New Brunswick Permanent Sample Plot Database (PSPDB v1.0): User's Guide and Analysis

Kevin B. Porter, David A. MacLean, Kathy P. Beaton, and John Upshall[1]

Information Report M-X-209E
Landscape Management Network

[1] Forest Management Branch, N.B. Department of Natural Resources & Energy,
P.O. Box 6000, Fredericton, N.B. E3B 5H1

Canadian Forest Service - Atlantic Forestry Centre
Natural Resources Canada
P.O. Box 4000, Fredericton, N.B. E3B 5P7

2001

ISSN 1195-3799
ISBN 0-662-29988-4
Catalogue No. Fo46-19/209E

Additional copies of this publication are available in limited quantities at no charge from:

Canadian Forest Service - Atlantic Forestry Centre
P.O. Box 4000
Fredericton, N.B. Canada E3B 5P7
(506) 452-3500
Fax (506) 452-3525

Photocopies or microfiches of this publication may also be purchased from:

Micromedia Ltd.
240 Catherine St., Suite 305
Ottawa, ON K2P 2G8
Tel: (613) 237-4250
Toll free: 1-800-567-1914
Fax: (613) 237-4251

Une copie française de ce rapport est disponible sur demande.

Editing, design and layout: Caroline Simpson

Canadian Cataloguing in Publications Data

Main entry under title :

New Brunswick permanent sample plot database (PSPDB v1.0) : user's guide and analysis

(Information report, ISSN 1195-3799 ; M-X-209E)
Issued also in French under title : Base de données sur les placettes d'échantillonnage permanentes du Nouveau-Brunswick (PSPDB v1.0)
Includes bibliographical references.
ISBN 0-662-29988-4
Cat. No. F046-19/209E

1. Trees -- New Brunswick -- Growth -- Databases -- Handbooks, manuals, etc.
2. Forest site quality -- New Brunswick -- Databases -- Handbooks, manuals, etc.

I. Porter, Kevin B., 1961 - .
II. Atlantic Forestry Centre
III. Title.
IV. Series: Information report (Atlantic Forestry Centre); M-X-209E.

SD146.N4N48 2001 634.9'285'0971511 C2001-980084-3

Abstract

The Canadian Forest Service and the New Brunswick Department of Natural Resources and Energy (NBDNRE) have cooperated to develop an interactive database system in support of the N.B. Cooperative Permanent Sample Plot (PSP) program. The program, initiated in 1987, includes approximately 2500 PSPs located throughout the province. These plots are representative of the entire provincial forest. Data from the PSPs can be used to define stand structures at specific points in time, calibrate stand growth models, and validate/invalidate projections made with stand models. These growth projections or yield curves represent the volume expectations that form the basis for forest management plans.

The Permanent Sample Plot Database (PSPDB) was created as a data management and reporting system. Microsoft Access® is used to facilitate access and transform the raw data into information using meaningful, built-in calculations and a flexible graphical user interface (GUI). PSPDB is updated annually with new measurement data from NBDNRE and can be downloaded via the Internet.

This report presents an overview of the N.B. Cooperative PSP program, the database structure and functions of PSPDB, installation instructions, and a tutorial. Selected calculated outputs from the system are also presented, including volume, periodic annual increment, and periodic mortality, by geographic area (Crown license and marketing board area), and by species class.

Résumé

Le Service canadien des forêts et le ministère des Ressources naturelles et de l'Énergie du Nouveau-Brunswick (MRNÉNB) ont élaboré conjointement un système interactif de base de données pour appuyer le programme coopératif néo-brunswickois des placettes d'échantillonnage permanentes (PEP). Ce programme a été lancé en 1987 et porte sur environ 2500 PEP qui sont réparties à l'échelle de la province. Ces placettes représentent la forêt provinciale en entier. Les données rassemblées sur les PEP permettent entre autres de définir la structure des peuplements à des moments précis, de calibrer les modèles de croissance des peuplements, et de valider ou d'invalider les projections établies au moyen de modèles de simulation de peuplements. Ces projections de croissance ou courbes de production volumique représentent les prévisions de volume sur lesquelles les plans d'aménagemet forestier sont fondés.

La base de données sur les placettes d'échantillonnage permanentes (PSPDB) est un système de gestion des données et de rapports. L'utilisation de l'application Microsoft Access[MD] facilite l'accès aux données brutes et permet de les transformer en information au moyen de calculs significatifs intégrés et d'une interface utilisateur graphique (IUG) souple. La PSPDB est mise à jour tous les ans à partir de nouvelles données de mesurage fournies par le MRNÉNB et on peut la télécharger par l'intermédiaire d'internet.

Le présent rapport donne un aperçu du programme coopératif néo-brunswickois des PEP, de la structure de la base de données et de la fonctionnalité de la PSPDB, et il contient les instructions d'installation requises ainsi qu'un tutoriel. On y présente les résultats de calculs sélectionnés qui ont été effectués au moyen du système pour déterminer certaines valeurs dont le volume, l'accroissement périodique moyen et la mortalité périodique par aire géographique (concessions de la Couronne, et terrains forestiers relevant des offices de commercialisation) et par classe d'essences forestières.

Table of Contents

1. Introduction

A permanent sample plot (PSP) is a specific location in a forest stand where characteristics of the stand and its vegetation are measured at periodic intervals. It provides a chronicle of how trees are changing over time, and can be used to represent the development of stands with similar characteristics. Currently there are over $1.5 milllion invested in the establishment and remeasurement of PSPs by the New Brunswick Department of Natural Resources & Energy (NBDNRE) and eight forest product companies in New Brunswick.

The NB Cooperative PSP program, initiated in 1987 (Wang *et al.* 1986), includes approximately 2500 PSPs located throughout the province, selected to be representative of the entire provincial forest. Crews from NBDNRE and forest products companies carry out the field measurements under the direction of the program coordinator from NBDNRE. The objectives of the Cooperative PSP program are to define stand structures at specific points in time and to validate/invalidate the stand growth projections made with stand models (Dunlap 1988). These growth projections or yield curves represent the volume expectations that form the basis for forest management plans. They supply the data necessary to analyze how the forest is currently growing and how it may be harvested in the future, and thereby represent a linchpin in determining sustainability of timber on Crown land and private woodlots in New Brunswick.

In proposing the Cooperative PSP program, Wang *et al.* (1986) envisaged that it should become an integral part of the information system of each land manager in the province. To realize this goal, NBDNRE and the Canadian Forest Service (CFS) have worked together to develop an interactive database system called PSPDB (Permanent Sample Plot Database). Prior to its development, there was no way for users to efficiently access these data. Ensuring quality for hundreds of thousands of tree measurements field collected over several years by a large number of crews requires stringent quality control standards and validation procedures. Procedure manuals guide the data collection process while the import of data into PSPDB features extensive checking to ensure that the database is clean and valid. NBDNRE maintains responsibility for the validation process, and users of the system can get updates to the database as the annual data acquisition provides additional plot assessments and tree measurements.

PSPDB uses Microsoft Access® to display a graphical user interface (GUI) and to provide the functionality necessary for managers to display and use PSP data. The system currently supports Access versions 7 and 8.

PSPDB allows users to analyze data by querying the database and displaying results in pre-defined charts and tabular reports. Examples of calculations include mean annual volume increment, periodic mortality and survivor growth, total merchantable volume, piece size, stand density, diameter distribution, basal area, and defoliation distribution. These summaries may be totals, or may be grouped by plot, year, or tree species. By learning some of the advanced capabilities of Access, users can also design their own charts and reports.

The objectives of this report are 1) to present an overview of the NB Cooperative PSP program and the database structure; 2) to describe the functionality of PSPDB, along with installation instructions and a tutorial; and 3) to present some calculated outputs from the PSPDB, including volume, periodic annual increment, and periodic mortality, by geographic area (Crown license and private woodlot marketing board area) and by species class.

2. Obtaining and Installing the Software

The system requirements for PSPDB include the following:

486 PC (Pentium recommended)
with Windows 95 or 98
16 MB memory (32 MB recommended)
Microsoft Access v.7 (Office 95) or
v.8 (Office97)
100 MB disk space (for PSPDB files)

If you have Internet access, PSPDB (software and data) can be downloaded via your web browser. Direct your web browser to the CFS-Atlantic Forestry Centre homepage at http://atl.cfs.nrcan.gc.ca and look under the Downloads section.

To install PSPDB on your personal computer, please folllow the instructions below (note that Microsoft Access v.7 or v.8 must already be installed for PSPDB to run):

- Open Windows Explorer and locate the self-extracting zip file that you downloaded.
- Double-click the file to extract the PSPDB files.
- When prompted with the WinZip Self-Extractor window, enter the name of the directory in which to place the PSPDB files. This directory will be created for you if it does not exist. The default is `c:\pspdata`.
- Once the files have been extracted, double-click on the `pspapp.mdb` file (containing charts, reports, and programs) in Windows Expolorer or start Access and open `pspapp.mdb`. This will start the PSPDB application. The first time the application is run, a dialog box will appear requiring you to identify the location of the file `pspdata.mdb` (containing the data tables). This will not need to be repeated unless `pspdata.mdb` is moved to another directory.
- PSPDB is now ready to use.

3. The New Brunswick Cooperative PSP Program

NBDNRE and provincial Crown licensees together determined the level of sampling for each plot type in the NBPSP program. In allocating the PSPs, several factors were considered, including uncertainties that exist in yield forecasts, a program target of 2500 PSPs, an equitable distribution of plots in each license and marketing board area, and replication of significant stand conditions (Dunlap 1988).

Within PSPDB there are seven primary data tables (Table 1). Five tables contain individual-tree information (one table for each type of plot). The other two tables contain plot-level data, one with static (unchanging) data, and the second with data that change with each measurement (*e.g.*, measurement year, development stage).

Figure 1 shows the locations of the 2499 PSPs. The entire landbase of the province is generally covered, with the exception of some large freehold blocks and federal lands.

The methodology used in establishing and measuring each plot varied depending on the development stage of the stand. The following sections briefly describe the sampling and data structure for each development stage.

Table 1. Description of the seven primary data tables used in PSPDB

Stand Type or Age Class	Data Table Name	Data Type
Young Immature Mature Overmature	*YIMO - tree*	Tree
Plantation	*PLANT - tree*	Tree
Cutover	*CUT - tree*	Tree
Regeneration	*REGEN - tree*	Tree
Thinning	*THIN - tree*	Tree
All plots	*PLOTS*	Plot (static)
	PLOTS_YR	Plot (dynamic)

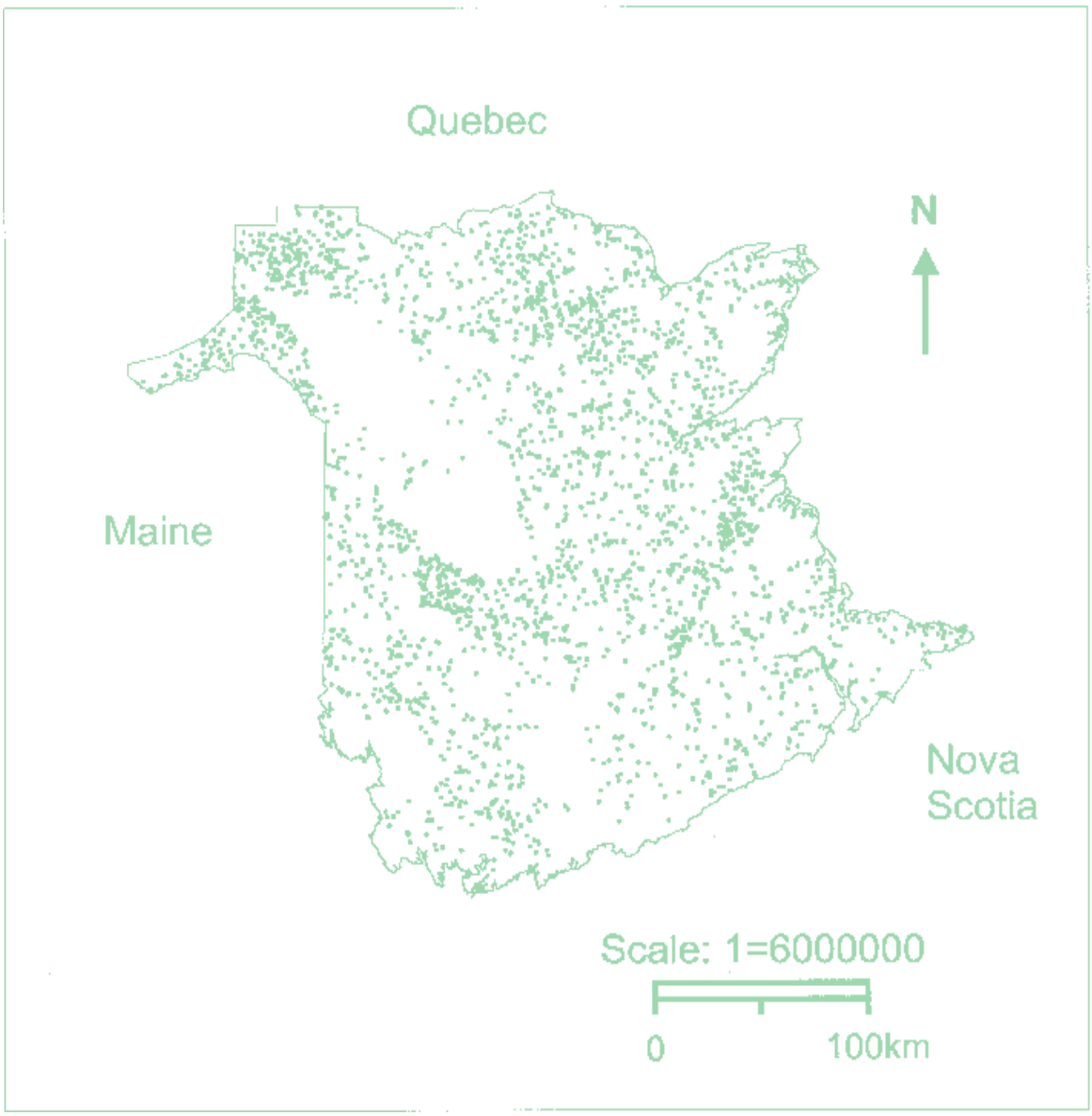


Figure 1. Location of 2499 growth and yield PSPs in New Brunswick. PSPs were measured from 1987 to 1998 on a 3- or 5-year cycle (depending on plot type) by NBDNRE and the forest industry.

Table 2. Age ranges (years) for each development stage by major species

Species	Young (Y)	Immature (I)	Mature (M)	Overmature (O)
Balsam fir	25-30	36-50	51-70	71+
Red spruce	30-45	46-70	71-110	111+
Black spruce	30-45	46-70	71-110	111+
White spruce	20-40	41-60	61-110	111+
White pine	30-50	51-90	91-160	161+
Jack pine	20-40	41-70	71-110	111+
Red pine	20-40	41-70	71-110	111+
Eastern cedar	30-45	46-70	71-110	111+
Eastern hemlock	30-50	51-90	91-140	141+
Larch	20-45	46-70	71-110	111+
Tolerant hardwoods	30-50	51-80	81-160	161+
Intolerant hardwoods	20-35	36-50	51-70	71+
Gray birch	15-25	26-40	41-50	51+

3.1 PSPDB Data Structure - Trees

3.1.1 Young, Immature, Mature, and Overmature Stands (YIMO)

Plots are included in this plot type if they meet criteria based on cover type (*i.e.*, softwood, softwood-hardwood, hardwood-softwood, hardwood), forest unit (*e.g.*, SPBF, BFSP, THIH), and development stage (*i.e.*, young, immature, mature, overmature). Table 2 presents the age class range (years) for each development stage and species. Dunlap (1989) and Upshall (1990) provided detailed information on plot establishment procedures. Appendix I lists the procedure manuals for the PSP program.

In the young (Y), immature (I), mature (M), and overmature (O) development stages, sampling is carried out on a 400-m^2 circular plot. All live trees greater than 5.1 cm diameter at breast height (dbh) are included, except for alder and mountain maple. (*Note: trees greater than 1.0 cm were also included for plots established in 1987 only.*) Upon remeasurement, any additional trees that have grown to meet these criteria are also included in the plot. Recent mortality (*i.e.*, trees dead within the past 5 years) is evaluated for spruce, jack pine, and balsam fir greater than 9.0 cm dbh.

Individual-tree variables measured in the YIMO plots are presented in Table 3. In PSPDB, these data are in the *YIMO-tree* table. The actual tree measurements are divided into two parts (Dunlap 1989). The first part consists of age class and height/dbh sampling. The age information is collected from trees just outside the plot, using increment cores taken from a minimum of two trees for each species/age class, to define the age classes present within the plot. The field crew use these data to qualitatively categorize each individual stem within the plot for age class. Height data are collected from trees greater than 9.0 cm dbh for all commercial species found within the plot. Height is measured for all trees included in the age class sampling, with any additional heights taken from within the plot. A maximum of 45 heights are measured.

The second part of the sampling deals with the tree-by-tree tally within the plot. Species, age class, dbh, and cause of death are recorded for recently dead trees. For all live trees, species, age class, dbh, and crown ratio are tallied. An additional set of variables (risk measurements) is quantified for each tree, with the objective of evaluating the probability of mortality for an individual tree. These variables consist of leader damage, current and cumulative defoliation, proportion of broken top, stem wounds, lean, thin crown, dead or broken main stem, and the presence of conks on the main stem. Additional details on the PSP sampling methods are available in Dunlap (1989) and Upshall (1990).

Table 3. Description of variables in the *YIMO-tree* data table, which contains individual-tree data for young, immature, mature, and overmature plots. Each time a tree is measured on a YIMO plot, a record is created

Field Name	Description
plot	Plot number
treenum	Tree number
meas#	Measurement number (*i.e.*, each time a tree is remeasured this number is incremented, beginning with 1 for the first measurement)
species	Tree species
cause	Cause of death
dbh	Diameter at breast height (mm)
agecl	Age class (young, immature, mature, overmature)
cr	Crown ratio (the ratio of live tree crown length to total tree height)
top	Proportion of top broken or dead
type	Wound type
depth	Wound depth
dim	Wound dimension (proportion of height or circumference)
ltbh	Wound below breast height
conks	Conks present (P or blank)
lean	Lean of the tree (%)
leaderda	Leader damage
curpct	Current defoliation class for spruce and fir (%)
cumpct	Cumulative defoliation class for spruce and fir (%)
thincr	Thin crown present on hardwoods (P or blank)
lat	Dead or broken main stem present on hardwoods (P or blank)
hgt	Height (m)
vol	Volume (m^3)

Note: a description of data codes and classes used for each variable is presented in Appendix III.

When tree measurements are imported to PSPDB, a set of regression equations predicts tree height and volume from species, plot location (License), and dbh for each tree of commercial species that is >9.0 cm dbh (Appendix II). The equations were calibrated from the height/dbh sampling information and the calculated values are stored with each tree measurement record.

3.1.2 Young Plantations

Plantation sampling was directed towards 4- to 8-year-old black spruce, white spruce, and jack pine plantations in a managed condition (Dunlap 1989). The managed condition refers to management of softwood density and the degree of hardwood competition present. The minimum number of planted trees required is 1500 stems/ha and the maximum number of softwood trees allowed is 3825 stems/ha in these 14 × 14-m plots. The majority of the softwoods must be 'free-to-grow', *i.e.*, not overtopped by hardwood species. Additional sampling information is available in Dunlap (1989).

Individual-tree data from plantations are recorded in the PSPDB *PLANT-tree* table. Variables measured in plantations and natural cutovers are identical, and are described in Table 4.

3.1.3 Cutovers

Young cutover sampling was directed toward 5- to 8-year-old stands of various species compositions and density conditions (Upshall 1989). For any one cutover, the objective was to sample a minimum of 100 trees per cover type (softwood, softwood-hardwood, hardwood-softwood or hardwood, which may be either predominantly tolerant or intolerant) per density class (low 10 000-29 999, medium 30 000-49 999, high 50 000-70 000 stems/ha).

Table 4. Description of variables in the *PLANT-tree* and *CUT-tree* tables, containing individual-tree data for young plantation and cutover plots, respectively

Field Name	Description
plot	Plot number
treenum	Tree number
meas#	Measurement number (*i.e.*, each time a tree is remeasured this number is incremented, beginning with 1 for the first measurement)
species	Tree species
origin	Origin of the tree (*i.e.*, planted, sprout or fork, *etc.*)
row	Row number of the tree location
yaxis	North-south position of the tree (from south boundary of plot in 0.1 m)
xaxis	East-west position of the tree (from west boundary of plot in 0.1 m)
dbh	Diameter at breast height (mm)
hgt	Total height (cm)
h1	Total height 1 year ago (cm)
h2	Total height 2 years ago (cm)
blc	Height of the base of the live crown (cm)
cw	Crown width (cm)
microsite	Soil composition in which the tree is planted
microtop	Topography in which the tree is planted (*i.e.*, level ground, top of mound, *etc.*)
survival	Assessment as to whether the tree will be alive in 5 years
buds	Causal agent for damage to the buds of the tree
curleader	Causal agent for damage to the current leader
lateral	Causal agent for damage to the branches
foliage	Causal agent for damage to the foliage
stem	Causal agent for damage to the stem
roots	Causal agent for damage to the roots
sp1, sp2, sp3, sp4	Species of potential competition (non-tagged) around the tagged softwood tree, in each of the four quadrants surrounding the tree
hgt1, hgt2, hgt3, hgt4	Height of the tallest non-tagged individual in each of the four quadrants surrounding the tree (cm)

Note: a description of data codes and classes used for each variable is presented in Appendix III.

Cutover plot shape was square, and size depended on the density class being sampled. The range of plot sizes was 4 × 4 m to 7 × 7 m. Growth measurements and risk assessments collected were identical to those in plantations (Table 4), including the collection of individual-tree positional information. In PSPDB, these data are in the *CUT-tree* table. Additional sampling information is available in Dunlap (1989).

3.1.4 Precommercial Thinnings

The objective for PSPs in thinnings was to determine tree growth rates and stand yields for the predominant precommercially thinned stand types on each license (Dunlap 1989). If possible, the thinnings to be sampled were distributed throughout the license. One plot per thinned area was generally the rule. However, if the thinned area was large or if obvious differences in site productivity or species composition existed, this warranted two plots for the area.

The plots were circular with a radius of 11.3 m. The growth measurements and risk assessments collected were identical to those in the regenerating natural stands, and are described in Table 5. In PSPDB, thinned-plot data are in the *THIN-tree*

Table 5. Description of variables in the *THIN-tree* and *REGEN-tree* tables, containing individual-tree data for thinned plots and young, regenerating plots, respectively

Field Name	Description
plot	Plot number
treenum	Tree number
meas#	Measurement number (*i.e.*, each time a tree is remeasured this number is incremented)
species	Tree species
origin	Origin of the tree (*i.e.*, planted, sprout or fork, etc.)
quarter	Division of the plot being measured (*i.e.*, NE quarter, NW quarter, *etc.*)
blc	Height of the base of the live crown
dbh	Diameter at breast height (mm)
ht	Total height (cm)
swh1	Height 1 year ago for softwoods only (cm)
swh2	Height 2 years ago for softwoods only (cm)
top	Proportion of top broken or dead
type	Wound type
depth	Wound depth
dim	Proportion of height or circumference affected by the wound
ltbh	Wound below breast height
browse	Browsed damage
lean	Lean of the tree (%)
leadrdam	Leader damage
curpct	Current defoliation class for spruce and fir (%)
cumpct	Cumulative defoliation class for spruce and fir (%)

Note: a description of data codes and classes used for each variable is presented in Appendix III.

table. Additional sampling information is described in Dunlap (1989).

3.1.5 Regenerating Natural Stands

Sampling in regenerating natural stands was directed towards uniform, fully stocked stands approximately 10 to 30 years old (Dunlap 1989). Densities sampled ranged from 10 000 to 30 000 stems/ha, and 80% of the trees to be sampled must have been taller than 2 m (Dunlap 1989). In addition, the number of stems with dbh > 9.0 cm must have been less than 20% of the sampled trees.

The plots were circular in shape and had a variable radius, depending on the density class sampled (Table 6). All trees $ 1 m in height were tagged. Variables measured are described in Table 5; in PSPDB, data from regenerating natural stands are in the *REGEN-tree* table. Additional sampling information is available in Dunlap (1989).

Table 6. Required plot radius based on density count for regenerating natural stands

Trees per 50 m^2	Plot radius (m)	Plot size (m^2)	Trees per hectare
50-60	6.30	125	10 000-12 000
61-75	5.64	100	12 001-15 000
76-100	5.05	80	15 001-20 000
101-125	4.37	60	20 001-25 000
126-150	3.98	50	25 001-30 000

3.2 PSPDB Data Structure - Plots

Characteristics of each plot were measured when the plot was established and also at each remeasurement. Static information about the plot that is not subject to change, such as location and site characterisitics, is stored in the *PLOTS* table in PSPDB (Table 7). Attributes, such as development stage and species composition, change over time and are reassessed each time the plot is measured. In PSPDB, these variables are stored in the *PLOTS_YR* (Table 8). For all plot types, the same plot-level information is recorded.

Table 7. Description of variables in the *PLOTS* table, containing plot-level data collected at plot establishment

Field Name	Description
plot	Plot number
mapno	Provincial map number on which the plot is located
stand	Stand number from NBDNRE geographic information system
region	Provincial NBDNRE Region
license	Ownership code (licensee or private woodlot marketing board number)
funaInterp	Dominating species on the plot at establishment based on photo interpretation
P1DS	Primary development stage
estab age	Age of the plot at establishment
density class	Density class of the plot at establishment (L, M, H)
site region (SR)	Subdivision of the province based on vegetation and soil information
treatment unit (TU)	Site classification of the plot based on vegetation and soil information
prod	Not used
soil	Mapped soil type
drainage	Soil drainage class
eco region	Breakdown of the province into regions by climate, elevation, and proximity to the coast
eco district	Breakdown of an ecoregion based on elevation, slope, terrain features, and geomorphology
eco section	Breakdown of an ecodistrict based on density and patterns of streams, and geopmorphology
eco site	Defined uniquely by ecodistrict based on elevation, slope, drainage, and soil attributes
silv_ID	Link to management prescription for managed stands
plot type	Type of plot (cutover, plantation, regenerating, thinning or YIMO)
photo	Photo number on which the plot appears
plotsize/size	Size of the plot (m^2)
measurement day	Date of plot establishment
measurement month	Month of plot establishment
measurement year	Year of plot establishment
year-treated	Year of silviculture treatment for managed stands

Note: a description of data codes and classes used for each variable is presented in Appendix III.

Table 8. Description of variables in the *PLOTS_YR* table. For each measurement of a plot, a record is added to the *PLOTS_YR* table, containing the following variables.

Field Name	Description
plot	Plot number
year	Year of measurement
meas#	Measurement number (*i.e.*, each time a plot is remeasured this number is incremented)
agency	Name of the agency that collected the data
remeas year	Next measurement year for the plot
funa	Predominant species in the dominant age class on the plot
dev stage	Stage of development of the plot

Note: a description of data codes and classes used for each variable is presented in Appendix III.

4. Using PSPDB

This section provides a brief overview of PSPDB and its main functions by describing the user interface and the elements associated with it. We illustrate how to use the main form, indicate the reports and charts that are available, explain how to build queries to filter the data going into reports and charts, demonstrate the look-up capability, and describe some of the utility features of the system.

Historic records of stand development like the ones created in the Cooperative PSP program are uniquely capable of telling an important story about the forests of New Brunswick. However, without some way for forest managers and planners to easily access this wealth of information, it would be little more than a data archive. Table 9 describes the PSPDB data distribution, up to and including 1997 remeasurement data. A total of 2499 plots contain over 221 000 trees. PSPDB now contains over 497 000 records, or individual tree measurements. About 65% of the PSPs, and 68% of the records are for YIMO plots. As the database grows with additional remeasurements, its value increases, but the need for an efficient means of accessing and analyzing the data also increases. PSPDB was created as a data management and reporting system to facilitate such access and, further, to transform the data into "value-added" information using meaningful built-in calculations (Appendix VI) and a flexible user interface.

Table 9. Description of data distribution

Plot type	No. plots	No. trees	Total No. records
YIMO	1630	125730	338508
Cutovers	249	27471	44483
Plantation	276	24863	38691
Regeneration	210	29287	50061
Thinning	134	14128	25418
Total	**2499**	**221479**	**497162**

NBDNRE will provide annual data updates to PSPDB as new measurements are taken. These updates may also include replacements of data already in the database to fix errors in previous measurements. Changes to tree records are performed on a plot and year basis. In other words, when a change is required for a tree record in the database, the complete set of tree records for that plot and measurement year is replaced by a new set. A separate import program accompanies PSPDB and is used to check all new data and load them into the database. It encapsulates all of the validation rules from the procedure manuals (Dunlap 1989) and ensures that all data in PSPDB meet these criteria. Only valid data are added to the database. Appendix IV provides a description of the validity checking performed and Appendix V briefly describes the use of the Import program.

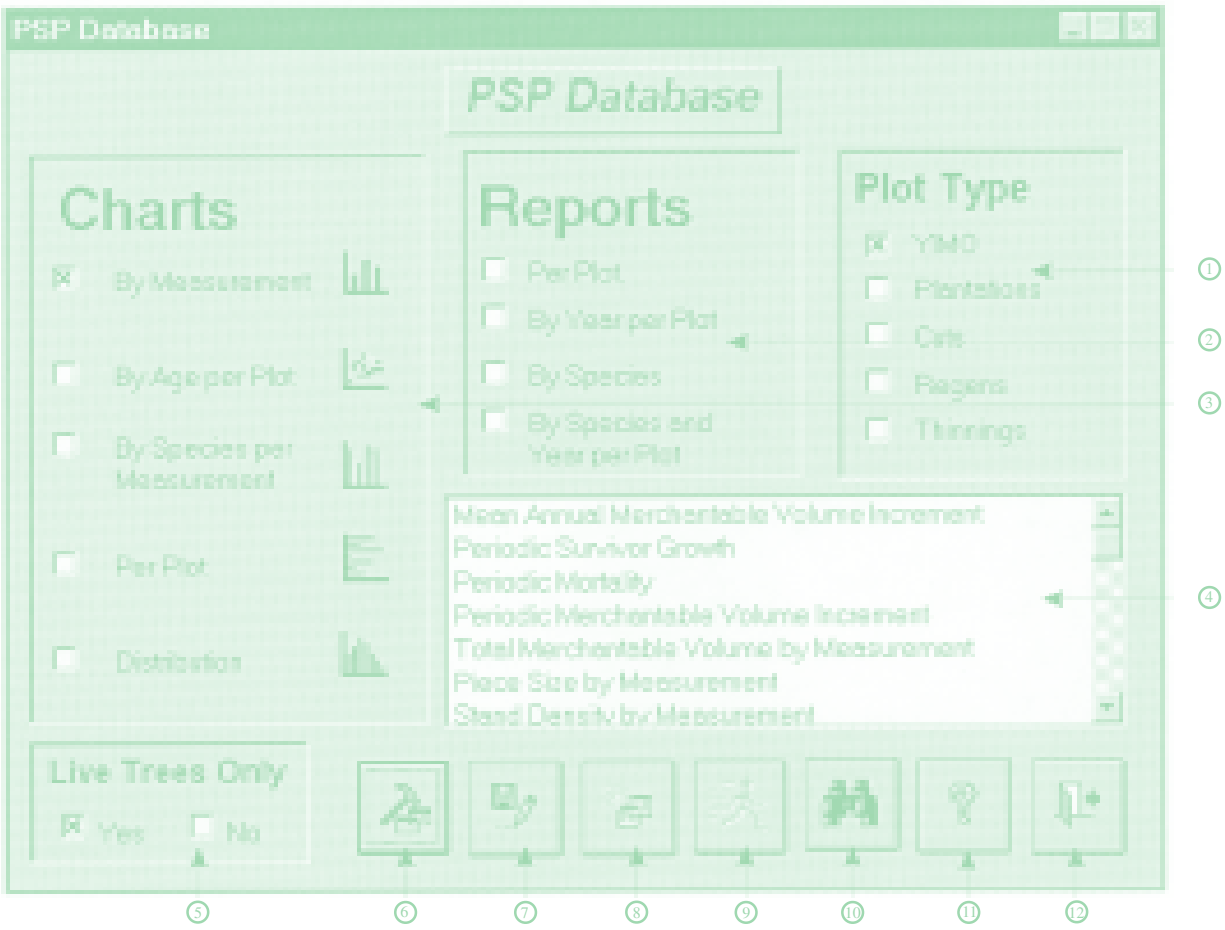
4.1 PSPDB Main Form

The PSPDB user interface is quite simple. All the customized functions are accessed using a mouse, from the main form (Figure 2), which represents a control pad for operating the system. In addition, the normal Access interface is retained so the user can use all of its standard functions. Figure 2 describes the main form and its components.

When generating a chart or report in PSPDB, the user typically follows these steps:

- select a plot type (item ① in Figure 2)
- choose a report or chart by selecting a group and a specific report or chart (items ②③④)
- decide whether to include all trees or just live trees (item ⑤)
- specify a query to indicate the selection criteria (item ⑥); see section 4.4.

Other functions on the main form allow the user to close the query builder, save the query specification (item ⑦), and reset the query to the default specification (item ⑧). The run button (item ⑨) runs the selected chart or report using the criteria specified in the query builder. If no selection criteria are specified, the chart/report will attempt to use the



① Plot Type: Selects type of plot to be displayed.

② Report group: Reports are organized into groups. When selected, the appropriate list of reports appears in the Chart/Report box.

③ Chart group: Charts are organized into groups; when a group is selected the appropriate list of charts appears in the Chart/Report box.

④ Chart/Report box: Allows selection of a single chart or report from the selected group.

⑤ Live Trees Only: When "Yes" is selected, only live trees are included in the calculations. If "No" is selected, both live and dead trees are included.

⑥ Query Builder: Starts the Query Builder (explained further in Section 4.4), which gives the user control over which data are included.

⑦ Save query: Closes the query builder and saves the query.

⑧ Reset Query: Resets the contents of the query builder to its defaults for that plot type.

⑨ Run: Generates the selected report or chart using the specified criteria.

⑩ Look-up: Provides a list of codes for any field in the database (explained in Section 4.6).

⑪ Help: Activates the PSPDB online help.

⑫ Exit: Closes PSPDB and exits Access.

Figure 2. View of the PSPDB main form, with a description of features and buttons.

entire database. In this case, a prompt is displayed, allowing continuation with the entire database or cancellation of the chart/report. Generating charts and reports based on the entire database (almost 500 000 records) can take several hours to complete.

The look-up button (item ⑩) opens a dialog box allowing the user to obtain more information about any field in the database. For example, if a user selects “species” from the drop-down list in the Look-Up Tables window, a listing of all species codes and their meanings is displayed. This can be used to find out what values or codes are used for a particular field in the database. Item ⑪ starts the online help system which illustrates how to perform tasks in PSPDB, such as generating a report or chart, and also explains the forms, dialog boxes, and buttons making up the user interface.

4.2 Available Charts

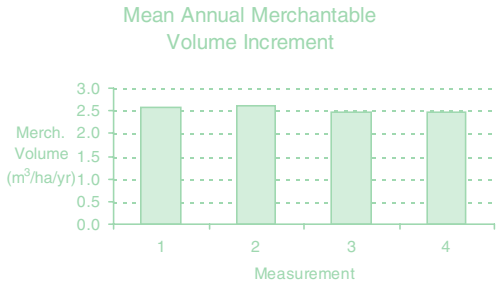
Table 10 lists the 33 charts in PSPDB, arranged in five groups, and indicates which charts are available for each type of plot. Group A includes a set of nine vertical bar charts showing volume, growth, mortality, density, piece size, and basal area for each successive measurement. Chart A1 in Figure 3 shows an example of Mean Annual Increment (MAI) by measurement. Group B depicts the same variables stratified by age per plot in the form of line graphs, with one line per plot. Chart B2 in Figure 3 presents Periodic Survivor Growth by Age per plot as an example.

Group C contains charts for volume, piece size, density, diameter, and basal area by species, for each successive measurement. Charts in this category take the form of grouped bars with measurements grouped by species (Figure 3, chart C3). Five horizontal bar charts showing volume, growth, density, diameter, and basal area by plot make up group D. Chart D2 in Figure 3 illustrates this using a Merchantable Volume by Plot example. The final group, E, contains distributions of diameter, cause of death, defoliation, and survival in the form of horizontal bar charts like chart E3 in Figure 3. Users may design their own charts using functions available in Microsoft Access.

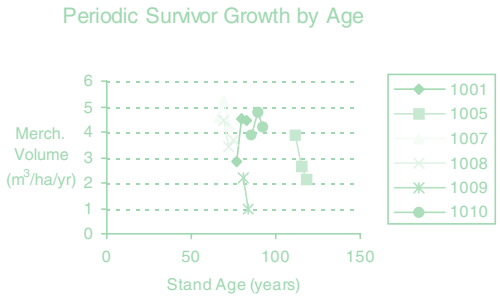
Table 10. List of charts available in PSPDB. Chart type refers to the examples presented in Figure 3

Chart Group	Type	Chart Name	Availability by Plot Type		
			YIMO	Plantations & Cuts	Thins & Regens
A. By measurement	A1	Mean annual merchantable volume increment	X		
	A2	Periodic survivor growth	X		
	A3	Periodic mortality	X		
	A4	Periodic merchantable volume increment	X		
	A5	Total merchantable volume by measurement	X		
	A6	Piece size by measurement	X		
	A7	Stand density by measurement	X	X	X
	A8	Average diameter by measurement	X	X	X
	A9	Stand basal area by measurement	X		
B. By age per plot	B1	Mean annual merchantable volume by increment by plot	X		
	B2	Periodic survivor growth by age	X		
	B3	Periodic mortality by age	X		
	B4	Total merchantable volume by age per plot	X		
	B5	Average piece size by age per plot	X		
	B6	Stand density by age per plot	X	X	X
	B7	Average diameter by age per plot	X	X	X
	B8	Stand basal area by age per plot	X		
C By species per measurement	C1	Merchantable volume by species per measurement	X		
	C2	Average stand density by species per measurement	X	X	X
	C3	Average diameter by species per measurement	X	X	X
	C4	Stand basal area by species per measurement	X		
D. Per plot	D1	Periodic merchantable volume increment per plot	X		
	D2	Merchantable volume by plot	X		
	D3	Stand density per plot	X	X	X
	D4	Average diameter per plot	X	X	X
	D5	Stand basal area per plot	X		
	D6	Cause of death by plot	X		
E. Distributions	E1	Diameter distribution	X	X	X
	E2	Cause of death distribution	X		
	E3	Cause of death distribution by species	X		
	E4	Current defoliation distribution	X		X
	E5	Cumulative defoliation distribution	X		X
	E6	Percent survival by basal area	X		

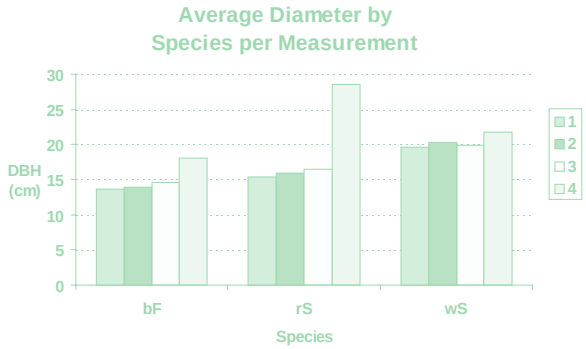
A1. **By measurement** chart



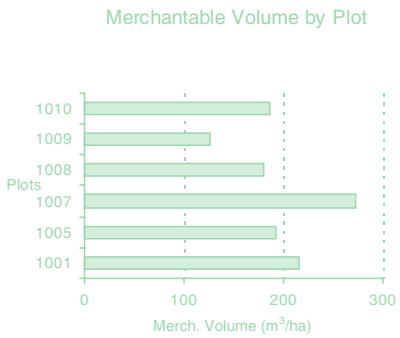
B2. **By age per plot** chart



C3. **By species per measurement** chart



D2. **Per plot** chart



E3. **Distribution** chart

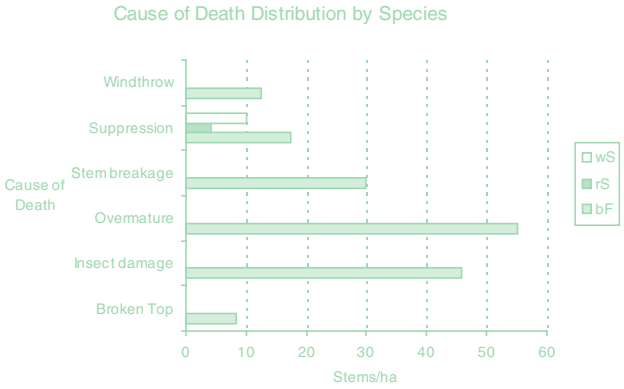


Figure 3. Examples of charts available in PSPDB. Chart groups A to E refer to the groups listed in Table 10.

4.3 Available Reports

Table 11 lists the 21 tabular reports in PSPDB, arranged in four groups, and indicates which reports are available for each type of plot. Group A includes reports showing volume increment and defoliation on a "per plot" basis. Reports A1 and A2 in Figure 4 show examples from this group. Each report contains a description of the query language (SQL) string that defines the tables, fields, and value ranges specified by the user with the query builder. Group B depicts the volume, survivor growth, mortality, volume increment, piece size, density, diameter, and basal area stratified by year per plot. Report B4 in Figure 4 presents Volume by Year per Plot as an example.

Group C contains a single report, Current Defoliation by Species, and is depicted as report C1 in Figure 4. Nine reports similar to those in group B, but stratified by species in addition to year and plot, make up group D. Reports D2, D4 and D9 in Figure 4 present examples. Users may also design their own reports using functions available in Microsoft Access.

Table 11. List of reports available in PSPDB. Report types refer to the examples presented in Figure 4

			Availability by Plot Type		
Report Group	Type	Report Name	YIMO	Plantations & Cuts	Thins & Regens
A. Per plot	A1	Periodic annual volume increment by plot	X		
	A2	Current defoliation distribution	X		X
	A3	Cumulative defoliation distribution	X		X
B. By year per plot	B1	Mean annual volume increment by year per plot	X		
	B2	Periodic survivor growth by year per plot	X		
	B3	Periodic mortality by year per plot	X		
	B4	Volume by year per plot	X		
	B5	Average piece size by year per plot	X		
	B6	Stand density by year per plot	X	X	X
	B7	Average diameter by year per plot	X	X	X
	B8	Basal area by year per plot	X		
C By species	C1	Current defoliation by species	X		X
D. By species and year per plot	D1	Tree distribution by maturity, species, and year per plot	X		
	D2	Diameter distribution by species and year per plot	X	X	X
	D3	Current defoliation by species and year per plot	X		X
	D4	Dead trees and their causes by plot	X		
	D5	Species distribution by year per plot	X	X	X
	D6	Average diameter by species and year per plot	X	X	X
	D7	Volume by species and year per plot	X		
	D8	Basal area by species and year per plot	X		
	D9	Cause of death distribution by species and year per plot	X		

A1. Periodic Annual Volume Increment by Plot

21-Apr-98

((([YIMO - tree].plot)>4020 And ([YIMO - tree].plot)<4042) AND ((PLOTS.[Estab Age])>50 And (PLOTS.[Estab Age])<80) AND ((PLOTS.License)=4) AND ((PLOTS.FunaInterp)= “spbf”))

Plot	Merch, Volume (m^3/ha)
4021	4.5889
4032	0.1407
4034	2.7254
4036	-4.3000
4041	5.7959
	Average Volume: 1.7902 m^3/ha

A2. Current Defoliation Distribution

21-Apr-98

((([YIMO - tree].plot)>4020 And ([YIMO - tree].plot)<4042) AND ((PLOTS.[Estab Age])>50 And (PLOTS.[Estab Age]<80) AND ((PLOTS.License)=4 AND ((PLOTS.FunaInterp)=“spbf”))

Plot	Current Defoliation	Trees/ha
4021	06-20%	200
4032	06-20%	400
	21-40%	25
4034	06-20%	500
	21-40%	525
	41-60%	75
	61-80%	50
4036	06-20%	425

B4. Volume by Year per Plot

21-Apr-98

((([YIMO - tree].plot)>4020 And ([YIMO - tree].plot)<4040) AND ((PLOTS.[Estab Age])>50 And (PLOTS.[Estab Age])<80) AND ((PLOTS.License)=4) AND ((PLOTS.FunaInterp)=“spbf”))

Plot	Year	Stand Age	Merch. Volume (m^3/ha)
4021	1989	62	139.2
	1992	65	151.0
	1995	68	157.2
4032	1987	64	174.8
	1990	67	187.0
	1993	70	197.2
4034	1987	64	209.3
	1990	67	221.6
	1993	70	228.1
		Average Volume:	**200.9876 m^3/ha**

...cont’d

Figure 4. Examples of report types available in PSPDB.

C1. Current Defoliation by Species

21-Apr-98

((([YIMO - tree].plot)>4020 And ([YIMO - tree].plot)<4042) AND ((PLOTS.[Estab Age])>50 And (PLOTS.[Estab Age])<80) AND ((PLOTS.License)=4) AND ((PLOTS.FunInterp)="spbf"))

Species	Current Defoliation	Trees/ha
bF	06-20%	355
	21-40%	175
	41-60%	55
	61-80%	55
	Species Total: 640	
rS	06-20%	130
	21-40%	10
	41-60%	5
		Species Total: 145

D2. Diameter Distribution by Species and Year per Plot

21-Apr-98

((([YIMO - tree].plot)>4020 And ([YIMO - tree].plot)<4042) AND ((PLOTS.[Estab Age])>50 And (PLOTS.[Estab Age])<80) AND ((PLOTS.License)=4) AND ((PLOTS.FunaInterp)="spbf"))

Plot	Year	Species	Diameter Class	Trees/ha
4021	1989	bF	4-6	50
			6-8	175
			8-10	100
			10-12	100
			12-14	50
			14-16	175
			16-18	75
			18-20	25
			20-22	100
			22-24	25
			24-26	125
			26-28	25
			28-30	25
				Species Total: 1050
4021	1989	rS	4-6	50
			8-10	50
			10-12	25
				Species Total: 125
4021	1989	wS	10-12	25
				Species Total: 25
				Year Total: 1200

...cont'd

Figure 4. Cont'd.

D4. Dead Trees and Their Causes by Plot

21-Apr-98

((([YIMO - tree].plot)>4020 And ([YIMO - tree].plot)<4042) AND ((PLOTS.[Estab Age])>50 And (PLOTS.[Estab Age])<80) AND ((PLOTS.License)=4) AND ((PLOTS.FunaInterp)="spbf"))

Plot	Year	Species	Cause	Average DBH (cm)	Dead Trees/ha
4032	1990	bF	Insect damage	11.8	50
			Windthrow	20.2	25
					Year Total: 75
4032	1993	bF	Overmature	13.7	25
			Windthrow	16.9	50
		rS	Windthrow	26.3	25
					Year Total: 100
					Plot Total: 175

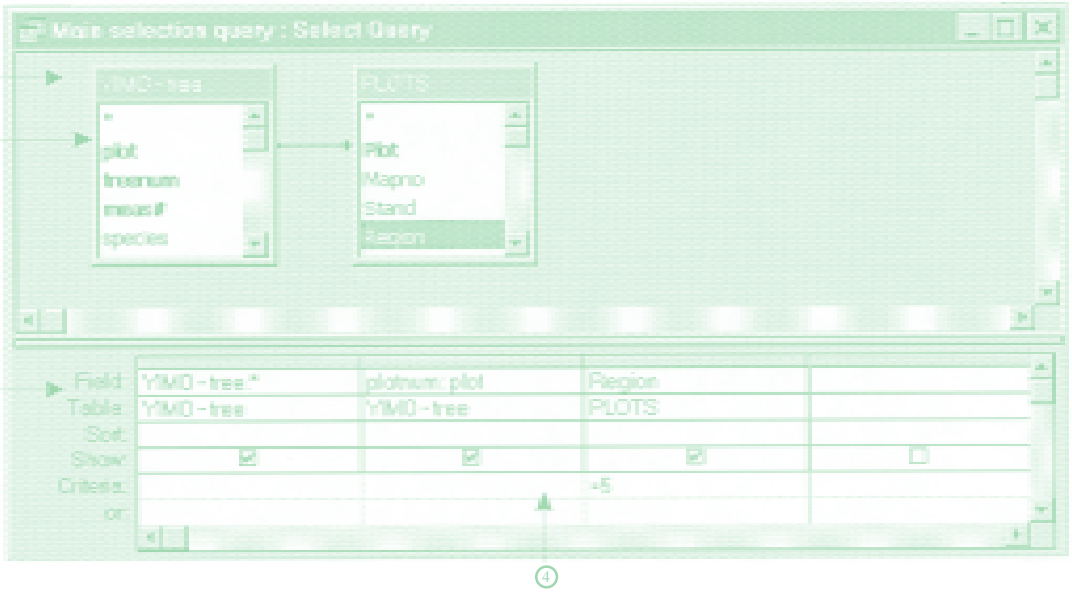
D9. Cause of Death Distribution by Species and Year per Plot

21-Apr-98

((([YIMO - tree].plot)>4020 And ([YIMO - tree].plot)<4042) AND ((PLOTS.[Estab Age])>50 And (PLOTS.[Estab Age])<80) AND ((PLOTS.License)=4) AND ((PLOTS.FunaInterp)="spbf"))

Plot	Year	Species	Cause	Trees/ha
4021	1992	bF	Unknown	25
4021	1992	wB	Stem wounds	25
			Unknown	50
4021	1995	bF	Unknown	25
			Windthrow	25
			Suppression	25
4032	1990	bF	Windthrow	25
			Insect damage	50
4032	1990	rS	Windthrow	25
4032	1993	bF	Overmature	25
			Windthrow	50

Figure 4. Cont'd.



① The top half of the query builder contains the data sources for the query (in this case, *YIMO-tree* and *PLOTS* data tables (Table 1)).

② Data table name and the list of fields contained. In the example, *YIMO-tree* is the name of the table and its scrollable list of fields appears in the *YIMO-tree* window.

③ Columns of the grid represent data fields used in the query. Each row of the grid represents a characteristic of the fields that can be used to precisely define the query.

④ The "Criteria" row contains selection criteria for fields. The criteria used in the above example indicate that the user wants to display only those plots from Region 5.

Figure 5. The query selection form in PSPDB.

4.4 The Query Builder

The query builder in PSPDB is the standard query builder of Microsoft Access with some customization. Its functions are fully described in the Access printed user documentation and in the online help system under Query by Example (QBE), and therefore will not be duplicated here. In PSPDB, the query builder allows the user to specify the selection criteria for generating a particular chart or report. For example, the user may only be interested in a particular species or license, or perhaps a certain range of plot numbers. The query builder provides a visual interface to achieve this. The upper pane of the query builder (① in Figure 5) contains data sources for the query. In Figure 5, the *YIMO-tree* and *PLOTS* data tables ② (Table 1) are used. They were displayed in the upper pane by clicking the right mouse button in the pane, selecting "Add Table..." from the menu, and selecting them from the list of tables that exist in the database. Other tables of data can be added to the query builder in the same way. Fields from the tables can be used to further specify selection criteria.

Any field can be added to the query by clicking on its name and dragging it to an empty column on the bottom half of the query builder, or by simply double-clicking the field to be included. This is how the contents of the columns in Figure 5 were created. Each column of the grid ③ on the bottom half of the query builder represents a field used in the query. Each row of the grid ④ represents a characteristic of the field for the active query. These include the field name, the table to which it belongs, whether the field is sorted, whether it should be included in the output recordset (it may be used for selection without being included in the result), and an expression defining the selection criteria for the field. The user simply clicks the mouse in a grid cell to get a drop-down list of options to select

from or uses the keyboard to enter valid input into the cells.

In Figure 5, the first column "YIMO-tree.*" is a special case, meaning that all of the fields in the *YIMO-tree* table are kept in the query results. This is part of the PSPDB application and is necessary so that reports and charts will function properly.

4.5 Chart/Report View

When a chart or report is run, the result is displayed in a view. From there, the user has several options, depending upon the chart or report view. Chart and report formats are shown in Figures 3 and 4.

4.5.1 Reports

A report view displays a print preview or "what-you-see-is-what-you-get" (WYSIWYG) version of the report, a standard feature in Access. From here, the user may change the page layout of the report, send it to a printer, view it at various sizes or scales, or export it to other applications such as Microsoft Word or Excel. These and other Access features are described in the Access hardcopy and online documentation.

4.5.2 Charts

A chart view displays the generated chart on a form with several buttons along the bottom. These buttons give the user access to some useful features of the PSPDB application, as described below.

Displays the data that are represented by the chart. These data show the results of all calculations and manipulations that were applied to the user-specified query to generate the chart. It serves as a starting point, allowing a user to "drill down" into the chart to investigate how the results were obtained and what plot- and tree-measurement data were used. Tracing back further into the generation of a report or chart requires more than a novice level of expertise in Access but is certainly within the reach of users willing to spend some time learning its more advanced capabilities.

Displays a report that relates to the currently displayed chart. This feature provides a link from charts to reports that may be helpful in detailing the contents of some charts.

Shows what the chart will look like when printed.

Displays a portion of the SQL statement for the query used in the generation of the chart. This indicates the selection criteria (albeit, in a somewhat cryptic form) and shows where the data came from. An example is:

```
(([YIMO - tree].plot)<1010))
```

This statement specifies that all trees (from the *YIMO-tree* table) with a plot number less than 1010 be included in the chart. This is the statement in Access that is produced internally when the user constructs a query with the query builder. Note that the SQL query statement is displayed on the top of each chart when printed, so that the selection criteria used to generate it are evident.

Closes the chart and returns to the PSPDB main form.

4.6. The Look-up Tables

The look-up table  button (item ⑩ in Figure 2) allows the user to view the data codes and their descriptions for each field in the database. When recording data, a number is often used as a code to represent the actual data value. For example, for cumulative defoliation, the code 1 is used in PSPDB to represent 6-20% defoliation (Figure 6). Look-up tables are included in PSPDB to help the user find the proper code, representing data, to be used in selection criteria within the query builder. To use the look-up table, select the field name from the drop-down list in the look-up table dialog box (Figure 6). The description of that item is then displayed. To close the look-up table window, click the Close button.

Appendix III of this report contains a complete listing of variables (names and descriptions), code values, and code descriptions used in PSPDB.

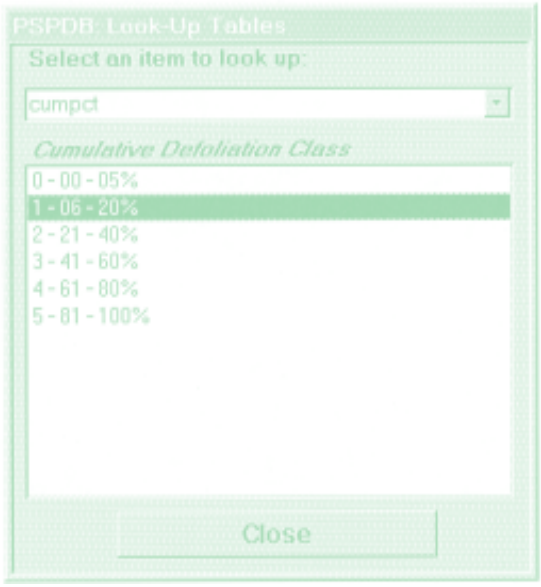


Figure 6 The Look-up Tables dialog box in PSPDB.

4.7 The Access Database Window

The contents of all tables in PSPDB can be accessed directly using the Access Database window. By default, this window is hidden from the user but can be made visible by selecting **Unhide** in the Window menu on the menu bar. This displays the **Unhide** Window with the **pspapp: Database** window selected. Click the **OK** button to display it.

Figure 7 shows a screen shot of this window with the tables list active and the *PLOTS* table selected. Opening a table causes its contents to be displayed, with labelled columns representing its fields. Notice that, in addition to tables, other Access objects like queries and reports may be reached through this window. Working with tables and other objects is described in the Access printed user documentation and the online help system.

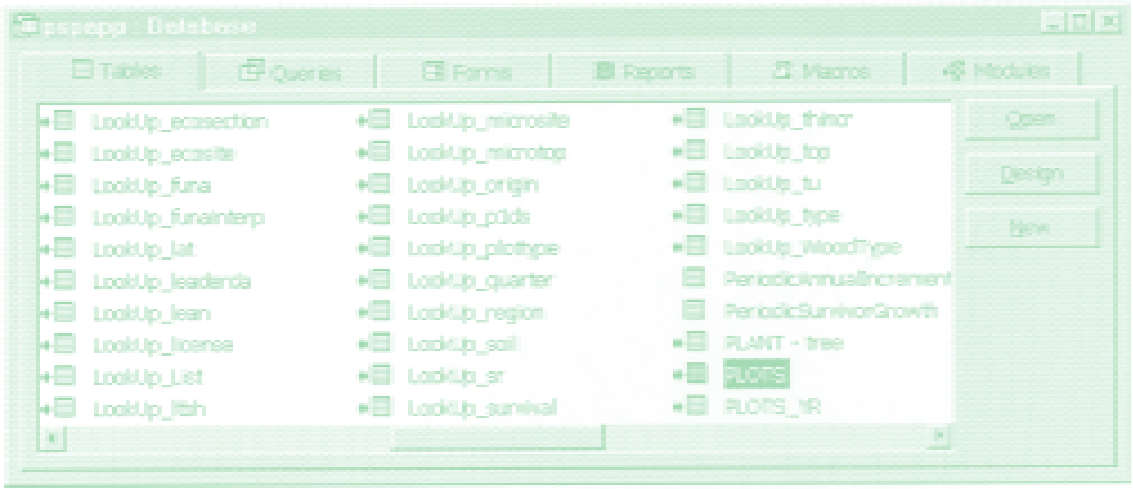


Figure 7 Access Database window from PSPDB with the Plots table selected.

4.8 Adding a Table

Some users may want to customize the PSPDB by adding their own data. The best way to do this is to create a separate linked database file (.mdb) so added data will be preserved in the event of an upgrade to PSPDB. The steps below provide an overview of how to do this, but the user should consult the Access documentation for a complete description.

- Select **File-New Database...** to add a new, blank database. Place it in the same directory as the PSPDB.
- Under the **Tables** tab in the database window, click the **New** button. Choose **Design View** in the dialog box that follows.
- Enter the names of the fields and their data types. Save the table (**File-Save**) and exit Design View.
- Click the **Open** button in the database window to begin entering data into the table. Data can be entered from the keyboard or imported from other sources.
- Once the table is completed, close this customized database and return to the `pspapp.mdb` (the regular PSPDB file).
- Click the right mouse button on the **Tables** tab and select **Link Tables**; navigate to the location of the customized database and select it.
- A list of the tables in the custom database will appear. Select the tables to be linked and press **OK**. This provides access to them from within PSPDB. The links are saved automatically.
- If a replacement copy of the `pspapp.mdb` (the regular PSPDB file) is installed, the user merely needs to re-link the tables from the custom database.

5. Tutorial

The following brief tutorial demonstrates how to use PSPDB to generate a chart of Total Merchantable Volume By Age per Plot for all plots in Eco Distrct 22 - Nashwaak River.

1. The first step when creating a chart with PSPDB is to choose which plot type is to be displayed. In this case, from the Plot Type section of the PSPDB main form (Figure 2), select **YIMO** by clicking on its check box.

2. Next, select the chart group in which the desired chart falls from the “Charts” section of the PSPDB main form. To display a chart of Merchantable Volume by age and plot, choose **By Age per Plot** from the Chart group.

3. For this chart, we would also like to include the volume of both live and dead trees found on the plot, so set the Live Trees Only check box to **No**.

4. After selecting a chart group, a list of all charts of that type appears in the selection box in the lower right of the PSPDB main form. Select the chart **Total Merchantable Volume by Age per Plot** from the selection box by clicking on its name. This will highlight the chart name. Only one chart can be selected at a time.

5. Now, instead of using the entire database, we will add some selection criteria to limit the number of plots included in our chart. Click the Build Query button  to open the query builder.

6. As we selected the YIMO plot type, a list of fields in the *YIMO-tree* table is displayed in the upper pane of the Query Builder window (Figure 8). Remember that we want to generate this chart for Eco District 22, so we need to include the Eco District field in our selection criteria.

   Place the cursor anywhere on the background of the upper pane of the query window (Figure 8) and click the right mouse button. Select **Show Table** from the menu that pops up to display a list of all tables in the database (Figure 9). Scroll down the list until you find *PLOTS* and select it (Figure 9). Press the Add button  to add the *PLOTS* table to our query. Press the Close button  to close the Show Table window.

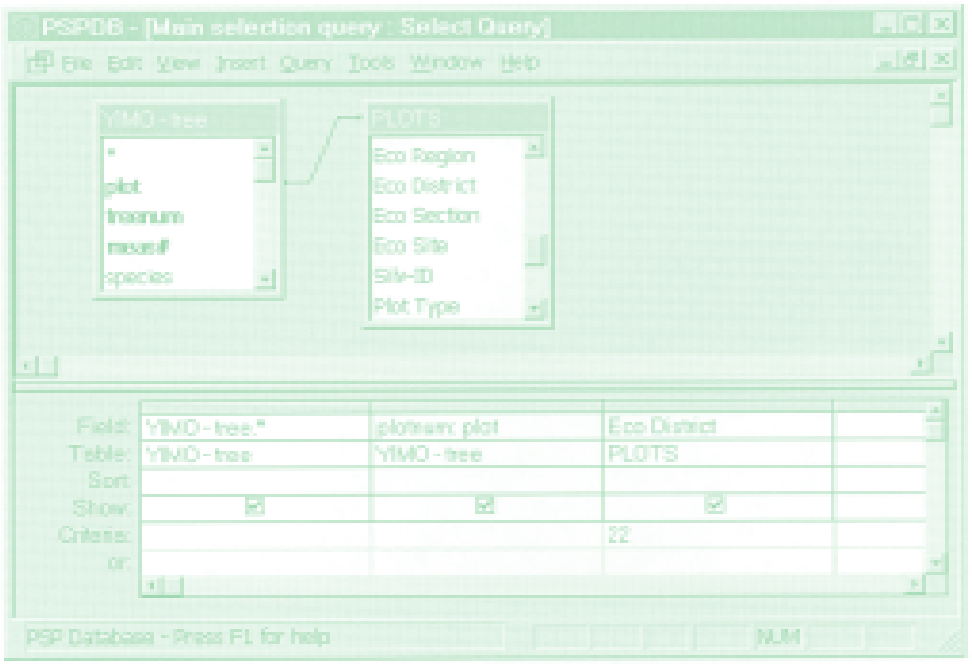


Figure 8 Query Builder window with the Eco District Criterion set to 22.

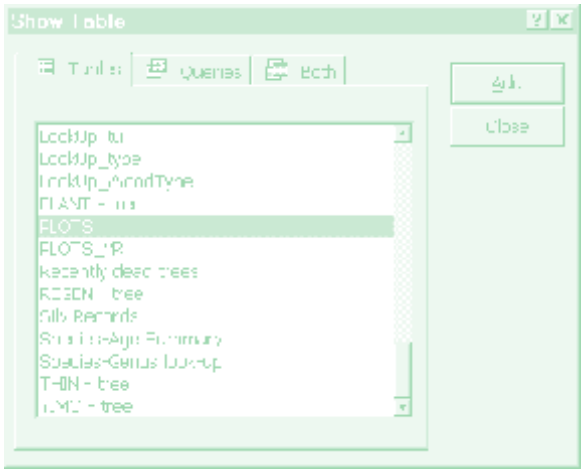


Figure 9. The Show Table window wiith the PLOTS table selected.

7. To specify Eco District 22 in our query, scroll down the list of fields in *PLOTS* to find **Eco District** and double-click it (Figure 8). Notice that it has been added to the lower pane of the query window (Figure 8). Now we can use it in our query.

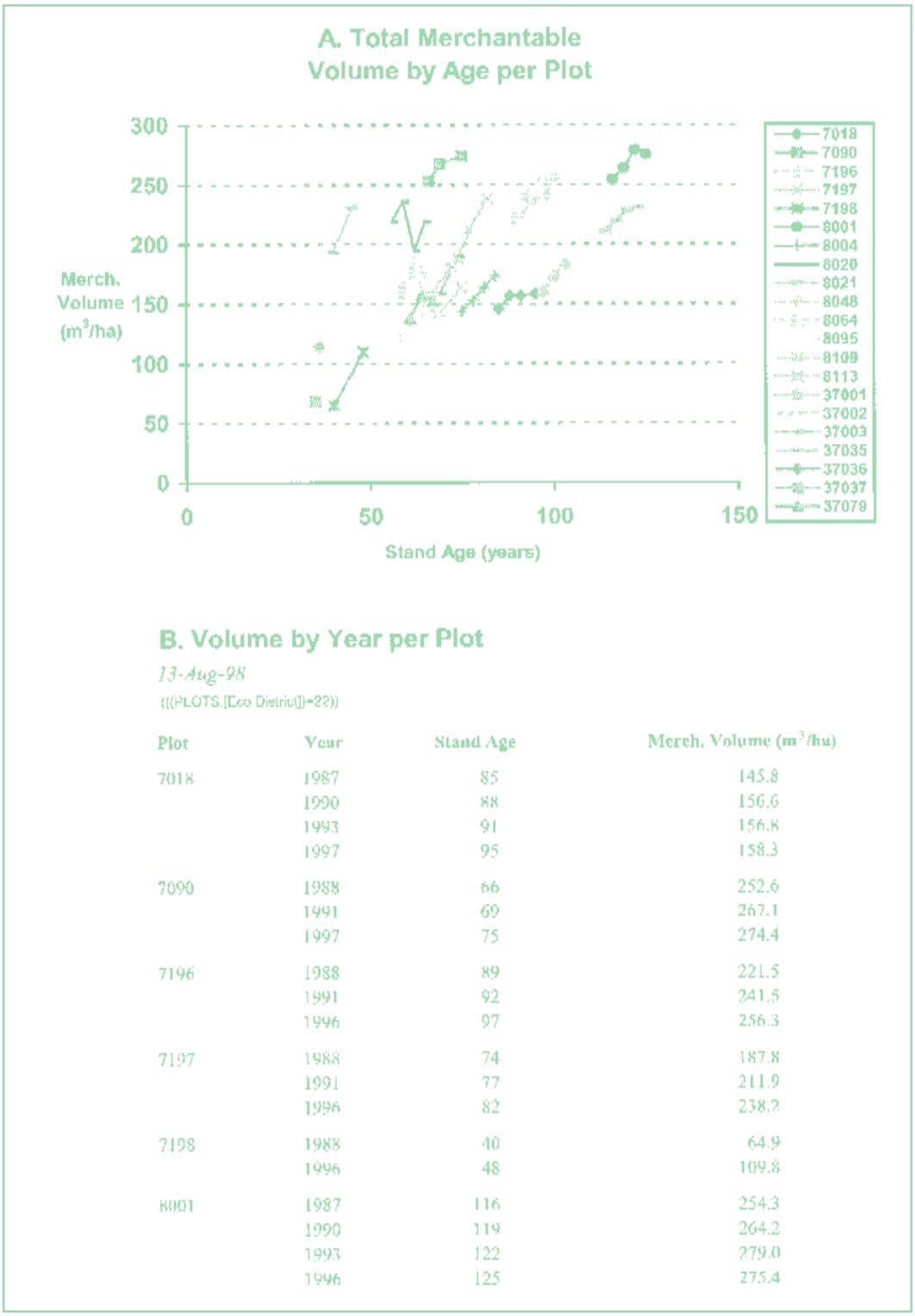
8. On the **Criteria** line in the **Eco District** column, type **22** (Figure 8). In PSPDB v1.0, this will select 21 plots.

9. Click the Save Query button (item ⑦ in Figure 2) to close and save the query. This saves the selection criteria so that the query may be reused without recreating it when the next chart or report is run. Whenever a new plot type is chosen, the selection criteria in the query builder will be reset to the defaults for that plot type.

10. Click the Run button (item ⑨ in Figure 2) to display the chart. It will take several seconds to run, the length of time depending on the database size and computer speed. The resulting chart is shown in Figure 10A.

11. After viewing the chart, click the Close Chart button Close Chart to close it and return to the interface.

To generate a sample report for similar data, follow the above steps but in step 2, select **By Year per Plot** from the **Reports** group; in step 4, select the report **Volume by Year per Plot**; and in step 9, click on the **Exit** button located in the upper left-hand corner of the report to close it. The resulting report is shown in Figure 10b, which was truncated to display only the first 6 out of 21 plots.



B. Volume by Year per Plot

13-Aug-98

(((PLOTS.[Eco District])=22))

Plot	Year	Stand Age	Merch. Volume (m^3/ha)
7018	1987	85	145.8
	1990	88	156.6
	1993	91	156.8
	1997	95	158.3
7090	1988	66	252.6
	1991	69	267.1
	1997	75	274.4
7196	1988	89	221.5
	1991	92	241.5
	1996	97	256.3
7197	1988	74	187.8
	1991	77	211.9
	1996	82	238.2
7198	1988	40	64.9
	1996	48	109.8
8001	1987	116	254.3
	1990	119	264.2
	1993	122	279.0
	1996	125	275.4

Figure 10. Sample chart (A) and report (B) from the tutorial example, showing merchantable volume versus age for 21 PSPs. The query involved all PSPs in Ecodistrict 22 (Nashwaak River). The report (B) shown above includes only the first 6 out of 21 plots.

6. Analysis of NB Cooperative PSP Data

The NB Cooperative PSP Database contains a wealth of data on development of forest stands in New Brunswick. Since 1987, 2499 PSPs have been measured on a 3- or 5-year cycle, providing some 497 000 tree measurement records. We expect that individual users will be interested in data for specific geographic areas, stand types, treatments, *etc.*; PSPDB allows easy queries and reporting.

To demonstrate the value of these data, we have included analysis of a few measures of stand development for the YIMO plots from 1987-97 in this report. These were subdivided by geographic area (ten Crown licenses and seven marketing board areas) and by stand type (selected Forest Units, known as FUNAs), including SPBF, BFSP, SPTH, SPIH, BFTH, BFIH, TOHW, and INHW (see description of FUNA codes in Appendix III). Variables calculated for each FUNA and landbase included mean merchantable volume by measurement period, mean periodic volume increment, and mean periodic mortality. The rationale for selecting these three variables was that merchantable volume shows what is there (the growing stock), periodic annual increment (PAI) shows the rate and direction of change (the "interest" on the growing stock), and periodic mortality demonstrates the rate of decline or break-up of stands.

6.1 Mean Merchantable Volume

Mean merchantable volume of the eight FUNAs for the 17 landbases and four measurement periods are summarized in Table 12. Y and I plots were remeasured every 5 years, while M and O plots were remeasured every 3 years. A total of 1169 PSPs were represented in these eight FUNAs, with 785 on Crown and 384 on small freehold land. The number of PSPs per FUNA per landbase ranged from a maximum of 73 BFSP on the Restigouche-Tobique License to nil or only 1-2 on some landbases. For any License or marketing board, the number of plots in a FUNA is generally in proportion to its area.

In some cases, the number of PSPs per landbase/FUNA was less in measurements 2 or 3 than in the initial measurement, because plots were lost to wildfire or cutting. Measurement 4 has only been completed for a subset of plots.

Most analyzed PSPs were in softwood stands (464 SPBF and 199 BFSP), but 192 were in mixedwood and 314 in hardwood stands. Merchantable volume in measurement 3 averaged 181 and 198 m^3/ha for SPBF on Crown and small freehold, respectively. Similar Crown and small freehold values for BFSP were 207 and 167 m^3/ha, and for TOHW were 186 and 144 m^3/ha. In total, there were 136 classes (17 landbases X 8 FUNAs) in Table 12. Sixteen classes had no data (*i.e.*, there were no PSPs in that FUNA on that landbase). Of the remaining 120 classes, 22 (18.3%) declined in volume from measurement period 1 to 3, and the rest increased in volume.

Figure 12 presents changes in merchantable volume as a function of stand age for one FUNA selected from each landbase. These PSP "yield curve segments" nicely show the variability in both volume and volume increment between measurements for plots within a given class. Of particular note is the "direction" (slope) of curve segments of plots, *i.e.*, whether individual PSPs are increasing, stable, or decreasing in volume. These data are valuable both for calibrating stand growth models and for validating yield curves used in management plans.

We have identified several individual PSPs in Figure 12 with letters (*a-m*) to note volume increment and mortality patterns in particular plots. Plots *a* and *b*, in 60- to 70-year-old SPBF on the Upsalquitch License, increased at PAI rates of 2.2-2.8 m^3/ha/yr in period 1 (from measurement 1 to measurement 2), and 6.1-6.4 m^3/ha/yr in period 2. Mortality was low, at 0.6-2.1 m^3/ha/yr. In contrast, plots *c* and *d*, also SPBF but 80-90 and 110-120 years old, sustained 9-11 and 22-30 m^3/ha/yr of mortality in periods 1 and 2, respectively, and all remaining trees in plot *c* died because of blowdown or stem breakage in period 3. Therefore, net PAI was -5.6 to -7.5 in period 1 and -19 to -30 m^3/ha/yr in period 2; plot *d* continued to decline (-5.2 m^3/ha/yr) in period 3. Plot *e* (BFSP on the Upper Miramichi License) sustained 25 m^3/ha/yr mortality in period 2, resulting in -22 m^3/ha/yr PAI.

Plot *f* (SPIH on the Fundy License) was also noteworthy because it exhibited rapid decline, with 19 m^3/ha/yr mortality in period 1 resulting in a -17 m^3/ha/yr PAI (Figure 12). Plots *g* and *h* (SPTH on the

York License) were interesting in that they declined in period 1 (16-20 m^3/ha/yr of mortality), but then recovered in period 2 (PAI of 6.0 for *g* and 7.6 for *h*) and period 3 (PAI 8.4 for *g* but -2.3 for *h*). Plots *i* (BFTH on the Carleton License) and *j* (TOHW on Madawaska Marketing Board) sustained heavy mortality in period 1 (19 m^3/ha/yr) or period 2 (10 m^3/ha/yr), respectively, but showed less decline in the other period. Plots *k* and *l* declined from 166 to 57 and from 205 to 122 m^3/ha in period 1, because of 39 and 23 m^3/ha/yr of mortality, but then showed moderate recovery (2-5 m^3/ha/yr) in period 2. It is clear that many of the NB PSPs are old enough that volume is relatively stable, except when heavy mortality results in overall declines.

Many of the small freehold (marketing board) PSPs tended to be in younger stands than Crown PSPs (Figure 12). This reflects the relative ages of forest on different ownerships. Plot *m* (INHW in the Southeastern NB Marketing Board) increased by 10-11 m^3/ha/yr in both periods 1 and 2, and sustained only 0.3-1.1 m^3/ha/yr of mortality.

6.2 Periodic Volume Increment

Table 13 summarizes mean PAI by FUNA for the ten Crown licenses and seven marketing boards. The range of PAI for classes that had at least five PSPs was from -6.4 m^3/ha/yr (SPBF on the Upsalquitch License) to 7.4 m^3/ha/yr (SPBF on the Carleton-Victoria Marketing Board). Overall, 33% of the SPBF and BFSP classes had negative PAI, compared with 23% of mixedwood classes and 18% of hardwood classes (Table 13).

PAI is a good overall indicator of the growth rates of forest in New Brunswick. It is evident that much of the fir forest, especially in northern NB, has "turned the corner" and is starting to decline in volume (negative period 3 PAI values for the Upsalquitch, Nepisiguit, Upper Miramichi, Kent, Queens-Charlotte, Fundy, York, and Carleton Licenses). It is also evident that there is considerable variation among geographic areas within a given FUNA.There should be close monitoring of the "fit" of yield curves used in management planning and Annual Allowable Cut (AAC) determination, to empirical yields from PSPs, as in Tables 12 and 13 and Figure 12.

6.3 Mortality

Rates of mortality are of particular interest in mature and overmature stands because they largely determine PAI and rates of stand decline. This is because survivor growth is relatively constant by this age; rapid declines are invariably caused by heavy mortality. Mortality is summarized by FUNA and landbase in Table 14.

Periodic rates of mortality were high in many of the forest classes, especially when it is recognized that they are expressed as annual rates (m^3/ha/yr). Mortality of SPBF and BFSP on Crown licenses averaged 4.5 and 3.9 m^3/ha/yr, with respective ranges of 2.3-12.2 and 0.6-7.5 m^3/ha/yr (Table 14). Mean values for the generally younger marketing board forests were 2.5 and 2.4 m^3/ha/yr for SPBF and BFSP. Mortality was generally lower for mixedwood and hardwood stands, but overall ranges were 0.3-19.1 and 0.6-16.0 m^3/ha/yr, respectively. The high values of 19.1 and 16.0 m^3/ha/yr mortality were for single PSPs on the Fundy and Restigouche-Tobique Licenses in periods 2-3 (Table 14).

The specifics of development of individual plots are not as important here as the illustration of the value of data residing in the PSPDB in analyzing stand development patterns. PSPDB facilitates the use of this valuable data set for a variety of growth and yield analyses. Such analyses ultimately determine the sustainability of forests in New Brunswick.

Table 12. Mean merchantable volume from permanent sample plots by forest unit for ten Crown licenses and seven small freehold marketing board areas in New Brunswick. Number of plots per forest unit and landbase is shown in parentheses

Crown license or marketing board	Meas.[b]	Mean volume by forest unit[a] and landbase (m^3/ha)							
		SPBF	BFSP	SPTH	SPIH	BFTH	BFIH	TOHW	INHW
1- Upsalquitch	1	185 (14)	197 (36)	201 (2)	159 (1)	166 (4)	153 (3)	168 (14)	148 (12)
	2	186 (14)	202 (36)	182 (2)	162 (1)	167 (4)	170 (3)	171 (13)	153 (12)
	3	186 (10)	204 (30)	----	173 (1)	181 (3)	174 (3)	178 (9)	164 (7)
	4	172 (7)	200 (29)	----	176 (1)	164 (2)	161 (1)	182 (5)	196 (1)
2 - Nepisiguit	1	171 (21)	216 (26)	----	155 (1)	186 (4)	206 (1)	163 (9)	174 (6)
	2	177 (21)	217 (26)	----	170 (1)	174 (4)	214 (1)	169 (9)	185 (6)
	3	182 (21)	208 (24)	----	181 (1)	173 (4)	217 (1)	172 (9)	191 (6)
	4	216 (6)	204 (12)	----	----	183 (3)	211 (1)	177 (8)	195 (4)
3 - Lower Miramichi	1	161 (50)	244 (4)	167 (4)	221 (1)	171 (2)	----	180 (7)	----
	2	160 (50)	253 (4)	181 (4)	217 (1)	183 (2)	----	176 (7)	----
	3	165 (46)	267 (4)	201 (3)	235 (1)	252 (1)	----	201 (6)	----
	4	154 (15)	----	----	----	----	----	171 (1)	----
4 - Upper Miramichi	1	156 (31)	178 (17)	190 (2)	180 (3)	----	165 (1)	195 (5)	159 (2)
	2	160 (30)	173 (17)	183 (1)	185 (3)	----	162 (1)	205 (5)	155 (2)
	3	172 (22)	171 (16)	176 (1)	175 (3)	----	----	----	124 (1)
	4	45 (1)	----	----	----	----	----	----	----
5 - Kent	1	147 (22)	----	104 (4)	----	57 (2)	----	186 (3)	155 (16)
	2	145 (21)	----	120 (4)	----	78 (2)	----	187 (3)	160 (15)
	3	136 (18)	----	132 (4)	----	94 (2)	----	150 (1)	159 (12)
	4	128 (13)	----	----	----	----	----	----	156 (8)
6 - Queens-Charlotte	1	153 (42)	142 (6)	176 (7)	174 (5)	63 (1)	----	161 (7)	105 (5)
	2	154 (41)	148 (6)	182 (7)	185 (5)	79 (1)	----	173 (7)	118 (5)
	3	152 (36)	150 (6)	193 (6)	185 (4)	88 (1)	----	219 (3)	116 (3)
	4	137 (22)	165 (5)	195 (5)	234 (2)	----	----	199 (1)	149 (1)
7 - Fundy	1	152 (62)	188 (1)	208 (3)	167 (7)	223 (1)	----	152 (9)	122 (4)
	2	156 (60)	209 (1)	231 (3)	161 (7)	242 (1)	----	167 (9)	130 (3)
	3	160 (49)	235 (1)	218 (3)	174 (4)	211 (1)	----	194 (5)	169 (1)
	4	154 (30)	----	165 (1)	----	191 (1)	----	----	178 (1)
8 - York	1	238 (28)	173 (2)	229 (12)	189 (5)	----	----	175 (19)	149 (8)
	2	239 (28)	166 (2)	227 (12)	184 (5)	----	----	187 (18)	167 (8)
	3	244 (23)	177 (2)	243 (10)	189 (5)	----	----	209 (5)	169 (5)
	4	243 (23)	191 (1)	239 (9)	174 (4)	----	----	205 (4)	168 (5)
9 - Carleton	1	197 (35)	221 (11)	237 (8)	----	210 (6)	----	162 (22)	----
	2	200 (35)	228 (11)	238 (8)	----	205 (6)	----	166 (21)	----
	3	207 (23)	241 (10)	255 (7)	----	208 (6)	----	174 (8)	----
	4	197 (22)	253 (7)	264 (6)	----	199 (5)	----	183 (3)	----
10 - Restigouche-Tobique	1	212 (39)	215 (73)	----	187 (3)	206 (8)	191 (4)	164 (9)	193 (3)
	2	210 (38)	213 (73)	----	196 (3)	212 (8)	205 (4)	171 (8)	208 (3)
	3	205 (34)	207 (62)	----	192 (3)	214 (6)	215 (3)	181 (7)	169 (2)
	4	210 (7)	235 (16)	----	----	228 (2)	123 (1)	221 (3)	----
33 - North Shore	1	152 (17)	138 (10)	194 (4)	132 (2)	176 (4)	91 (1)	149 (12)	137 (9)
	2	170 (13)	153 (8)	210 (3)	150 (2)	192 (4)	109 (1)	167 (10)	150 (8)
	3	189 (5)	174 (4)	260 (2)	177 (1)	172 (2)	----	123 (2)	258 (1)
	4	----	----	----	----	----	----	----	----

Table 12. Continued.

Crown license or marketing board	Meas.[b]	Mean volume by forest unit[a] and landbase (m^3/ha)							
		SPBF	BFSP	SPTH	SPIH	BFTH	BFIH	TOHW	INHW
34 - Madawaska	1	180 (2)	162 (2)	198 (1)	212 (1)	185 (3)	172 (2)	145 (16)	145 (13)
	2	246 (1)	175 (1)	214 (1)	228 (1)	210 (3)	252 (1)	147 (15)	156 (11)
	3	260 (1)	200 (1)	215 (1)	245 (1)	218 (3)	----	150 (15)	205 (6)
	4	268 (1)	----	----	----	----	----	153 (2)	182 (1)
35 - Carleton-Victoria	1	172 (10)	104 (1)	140 (5)	161 (3)	195 (2)	138 (1)	140 (27)	175 (7)
	2	196 (8)	----	152 (5)	181 (3)	205 (2)	144 (1)	136 (23)	184 (5)
	3	218 (8)	----	165 (3)	----	----	114 (1)	133 (15)	206 (4)
	4	198 (14)	----	----	----	----	125 (1)	107 (2)	189 (3)
36 - Northumberland	1	124 (29)	123 (2)	143 (6)	117 (6)	109 (4)	105 (5)	127 (2)	109 (6)
	2	129 (27)	122 (2)	117 (4)	130 (6)	134 (4)	111 (5)	124 (2)	123 (6)
	3	133 (23)	175 (1)	127 (4)	143 (3)	154 (4)	125 (5)	113 (1)	140 (4)
	4	148 (14)	185 (1)	134 (2)	201 (4)	----	175 (3)	----	104 (1)
37 - Y.S.C.[c]	1	169 (17)	125 (3)	158 (7)	147 (4)	142 (3)	189 (3)	160 (18)	147 (11)
	2	185 (17)	141 (3)	169 (6)	190 (3)	152 (3)	209 (3)	169 (16)	159 (9)
	3	202 (6)	176 (1)	228 (3)	129 (1)	157 (2)	260 (1)	178 (11)	148 (4)
	4	195 (1)	----	----	----	----	----	----	----
38 - S.N.B.[c]	1	160 (27)	164 (3)	147 (4)	156 (5)	125 (2)	156 (1)	118 (1)	141 (13)
	2	183 (21)	183 (2)	166 (3)	176 (5)	100 (1)	165 (1)	131 (1)	165 (13)
	3	195 (7)	191 (1)	148 (1)	----	----	178 (1)	----	210 (10)
	4	----	----	----	----	----	----	----	----
39 - S.E.N.B.[c]	1	166 (18)	97 (2)	156 (1)	171 (6)	----	139 (1)	135 (6)	164 (13)
	2	188 (17)	121 (2)	165 (1)	199 (5)	----	----	150 (6)	179 (12)
	3	190 (7)	87 (1)	181 (1)	179 (2)	----	----	169 (3)	192 (6)
	4	----	----	----	----	----	----	----	----

[a] Species abbreviations for forest units: SP spruce, BF balsam fir, TH or TOHW tolerant hardwood, IH or INHW intolerant hardwood.

[b] Measurements were generally conducted from 1987-1990 (1), 1990-1993 (2), 1993-1996 (3), and 1997 (4) for mature and overmature plots (3-yr remeasurement), and generally from 1987-1990 (1), 1992-1995 (2), and 1997 (3) for young and immature plots (5-yr remeasurement).

[c] Marketing boards: Y.S.C. - York-Sunbury-Charlotte, S.N.B. = Southern New Brunswick, S.E.N.B. = Southeastern New Brunswick.

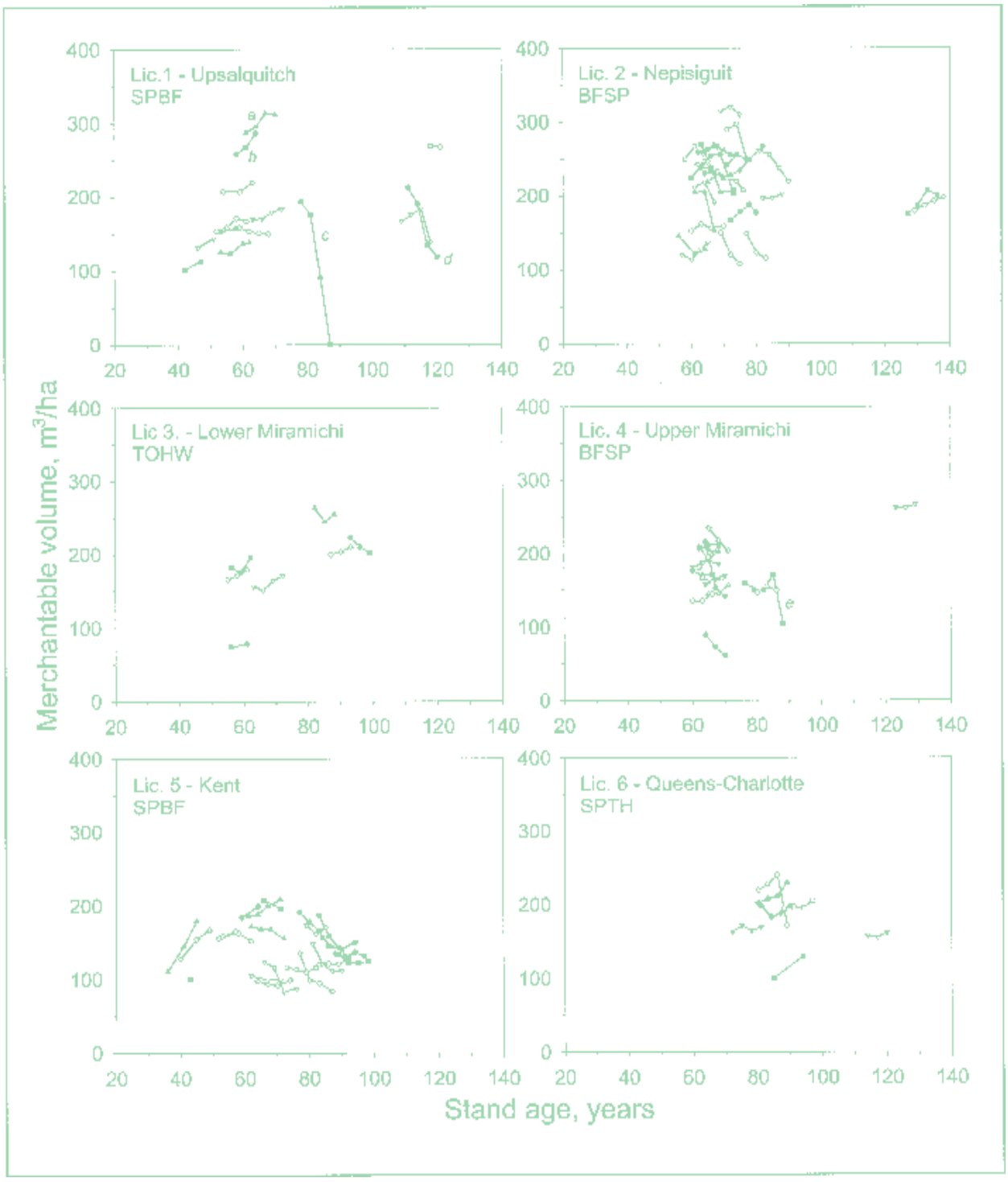


Figure 12. Volume development in PSPs representing ten Crown licenses and seven marketing board areas in New Brunswick. Individual plots are shown for one forest unit selected from each landbase; means are presented in Table 12. Letters on some of the plots are referred to in the text.

.....Cont'd

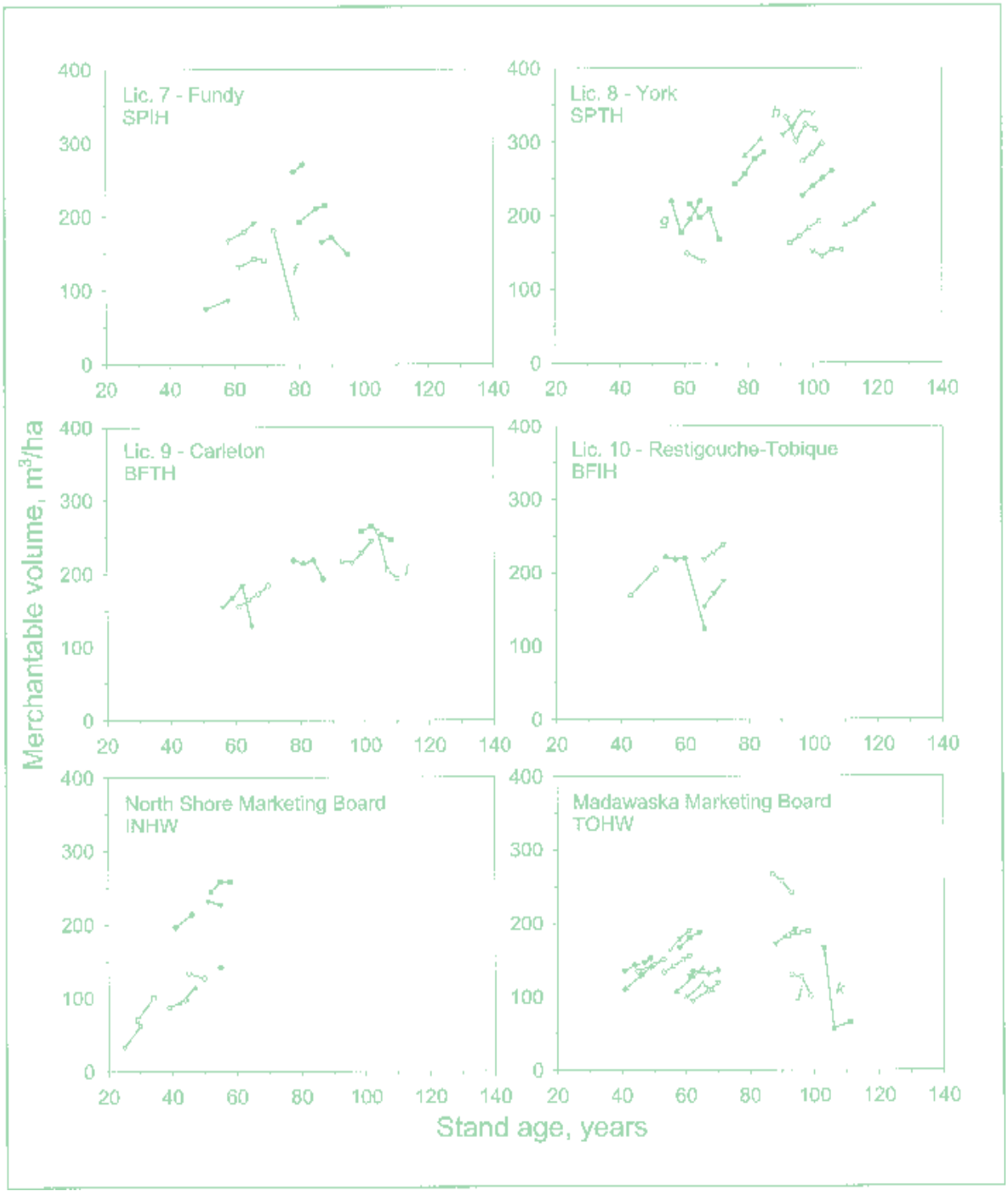


Figure 12. ....Cont'd

....Cont'd

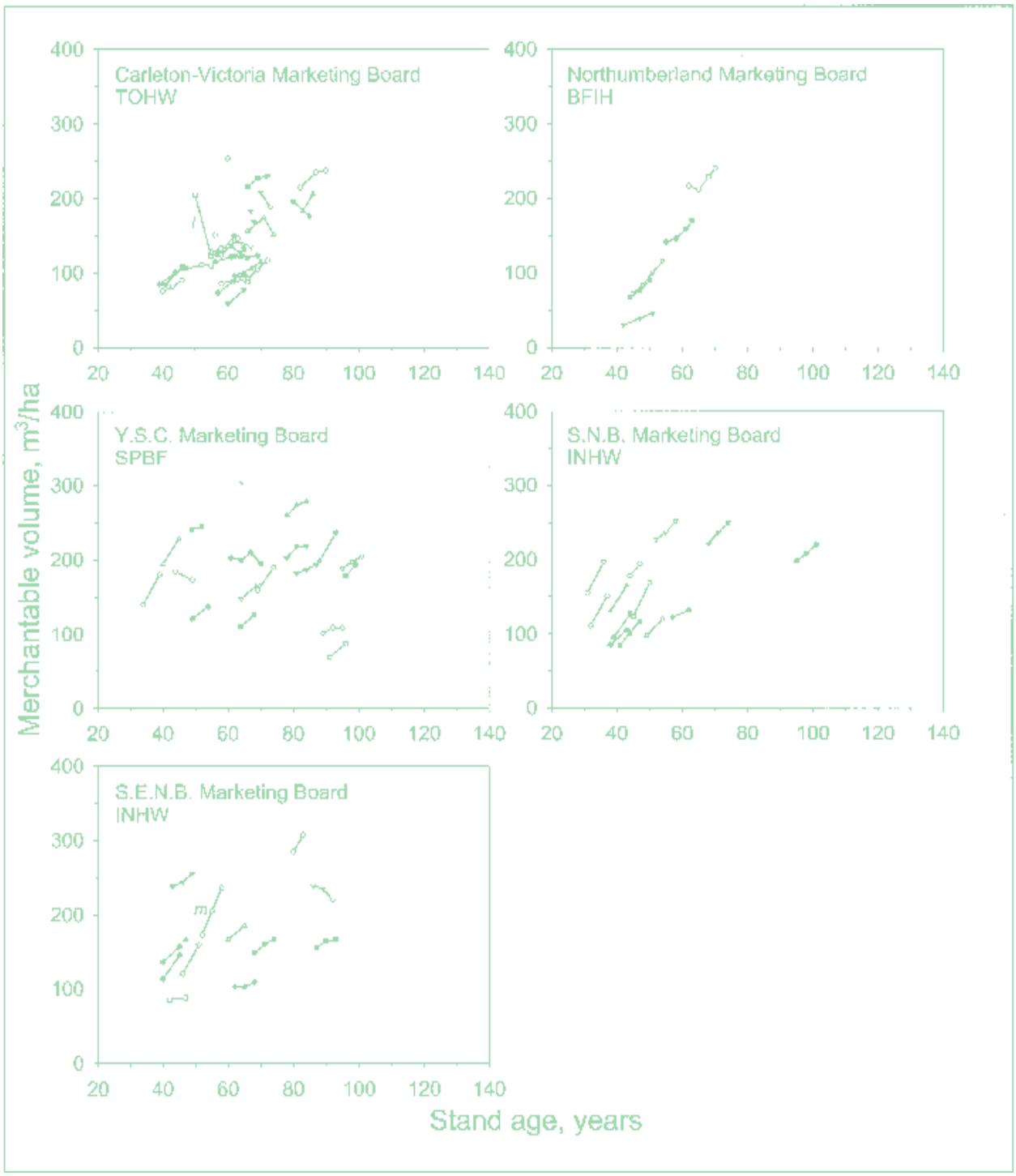


Figure 12. ....Cont'd

Table 13. Mean periodic volume increment calculated from permanent sample plots by forest unit for ten Crown licenses and seven small freehold marketing board areas in New Brunswick. Number of plots per forest unit and landbase is shown in parentheses

Crown license or marketing board	Meas.[c] period	Mean periodic volume increment[a] by forest unit[b] and landbase (m^3/ha/yr)							
		SPBF	BFSP	SPTH	SPIH	BFTH	BFIH	TOHW	INHW
1- Upsalquitch	1-2	-0.01 (14)	0.80 (36)	-3.87 (2)	1.14 (1)	-1.04 (4)	2.35 (3)	1.61 (13)	1.06 (12)
	2-3	-1.92 (10)	-1.52 (30)	----	3.53 (1)	-0.60 (3)	0.98 (3)	0.95 (9)	1.77 (7)
	3-4	-6.39 (8)	-1.70 (29)	----	0.96 (1)	-5.47 (2)	-2.91 (1)	-1.92 (5)	0.77 (1)
2 - Nepisiguit	1-2	1.72 (21)	0.48 (26)	----	2.94 (1)	-4.07 (4)	2.87 (1)	1.67 (9)	2.25 (6)
	2-3	1.28 (21)	-2.42 (24)	----	3.89 (1)	-0.47 (4)	1.03 (1)	1.10 (9)	2.23 (6)
	3-4	-0.13 (6)	-2.07 (13)	----	----	-1.07 (3)	-2.14 (1)	1.13 (8)	0.41 (4)
3 - Lower Miramichi	1-2	-0.75 (50)	3.19 (4)	3.76 (4)	-1.40 (1)	3.27 (2)	----	-1.50 (7)	----
	2-3	1.41 (46)	4.51 (4)	4.24 (3)	5.87 (1)	3.22 (1)	----	2.65 (6)	----
	3-4	1.79 (15)	----	----	----	----	----	2.42 (1)	----
4 - Upper Miramichi	1-2	0.37 (30)	-1.58 (17)	-0.24 (1)	1.90 (3)	----	-0.97 (1)	2.10 (5)	-1.24 (2)
	2-3	0.39 (23)	-1.14 (16)	-2.20 (1)	-1.38 (3)	----	----	----	-8.15 (1)
	3-4	-10.54 (1)	----	----	----	---	----	----	----
5 - Kent	1-2	-1.84 (21)	----	3.01 (4)	----	4.17 (2)	----	0.31 (3)	1.58 (15)
	2-3	-0.71 (17)	----	3.23 (4)	----	3.94 (2)	----	3.32 (1)	3.23 (11)
	3-4	-0.55 (13)	----	----	----	----	----	----	1.21 (8)
6 - Queens-Charlotte	1-2	0.11 (40)	1.81 (6)	0.83 (7)	2.69 (5)	3.08 (1)	----	3.08 (7)	2.07 (5)
	2-3	0.49 (36)	1.12 (6)	1.06 (6)	1.99 (4)	3.05 (1)	----	2.42 (3)	2.00 (2)
	3-4	-1.02 (23)	1.02 (5)	-2.02 (5)	0.17 (2)	----	----	2.45 (1)	-3.61 (1)
7 - Fundy	1-2	1.13 (59)	7.09 (1)	4.38 (3)	-0.23 (7)	6.39 (1)	----	3.23 (9)	-0.31 (3)
	2-3	1.07 (49)	5.31 (1)	-0.47 (3)	0.13 (4)	-7.67 (1)	----	3.38 (5)	1.76 (2)
	3-4	-1.24 (30)	----	3.01 (1)	----	-10.45 (1)	----	----	4.60 (1)
8 - York	1-2	-0.07 (28)	-2.51 (2)	-0.89 (12)	-1.75 (5)	----	----	2.25 (18)	4.17 (8)
	2-3	3.43 (23)	3.58 (2)	5.02 (10)	1.68 (5)	----	----	3.62 (5)	2.22 (5)
	3-4	-0.39 (23)	2.68 (1)	0.41 (9)	-4.54 (4)	----	----	-0.18 (4)	-0.41 (5)
9 - Carleton	1-2	0.04 (35)	1.61 (11)	0.56 (8)	----	-1.60 (6)	----	1.00 (21)	----
	2-3	2.48 (23)	4.06 (10)	3.16 (7)	----	1.10 (6)	----	0.82 (8)	----
	3-4	-2.17 (23)	2.13 (7)	3.15 (6)	----	-4.15 (5)	----	-1.04 (3)	----
10 - Restigouche-Tobique	1-2	-0.72 (38)	-1.09 (72)	----	2.17 (3)	1.74 (8)	3.07 (4)	3.39 (8)	3.33 (3)
	2-3	-1.22 (34)	-2.00 (61)	----	-1.13 (3)	3.86 (6)	3.25 (3)	3.35 (7)	-3.68 (2)
	3-4	1.96 (7)	1.68 (16)	----	----	4.69 (2)	-16.14 (1)	-0.87 (3)	----
33 - North Shore	1-2	2.59 (13)	3.31 (8)	0.39 (3)	4.21 (2)	3.66 (4)	3.30 (1)	2.00 (10)	2.77 (8)
	2-3	-0.55 (5)	3.01 (4)	3.58 (2)	2.13 (1)	1.16 (2)	----	2.82 (2)	0.23 (1)
	3-4	----	----	----	----	----	----	----	----
34 - Madawaska	1-2	3.28 (1)	8.29 (1)	5.39 (1)	5.52 (1)	5.85 (3)	8.17 (1)	-0.38 (15)	3.68 (11)
	2-3	4.94 (1)	8.48 (1)	0.37 (1)	5.51 (1)	2.74 (3)	----	-0.86 (15)	5.29 (6)
	3-4	4.03 (1)	----	----	----	----	----	2.65 (2)	3.61 (1)
35 - Carleton-Victoria	1-2	6.96 (8)	----	3.28 (5)	4.51 (3)	3.30 (2)	2.04 (1)	1.22 (23)	0.50 (5)
	2-3	7.39 (8)	----	5.84 (3)	----	----	-10.13 (1)	0.49 (15)	6.41 (4)
	3-4	3.35 (3)	----	----	----	----	5.19 (1)	1.58 (2)	0.37 (3)
36 - Northumberland	1-2	0.04 (27)	-0.73 (2)	0.38 (4)	3.00 (6)	4.82 (4)	1.66 (5)	-1.17 (2)	1.91 (6)
	2-3	1.85 (23)	5.08 (1)	2.80 (4)	3.81 (3)	5.06 (4)	4.36 (5)	2.74 (1)	1.90 (4)
	3-4	2.53 (14)	5.01 (1)	0.88 (2)	8.51 (1)	----	5.53 (3)	----	2.15 (1)

Table 13. Continued.

Crown license or marketing board	Meas.[c] period	Mean periodic volume increment[a] by forest unit[b] and landbase (m^3/ha/yr)							
		SPBF	BFSP	SPTH	SPIH	BFTH	BFIH	TOHW	INHW
37 - Y.S.C.[d]	1-2	3.72 (17)	2.69 (3)	3.09 (6)	4.17 (3)	2.58 (3)	4.97 (3)	2.06 (16)	2.29 (9)
	2-3	1.69 (6)	7.85 (1)	3.42 (3)	4.07 (1)	2.38 (2)	2.52 (1)	1.57 (11)	0.57 (4)
	3-4	-4.88 (1)	----	----	----	----	----	----	----
38 - S.N.B.[d]	1-2	4.24 (21)	4.84 (2)	4.23 (3)	4.06 (5)	2.32 (1)	3.06 (1)	2.38 (1)	5.45 (13)
	2-3	1.66 (7)	3.54 (1)	-2.59 (1)	----	----	4.13 (1)	----	4.65 (4)
	3-4	----	----	----	----	----	----	----	----
39 - S.E.N.B.[d]	1-2	4.31 (17)	6.03 (2)	3.14 (1)	5.71 (5)	----	----	3.55 (6)	4.01 (12)
	2-3	2.23 (7)	0.91 (1)	5.43 (1)	3.06 (2)	----	----	0.95 (3)	2.41 (6)
	3-4	----	----	----	----	----	----	----	----

[a] Periodic annual volume increment = (survivor growth - mortality/no. years).

[b] Species abbreviations for forest units: Sp spruce, BF balsam fir, TH or TOHW tolerant hardwood, IH or INHW intolerant hardwood.

[c] Measurements were generally conducted from 1987-1990 (1), 1990-1993 (2), 1993-1996 (3), and 1997 (4) for mature and overmature plots (3-yr remeasurement), and generally from 1987-1990 (1), 1992-1995 (2), and 1997 (3) for young and immature plots (5-yr remeasurement). PAI was calculated from measurement 1 to 2 (1-2) and from 2 to 3 (2-3).

[d] Marketing boards: Y.S.C. = York-Sunbury-Charlotte, S.N.B. = Southern New Brunswick, S.E.N.B. = Southeastern New Brunswick.

Table 14. Mean periodic mortality calculated from permanent sample plots by forest unit for ten Crown licenses and several small freehold marketing board areas in New Brunswick. Number of plots per forest unit and landbase is shown in parentheses

Crown license or marketing board	Meas.[b] period	Mean mortality by forest unit[a] and landbase (m^3/ha/yr)							
		SPBF	BFSP	SPTH	SPIH	BFTH	BFIH	TOHW	INHW
1 - Upsalquitch	1-2	3.8 (14)	4.0 (33)	8.5 (2)	2.9 (1)	11.2 (2)	6.5 (2)	2.7 (9)	3.7 (10)
	2-3	8.3 (8)	6.4 (29)	----	----	4.8 (3)	4.2 (3)	2.8 (8)	3.9 (6)
	3-4	9.8 (8)	6.4 (27)	----	3.2 (1)	9.7 (2)	6.6 (1)	6.4 (4)	2.0 (1)
2 - Nepisiguit	1-2	2.7 (19)	4.3 (25)	----	1.3 (1)	8.6 (4)	4.6 (1)	5.1 (4)	3.1 (6)
	2-3	3.2 (14)	7.1 (21)	----	0.5 (1)	5.0 (4)	2.8 (1)	3.8 (6)	3.5 (6)
	3-4	4.8 (5)	6.4 (11)	----	----	5.7 (2)	5.4 (1)	3.4 (6)	4.0 (4)
3 - Lower Miramichi	1-2	4.4 (43)	1.6 (4)	2.0 (3)	6.9 (1)	1.4 (2)	----	6.5 (7)	----
	2-3	2.8 (34)	0.8 (3)	0.9 (2)	----	----	----	2.1 (5)	----
	3-4	2.6 (11)	----	----	----	----	----	1.2 (1)	----
4 - Upper Miramichi	1-2	3.6 (27)	6.2 (14)	3.2 (1)	2.6 (3)	----	4.8 (1)	2.9 (4)	5.7 (2)
	2-3	3.7 (21)	5.4 (14)	5.4 (1)	4.8 (3)	----	----	----	11.7 (1)
	3-4	12.2 (1)	----	----	----	----	----	----	----
5 - Kent	1-2	4.7 (21)	----	6.1 (1)	----	----	----	3.4 (3)	3.9 (13)
	2-3	3.9 (17)	----	1.5 (2)	----	----	----	----	3.3 (5)
	3-4	3.1 (11)	----	----	----	----	----	----	5.0 (5)
6 - Queens-Charlotte	1-2	3.5 (31)	2.6 (5)	3.7 (6)	1.5 (4)	----	----	2.1 (3)	1.9 (4)
	2-3	3.1 (26)	3.8 (3)	3.6 (5)	1.8 (3)	----	----	0.6 (1)	1.8 (2)
	3-4	4.0 (17)	2.7 (4)	12.9 (2)	3.2 (1)	----	----	----	6.5 (1)
7 - Fundy	1-2	2.4 (46)	0.8 (1)	0.5 (3)	4.7 (6)	----	----	1.8 (6)	4.3 (3)
	2-3	2.7 (28)	0.6 (1)	7.2 (3)	4.3 (3)	11.1 (1)	----	0.7 (2)	2.2 (2)
	3-4	5.9 (23)	----	1.0 (1)	----	16.0 (1)	----	----	0.7 (1)
8 - York	1-2	4.5 (25)	5.8 (2)	9.3 (6)	8.4 (4)	----	----	2.9 (15)	1.0 (6)
	2-3	2.3 (13)	1.3 (1)	0.9 (5)	4.1 (4)	----	----	1.5 (4)	2.0 (5)
	3-4	5.3 (15)	1.5 (1)	5.5 (6)	7.9 (4)	----	----	3.7 (4)	3.8 (5)
9 - Carleton	1-2	4.5 (28)	2.8 (10)	3.4 (8)	----	6.4 (5)	----	4.7 (13)	----
	2-3	2.9 (16)	1.4 (7)	2.2 (5)	----	4.7 (5)	----	3.5 (6)	----
	3-4	6.2 (20)	2.4 (4)	3.5 (3)	----	10.2 (4)	----	3.3 (3)	----
10 - Restigouche-Tobique	1-2	5.3 (33)	6.8 (68)	----	3.4 (2)	4.3 (5)	4.0 (3)	1.1 (2)	2.4 (2)
	2-3	5.3 (29)	7.5 (55)	----	5.7 (3)	9.5 (1)	4.1 (2)	----	8.6 (2)
	3-4	3.7 (4)	4.6 (12)	----	----	----	19.1 (1)	16.0 (1)	----
33 - North Shore	1-2	2.5 (10)	1.7 (7)	5.1 (3)	1.1 (2)	1.8 (4)	2.0 (1)	1.9 (9)	3.2 (8)
	2-3	4.4 (5)	2.3 (4)	1.5 (2)	1.2 (1)	2.6 (2)	----	2.4 (2)	5.1 (1)
	3-4	----	----	----	----	----	----	----	----
34 - Madawaska	1-2	2.1 (1)	----	1.3 (1)	----	3.9 (1)	0.1 (1)	5.3 (11)	2.5 (9)
	2-3	----	----	5.3 (1)	0.7 (1)	6.1 (2)	----	3.3 (13)	0.9 (5)
	3-4	1.0 (1)	----	----	----	----	----	----	2.7 (1)
35 - Carleton-Victoria	1-2	1.5 (7)	----	2.2 (4)	3.7 (2)	4.5 (2)	4.5 (1)	3.1 (21)	7.2 (5)
	2-3	0.4 (5)	----	0.6 (2)	----	----	16.6 (1)	3.4 (11)	2.5 (3)
	3-4	2.0 (3)	----	----	----	----	1.8 (1)	2.0 (2)	6.0 3)
36 - Northumberland	1-2	3.6 (25)	6.0 (1)	3.3 (4)	3.2 (5)	2.4 (3)	2.4 (5)	4.5 (2)	4.1 (6)
	2-3	2.6 (21)	----	2.8 (3)	2.7 (2)	2.2 (2)	1.0 (3)	1.7 (1)	4.7 (3)
	3-4	1.7 (8)	1.1 (1)	2.9 (2)	----	----	0.7 (2)	----	----

Table 14. Continued.

Crown license or marketing board	Meas.[b] period	Mean mortality by forest unit[a] and landbase (m^3/ha/yr)							
		SPBF	BFSP	SPTH	SPIH	BFTH	BFIH	TOHW	INHW
37 - Y.S.C.[c]	1-2	2.0 (11)	4.3 (3)	2.3 (3)	0.7 (3)	2.1 (3)	2.3 (2)	2.7 (12)	3.4 (9)
	2-3	2.5 (4)	----	1.5 (2)	1.2 (1)	2.2 (2)	2.8 (1)	3.1 (7)	4.2 (3)
	3-4	7.4 (1)	----	----	----	----	----	----	----
38 - S.N.B.[c]	1-2	1.3 (17)	2.3 (2)	1.6 (3)	2.0 (5)	2.7 (1)	3.2 (1)	2.3 (1)	1.2 (11)
	2-3	2.8 (4)	2.8 (1)	7.3 (1)	----	----	1.9 (1)	----	3.2 (2)
	3-4	----	----	----	----	----	----	----	----
39 - S.E.N.B.[c]	1-2	2.5 (12)	0.5 (1)	3.5 (1)	0.3 (1)	----	----	1.6 (6)	2.5 (11)
	2-3	1.7 (7)	0.7 (1)	0.4 (1)	0.6 (1)	----	----	2.4 (2)	2.5 (5)
	3-4	----	----	----	----	----	----	----	----

[a] Species abbreviations for forest units: SP spruce, BF balsam fir, TH or TOHW tolerant hardwood, IH or INHW intolerant hardwood.

[b] Measurements were generally conducted from 1987-1990 (1), 1990-1993 (2), 1993-1996 (3), and 1997 (4) for mature and overmature plots (3-yr remeasurement), and generally from 1987-1990 (1), 1992-1995 (2), and 1997 (3) for young and immature plots (5-yr remeasurement). Mortality was calculated from measurement 1 to 2 (1-2) and from 2 to 3 (2-3).

[c] Marketing boards: Y.S.C. = York-Sunbury-Charlotte, S.N.B. = Southern New Brunswick, S.E.N.B. = Southeastern New Brunswick.

7. Acknowledgements

Development of PSPDB has been financially supported by the N.B. Forest Research Advisory Committee, the Canadian Forest Service - Landscape Management Network, and the Canada Green Plan. The following programmers contributed significantly to the development of this system: Jeff Kerr, Jason Doyle, Mike Reeves, Michael Metcalfe, Kyla Barry, and Alastair Holmes. We wish to thank the following memebers of the N.B. forestry community who acted as our beta testers and/or report reviewers: Craig Frame, Vince Zelazny, Liz Rainer, Luc Gagnon, David Young, Walter Emrich, Roland Gagnon, Joe Pelham, Tim Fox, Thom Erdle, Ed Hurley, John Kershaw, Steve Spears, Gord Whitmore, and Ian Prior.

8. References

Dunlap, J.A. 1998. 1987 Permanent sampling program annual report. New Brunswick Department of Natural Resources and Energy, Timber Management Branch, Fredericton, N.B. 27 p.

Dunlap, J.A. 1989. A Cooperative N.B. Permanent Sample Plot Program. New Brunswick Department of Natural Resources and Energy, Timber Management Branch. Fredericton, N.B. Doc. #0223J. 26 p.

Upshall, J.R..B. 1990. 1989 Permanent sampling program annual report. New Brunswick Department of Natural Resources and Energy, Timber Management Branch, Fredericton, N.B. 28 p.

Wang, E., Erdle, T., Litchfield, M., and Brackley, A. 1986. A proposal for a growth and yield program in New Brunswick. N.B. Forest Research Advisory Committee, Fredericton, N.B. 17 p.

For more information on Microsoft Access, refer to the printed user documentation accompanying the product or the online help system accessible from its Help menu.

APPENDICES

Appendix I
List of Procedure Manuals for the NB Cooperative PSP Program

The following documents specify the operational procedures used by field crews to establish and measure the Cooperative PSPs. They are available from John Upshall, of the New Brunswick Department of Natural Resources and Energy (NBDNRE), Forest Management Branch, in Fredericton.

Young, Immature, Mature, and Overmature Development Stages - Permanent Sample Plot Procedure Manual. Revised: April 11, 1989.

Young, Immature, Mature, and Overmature Development Stages Permanent Sample Plot (PSP) Remeasurement Manual. Revised August, 1996.

Guidelines and Procedures for Establishing a PSP in the Rengenerating Stage (R Plot). Prepared April 27, 1989.

Guidelines for Establishing/Measuring a PSP in a Pre-commercially Thinned Stand (T Plot). Prepared: June 8, 1989.

Regeneration and Thinning Permanent Sample Plot (PSP) Remeasurement Manual. Revised: May 22, 1997.

Permanent Sample Plot Procedure Manual for Young Plantations (4 to 8 years old). Revised: May 5, 1989.

Plantation Permanent Sample Plot Remeasurement Manual. Revised: May 22, 1997.

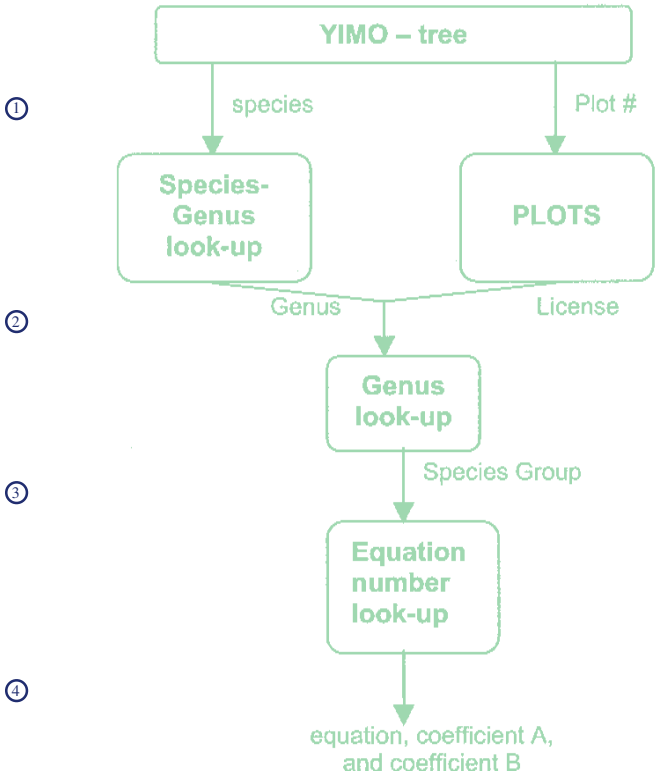
Permanent Sample Plot Procedure Manual for Young Cutovers (4 to 8 years old). Prepared: June 5, 1989.

Permanent Sample Plot Procedure Manual for Young Cutovers (4 to 8 years old). Prepared: June 5, 1989.

Appendix II
Tree Height and Volume Calculations

Height and volume are calculated for all commercial species trees greater than 9 cm dbh in YIMO plots. Tree species and plot location (License code) are used to select the appropriate equation, calibrated from height and diameter samples collected during the establishment of YIMO plots, to estimate tree height (m) and volume (m^3). These estimates are stored with each tree measurement record in the database.

Program flow for calculations of height and volume



① There are no height or volume calculations made for trees with a dbh less than 91 mm. If the dbh of the tree is greater than or equal to 91 mm, then the species number is used to find the Genus code in the Species-Genus look-up table and the plot number is used to find the License number in the PLOTS table.

② The Genus code obtained from the Species-Genus look-up table ① and the License number obtained from the PLOTS table ① are used in the Genus look-up table to find the Species Group.

③ The Species Group obtained from the Genus look-up table ② is used in the Equation number look-up table (p. 49) to find the equation, coefficient A, and coefficient B values.

④ The equation, coefficient A, and coefficient B values obtained from the Equation number look-up table ③ are used in the height and volume calculations.

Height Calculation

If equation = 1:

$$Height = 1.37 + A \times \frac{dbh}{10} + B \times \left(\frac{dbh}{10}\right)^2$$

If equation = 2:

$$Height = (10)^{A + B \times \log_{10} \frac{ldbh}{10}}$$

If equation = 3:

$$Height = A + B \times log_{10} \frac{dbh}{10}$$

If equation = 4:

$$Height = (10)^{A + \frac{B}{\frac{dbh}{10}}}$$

If equation = 5:

$$Height = 1.37 + 10^{A + B \times log_{10} \frac{dbh}{10}}$$

Volume Calculation

Softwood

$$Volume = 0.000079442 \times \left(\frac{dbh}{10}\right)^{1.7788} \times Height^{0.9627} \times \left(0.9465 + \left(-0.8169 \times \left(\frac{65}{\left(\frac{dbh}{10}\right)^2} \times \left(1 + \frac{0.15}{Height}\right)\right)^2\right)\right)$$

Hardwood

$$Total = \frac{0.0043891 \times \left(\frac{dbh}{10}\right)^2 \times (1 - 0.04365 \times 0.145)^2}{1.046 + 0.3048 \times \frac{383.972}{Height}}$$

$$X3 = \frac{49}{\left(\frac{dbh}{10}\right)^2 \times (1 - 0.04365 \times 0.145)^2} \times \left(1 + \frac{0.15}{Height}\right)$$

$$Volume = Total \times \left(0.9057 + (-0.0708 \times X3) + \left(-0.8375 \times X3^2\right)\right)$$

Equation Number Look-Up Table[a]

Genus	License or marketing board[b]	Species group	Equation no.	Coefficient A	Coefficient B
Spruce	10	1	2	0.333785	0.609209
Spruce	1	2	2	0.449349	0.52849
Spruce	2	3	1	0.913854	-0.01171
Spruce	3	4	3	-7.292194	16.678911
Spruce	4	5	3	-6.064905	15.381261
Spruce	5	6	3	-6.872705	16.715532
Spruce	6	7	3	-4.615277	14.586294
Spruce	7	8	3	-10.732867	20.064692
Spruce	8	9	4	1.400998	-4.282661
Spruce	9	10	3	-11.167757	19.667805
Fir	10	11	3	-9.5192	18.584255
Fir	1	12	3	-8.02777	17.241755
Fir	2	13	2	0.34867	0.631581
Fir	3	14	4	1.383176	-4.189598
Fir	4	15	1	0.813211	-0.012245
Fir	5	16	2	0.354599	0.624162
Fir	6	17	1	0.937626	-0.015775
Fir	7	18	4	1.465049	-5.281684
Fir	8	19	4	1.449715	-4.587453
Fir	9	20	3	-8.759159	18.217949
White & red pine	1-10, 33-39	21	3	-15.328716	22.183819
Jack pine	1-10, 33-39	22	3	-8.668627	19.483355
Cedar	1-5,10,33-36	23	3	-2.101445	10.584874
Cedar	6-9,10,37-39	24	2	0.422902	0.489834
Hemlock & larch	1-10, 33-39	25	3	-2.028566	12.985087
Tolerant hardwood	6-8, 37-39	26	3	-1.079266	12.742338
Tolerant hardwood	1-5, 9, 10, 33-36	27	4	1.335968	-2.894519
Intolerant hardwood	6-8, 37-39	28	3	-5.619322	17.304132
Intolerant hardwood	1-5, 9, 10, 33-36	29	3	-6.595758	17.97905
Spruce	33	30	3	-6.777939	15.534673
Spruce	34	31	3	-10.488533	19.143862
Spruce	35	32	1	0.814643	-0.008596
Spruce	36	33	2	0.354458	0.589261
Spruce	37	34	3	-7.594087	16.810932
Spruce	38	35	1	0.877606	-0.012616
Spruce	39	36	2	0.480463	0.509401
Fir	33	37	3	-6.899913	15.852696
Fir	34	38	3	-11.936621	20.771233
Fir	35	39	1	0.843495	-0.007472
Fir	36	40	5	0.076232	0.779402
Fir	37	41	3	-11.264785	20.339771
Fir	38	42	2	0.26616	0.674531
Fir	39	43	1	0.89918	-0.012155

[a] The Genus and License or Marketing Board columns in the table are included to allow interpretation of the Species Group codes.
[b] See Appendix III, p.50 for definition of these codes.

Appendix III
Field Names, Codes, and Code Descriptions Used in PSPDB

Field Name	Description	Code	Code Description
agecl	Age class	Y	Young
		I	Immature
		M	Mature
		O	Overmature
Agency	Agency that collected the data	DNR	Department of Natural Resources and Energy
		LIC	Licensee
		MKB	Marketing Board
		L&D	Licensee and NBDNRE
browse	Browsed damage	blank	Browsing absent
		1	Light - < 10% of total foliage and twigs consumed
		2	Moderate - 11% - 50%
		3	Heavy - 51% - 75%
		4	Very heavy - > 75%
buds	Damage to buds	blank	No damage
		I	Insect (budworm, etc.)
		D	Disease/fungus, rust, galls, etc.
		M	Mechanical/snow, ice, frost damage
		A	Animal (rabbit, mice, porcupine, deer, etc.)
		P	Poor planting technique/J-root, balled roots
		S	Poor microsite
		H	Herbicide
		O	Other
		U	Unknown
cause	Cause of death	1	Insect damage
		2	Windthrow
		3	Stem wounds
		4	Broken top
		5	Stem breakage
		6	Suppression
		7	Overmature
		8	Other
		9	Unknown
conks	Conks present	blank	Conk(s) absent
		P	Conk(s) present
cr	Crown ratio	0 or blank	Dead tree or DBH < 9
		1	1 - 10%
		2	11 - 20%
		3	21 - 30%
		4	31 - 40%
		5	41 - 50%
		6	51 - 60%
		7	61 - 70%
		8	71 - 80%
		9	81 - 100%
cumpct curpct	Cumulative and current defoliation	0	00-05%
		1	06-20%
		2	21-40%
		3	41-60%
		4	61-80%
		5	81-100%
curleader	Damage to leader	blank	No damage
		I	Insect (budworm, etc.)
		D	Disease/fungus, rust, galls, etc.
		M	Mechanical/snow, ice, frost damage
		A	Animal (rabbit, mice, porcupine, deer, etc.)
		P	Poor planting technique/J-root, balled roots
		S	Poor microsite
		H	Herbicide
		O	Other
		U	Unknown
Density Class	Density class of the plot	L	Low
		M	Medium
		H	High

Field Name	Description	Code	Code Description
depth	Wound depth	blank	No wound present
		1	Deep (penetrating the xylem)
		2	Shallow (penetrating the cambium)
		3	Shallow with decay
Dev Stage	Stage of development of the plot	blank	No data
		R	Regen
		Y	Young
		I	Immature
		M	Mature
		O	Overmature
		C	Cut
dim	Wound dimension	blank	No wound present
		1	0 - 5% of the total height (or circumference)
		2	6 - 15% of the total height (or circumference)
		3	16 - 30% of the toal height (or circumference)
		4	31 - 50% of the total height (or circumference)
		5	> 50% of the total height (or circumference)
Drainage	Soil moisture	1	Dominantly rapidly drained with significant well drained
		2	Dominantly well drained with significant rapidly or moderately well drained
		3	Dominantly moderately well drained with significant well or imperfectly drained
		4	Dominantly imperfectly drained with significant moderately well or poorly drained
		5	Dominantly poorly drained with significant imperfectly or very poorly drained
		6	Dominantly very poorly drained with significant poorly drained and organic soils
		7	Organic soils
Eco District	Breakdown of an Eco Region based on slope, terrain, elevation, and geomorphology	1	Kedgwick River
		2	Nepisiguit – Miramichi
		3	Madawaska River
		4	Restigouche - Upsalquitch
		5	Sisson Branch Reservoir
		6	Serpentine
		7	Tetagouche Lake
		8	Jacquet Lake
		9	Northwest Miramichi River
		10	Gulquac River
		11	McKiel Lake
		12	Fundy Plateau
		13	Chaleur Coastal
		14	Tabusintac
		15	Acadian Peninsula Coastal
		16	Salmon River
		17	Lower Miramichi River
		18	Tobique River
		19	Saint John River
		20	Taxis River
		21	Southwest Miramichi River
		22	Nashwaak River
		23	Nackawic Stream
		24	Northumberland Coastal
		25	Oromocto Lake
		26	Lepreau River
		27	Spendic Lake
		28	Magaguadavic Lake
		29	Anagance Ridge
		30	Petitcodiac River
		31	Kennabecasis River
		32	Fundy Coastal
		33	Oromocto River
		34	Grand Lake
Eco Region	Breakdown of N.B. on climate, elevation, and proximity to coast	1	Highlands
		2	Northern Uplands
		3	Southern Uplands
		4	Fundy Coastal
		5	Continental Lowlands
		6	Eastern Lowlands
		7	Grand Lake

Field Name	Description	Code	Code Description
Eco Section	Breakdown of Eco District based on density and patterns of streams, and geomorphology	1 2 3 4 5 6 7 8 9 10	These numeric values are simply used to identify the Ecosection within an ecodistrict. There may be a maximum of 10 Ecosections within an ecodistrict.
Eco Site	Designation of forest stand based on slope, elevation, soil type & drainage	1 1s 2 2c 2h 2s 3 3b 4 4c 5 5c 5h 6 6b 6c 6l 6t 7 7b 7c 7l 8 8c 8l 9	Coniferous dry acidic outcrop or coarse-textured deposit Coniferous steep acidic valley slope Coniferous acidic valley slope or coarse-textured deposit Transitional coniferous calcareous steep slope Sub-boreal coniferous acidic high hills Sub-boreal coniferous steep valley slope Coniferous wet acidic till plain Bog Dry mixedwood slope Mixedwood steep calcareous slope Coniferous or mixedwood moist slope Mixed calcareous slope Boreal or coastal coniferous high plateau Coniferous or mixedwood wet till plain Acadian wet bottomland Coniferous or mixedwood wet calcareous till plain Coniferous wet highly calcareous till plain Coastal marsh Mixedwood upper slope Acadian moist bottomland Mixedwood calcareous upper slope Mixedwood highly calcareous upper slope Hardwood ridge Hardwood calcareous ridge Hardwood highly calcareous ridge Hardwood dry ridge or steep slope
foliage	Damage to foliage	blank I D M A P S H O U	No damage Insect (budworm, etc.) Disease/fungus, rust, galls, etc. Mechanical/snow, ice, frost damage Animal (rabbit, mice, porcupine, deer, etc.) Poor planting technique/J-root, balled roots Poor microsite Herbicide Other Unknown
funa	Predominant species assessed from ground data	SPBF BFSP PINE PSSP OTSW SPTH SPIH BFTH BFIH THSP IHSP THBF IHBF TOHW THIH INHW IHTH CC (BS) (WS) (JP)	Spruce - balsam fir Balsam fir - spruce Pine Poor site spruce Other softwood Spruce - tolerant hardwood Spruce - intolerant hardwood Balsam fir - tolerant hardwood Balsam fir - intolerant hardwood Tolerant hardwood - spruce Intolerant hardwood - spruce Tolerant hardwood - balsam fir Intolerant hardwood - balsam fir Tolerant hardwood Tolerant hardwood - intolerant hardwood Intolerant hardwood Intolerant hardwood - tolerant hardwood Clear cut Black spruce plantation White spruce plantation Jack pine plantation
lat	Dead/broken main stem	blank P	Absent Present

Field Name	Description	Code	Code Description
lateral	Damage to branches	blank	No damage
		I	Insect (budworm, etc.)
		D	Disease/fungus, rust, galls, etc.
		M	Mechanical/snow, ice, frost damage
		A	Animal (rabbit, mice, porcupine, deer, etc.)
		P	Poor planting technique/J-root, balled roots
		S	Poor microsite
		H	Herbicide
		O	Other
		U	Unknown
leaderda	Current leader damage	1	Shoot above top whorl completely defoliated, but terminal bud intact
		2	Leading shoot dead or broken, but lateral shoots in first whorl turning up
		3	Leading shoot dead or broken, no lateral shoot response
lean	Tree leaning	blank	0 - 5 degrees
		1	6 - 15 degrees
		2	16 - 30 degrees
		3	31- 45 degrees
		4	> 45 degrees
License	Ownership	1	Upsalquitch License
		2	Nepisiguit License
		3	Lower Miramichi License
		4	Upper Miramichi License
		5	Kent License
		6	Queens-Charlotte License
		7	Fundy License
		8	York License
		9	Carleton License
		10	Restigouche-Tobique License
		33	North Shore Marketing Board
		34	Madawaska Marketing Board
		35	Carleton-Victoria Marketing Board
		36	Northumberland Marketing Board
		37	York-Sunbury-Charlotte Marketing Board
		38	Southeastern New Brunswick Marketing Board
		39	Southern New Brunswick Marketing Board
ltbh	Wound below breast height	blank	No wound is present below breast height
		1	Wound extends below or is situated below breast height
microsite	Soil composition where tree is planted		1 LFH layer intact
		2	Mixture of organic and mineral soil
		3	BMS (bare mineral soil) exposed
microtop	Topography where tree is planted	L	Relatively level ground
		T	Top of mound
		B	Bottom of depression
origin	Origin of tree	1	Planted
		2	Natural seedling (single stemmed) or sucker
		3	Stump sprout
		4	Residual
		5	Layering
P1DS	Primary development stage of plot	C	Cutover
		I	Immature
		M	Mature
		O	Overmature
		R	Regenerating
		Y	Young
Plot Type	The PSPDB plot type – identifies the tree table		C Cut
		P	Plantation
		R	Regen
		T	Thin
		M	Young, immature, mature, or overmature
quarter	Division of plot into 4 equal parts	1	NE quarter
		2	SE quarter
		3	SW quarter
		4	NW quarter
Prod	Not used		
region	NBDNRE Region	1	NBDNRE Region 1
		2	NBDNRE Region 2
		3	NBDNRE Region 3

Field Name	Description	Code	Code Description
		4	NBDNRE Region 4
		5	NBDNRE Region 5
roots	Damage to roots	blank	No damage
		I	Insect (budworm, etc.)
		D	Disease/fungus, rust, galls, etc.
		M	Mechanical/snow, ice, frost damage
		A	Animal (rabbit, mice, porcupine, deer, etc.)
		P	Poor planting technique/J-root, balled roots
		S	Poor microsite
		H	Herbicide
		O	Other
		U	Unknown
Site Region	Subdivision of Province	1	KE Kedgwick
		2	RE Restigouche
		3	UP Upsalquitch
		4	BB Big Bald
		5	SE Sevogle
		6	CT Cains-Tracadie
		7	NT Napadogan-Tobique
		8	HH Harvey-Harcourt
		9	FU Fundy
Soil	Mapped soil type	AC	Acadia
		BB	Barrieau-Buctouche
		BD	Big Bald Mountain
		BE	Becaguimec
		BR	Britt Brook
		CA	Caribou
		CH	Cornhill
		CR	Carleton
		CT	Catamaran
		EB	Erb Settlement
		FA	Fair Isle
		GE	Glassville
		GF	Grand Falls
		GG	Gagetown
		HM	Holmesville
		HT	Harcourt
		IN	Interval
		IR	Irving
		JR	Jacket River
		JU	Juniper
		KE	Kedgwick
		KI	Kingston
		KN	Kennebecasis
		LL	Long Lake
		LO	Lomond
		MD	Mining Debris
		MG	McGee
		MU	Muniac
		MV	Mafic Volcanic
		OS	Organic Soil
		PD	Popple Depot
		PI	Pinder
		PR	Parry
		PT	Parleeville-Tobique
		RE	Reece
		RG	Rogersville
		RI	Riverbank
		SA	Salisbury
		SB	Stony Brook
		SE	Siegas
		SN	Sunbury
		SP	Serpentine
		SS	Saltsprings
		TD	Tracadie
		TH	Thibault
		TR	Tracy
		TT	Tetagouche
		TU	Tuadook
		UN	Undine

Field Name	Description	Code	Code Description
		VI	Victoria
species	Tree species	001	Black spruce
		002	White spruce
		003	Red spruce
		005	Balsam fir
		006	White pine
		007	Jack pine
		008	Red pine
		009	Eastern white cedar
		010	Eastern hemlock
		011	Tamarack
		012	Red maple
		013	Sugar maple
		014	Yellow birch
		015	Beech
		016	Ironwood
		017	Red oak
		018	White ash
		019	White birch
		020	Trembling aspen
		021	Large-tooth aspen
		022	Alder
		023	Mountain maple
		024	Striped maple
		025	American mountain ash
		034	Serviceberry
		035	Hazel
		043	Willow
		131	Grey birch
		159	Pin cherry
		163	Choke cherry
		172	Black ash
		183	Balsam poplar
		194	Black cherry
		219	Elm
		220	Apple
		224	Butternut
sp1, sp2, sp3, sp4	Species of competition trees	See species	
stem	Damage to stem	blank	No damage
		I	Insect (budworm, etc.)
		D	Disease/fungus, rust, galls, etc.
		M	Mechanical/snow, ice, frost damage
		A	Animal (rabbit, mice, porcupine, deer, etc.)
		P	Poor planting technique/J-root, balled roots
		S	Poor microsite
		H	Herbicide
		O	Other
		U	Unknown
survival	Expectation of tree's survival in next 5 years	Y	Yes
		N	No
		M	Maybe
thincr	Thin crown – hardwood only	blank	Absent
		P	Present
top	Dead/broken top	blank	Broken or dead top
		1	< 10% of live crown length broken or dead
		2	10 - 30% of live crown length broken or dead
		3	30 - 60% of live crown length broken or dead
		4	>= 61% of live crown length broken or dead
Treatment Unit (TU)	Site class; based on soil and vegetation	BB 1	Very Dry, Very Poor, Pine – Softwood
		BB 2	Dry, Poor, Softwood
		BB 3	Moist, Poor, Softwood
		BB 4	Wet, Poor, Softwood
		BB 5	Very Dry, Moderately Poor, Softwood
		BB 6	Dry, Moderately Poor, Softwood
		BB 7	Moist, Moderately Poor, Softwood
		BB 8	Dry, Moderately Rich, IH - Mixedwood
		BB 9	Dry -> Moist, Moderately Rich, IH - Mixedwood
		BB 10	Wet, Moderately Rich, IH - Mixedwood
		BB 11	Dry -> Moist, Very Rich, TH - Mixedwood

Field Name	Description	Code	Code Description
		BB 12	Very Dry, Rich, TH - Mixedwood
		CT 1	Dry, Very Poor, Pine - Softwood
		CT 2	Moist, Poor, Softwood
		CT 3	Wet, Poor, Softwood
		CT 4	Wet, Moderately Rich, Cedar - Softwood
		CT 5	Dry -> Moist, Moderately Poor, Softwood
		CT 6	Very Dry, Moderately Poor, Pine - Softwood
		CT 7	Moist, Moderately Rich, IH - Mixedwood
		CT 8	Dry, Moderately Rich, IH - Mixedwood
		CT 9	Moist, Very Rich, TH - Mixedwood
		CT 10	Dry, Rich, TH - Mixedwood
		FU 1	Very Dry, Poor, Softwood
		FU 2	Dry, Poor, Softwood
		FU 3	Moist, Moderately Poor, Softwood
		FU 4	Very Wet, Very Poor, Softwood
		FU 5	Wet, Moderately Poor, Softwood
		FU 6	Moist, Rich, Softwood
		FU 7	Moist, Moderately Rich, IH - Softwood
		FU 8	Wet, Moderately Poor, Softwood
		FU 9	Dry, Moderately Rich, IH - Mixedwood
		FU 10	Dry -> Moist, Rich, Hardwood
		HH 1	Very Dry, Very Poor, Pine - Softwood
		HH 2	Dry -> Moist, Poor, Pine - Softwood
		HH 3	Wet, Poor, Softwood
		HH 4	Very Wet, Very Poor, Softwood
		HH 5	Very Dry, Moderately Poor, IH - Mixedwood
		HH 6	Dry, Moderately Poor, IH - Mixedwood
		HH 7	Moist, Moderately Poor, IH - Mixedwood
		HH 8	Wet, Moderately Rich IH - Mixedwood
		HH 9	Moist, Rich, Cedar - Softwood
		HH 10	Moist, Rich, IH - Mixedwood
		HH 11	Moist, Very Rich, IH - Mixedwood
		HH 12	Dry, Rich, IH - Mixedwood
		HH 13	Moist, Rich, Hardwood
		HH 14	Dry, Rich, Hardwood
		HH 15	Dry, Moderately Rich, Hardwood
		KE 1	Dry, Poor, Softwood
		KE 2	Dry, Moderately Poor, Softwood
		KE 3	Moist, Moderately Poor, Softwood
		KE 4	Wet, Moderately Poor, Softwood
		KE 5	Wet, Rich, Softwood
		KE 6	Moist, Rich, IH - Mixedwood
		KE 7	Dry, Moderately Rich, IH - Mixedwood
		KE 8	Dry, Rich, IH - Mixedwood
		NT 1	Very Dry, Very Poor -> Poor, Softwood
		NT 2	Dry, Poor, Softwood
		NT 3	Dry -> Moist, Moderately Poor, Softwood
		NT 4	Wet, Very Poor, Softwood
		NT 5	Very Wet, Poor, Softwood
		NT 6	Moist -> Wet, Moderately Poor, Softwood
		NT 7	Moist, Very Rich, Cedar - Softwood
		NT 8	Moist, Very Rich, TH - Mixedwood
		NT 9	Dry, Moderately Rich, IH - Mixedwood
		NT 10	Very Dry, Moderately Rich, IH - Mixedwood
		NT 11	Dry, Rich, Hardwood
		NT 12	Very Dry, Rich, Hardwood
		RE 1	Very Dry, Poor, Softwood
		RE 2	Very Dry, Moderately Poor, Softwood
		RE 3	Dry -> Moist, Moderately Poor, IH - Mixedwood
		RE 4	Wet, Moderately Poor, Softwood
		RE 5	Wet, Rich, Cedar - Softwood
		RE 6	Moist, Rich, Softwood
		RE 7	Dry, Moderately Rich, TH - Mixedwood
		RE 8	Dry, Rich, Softwood
		RE 9	Dry, Rich, TH - Mixedwood
		RE 10	Moist, Very Rich, TH - Mixedwood
		RE 11	Dry-> Moist, Rich, Hardwood
		RE 12	Very Dry, Moderately Rich, Hardwood
		SE 1	Very Dry, Very Poor, Pine - Softwood
		SE 2	Dry, Poor, Softwood

Field Name	Description	Code	Code Description
		SE 3	Moist, Very Poor, Pine - Softwood
		SE 4	Very Wet, Poor, Softwood
		SE 5	Wet, Poor, Softwood
		SE 6	Dry, Moderately Poor, Softwood
		SE 7	Moist, Moderately Rich, Softwood
		SE 8	Wet, Moderately Rich, Softwood
		SE 9	Very Wet, Moderately Rich, Cedar - Softwood
		SE 10	Wet, Very Rich, TH - Mixedwood
		SE 11	Dry, Rich, Hardwood
		UP 1	Dry, Very Poor, Pine - Softwood
		UP 2	Dry, Poor, Pine - Softwood
		UP 3	Dry, Poor, IH – Mixedwood
		UP 4	Dry, Moderately Poor, IH - Mixedwood
		UP 5	Dry -> Moist, Moderately Rich, IH - Mixedwood
		UP 6	Moist, Poor, Softwood
		UP 7	Wet, Moderately Rich, Cedar - Softwood
		UP 8	Moist, Rich, Cedar - Softwood
		UP 9	Dry -> Moist, Rich, Softwood
		UP 10	Dry, Moderately Rich, Softwood
		UP 11	Dry, Very Rich, TH - Mixedwood
		UP 12	Dry, Rich, TH – Mixedwood
type	Wound type	Blank	No wound present
		1	Frost crack type (deep and narrow)
		2	Broad wound
		3	Nail crack

Appendix IV
Data Validation Checks

The following tables describe valid codes for each variable used in PSPDB. Data codes are included for the seven primary data tables in PSPDB: *PLOTS*, *PLOTS_YR, YIMO – tree, REGEN – tree, THIN – tree, PLANT – tree, and CUT – tree.*

Valid codes for the *PLOTS* data table

Field Name	Valid Data
License	1-20, 31, 33-39, 88
Plot	numeric, >0
Mapno	numeric, [1]0, >0
Stand	numeric, [1]0, >0
Region	1-5
FunaInterp	Cuts, Regens, and thins: (SW), (IH), (TH), Plants:(BS), (WS), (JP), YIMOs: SPBF, BFSP, PINE, PSSP, OTSW, SPTH, SPIH, BFTH, BFIH, THSP, IHSP, IHBF, IHBF, TOHW, THIH, INHW, IHTH
P1DS	blank, R, Y, I, M, O, C, B, F
Estab Age	numeric, >0
Density Class	L, M, H
Site Region (SR)	See LookUp_sr table in Appendix III
Treatment Unit (TU)	See LookUp_tu table in Appendix III
Prod	No checking done
Soil	See LookUp_soil table in Appendix III
Drainage	See LookUp_drainage table in Appendix III
Eco Region	numeric, 1-7
Eco Section	numeric, 1-10, Eco District/Eco Section combination must exist in the Eco District/ Section lookup table in PSPDB
Eco Site (1)	numeric, 1-9
(2)	m, s, h, c, l, b, t, blank (lower case)
Silv-ID	numeric
	Plants and Thins: [1]0, [1] blank
Plot Type	C, P, R, T, M
Photo(1)	N, F
(2,3)	numeric, 81-85 or >= 93
(4-6)	numeric, 500-599
(7-9)	numeric, >= 1
Plotsize/Size	Cuts: numeric, <= 100 and > 0 Plants: 196 or 200 Regens: 50, 60, 80, 100, or 125 Thins or YIMOs: 400
Measurement Day	numeric, 1-31, 99
Measurement Month	numeric, 1-12, 99
Measurement Year	numeric, >=85
Year-Treated	numeric, >=78, 0

Valid codes for the *PLOTS_YR* data table

Field Name	Valid Data
Plot	numeric, >0
Year	numeric, >=85
meas#	>0
Agency	DNR, LIC, MKB, L&D
Remeasurement Year	numeric, >Year or 0, NN
Funa	Dev Stage = P: (JP), (WS), (BS) Other Dev Stages: SPBF, BFSP, PINE, PSSP, SPIH OTSW, SPTH, , BFTH, BFIH, THBF, IHBF, THSP, IHSP, TOHW, THIH, INHW, IHTH,
Dev Stage	blank, R, Y, I, M, O, C, P, T

Valid codes for the *PLANT* – tree (plantation) and *CUT* – tree (cutover) data tables

Field Name	Valid Data
Plot	numeric, >0
Treenum	numeric, [1]blank, >=0
meas#	>0
Species	numeric, [1]blank, valid species code from list of plant species table
Origin	Plants: 1-5 Cuts: 2-5
Row	Plants: 1-7 Cuts: 1-9
Yaxis	Plants: 0 - 140, increments of 10 Cuts: 0-995, increments of 5
Xaxis	Plants: 0-20 Cuts: 0-95, increments of 5
Dbh	numeric, 0, >=3.1cm
Hgt	numeric, >=0
h1	numeric, >=0
h2	numeric, >=0
Cw	numeric, >=0
Blc	numeric, >=0
Microsite	Origin=1: 1-3 Origin [1]1: blank, 0
Microtop	Origin=1: L, T, B, M Origin [1]1: blank
Survival	Y, N, M
Buds	blank, I,D,M,A,P,S,H,O,U
Curleader	blank, I,D,M,A,P,S,H,O,U
Lateral	blank, I,D,M,A,P,S,H,O,U
Foliage	blank, I,D,M,A,P,S,H,O,U
Stem	blank, I,D,M,A,P,S,H,O,U
Roots	blank, I,D,M,A,P,S,H,O,U
sp1-sp4	numeric, >=0
hgt1-hgt4	numeric, >=0

Valid codes for the *YIMO – tree* data table

Field Name	Valid Data
Plot	numeric, >0
Treenum	numeric, [1]blank dbh >= 9.1 cm:-1
meas#	[1]blank, >0
Cause	numeric, blank
Dbh	numeric, [1]blank, >5.1cm treenum = -1: >9.1cm Estab Year = 1987: >=1.0cm
Agecl	Commercial species and dbh >9,1 cm: Y, I, M, O, R non-commercial species or dbh <9.1cm: blank
Cr	treenum = -1: no checking dbh < 91 and cause=0 (alive): numeric, 0, blank dbh >= 91 and cause= 0 (dead): numeric, [1] 0, [1] blank cause[1] 0: 0, blank
Top	treenum = -1: no checking blank, 1-4
Type	treenum = -1: no checking blank, 1-3
Depth	treenum = -1: no checking blank, 1-3
Dim	treenum = -1: no checking blank, 1-5
Ltbh	treenum = -1: no checking blank, 1
conks	treenum = -1: no checking blank, P
lean	treenum = -1: no checking blank, 1-4
leaderdam	treenum = -1: no checking blank, 1-3
curpct	treenum = -1: no checking blank, 1-5 blank
cumpct	treenum = -1: no checking species is 1-5 (spruce or fir): blank, 1-5 blank
thincr	treenum = -1: no checking species <12 (softwood): blank species >=12 (hardwood): blank, P
Lat	treenum = -1: no checking species <12 (softwood): blank species >=12 (hardwood): blank, P
Hgt	dbh<91 or non-comercial hardwood : -1> 0
Vol	dbh<91 or non-comercial hardwood : -1 > 0

Valid codes for the REGEN – tree (regeneration) and THIN – tree (thinning) data tables

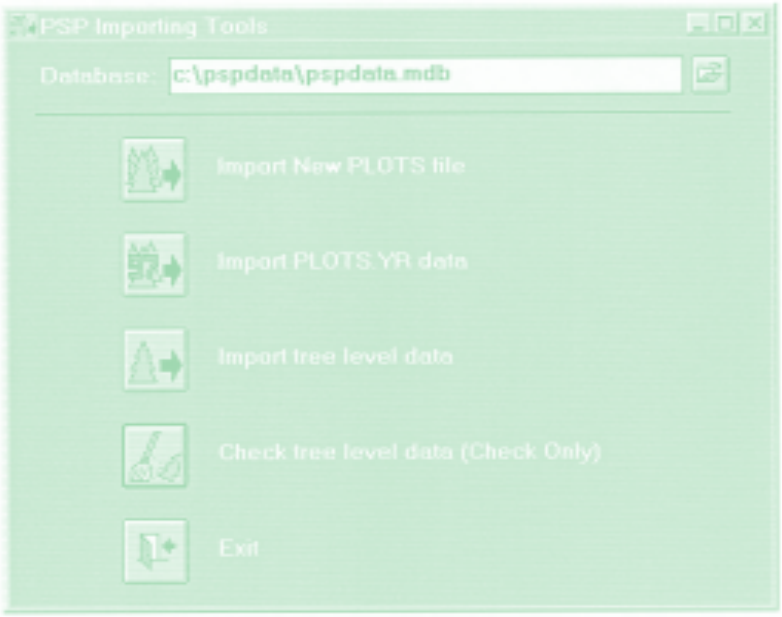
Field Name	Valid Data
Plot	numeric, >0
Treenum	numeric, [1]blank, >=0
Meas#	numeric, >0
Species	numeric, [1]blank, valid species code from list of plant species table
Origin	Thins: 1-5 Regens: 2-5
Quarter	1-4
blc	species>11 (hardwoods): 0 species <12 (softwoods): numeric, >0
dbh	numeric, [1]blank, 0 or >3.1cm
ht	numeric, 0, >=1
swh1	numeric, >=0, blank
swh2	numeric, >=0, blank
top	blank, 1-4
type	blank, 1-3
depth	blank, 1-3
dim	blank, 1-5
ltbh	blank, 1
browse	blank, 1-4
lean	blank, 1-4
leadrdam	blank, 1-3
curpct	species = 1-5 (spruce or fir : blank, 1-5 species >5: blank
cumpct	species = 1-5 (spruce or fir): blank, 1-5 species >5: blank

Appendix V
The PSPDB Import Program

The NB Department of Natural Resources and Energy will continually update the database with new measurement data and periodically provide up-to-date versions. This Appendix describes how the measurement data are loaded into PSPDB.

New data from plot remeasurements are added to the PSPDB using an external program called **Import** (`import.exe`). This software can be obtained from NBDNRE if users wish to load cooperative PSP data themselves. It uses the `pspdata.mdb` file containing all of the PSPDB data and encapsulates the validation rules from the procedure manuals (Dunlap 1989), as described in Appendix IV, to ensure that all data in PSPDB meet these criteria. Only valid data are added to the database. Below is a description of how to use the **Import** program.

Data are typically added to PSPDB on an annual basis. Several plots are remeasured in any given year and the recorded data are validated and added to the database. Theoretically, as more periodic measurements are done on a plot over time, the data become more representative as indicators of forest condition and development. **Import** also allows records in the database to be replaced with corrected data on a plot and measurement year basis.



A

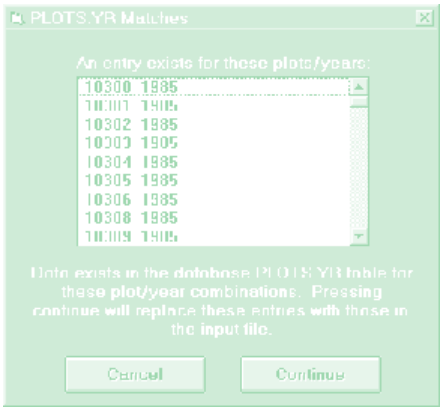
The following steps summarize the use of Import (the order of the steps is important):

1. **Select the appropriate database.**
   Click on the database buttor to select the `pspdata.mdb` file containing the data portion of the PSPDB system. Use the subsequent dialog box to locate the file. **Import** verifies that the file selected is a valid Access database and contains the necessary PSPDB data tables.

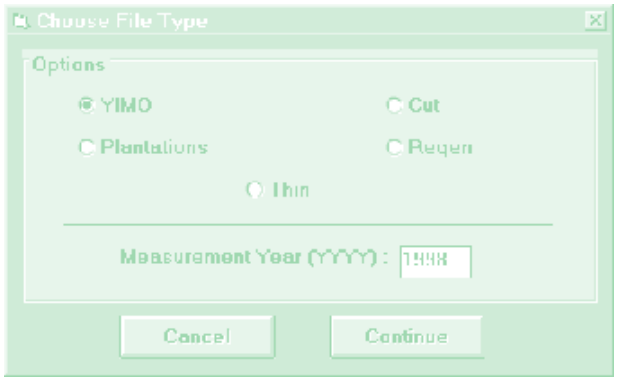
2. **Import plot establishment data.**
   When a plot is established, several attributes are recorded that do not change over time. These data are loaded into the *PLOTS* table (Section 3.2) using the button labeled *Import PLOTS data* . This is used initially to build *PLOTS* or, in the case of making corrections, to replace the contents of *PLOTS* with a new version. PLOTS cannot be updated on a record-by-record basis; rather, its contents are completely

replaced if any corrections are necessary. Validation checking is performed before any of the data can be included in PSPDB (Applendix IV). Before replacing the table, a dialog box is displayed to remind the user that *the table being imported is replacing the PLOTS table*. A *PLOTS* record must exist in PSPDB before *PLOTS_YR* or tree data can be imported.

3. **Import periodic plot-level data.**
Each time the trees in a plot are measured, a set of plot-specific attributes are recorded and stored in the *PLOTS_YR* table in PSPDB (Section 3.2). These periodic data are loaded into the system using the button labeled *Import PLOTS_YR data* . Validation checking is performed before the data can be included in PSPDB (Appendix IV). **Import** also checks to see if a *PLOTS_YR* record already exists for each Plot and Year combination in the file being imported. If any are found, they are displayed in a dialog box (see B below) prompting the user to either approve their replacement or cancel the import. A *PLOTS_YR* record for the measurement must exist in PSPDB before tree data for the measurement can be entered. Therefore, in a typical data import session, the user has an import file of *PLOTS_YR* data containing a record for each plot for which tree data will be entered.



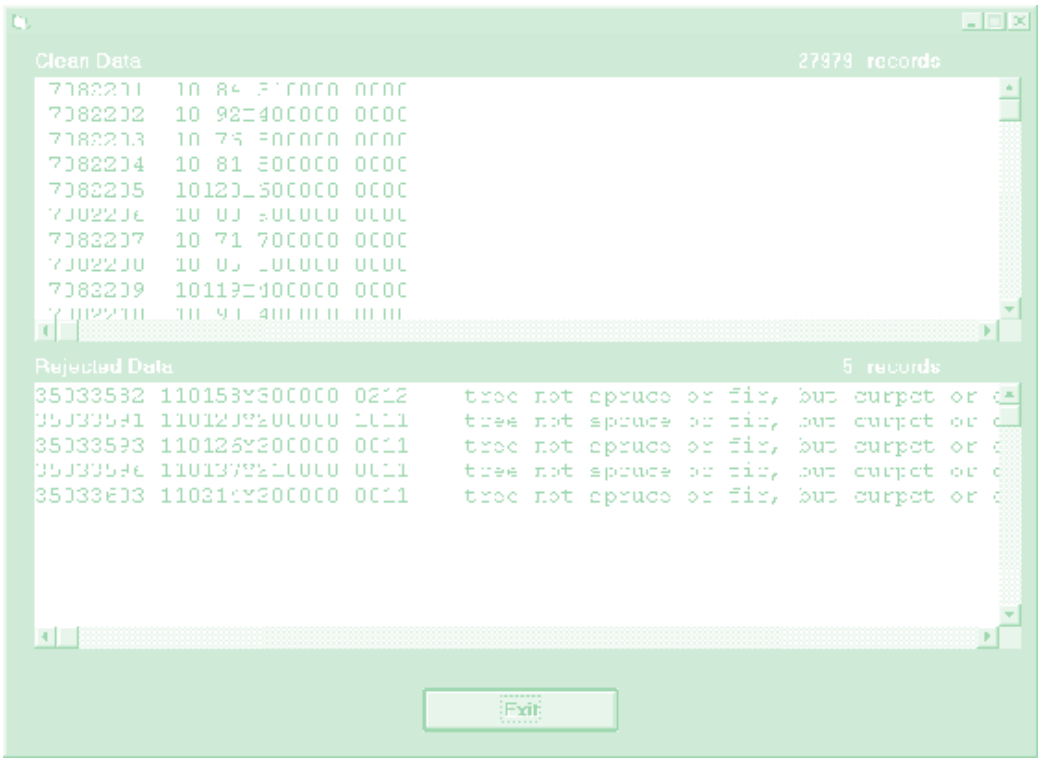
B



C

4. **Validate the tree data for each plot type.**
As the field measurement and recording of tree data are prone to errors, extensive validation checking is performed before any data can be included in PSPDB (Appendix IV). Step 5 below runs these checks automatically to prevent entry of invalid data, and the button labeled *Check tree data (check only)* gives the user the option of running these checks without the validated data being added to the system. The dialog box above (C) prompts the user to select the plot type and year being imported. Tree data must be organized into separate import files by plot type and year. For example, after data are collected for 1998, the user would create one import file for plantation plots measured, one for thinning plots measured, and so on (*e.g.*, `plant98.dat, thin98.dat, yimo98.dat, regen98.dat, cut98.dat`).

The output from performing this step on an import file is a `clean.dat` file containing all records that passed the checks, and a `reject.dat` file listing all records that failed the checks, along with a message for each one indicating the first check that it failed (see D on next page). Once the checking is complete, **Import** displays the `clean.dat` and `reject.dat` files as scrollable lists, allowing the user to easily view them before proceeding. If there is more than one problem with a particular import record, only the first will be detected. Any remaining problems will be detected after the first is fixed and the record is re-checked.



D

5. **Import tree data.**
The button labeled *Import tree data* is used to load tree data records into PSPDB and automatically perform step 4 above. If all import records in the file pass the checks, they are added to the database. If records are rejected, a message informs the user that none of the records in the import file were added, and the clean and rejected data are displayed as in step 4. The user should correct the problems and re-check the (corrected) import file. Importing less than the full complement of records for a plot measurement would result in incomplete and misleading data in the database and should be avoided. In other words, do not import any records for a plot and measurement until all records for it pass the validation checks.

Appendix VI
Formulae Used in Report and Chart Calculations

Tree-level measures:

Average dbh (cm):

$$ave\_dbh = \frac{\sum_i dbh}{\frac{n}{10}}$$, where

i represents the set of selected trees
n is the quantity of trees selected
Note: dbh is in millimeters

Tree volume (m^3):

tree_vol = [see Appendix II]
Note: uses species-specific equations based on dbh and height

Total tree volume (m^3):

$$\sum_i tree\_vol$$, where **i** represents the set of selected trees

Average tree volume (m^3):

$$\frac{\sum_i tree\_vol}{n}$$, where

i represents the set of selected trees
n is the quantity of trees selected

Tree growth (m^3):

$$tree\_growth_t = tree\_vol_t - tree\_vol_{t-1}$$, where

t is a particular measurement
t-1 is the previous measurement

Average height (m):

$$\frac{\sum_i hgt}{n}$$, where

i represents the set of selected trees
n is the quantity of trees selected

Stand-level measures:

Stand density (trees/ha):

$$density = \frac{n}{plotsize}$$

n is the quantity of trees selected
plotsize is the size of the plot in hectares

Average stand density (trees/ha):

$$ave\_density = \frac{\sum_k density}{m}$$, where

k represents the set of selected plots
m is the quantity of plots selected
Note: this formula gives equal weight to each selected plot

Average stand volume (m^3/ha):

$$vph = \frac{\sum_k \frac{\sum_i tree\_vol}{plotsize}}{m}$$, where

k represents the set of selected plots
m is the quantity of plots selected
i represents the set of selected trees in each plot
plotsize is the size of the plot in hectares
Note: this formula gives equal weight to each selected plot even if the plot sizes differ

Stand age at a particular measurement (years):

$$stand\_age = stand\_age_0 + year_t - year_0$$, where

t is a particular measurement
0 is the establishment measurement
year is the calendar year for a measurement
stand_age$_0$ is based on the age of the predominant species at the time of plot establishment and is determined through destructive sampling near the plot

Average periodic survivor growth (m^3/ha):

$$psgrowth_t = \frac{\sum_k \frac{\sum_i tree\_growth}{plotsize}}{m}$$

t is a particular measurement
k represents the set of selected plots
m is the quantity of plots selected
i represents all living selected trees in measurement year t within a plot
plotsize is the size of the plot in hectares

Average periodic mortality (m^3/ha):

$$mortpha_t = \frac{\sum_k \frac{\sum_j tree\_vol_{t-1}}{plotsize}}{m}$$

t is a particular measurement
t-1 is the previous measurement
k represents the set of selected plots
m is the quantity of plots selected
j represents all newly dead selected trees at time t that were alive at time t-1
plotsize is the size of the plot in hectares

Average periodic annual increment (m^3/ha/year):

$$pai_t = \frac{\sum_k \frac{\sum_i tree\_growth_t - \sum_j tree\_vol_{t-1} + \sum_l tree\_vol_t}{period}}{\frac{plotsize}{m}}$$

t is a particular measurement
t-1 is the previous measurement
i represents all living selected trees in measurement year t, within a plot
j represents all newly dead selected trees at time t that were alive at time t-1
l represents all new trees in the plot (ingrowth). These are trees that were not included in the plot until the most recent measurement, because they were not large enough
k represents the set of selected plots
m is the quantity of plots selected
period is the number of years between measurements for the plot
plotsize is the size of the plot in hectares

Average mean annual increment (m^3/ha/year):

$$mai = \frac{\sum_k \frac{\frac{\sum_i tree\_vol}{stand\_age}}{plotsize}}{m}$$

k represents the set of selected plots
m is the quantity of plots selected
i represents the set of selected trees within a plot
plotsize is the size of the plot in hectares

Average basal area (m^2/ha):

$$ba = \frac{\sum_k \frac{\sum_i \pi \left(\frac{dbh/2}{1000}\right)^2}{plotsize}}{m}$$

i represents all selected trees within a plot
k represents the set of selected plots
m is the quantity of plots selected
plotsize is the size of the plot in hectares
Note: this is calculated for a group of trees; usually a plot or set of plots. This formula gives equal weight to each selected plot even if the plot sizes are different. General formula for basal area of a tree is Br^2 with r=dbh/2.

Average current and average cumulative defoliation (%):

1. Convert the defoliation class to class midpoint (%) for each tree.
2. G defol% / no_of_trees

Average crown ratio (%):

1. Convert CR class into class midpoint (%) for each tree.
2. G cr% / no_of_trees