--ENDIF
          | | |     IF ((STABLE .OR. DEBUG).AND.
        * | | |      (ID .EQ. NDIAM).AND.(IH .EQ. NHOSTS))
        * | | |      CALL PTSTBL()
          | | +--ENDIF
          | |
  c  Add|recruitment (# stems that grow into the smallest diam. class)
  c      for first diameter class only (=NEWST)
  c ISHADE(ih,1) = shading tolerance class (1= most tol., 5=least tol.)
  c RSTOCK = relative stocking for stand (calc. in tree1)
  c ISEED(1) = pseudo-random number seed for recruitment.
  c RECRUT(ih) = maximum number of trees that can be recruited in one
  c    year by species ih (arbitrarily set by k.sheehan)
  c STOKX & STOKY store parameters that adjust max. # of trees recruited
  c    based on ISHADE(ih) and RSTOCK.
          | |
          | | +--IF (ID .EQ. 1) THEN
          | | | +--DO IN = 1, 4
          | | | |     TEMPX(IN) = STOKX(ISHADE(IH, 1), IN)
          | | | |     TEMPY(IN) = STOKY(ISHADE(IH, 1), IN)
          | | | +--ENDDO
          | | |     RSHADE = SLIP(RSTOCK, TEMPX, TEMPY, 4)
          | | |     CALL RANDS(ISEED(1), RANDRC)
          | | |     NEWST = RECRUT(IH)*RANDRC*RSHADE
          | | |     STEMS(IH, 1) = STEMS(IH, 1) + NEWST
          | | |
  c ***********************************************************************
          | | | +--IF (DEBUG) THEN
          | | | |     WRITE (JSOUT1, 10050) NEWST, STEMS(IH, 1), RANDRC,
        * | | | |      RSHADE, RECRUT(IH)
          | | | |     CALL PTSTBL()
          | | | +--ENDIF
          | | +--ENDIF
          | |
  c Calculate basal area in m2/ha and volume in m3/ha for the
  c Current species and diameter class.
          | |
          | |     BASAL = (DIAM(ID)**2*(3.14159/4.))*STEMS(IH, ID)/1E4
```

```
          | |
c Volume = vol. of right-circular cone, [pi*r**2]*h/3.
          | |
          | |     VOLUME = HEIGHT(IH, ID)*BASAL/300.
          | |     DIAMCL = DIAM(ID)*DIAM(ID)*STEMS(IH, ID)
          | |     TSTEM = STEMS(IH, ID)
          | |
c Sum variables for this diameter class according to strata.
c   DMEAN= quadratic mean dbh
c   STEM = number of stems (by host & strata)
c   BA|= basal area (by host & strata)
c   VOL = total live tree volume (by host & strata)
c   YLD = yield (volume of harvested trees, by host & strata)
          | |
          | |     ISTRAT = 1
          | | +--IF (IBOUND .EQ. 1) THEN
          | | |     IF (HEIGHT(IH, ID) .LT. HOVER) ISTRAT = 2
          | | +--ELSE
          | | |     IF (DIAM(ID) .LT. HOVER) ISTRAT = 2
          | | +--ENDIF
          | |     BA(IH, ISTRAT) = BA(IH, ISTRAT) + BASAL
          | |     STEM(IH, ISTRAT) = STEM(IH, ISTRAT) + TSTEM
          | |     VOL(IH, ISTRAT) = VOL(IH, ISTRAT) + VOLUME
          | |     YLD(IH, ISTRAT) = YLD(IH, ISTRAT) + YIELD
          | |     DMEAN(IH, ISTRAT) = DMEAN(IH, ISTRAT) + DIAMCL
          | |
c  Total variables for graphics output
          | |
          | |     TOTSTM(IH) = TOTSTM(IH) + TSTEM
          | |     TOTBA(IH) = TOTBA(IH) + BASAL
          | |     TOTVOL(IH) = TOTVOL(IH) + VOLUME
          | |
          | +--ENDDO
          |
c Calculate the quadratic mean diameter for each host.
          |
          |    TOTDBH(IH) = SQRT((DMEAN(IH, 1) + DMEAN(IH, 2))/(STEM(IH, 1)
         *|     + STEM(IH, 2)))
          |
c Convert the summed growth and mortality causes to averages by
c dividing the sums by the number of overstory stems (OVERS) or
c understory stems (UNDERS).
          |
          | +--IF (OVERS(IH) .GT. 0.00001) THEN
          | |     SMPGRO(IH, 1) = SMPGRO(IH, 1)/OVERS(IH)
          | |     SMGROW(IH, 1) = SMGROW(IH, 1)/OVERS(IH)
          | |     SMSHAD(IH, 1) = SMSHAD(IH, 1)/OVERS(IH)
          | |     SMTDIE(IH, 1) = SMTDIE(IH, 1)/OVERS(IH)
          | |     SMGDIE(IH, 1) = SMGDIE(IH, 1)/OVERS(IH)
          | |     SMFDIE(IH, 1) = SMFDIE(IH, 1)/OVERS(IH)
          | |     RSTRES(IH, 1) = RSTRES(IH, 1)/OVERS(IH)
          | |     DMEAN(IH, 1) = SQRT(DMEAN(IH, 1)/OVERS(IH))
          | +--ENDIF
          | +--IF (UNDERS(IH) .GT. 0.00001) THEN
          | |     SMPGRO(IH, 2) = SMPGRO(IH, 2)/UNDERS(IH)
```

```
        | |    SMGROW(IH, 2) = SMGROW(IH, 2)/UNDERS(IH)
        | |    SMSHAD(IH, 2) = SMSHAD(IH, 2)/UNDERS(IH)
        | |    SMTDIE(IH, 2) = SMTDIE(IH, 2)/UNDERS(IH)
        | |    SMGDIE(IH, 2) = SMGDIE(IH, 2)/UNDERS(IH)
        | |    SMFDIE(IH, 2) = SMFDIE(IH, 2)/UNDERS(IH)
        | |    RSTRES(IH, 2) = RSTRES(IH, 2)/UNDERS(IH)
        | |    DMEAN(IH, 2) = SQRT(DMEAN(IH, 2)/UNDERS(IH))
        | +--ENDIF
        | +--IF (.NOT. METRIC) THEN
        | |    SMPGRO(IH, 1) = SMPGRO(IH, 1)/2.54
        | |    SMPGRO(IH, 2) = SMPGRO(IH, 2)/2.54
        | |    SMGROW(IH, 1) = SMGROW(IH, 1)/2.54
        | |    SMGROW(IH, 2) = SMGROW(IH, 2)/2.54
        | +--ENDIF
        |
c Reset defoliation history
        |
        | +--DO IS = 1, 2
        | |    IDHIST(IH, IS, 2) = IDHIST(IH, IS, 1)
        | | +--IF (DEFL(IH, IS) .LE. 0.0) THEN
        | | |    IDHIST(IH, IS, 1) = 0
        | | +--ELSEIF (DEFL(IH, IS) .LE. 30.0) THEN
        | | |    IDHIST(IH, IS, 1) = 1
        | | +--ELSEIF (DEFL(IH, IS) .LE. 65.0) THEN
        | | |    IDHIST(IH, IS, 1) = 2
        | | +--ELSE
        | | |    IDHIST(IH, IS, 1) = 3
        | | +--ENDIF
        | +--ENDDO
        |
        +--ENDDO

c Change from metric to English units if METRIC = False.
c  1 sq ft/ac = 1 / 4.355983 sq m/ha
c  1 cu ft/ac = 1 / 14.29123 cu m/ha
c  1 inch = 2.540005 cm

        +--IF (.NOT. METRIC) THEN
        | +--DO IH = 1, NHOSTS
        | | +--DO IS = 1, 2
        | | |    BA(IH, IS) = BA(IH, IS)*4.355983
        | | |    STEM(IH, IS) = STEM(IH, IS)/2.471044
        | | |    VOL(IH, IS) = VOL(IH, IS)*14.29123
        | | |    YLD(IH, IS) = YLD(IH, IS)*14.29123
        | | |    DMEAN(IH, IS) = DMEAN(IH, IS)/2.540005
        | | +--ENDDO
        | |    TOTSTM(IH) = TOTSTM(IH)/2.471044
        | |    TOTBA(IH) = TOTBA (IH)*4.355983
        | |    TOTVOL(IH) = TOTVOL(IH)*14.29123
        | |    TOTDBH(IH) = TOTDBH(IH)/2.540005
        | +--ENDDO
        +--ENDIF
           RETURN
           END
c  ***  End of Subroutine TREE22  --  File name TREE22.FOR  ***
```

```
c       *****   Subroutine WASCII, file: WRITASCI.FOR   *****
c A portion of the:
c Stand-Damage Model - a portion of the Gypsy Moth Life System Model
c       (the stand submodel) converted to a stand-alone model.  Last
c       revised by K.Sheehan January 1988; revised starting in 1989
c       by Colbert and Racin.
c
c              J. Colbert, Northeastern Forest Experiment Station
c            180 Canfield St., Morgantown, WV  26505  (304)-285-1600

c    This section writes to the ASCII data files.
c          Called from main program DAMSR.
c          No calls to subroutines are made by this routine.

c  **  local variables, parameters, and inputs required
c                                by subroutine WASCII **
c  the following designations for LOCATIONs apply:
c        (1) - l := local variable
c        (2) - n := new parameter; not yet assigned to a common block
c        (3) - cp:= call parameter of this subroutine
c        (4) - s := subroutine called from within this code
c        (5) -XXN:= caps or caps+digit indicate a common block name
c-------------------------------------------------------------------
c NAME - LOCATION - DESCRIPTION
c-------------------------------------------------------------------
c BA          S2   - Basal area, by host and strata
c DMEAN       S2   - Mean diameter, by host and strata
c ICAT        S4   - Tree graphics category: 1=overstory, 2=understory
c                    3=total
c IGYEAR      S4   - Interval (years) for printing stand graph files
c IH           l   - Host index
c ISYEAR     GEN1  - Starting year
c JSOUT2     GEN1  - File number: number of stems (for graph)
c JSOUT3     GEN1  - File number: basal area (for graph)
c JSOUT4     GEN1  - File number: volume (for graph)
c JSOUT5     GEN1  - File number: mean DBH (for graph)
c KGYEAR      S4   - Counter for number of years since last
c                    writing of ASCII data for file(s).
c NHOSTS     GEN1  - Number of hosts to be simulated
c STEM        S2   - Number of stems, by host and strata
c TGBA       LOG2  - True to get basal area graph file
c TGDBH      LOG2  - True to get mean DBH graph file
c TGSTEM     LOG2  - True to get stem number graph file
c TGVOL      LOG2  - True to get volume graph file
c TOTBA      SUM   - Total basal area (over+understory), by host
c TOTDBH     SUM   - Mean diameter for all trees, by host species.
c TOTSTM     SUM   - Total number of trees (over+understory), by host
c TOTVOL     SUM   - Total volume (over+understory), by host
c VOL         S2   - Stand volume by host and strata
c-------------------------------------------------------------------

           SUBROUTINE WASCII
  10000    FORMAT (I5, 12F9.2)
  10010    FORMAT (I5, 12F11.2)
  10020    FORMAT (I5, 12F9.3)
```

```
        INCLUDE 'CHAR1.CMB'
        INCLUDE 'GEN1.CMB'
        INCLUDE 'LOG2.CMB'
        INCLUDE 'S2.CMB'
        INCLUDE 'S4.CMB'
        INCLUDE 'SUM.CMB'

c Write data to ASCII files.

     +--IF (KGYEAR .EQ. IGYEAR) THEN
     | +--IF (ICAT .EQ. 1) THEN
     | |    IF (TGSTEM) WRITE (JSOUT2, 10000) ISYEAR, (STEM(IH, 1), IH
    *| |     = 1, NHOSTS)
     | |    IF (TGBA) WRITE (JSOUT3, 10000) ISYEAR, (BA(IH, 1), IH = 1,
    *| |     NHOSTS)
     | |    IF (TGVOL) WRITE (JSOUT4, 10010) ISYEAR, (VOL(IH, 1), IH =
    *| |     1, NHOSTS)
     | |    IF (TGDBH) WRITE (JSOUT5, 10020) ISYEAR, (DMEAN(IH, 1), IH
    *| |     = 1, NHOSTS)
     | +--ELSEIF (ICAT .EQ. 2) THEN
     | |    IF (TGSTEM) WRITE (JSOUT2, 10000) ISYEAR, (STEM(IH, 2), IH
    *| |     = 1, NHOSTS)
     | |    IF (TGBA) WRITE (JSOUT3, 10000) ISYEAR, (BA(IH, 2), IH = 1,
    *| |     NHOSTS)
     | |    IF (TGVOL) WRITE (JSOUT4, 10010) ISYEAR, (VOL(IH, 2), IH =
    *| |     1, NHOSTS)
     | |    IF (TGDBH) WRITE (JSOUT5, 10020) ISYEAR, (DMEAN(IH, 2), IH
    *| |     = 1, NHOSTS)
     | +--ELSE
     | |    IF (TGSTEM) WRITE (JSOUT2, 10000) ISYEAR, (TOTSTM(IH), IH =
    *| |     1, NHOSTS)
     | |    IF (TGBA) WRITE (JSOUT3, 10000) ISYEAR, (TOTBA(IH), IH = 1,
    *| |     NHOSTS)
     | |    IF (TGVOL) WRITE (JSOUT4, 10010) ISYEAR, (TOTVOL(IH), IH =
    *| |     1, NHOSTS)
     | |    IF (TGDBH) WRITE (JSOUT5, 10020) ISYEAR, (TOTDBH(IH), IH =
    *| |     1, NHOSTS)
     | +--ENDIF
     |    KGYEAR = 0
     |
     +--ENDIF
        RETURN
        END

c  End of subroutine WASCII  --  File name WRITASCI.FOR
```

Appendix D Common Blocks for Stand-Damage Model

Each common block is contained in a separate file with the ".CMB" extension. Using these blocks (file contents) where needed is accomplished using INCLUDE statements. The contents of each file follows.

```
-- File CHAR1.CMB taken from DAMAGE.FOR 11/21/89.

      CHARACTER STRATA*5,TNAME*2
      CHARACTER UNITS*7,UNITS2*2,UNITS3*2,UNITS4*2,RNSPC1*12
      CHARACTER*20 RNSPC2,RNSPC3,RNSPC4,RNSPC5

      COMMON /CHAR1/STRATA(4),TNAME(12),UNITS,UNITS2,UNITS3,
     *       UNITS4,RNSPC1,RNSPC2,RNSPC3,RNSPC4,RNSPC5

-- File GEN1.CMB taken from DAMAGE.FOR  11/21/89.

      COMMON /GEN1/IYEAR,NHOSTS,NWEAYR,NYEARS,IPYEAR,JGEN,JTIN,JDB,
     *      ISEED(10),JWIN,JDEF,JSOUT1,JSOUT2,JSOUT3,JSOUT4,
     *      JSOUT5,IWFORM,IWOPT,ISYEAR,NUMLIN,JSTRS,NLINES

-- File LOG1.CMB taken from INITW.FOR 11/21/89.

      LOGICAL       LRAIN,DEBUG
      COMMON /LOG1/LRAIN,DEBUG

-- File LOG2.CMB taken from DAMAGE.FOR 11/21/89.

      LOGICAL METRIC,LDEFOL,TGSTEM,TGBA,TGVOL,TGDBH,STABLE,TEMPC
      COMMON /LOG2/METRIC,LDEFOL,TGSTEM,TGBA,TGVOL,TGDBH,STABLE,TEMPC

-- File S1.CMB taken from TPRINT.FOR 11/21/89.

      COMMON /S1/STEMS(12,20),HEIGHT(12,20),DIAM(20),DLEN(20),
     *       SURFAR(12),B1(12),B2(12),F1(12),F2(12),GROWR(12),DMAX(12),
     *       HMAX(12),SHADMN,BDIE(12),FDIE(12,3,3),STRFAC(2),STRESS(3),
     *       CR1(12),CR2(12),CR3(12),CR4(12),ISTOKG(12),RESTIN(12,2),
     *       SHX(6,4),SHY(6,4),AGEMAX(12),SLOWD(12),RECRUT(12),
     *       STOKX(6,4),STOKY(6,4),TEMPMN

-- File S2.CMB taken from DAMAGE.FOR 11/21/89.

      COMMON /S2/DMEAN(12,2),SMSHAD(12,2),SMFDIE(12,2),RSTRES(12,2),
     *      PLOTSZ,DEFIND(12,2),TEMP(12),BA(12,2),STEM(12,2),VOL(12,2),
     *      YLD(12,2),SMGROW(12,2),SMTDIE(12,2),SMGDIE(12,2),TLIGHT,
     *      TKL,CROWD,GROWMX(12,20),SMPGRO(12,2),HOVER,PRTMIN,COLD(12),
     *      HOT(12),RSMULT,EPSIGR,EPSITR,CRWDMN,SGMORT,STOCKS(3,3),
     *      SUMLFA(12,20)

-- File S3.CMB taken from DAMAGE.FOR 11/21/89.

      COMMON /S3/IDFOLY,DEFL(12,3),DFLC(2,2),OVERS(12),UNDERS(12),
     *       RSTOCK,ACTFOL(12,3),FOL(12,3),OVERBA(12),UNDBA(12),
     *       RSITES(12,4),DFOLDE,IDHIST(12,2,2),PLOTAR,STNDAR

-- File S4.CMB taken from DAMAGE.FOR 11/21/89.

      COMMON /S4/ISHADE(12,2),ISOPT,ISTR(15),NDIAM,ISITE,IGYEAR,KGYEAR,
     *      ICAT,IBOUND,IVIEW(20),NSTRYR,ISTRYR,ISTRES,MANAGE,MTOTAL,
     *      MYEARS,CUTMIN(12),CUTMAX(12),PCUT(12),TARGET(12),EPSIMG(3),
     *      CUTPR(12),TOBCUT(12)

-- File SUM.CMB was created on 08:51 24-09-91 as TREE2 was broken apart.

      COMMON /SUM/TOTSTM(12), TOTBA(12), TOTVOL(12), TOTDBH(12)

-- File WTHR1.CMB taken from DAMAGE.FOR 11/21/89

      COMMON /WTHR1/TFAC,TRETHR,DEGDT,ANNDD(100)
```

Location of common blocks, i.e., the routines in which they are included through use of an INCLUDE statement.

Routine Name	Common Blocks									
	CHAR1	GEN1	LOG1	LOG2	S1	S2	S3	S4	SUM	WTHR1
BLK. DATA	X	X						X		
CLEAN			X	X						
DAMSR	X	X	X	X		X	X	X		X
DEFOL		X		X			X			
FLUPDT		X					X			
GNXTMG		X						X		
GTCRWD						X	X			
INITW		X	X							X
PINIT	X	X	X	X	X	X	X	X		
PRNOTE										
PRTMGT	X	X		X		X		X		
PTSTBL	X	X		X	X			X		
RANDS										
RELSTK		X			X	X	X	X		
SLIP										
THGHTS		X			X			X		
TINIT	X	X	X	X	X	X	X	X		X
TPRINT	X	X		X	X	X	X			
TREE1		X	X		X	X	X	X		
TREE21		X	X	X	X	X	X	X		
TREE22	X	X	X	X	X	X	X	X	X	X
WASCII	X	X		X		X		X	X	

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