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2001 Workshop Proceedings
Forest Measurements for Natural Resource Professionals

Caroline A. Fox Research
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Hillsborough, NH

Sampling & Management of Coarse Woody Debris- October 12
Getting the Most from Your Cruise- October 19
Cruising Hardware & Software for Foresters- November 9

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The Caroline A. Fox Research and Demonstration Forest (Fox Forest) is in Hillsborough, NH. Its focus is applied practical research, demonstration forests, and education and outreach for a variety of audiences.

A Workshop Series on Forest Measurements for Natural Resource Professionals was held in the fall of 2001. These proceedings were prepared as a supplement to the workshop. Papers submitted were not peer-reviewed or edited. They were compiled by Karen P. Bennett, Extension Specialist in Forest Resources and Ken Desmarais, Forester with the NH Division of Forests and Lands. Readers who did not attend the workshop are encouraged to contact authors directly for clarifications. Workshop attendees received additional supplemental materials.

Sampling and Management for Down Coarse Woody Debris in New England: A Workshop- October 12, 2001

The What and Why of CWD– *Mark Ducey,* Assistant Professor, UNH Department of Natural Resources
New Hampshire's Logging Efficiency– *Ken Desmarais,* Forester/ Researcher, Fox State Forest
The Regional Level: Characteristics of DDW in Maine, NH and VT– *Linda Heath,* Research Forester, USDA Forest Service, Northeastern Research Station, Durham, NH
The Effects of Management on CWD for Wildlife Habitat– *Mariko Yamasaki,* Research Wildlife Biologist, USDA Forest Service, Northeastern Research Station, Durham, NH
How Do Silvicultural Methods Affect Amounts of CWD?– *Bill Leak,* Research Forester, USDA Forest Service, Northeastern Research Station, Durham, NH
Methods for Sampling CWD: LIS– *Mark Ducey,* Assistant Professor, UNH
Methods for Sampling CWD: The Relascope Connection– *Jeff Gove,* Research Forester, USDA Forest Service, Northeastern Research Station, Durham, NH

Getting the Most From Your Cruise- October 19, 2001

Pre-Cruise Planning– *Mark Ducey,* Assistant Professor, UNH
Field Techniques– *John Bozak,* Professor, UNH Thompson School
What Do Your Results Mean?– *Ken Desmarais*, Forester/ Researcher, Fox State Forest
Writing an Integrated Prescription From Your Cruise Results– *Bill Leak,* Research Forester, *& Mariko Yamasaki*, Research Wildlife Biologist, USDA Forest Service, Northeastern Research Station, Durham, NH

Cruising Hardware and Software for Foresters- November 9, 2001

Forestry Tools- *Steve Bick*, Northeast Forests, LLC. Thendara, NY
Multicruise- *Tom Hahn*, FORECO
Flex-Fiber- *Tom Brann*, University of Maine University of Maine
Informal Use of Field Data Loggers- *Jeff Underhill*, Foresters Inc., Blacksburg, VA
Two-Dogs- *Jeff Underhill*, Foresters Inc., Blacksburg, VA
NED- *Mark Twery*, USDA-Forest Service, Northeastern Research Station, Burlington, VT
The Biotimber Inventory- *Andrea Alderman*, Society for the Protection of NH Forests

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The What and Why of Coarse Woody Material

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Introduction

The need to maintain or enhance downed coarse woody material, or CWM, has become something of a "hot topic" in forestry lately. In part, this is because of the many roles CWM can play in forest ecosystems (Hagan and Grove 1999); in part, it is because of perceptions - right or wrong - that our managed woodlands don't have enough CWM. As foresters, we should be ahead of the curve on this issue, so we can make intelligent, informed decisions about our management strategies.

CWM is like an outlaw on a wanted poster from the wild, wild, west: it has many aliases. Much of the literature on CWM refers to it as coarse woody debris or CWD. That name is starting to fall by the wayside, because it carries an implied value judgement that CWM is "just" debris. A more descriptive name, dead and downed wood or DDW, never quite seemed to catch on. Perhaps this is because a downed log actually contains and supports a lot of life, or maybe the name just wasn't catchy enough. No matter what you call it, we all know what this CWM looks like in the woods: it's dead wood (plus associated life forms), down on the ground, and large enough to stick around for a while.

This paper is designed to give a quick overview of CWM in preparation for the other papers from the workshop. We'll take a quick look at the roles - positive and negative - of CWM in managed forests. We'll see what public perception and sustainability certification have to say about CWM. Then, we'll explore how CWM quantity and quality are usually described, to demystify the jargon that sometimes surrounds CWM issues.

Roles of CWM in Managed Forests

CWM plays several important ecological roles in managed forests. Whether you view those roles as positive or negative depends on your management objectives. Some of those roles are ones that most of us would find positive on most of the land we deal with. But some of those roles can be negative, and we don't want to approach CWM management with rose-colored glasses. Some points to consider:

1. Much of the material we call CWM is the same stuff fire ecologists call "fuel." That's important to remember, though with the fire regimes most of us face in New England, it's not the fuel we are most concerned with, even in fire suppression mode. (By the time 100-hour fuels really matter, you have other problems to deal with.)
2. From a whole-ecosystem perspective, CWM can be an important player in carbon storage and nutrient cycling (Harmon *et al.* 1986). Carbon storage in CWM can be a significant fraction of aboveground ecosystem carbon, and links to cycling of nitrogen and phosphorus have been

shown in many forest types (Harmon *et al.* 1986, Berg and McClaugherty 1989). However, given the relatively small fraction of total stand nutrient use that is actually stored in woody material over a single rotation, it is not likely that changes in management of CWM would manifest themselves in obvious differences in site quality until many rotations had gone by, even on the poorest sites.

3. In some forest types, CWM provides a seedbed for regeneration of commercial tree species -- something nearly every forester cares about. The link to commercial tree species has been established most clearly in the Pacific Northwest (Harmon and Franklin 1989) and the Lake States (Corinth 1995). Although an ecological rationale for the importance of CWM as a seedbed can be established, especially where growing-season moisture is a serious limitation to regeneration, it is unclear whether that importance is practically significant in the climate and forest types of New England (Ducey and Gove 2000). But there is still a lot to learn. It also is plausible, but remains to be demonstrated in New England, that CWM provides important habitat for rare plants and fungi as shown in Scandinavia.

4. CWM is an important habitat feature for many wildlife species. For example, over 30% of the mammal species and nearly 50% of the amphibians and reptiles occurring in northern New England use CWM at some point in their life cycle (DeGraaf *et al.* 1992). Rodents and their fur-bearing predators use CWM to provide access under the snow during winter months. Many bird species, including game species such as ruffed grouse as well as several ground-nesting songbird species, use CWM for different purposes. It's worth emphasizing that we don't know of any vertebrate species that is absolutely dependent on CWM, or that is endangered or threatened by loss of CWM in New England forests. But there are a lot of species that can and do benefit from enhanced CWM quality.

There's another reason to be concerned over CWM, and depending on your perspective it may be even more compelling. There are influential voices in the natural resource community that *want* us to be more concerned over CWM. For example, the draft Forest Stewardship Council certification guidelines (FSC 1999) for the Northeast read, in part,

6.3.c.1. Biological legacies of the forest community -- including, but not limited to, coarse dead wood, logs, and snags; trees that are large, living, and old; soil organic matter -- are retained to aid in post-harvest recovery and to retain forest complexity.

Whether or not you intend to pursue certification, it's important to realize that the perception of sustainability includes attention to these non-timber attributes of our forests. If we foresters really are good managers of timber and the whole ecosystem, it behooves us to be aware of features like CWM that are tied to ecosystem structure and function. We may not always rank CWM as an important management objective, or we may try aggressively to improve CWM in some stands, or we may knowingly reduce it significantly in others. Those decisions may be perfectly sound depending on landowner objectives and the ecological context, but they should be informed and intentional, not uninformed and accidental.

What is Good CWM?

CWM is like sawtimber; there are quality considerations. When you think about the multiple roles for CWM outlined above, it should also be clear that good CWM for one purpose is not necessarily good CWM for another. Just like sawtimber, an important consideration is size. When we scale sawtimber logs, we measure diameter at the small end because the small end limits the mill's ability to get boards out. But from the perspective of, say, a gray fox looking for a den site, it doesn't matter much whether the small end of that log broke off at 10", or 4", or even if the twigs are still attached to the top. What matters is the size at the large end: is this log big enough to den in, or not? So we often view the large end as the "scaling diameter" for downed CWM.

When we are looking at CWM for carbon or nutrient content, however, we're really looking at things that are closely related to cubic volume. Diameter is important, but we are likely to want both the small and large end, or some other diameter closer to the midpoint. We also want to know length. Diameter is not just important for the carbon or nutrient content, but its fate: per unit volume, large logs decay more slowly than small logs.

Speaking of decay, it should be clear that a fresh log is good for some things (like containing maximum amounts of carbon) but bad for others (like serving as seedbed). There are many systems in place for describing tree decay, but most use a simplified set of subjective structural decay classes. One that has been developed for the Northeast by Pyle and Brown (1998), in somewhat simplified form, includes the following characteristics:

Class I: Fresh logs with bark still intact, fresh-colored firm wood, surface of the log covered primarily by bark, intact structure, and twigs often present.
Class II: Bark is loose if present, wood is firm but discolored, surface of the log is primarily hardened wood, and structure is generally intact.
Class III: Bark is absent for most species (except paper birch), wood has become partly spongy with a soft, flaky surface, and the structure is firm but may sag.
Class IV: Bark is absent, wood is spongy with a spongy or powdery surface. The structure is weak and the log cleaves or crushes easily.
Class V: Bark is absent, and the wood has become a structureless powder.

These classes are subjective, and there are intermediate logs. Many logs seem to be partly in one class and partly in another. Nonetheless, they do give some indication of the character of the CWM in a stand.

Finally, it's important to know whether a downed log is hollow or sound. Hollowness is critical for many wildlife uses, but it rarely develops after a log has fallen. Most hollow logs started as hollow trees; that's one reason good quality CWM management has to start with good quality snag management.

Conclusions

The other papers from this workshop go into greater depth about the ecology, management, and measurement of CWM. Our goal in this workshop isn't to advocate one particular management strategy or another. As a practicing forester, developing a management strategy is *your* job, and what constitutes a good strategy should vary from ownership to ownership. But if you read through the other papers, you'll have a pretty good handle on the state of scientific knowledge about CWM in the Northeast. I hope you'll enjoy learning about this ecologically complicated "dead stuff" - it's not the debris we used to think it was. And, as you'll see, managing it doesn't have to be expensive. It's an area where many foresters already have strong positive impacts on the woods they manage, and where a little thought and effort go a long way.

References

Berg, B. and C. McClaugherty. 1989. Nitrogen and phosphorus release from decomposing litter in relation to the disappearance of lignin. *Canadian Journal of Botany* 67: 1148-1156.

Corinth, R.L. 1995. Coarse woody debris and regeneration of eastern hemlock. *In* Hemlock Ecology and Management, Mroz, G.; Martin, J., eds. Madison, WI: Department of Forestry, University of Wisconsin – Madison: 73-90.

DeGraaf, R.M., M. Yamasaki, W.B. Leak, and J.W. Lanier. 1992. New England wildlife: management of forested habitats. U.S.D.A. Forest Service, Northeastern For. Exp. Sta., Gen. Tech. Rpt. NE-144.

Ducey, M. J. and J. H. Gove. 2000. Downed wood as seedbed: measurement and management guidelines. pp. 34-42 *in* K.A. McManus, K.S. Shields, and D. Souto, eds. Proc. Symposium on Sustainable Management of Hemlock Ecosystems in Eastern North America, Durham, New Hampshire, June 22-24, 1999. U.S.D.A. Forest Service, Northeast Research Station, General Technical Report GTR-NE-267.

FSC (Forest Stewardship Council) 1999. Northeast working group draft standards. http://www.fscus.org/standards_policies/us_regional_standards/north_east1.html.

Hagan, J.M. and S.L. Grove. 1999. Coarse woody debris. *Journal of Forestry* 97(1): 6-11.

Harmon, M.E. and J.F. Franklin. 1989. Tree seedlings on logs in *Picea-Tsuga* forests of Oregon and Washington. *Ecology* 70: 48-59.

Harmon, M.E., J.F. Franklin, F.J. Swanson, P. Sollins, S.V. Gregory, J.D. Lattin, N.H. Anderson, S.P. Cline, N.G. Aumen, J.R. Sedell, G.W. Lienkamper, K. Cromack Jr., and K.W. Cummings. 1986. Ecology of coarse woody debris in temperate ecosystems. *Advances in Ecological Research* 15: 133-302.

Pyle, C., and Brown, M.M. 1998. A rapid system of decay classification for hardwood logs of the eastern deciduous forest floor. *J. Torrey Bot. Soc.* 125: 237-245.

**Down Dead Wood in Maine, New Hampshire, and Vermont:
Regional Characteristics (1993-1995)**

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The purpose of my presentation was to present estimates of down dead wood in Maine, New Hampshire, and Vermont, to give an idea of the magnitude of down dead wood that may be found in these forests. I describe the methods of the study, discuss some things that should be considered before going into the field, along with a few observations about the results. This study was conducted by the USDA Forest Service, Northern Global Change Program in conjunction with the USDA Forest Service, Forest Inventory & Analysis (FIA) survey of forests of the three States. Field data were collected in Maine during the years 1994-1996; New Hampshire and Vermont were surveyed during the years 1996-1998. FIA samples plots in all forest owner groups, including private landowners. See Griffith and Alerich (1996), Frieswyk and Widmann (2000a), and Frieswyk and Widmann (2000b) for statistics of other forest attributes measured in the surveys. The main purpose of the study was to obtain estimates of carbon in dead wood in forests; however, volume, number of pieces, and biomass can be calculated from the same data.

Methods

The line intersect method (Warren and Olson 1964) was used to sample down dead wood. The design used by FIA utilizes two phases, with the first phase stratifying land area by land use and timber volume class using points on aerial photographs, and the second phase consisting of field measurement of ground plots located at a subset of the photo points. In NH and VT, the ground plots consisted of four circular subplots of 24-foot radius. Two line transects of 24 foot length, emanating from plot center, were superimposed on each of the subplots of the existing forest inventory sampling design. In ME, each plot location featured one circular fixed radius plot, with two transects of length 52.7 feet emanating from plot center.

Down dead wood was tallied if it was intersected by the line transect plane, was at least 3 inches in diameter, 3 feet long, and in decay class 1, 2, or 3 at the point of intersection. If the piece was crossed twice by the transect, it was tallied twice (Figure 1). If the piece is a branch of the main bole, only the branch was measured (Figure 1). I used decay class as an indication of the biomass density of the piece. In the western U.S., a system of 5 decay classes is often used. In the eastern U.S., several systems of decay have been proposed. I adopted a system of 4 classes of decay, where the 4^{th} class described a piece that was very decomposed: with no branch stubs, little bark, and little structural integrity. Pieces of decay class 4 were not sampled. Another feature to consider about dead wood is that down dead wood is occasionally found stacked systematically, such as in residue piles from harvesting operations and windrows, or in beaverdams. Piles were determined to have one of four shapes, and measurements were taken depending on the shape. For more details of the methods, see Heath and Chojacky (2000).

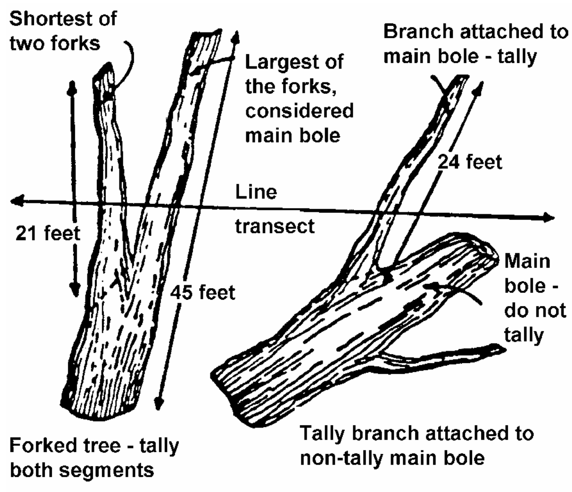

Figure 1. Illustrations of some measurement rules for pieces of down dead wood.

Results

There are about 3,985 forested FIA plots in the three States. Table 1 shows the average volume per acre of live tree, down dead pieces, and the amount of volume per acre in piles of dead wood by State. Down dead wood ranges from about 15 percent of live growing stock tree volume per acre in New Hampshire to 35% of live growing stock tree volume per acre in Maine. The amount of volume per acre in piles of wood in ME is about 8 percent of live growing stock tree volume per acre, while the amount in piles in NH and VT is less than 1 percent. The protocols for sampling piles of wood were slightly different in ME, and some of the difference between the States may be due to the protocol changes.

Table 1. Preliminary estimates of growing stock live tree, down dead, and pile volume (cubic feet per acre) by State.

State	Live tree (cu. ft. per acre)	Down dead pieces (cu. ft. per acre)	Dead wood piles (cu. ft. per acre)
Maine	1233.3	429	97.5
New Hampshire	1886.9	260	12.1
Vermont	1451.4	274.2	9.2

In terms of biomass, the range of biomass of down dead wood is from 0 to about 30 metric tons per acre. Approximately 30 percent of the plots had no down dead wood. Eighty-five percent of the plots featured 4 metric tons per acre of biomass or less.

The diameter of both the small- and large-end of the pieces were measured to provide information about size class of the pieces. Approximately 13,500 pieces were measured for this study. Of these, about 5% were greater than 14 inches at the large-end diameter. The largest diameter measured was 32 inches. Approximately 40 percent of the pieces measured for this study had a large-end diameter of five inches or smaller.

Considerations and implications

There are a number of factors to consider before going into the field. What size pieces are of interest? Is decay of the piece an important attribute for the purpose of the survey? Are piles of wood of interest? Should buried wood be included in the survey? At what point does a standing dead tree become a down piece of wood? In terms of management implications, results indicate that there are few large dead trees on the ground. A limiting factor for size of down dead wood is that it can be no larger than standing live trees. If a manager is interested in large down dead trees for wildlife purposes, one must grow large live trees. Another consideration is that piles may be locally important in terms of magnitude of dead wood. How piles should be sampled and analyzed should be given special consideration. The amount of dead wood in a pile can change dramatically by changing the assumption about air space in the pile.

References

Frieswyk, Thomas S., and Richard H. Widmann. 2000a. Forest statistics for New Hampshire: 1983 and 1997. USDA Forest Service, Northeastern Research Station, Resource Bulletin NE-146. Radnor, PA. 130 p.

Frieswyk, Thomas S., and Richard H. Widmann. 2000b. Forest statistics for Vermont: 1983 and 1997. USDA Forest Service, Northeastern Research Station, Resource Bulletin NE-145. Radnor, PA. 130 p.

Griffith, Douglas M., and Carol L. Alerich. 1996. Forest statistics of Maine, 1995. USDA Forest Service, Northeastern Forest Experiment Station, Resource Bulletin NE-135. Radnor, PA. 134 p.

Heath, Linda S., and David C. Chojnacky. 2000. Down dead wood statistics for Maine timberlands, 1995. Northeastern Research Station, Resource Bulletin NE-150. Newtown Square, PA. 80 p.

Warren, C.E., and P.E. Olsen. 1964. A line intersect technique for assessing logging waste. Forest Science 10: 267-276.

Coarse Woody Debris on the Bartlett Experimental Forest

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Foresters and wildlife biologists recognize coarse woody debris (CWD) as an important wildlife habitat component within forested stands across North America. Coarse woody debris provides a structural cover and foraging component on the forest floor for a variety of wildlife species like redback salamander (*Plethodon cinereus),* red-backed vole (*Clethrionomys gapperi*), woodland jumping mouse (*Napaeozapus insignis*), pine marten (*Martes americana),* and black bear (*Ursus americanus)* (DeGraaf and Yamasaki 2001).

We have few reference characterizations of CWD for the variety of forest types found in New England. Various silvicultural systems used in New England – single-tree and group selection, shelterwood, and clearcutting – influence the recruitment of larger-diameter woody debris to the forest floor in contrast with the recruitment of CWD in unmanaged or natural forest conditions over time. The occurrence, distribution, and condition of CWD pieces > 6 inches at the midpoint were sampled relative to the dominant overstory and management history, across the Bartlett Experimental Forest (BEF) in New Hampshire on the existing 0.25-acre cruise plot grid system (Leak 1987; Leak and Smith 1996).

Two hundred and twenty randomly selected cruise plots were inventoried across three levels of stand history (stands under some form of vegetation management (n = 129); stands cut 100 years ago and since left to grow (n = 47); and stands that have remained uncut (n = 44)). Measurements included: 1) an ocular estimate of overstory dominance (hardwood, mixedwood, or softwood) on each cruise plot; and 2) for each CWD piece – species, length to a 4-inch diameter top, diameter at the midpoint, log condition, and signs of wildlife usage.

Mean CWD percent coverage ranges from 1.2 on managed plots to 2.5 on uncut plots (Table 1). CWD coverage was slightly higher under mixedwood and softwood overstory conditions than under hardwoods. Mean number of CWD pieces per acre ranges from 43.6 on managed plots to 83.6 on uncut plots (Table 2).

Mean number of large standing snags (> 16 in dbh) per acre ranges from 0.6 on managed plots to 3.3 on uncut plots (Table 3). The occurrence of large standing snags appears to be greater under mixedwood overstory conditions than under either hardwood or softwood overstory conditions.

Mean number of large CWD pieces (> 16 in midpoint diameter) per acre ranges 0.67 to 2.46 (Table 4). If the two larger diameter categories are combined (> 12 in midpoint diameter), the mean number of CWD pieces per acre ranges from 4.8 to 8.44. CWD pieces per acre appear to be greater under mixedwood overstory condition than either hardwood or softwood overstory conditions.

Inspection of CWD pieces for evidence of past woodpecker use revealed foraging evidence on roughly 15 to 31 percent of the pieces (Table 5). Evidence of excavated cavities ranges from 0 to 3. 7 percent and was considerably less than the visible foraging evidence.

Results suggest that active management over time can influence the distribution and abundance of CWD (Tritton 1980; Roskoski 1977). Stands cut and then left unmanaged for an extended time period appear to be intermediate within the observed range of CWD characteristics to either managed or uncut stands. Large diameter CWD, especially large hollow logs, probably is the component least abundant in managed and unmanaged stands. Foresters and wildlife biologists can insure a minimal availability of large diameter CWD by leaving cull logs in the woods and using other practices and recommendations as suggested in Tubbs et al. (1987).

Table 1. Average coarse woody debris (CWD) percent coverage on 0.25-acre plots across the Bartlett Experimental Forest, NH (number of plots in parentheses).

	------	Overstory (number of plots)	------
Stand History	Hardwood	Mixedwood	Softwood
Managed	1.20 (109)	1.29 (13)	1.42 (7)
Unmanaged	1.66 (18)	1.85 (19)	1.61 (10)
Uncut	1.94 (16)	1.60 (18)	2.50 (10)

Table 2. Average CWD pieces (> 6 inches midpoint diameter) per acre across the BEF.

	------	Overstory	------
Stand History	Hardwood	Mixedwood	Softwood
Managed	43.60	43.69	53.14
Unmanaged	66.00	55.37	45.60
Uncut	70.50	58.67	83.60

Table 3. Average large standing snags > 16 in dbh per acre across the BEF.

	------	Overstory	------
Stand History	Hardwood	Mixedwood	Softwood
Managed	1.10	0.61	1.71
Unmanaged	0.89	2.10	1.20
Uncut	2.25	3.33	2.40

Table 4. Average large CWD pieces per acre across the BEF.

		------	Overstory	------
Midpoint diameter (in)	Stand History	Hardwood	Mixedwood	Softwood
12 – 15.9	Managed	5.50	5.23	5.71
> 16		1.76	2.46	1.71
12 – 15.9	Unmanaged	5.33	6.53	4.80
> 16		0.89	1.47	2.00
12 – 15.9	Uncut	6.75	7.78	3.20
> 16		1.00	0.67	1.60

Table 5. Evidence of woodpecker use in CWD by percent across the BEF.

		------	Overstory	------
Type of use	Stand History	Hardwood	Mixedwood	Softwood
Cavities	Managed	0.94	0.00	0.84
	Unmanaged	3.25	0.00	0.00
	Uncut	0.00	0.79	0.45
Foraging	Managed	20.68	21.33	14.86
	Unmanaged	29.67	19.50	25.31
	Uncut	23.22	30.78	21.11
Both	Managed	1.21	0.00	0.00
	Unmanaged	0.44	2.12	2.50
	Uncut	1.11	0.56	0.91

Literature Cited

DeGraaf, R.M. and M. Yamasaki. 2001. New England Wildlife: Habitat, Natural History, and Distribution. Hanover, NH: University Press of New England. 482 p.

Leak, W.B. 1987. Fifty years of compositional change in deciduous and coniferous forest types in New Hampshire. Canadian Journal of Forest Research. 17: 388-393.

Leak, W.B. and M.-L. Smith. 1996. Sixty years of management and natural disturbance in a New England forested landscape. Forest Ecology and Management. 81: 63-73.

Roskoski, J.P. 1977. Nitrogen fixation in northern hardwood forests. New Haven, CT: Yale University. PhD dissertation.

Tritton, L.M. 1980. Dead wood in the northern hardwood forest ecosystem. New Haven, CT: Yale University. PhD dissertation.

Tubbs, C.H., R.M. DeGraaf, M. Yamasaki, and W.M. Healy. 1987. Guide to wildlife tree management in New England northern hardwoods. USDA For. Serv. Gen. Tech. Report NE-118. 30 p.

Effects of Silviculture on Coarse Woody Debris

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There are two major inputs into the pool of coarse woody debris in a managed forest stand: mortality and slash.

The input from mortality is inversely related to net growth of the stand:

Gross growth minus net growth equals mortality.

The gross growth of a stand (the total wood production) does not vary too much between a stand that is intensively managed, extensively managed, or not managed at all. However, the net growth and mortality vary greatly. In an intensively managed stand (frequent entries, careful harvesting of risk trees, etc), the net growth will be relatively high and the mortality quite low. At the other extreme, an unmanaged stand will eventually reach the point where all of the gross growth equals the mortality, i.e. there is no net growth. The data in Tables 1-3 show the effects of management on net growth vs mortality. The bottom line is that you cannot maximize both net growth and the input of mortality into coarse, woody debris – you must determine what level of compromise best serves the objectives of the ownership. Another interesting message is that even in managed stands, about 20-25% of the gross growth still is transformed into coarse, woody debris by mortality.

Slash is the second major input into coarse, woody debris in a managed stand – although most of this is fairly small material. Whole-tree biomass operations in spruce-fir and northern hardwoods left only 4-10% of the original standing biomass on the site – primarily as broken material that could not feasibly be removed. In merchantable stem-only operations, however, 25-35% of the biomass was left on-site as input to coarse, woody debris (Table 4, Pierce et al 1993). In general, then, we can say that about 30% of the biomass in harvested trees is left in the woods by leaving the tops.

Under conventional merchantable stem-only clearcutting, the input to coarse woody debris is substantial, but lasts for less than 18 years (Table 5); by age 56, woody debris has risen again due to the input from stand mortality. Note also that the majority of the deadwood is on the ground rather than standing.

In summary: under moderately intensive management, about 25% of the gross growth is allotted to mortality. In addition, by leaving tops in the woods, about 30% of the biomass in harvested trees remains as coarse woody debris. It is not known whether this is enough to maintain optimum wildlife habitat conditions. However, it would seem prudent to devote special management attention to providing the types of coarse woody debris and living culls that seems to be in short supply: large material in trees over 16-18 inches dbh, and large trees with cavities and hollow centers.

Table 1.—Effects of stand density on gross basal area growth and mortality in a 60-80 year old northern hardwood stand (basal area/acre in square feet)(Solomon 1977).

Residual Basal Area	**Annual Gross Growth**	**Annual Mortality**
40	2.63	.61
60	2.41	.40
80	2.08	.58
100	2.16	.87

Table 2.—Effects of thinning on mortality in 60-80 year-old northern hardwoods (annual basal area/acre) (Wilson 1953).

Treatment	**Gross Growth**	**Net Growth**	**Mortality**
Thinned	3.2	2.6	0.6
Unthinned	2.5	0.7	1.8

Table 3.—Effects of unevenaged management on mortality: single-tree and group selection (no marking between the groups) (annual basal area/acre)(Filip 1978, Leak 1999)

Treatment	**Gross Growth**	**Net Growth**	**Mortality**
Single-tree	1.9	1.6	0.3
Group	1.9	1.0	0.9
Uncut	2.0	0.6	1.4

Table 4.—Percent of biomass left after complete clearcutting: whole-tree harvest vs merchantable stem-only (Pierce et al 1993).

Forest Type	Whole-tree	Merchantable Stem-only
Spruce-fir	10	35
Northern Hardwood-NH	4	25
Northern Hardwood-VT	9	35

Table 5.—Estimates of deadwood in unmanaged northern hardwood stands following conventional clearcutting (metric tons/hectare) (Bormann and Likens 1979).

Stand Age (years)	On Forest Floor	Standing	Total
4	37.7		37.7
8	58.6		58.6
18	6.9		6.9
40	9.1		9.1
56	29.4	4.4	33.8
57	20.9		20.9
170	34.4		34.4
170	28.6	4.9	28.6

Literature Cited

Bormann, F.H. and G.E. Likens 1979. Pattern and process in a forested ecosystem. Springer-Verlag, New York. 253 p.

Filip, S. M. 1978. Impact of beech bark disease on uneven-age management of a northern hardwood forest (1952-1976). USDA Forest Service Gen. Tech. Report NE-45, 7 p.

Leak, W.B. 1999. Species composition and structure of a northern hardwood stand after 61 years of group/patch selection. North. J. Appl. For. 16(3):151-153.

Pierce, R.S. (plus 6 other authors). 1993. Whole-tree clearcutting in New England: manager's guide to impacts on soils, streams, and regeneration. USDA For. Serv. Gen. Tech. Report NE-172, 23 p.

Solomon, D.S. 1977. The influence of stand density and structure on growth of northern hardwoods in New England. USDA For. Serv. Res. Pap. NE-362, 13 p.

Wilson, R.W. Jr. 1953. How second-growth northern hardwoods develop after thinning. USDA For. Serv., Northeast. For. Expt. Sta., Sta. Pap. 62, 12 p.

Line Intercept Sampling for Coarse Woody Material

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Introduction

It's unlikely in any sort of management operation that it would be necessary or even desirable to conduct a CWM inventory in every stand. But should the need ever arise, you should know that the methods are simple and straightforward. There are two methods of CWM inventory that we know are quick and reasonably accurate: line intersect sampling (or LIS), and point relascope sampling (or PRS). Here, we'll briefly describe a simple way of implementing LIS that is compatible with common methods of forest inventory.

Inventorying downed CWM is similar in many ways to inventorying standing timber. You want to get good confidence limits on the amount of CWM, without spending huge amounts of expensive field time doing it. Once upon a time, most timber inventory was done with fixed-area plots or fixed-width strips, but those methods have been supplanted by prism cruising. Prism cruising is more efficient because it focuses sampling effort on larger, more valuable trees. Now, you could also use fixed-area plots or fixed-width strips to inventory CWM, and many people still do. The problem is that there are many more small than large pieces of CWM out there, and the large ones tend to be more valuable ecologically. It would be nice to have methods, like prism cruising, that focus attention on those larger pieces. PRS, which will be dealt with in a later paper, is directly analogous to prism cruising. LIS is an older, more widely used method that shares an important attribute: it samples downed logs with probability proportional to their size.

LIS was originally developed as a tool for sampling logging slash and waste (Warren and Olsen 1964, Bailey 1970), and was later refined for forest fuel measurements (Van Wagner 1968, Brown 1974). Just like prism cruising, it's very easy to do in the woods, but doing the mathematical proofs that show why it works is fairly involved. In this paper I'll skip those proofs; if you're so inclined, you can find more detailed mathematical treatment elsewhere (Kaiser 1983, Shiver and Borders 1996).

Basic Procedure

There are several ways of implementing LIS in the woods. Here, I'll describe a version that is easy to do and that allows easy analysis of the data. I'm going to assume you are already planning on visiting a set of sample points, laid out on a grid, on a line-plot design, or randomly, in your stand or tract. In other words, you're already doing a timber inventory and you will be establishing a bunch of "plot centers." We'll use those plot centers as the centers for a bunch of LIS lines. The procedure I'll describe takes some fairly harmless shortcuts, with the goal of having a good (but not necessarily research-grade) estimate of CWM abundance.

At each plot center, do the following:

1. Lay out a single line of known horizontal length centered on the sample point, or a pair of lines at right angles making an X centered on the sample point. If you want numbers comparable in accuracy to a typical overstory inventory, you will need a combined length of 4 or more chains per sample point. If less accuracy is needed, then 2 chains per sample point is a reasonable amount.

> *Details:* ideally, the line (or pair of lines) should have a randomly chosen orientation. Technically, LIS in the form we'll use here assumes that either the lines or the logs are randomly and independently oriented. We know that after timber harvests or natural disturbances that logs tend to be laid out in similar directions. The risk in always running your line in the same direction is that you would tend to always run parallel to the logs (and not count enough) or perpendicular to the logs (and count far too many). If random orientation is a hassle, then use two equal lines at 90 degrees from each other, forming an X. That way, if one line is parallel the other will be perpendicular, and the effects will nearly average themselves out.
>
> A simple alternative if you are not worried too much about the orientation issue is to use the first few chains on the way to your next sample point as the line. Bear in mind you need to keep that line segment straight and of the correct length if you are going to get accurate numbers.

2. Tally all the logs that cross the line (or pair of lines). Ignore all the others.

> *Details:* If a log crosses the line twice (either because it is crooked, or because you have lines at right angles), it gets tallied twice!

3. Take the measurements you need on each tallied log. In addition to the dimensional measurements for volume (you will pick 3a or 3b below), you would typically record the decay class and whether or not the log is hollow. You could record any other attributes of the log that were relevant to your management.

3a. If you are only interested in cubic volume, or closely related attributes like biomass or nutrient content, then the only dimensional measurement needed on each log is the diameter at every point where the line crosses. So if the line crosses twice, you need two diameters. If you choose this option, you do not need to measure the log length. This method is theoretically unbiased but doesn't allow calculating many of the numbers foresters want to know about CWM; for the rest of this paper, we'll assume you picked 3b instead.

> *Details:* On steeply sloping terrain, or if the log is lying far from the vertical, additional measurements would be needed to compensate for slope. We won't go into that here; Brown (1974) provides some discussion.

3b. If you are interested in logs per acre and their size distribution, in addition to volume, then a different measurement protocol for the logs is more efficient. Measure the diameter at the large end and the small end of the log, and measure the length of the log along the bole. If the log is tilted out of the horizontal, or is crooked, also measure the horizontal distance between the ends of the log.

> *Details:* This protocol is quick and easy. There can be a slight bias in the results but it is usually swamped out by the sampling variability associated with CWM measurement.

Once you have completed these steps for a sample point, you just go on to the next one. It's that simple.

First Step in Calculations: The Length Factor

At this point, you should be wondering how all these intersections of logs with lines can be converted into per-acre numbers. The trick is that your lines have a "length factor" that works just like the basal area factor in prism cruising. I won't derive the length factor here, just explain it and give the formula.

Think about logs of different length scattered about in the woods. Which logs are more likely to be crossed by an LIS line, short logs or long logs? Clearly the long logs have a bigger chance of getting a line across them. It turns out, after some fairly scary math, that the probability of crossing a log with a line, and tallying it, is directly proportional to the length of the log as projected into the horizontal plane. So LIS is what biometricians call a "probability proportional to size", or PPS, sampling method, where the probability is proportional to log length. As a forester, you already use a PPS sampling method: prism cruising. In prism cruising, we sample with probability proportional to basal area, and each tree counts as a fixed amount of basal area per acre – the basal area factor. In LIS, with probability proportional to length, each log counts as a fixed amount of linear length per acre – the "length factor."

Now, in prism cruising, the BAF depends on the angle of the gauge (or the diopter of the prism). In LIS, the length factor depends on how much line you ran for each sample point. Think about it: if you run longer lines at each sample point, you tally more logs, so each log should count for less length per acre. The formula for the length factor is very simple:

$$LF\ \text{(feet/acre)}=43560*3.14159/(2L)$$

where L is the total length of LIS line you ran at the sample point, in feet.

For example, suppose at each point I ran 2 line segments of 2 chains each, forming an X. So my total line length, L, is 4 chains, or 264 feet. My length factor, LF, is just 43560*3.14159/(2*264)=259.2 feet per acre. So each log I tally represents 259.2 linear feet per acre of logs like it. If a log was 26 feet long, it would represent about 10 similar logs per acre; if a log was 13 feet long, it would have to represent about 20 similar logs per acre to add up to the same length factor.

Calculations for Each Sample Point

Armed with the length factor, how do we work up the data for each point? It works almost exactly like analyzing prism data. The basic principles:

1. We noted above that each log counts as *LF* linear feet of logs per acre. That means each log has to count as LF/l_H logs per acre, where l_H is the straight-line horizontal distance between the ends of the log (*i.e.* the log's length in the horizontal plane). Call the number of logs per acre each log counts as, its *expansion factor*.

2. One of the attributes we are almost certainly interested in is the cubic volume per acre of logs. Recall that using Smalian's formula, if your large and small-end diameters (d_L and d_S) are in inches and the length of the log along the bole (l_B) is in feet, then the cubic volume of the log is just $V=0.005454(d_L^2+d_S^2)*l_B/2$. To find out how much volume per acre a log counts as, we just multiply its volume times its expansion factor.

3. For a single point, our estimate of the number of logs per acre is just the sum of the expansion factors of the tallied logs. Our estimate of the volume, in cubic feet per acre, is just the sum of the (log volume times expansion factor) numbers. This can be done for all logs, or for only those logs meeting certain decay or size criteria to make the CWM version of a "stand and stock" table.

4. With multiple points, the best estimate of logs per acre is just the average of the estimates from the individual points. The same is true for volume per acre. The standard error of the individual point estimates serves as the basis for calculating confidence limits.

Here's a simple example for a single point. Suppose we used the design of 2 crossing lines each 2 chains long, that we calculated above would give us an *LF* of 259.2 feet per acre. At our sample point, we tallied 3 logs. Right away we would estimate there are 3*259.2 ft/ac or 777.6 linear feet of logs per acre in the tract. Our tract is level, and these are nice straight conifer logs, so $l_H=l_B$ and we only needed to record one length per log; they were 50, 10, and 4 feet long. We've already worked up the volumes of our three logs using Smalian's formula as 20, 3, and 5 cubic feet, respectively. Now we just set up a simple table, maybe in a spreadsheet, to finish off the calculations:

Length (ft)	Vol (ft^3)	Logs/ac =*LF*/length	ft^3/ac =vol*(Logs/ac)
50	20	5.2	104
10	3	25.9	78
4	5	64.8	324
TOTAL		95.9 logs/ac	506 ft^3/ac

So we would estimate, based on this one point, that there are about 96 logs per acre, comprising 506 cubic feet per acre. Of course, you'd never inventory a stand with just one prism point, and the same thing applies for LIS. If you want numbers you can trust, with decent confidence limits, you'll need quite a few more sample points.

Conclusions

LIS is simple and easy to do in the woods. The data analysis isn't any more complicated than prism cruising – in fact, if you can work up prism data by hand or in a spreadsheet, you can do the same for LIS. There are a lot of bells and whistles you can add to LIS, or modifications you can make, to fit it to a particular application. For research purposes, you might want to go a little farther than the protocol outlined here. But for straightforward operational inventory, it's been the method to beat for about 30 years. It's only lately that a real contender has emerged – that's PRS, and you can read about it in the next paper.

References

Bailey, G.R. 1970. A simplified method of sampling logging residue. *Forestry Chronicle* 46: 288-294.

Brown, J.K. 1974. Handbook for inventorying downed woody material. Gen. Tech. Rep. INT-16. Ogden, UT: U.S.D.A. Forest Service, Intermountain Forest and Range Experiment Station, 24 pp.

Kaiser, L. 1983. Unbiased estimation in line-intercept sampling. *Biometrics* 39: 965-976.

Shiver, B.D. and B.E. Borders. 1996. *Sampling Techniques for Forest Resource Inventory*. New York: John Wiley & Sons.

Van Wagner, C.E. 1968. The line intersect method in forest fuel sampling. *Forest Science* 15: 20-26.

Warren, W.G. and P.F. Olsen. 1964. A line intersect technique for assuming logging waste. *Forest Science* 10: 267-276.

Sampling down coarse woody debris with an angle gauge

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Foresters and landowners have become more aware that down coarse woody debris (CWD) plays an important role in the forest ecosystem. Questions concerning how much is enough, what size distributions are optimal, and how CWD should be spatially distributed are being asked with increasing frequency. Such questions are difficult to answer because they implicitly include multiple goals (wildlife habitat, seedbeds, fire risk, etc.) and certainly depend on the forest site, type and structure; and research into these questions, while ongoing, is in it's infancy in the northeastern U.S. Recent research has, however, produced new methods to sample CWD that show promise both in the field and in their relation to methods for sampling standing timber. These methods employ an angle gauge and may be used along a line (transect relascope sampling—TRS) or at a point (point relascope sampling—PRS). The former was developed by Ståhl [4] for sampling sparsely distributed CWD in Swedish forests. The later was developed to provide a system for sampling CWD that is complementary to horizontal point sampling (HPS) [2]. Here, an overview of sampling down CWD with an angle gauge (relascope) using PRS is presented. A brief comparison of PRS and HPS is presented in Table 1.

In PRS, the angle gauge is used at a sample point to select pieces of down CWD (logs) by sighting on their length: if a log's length appears greater than the projected angle, the log is "in" and is included in the sample on that point. The angle projected by the gauge (ν) is in degrees: $0 < \nu \leq 90°$. In contrast, the angles projected in HPS are normally specified in terms of minutes because they are much smaller. For example, a 20 basal area factor (BAF) prism, commonly used in the northeast for inventorying standing timber, has a critical angle of 147.34 minutes. In point relascope sampling, studies thus far in the New England region have found that angles of approximately 28–53° would be most useful in the majority of forest stands, while angles approaching 90° would be used in heavily cutover stands, such as in clear cuts or diameter limit cuts. The reason for this choice of angles is analogous to the choice of a BAF in prism cruising: smaller angles reach out farther from the point center. Thus, for a given distribution of CWD on the forest floor, a smaller angle will always select more logs into the sample on a given point than a larger angle. In heavily cutover stands, with higher levels of down CWD contributed from harvesting, one does not want to have to walk through the slash very far from the sample point center to measure logs, and the likelihood of missing logs further from the point center that are "in" with the angle gauge is high. In such stands, an adequate sample in terms of number of pieces per point selected with the

Table 1: Comparison of HPS and PRS for common components of an inventory illustrating how parallel the two methods are.

Task	HPS	PRS	PRS Reference
Angle	Minutes	Degrees	[3]
Angle Gauge	Wedge prism or homemade gauge	Homemade gauge	[3]
Sight On	Tree dbh	Log length	[2]
Blowup Factor	BAF: Basal area factor	SLF: Squared length factor	[2]
Borderline Condition	Limiting distance	Limiting length	[2]
Boundary Overlap	Mirage method	Mirage method; Boundary reflection or "Walk-through" methods	[1], [2]
Slope Correction	Required: Various simple methods	Required: Simple length correction	[5]

angle gauge will generally be achieved with the larger angle simply because of the higher "stocking" of down material. Figure 1 shows the the similarities graphically. Note in PRS that, for a log of constant size, different angles will produce different shaped log-circles on both sides of the log. If a sample point happens to fall within either of these circles, the log will be chosen with the angle gauge. It may be helpful to remember how the angle affects the shape of these log-circles by recalling the process of cell division (mitosis) from biology. If cells were perfectly round, the 90°angle would apply to the cell before division (e.g., prophase) while successively smaller angles would progressively lead to the formation of two new daughter cells (telophase). Of course the analogy is not perfect because in Figure 1, with a constant log length, the log-circles just get larger and larger, but the concept of "mitotic" log-circles may nevertheless be a helpful one.

An angle gauge can be made very simply for use in PRS. The procedure is described in detail in [3] where an example is given. Gauge construction is based on a right triangle from half the projected angle (ν) just like in HPS. All that is required is a piece of straight wood for the gauge itself, two nails, and a length of string. The nails are inserted into the wood; the distance between the nails coupled with the distance from the eye to the nails (perpendicular to the gauge) determines the relascope angle.

Calculations for PRS are also very similar to HPS. Suppose that TVol is the volume of a tree with dbh of 24 inches. Suppose further that this tree was sampled on a HPS point with a 20 BAF prism. Then the blowup factor for the tree is equal to the BAF divided by tree basal area. The formula for the volume per acre represented for this tree is

$$\text{Vol/Ac} = \frac{20 \times \text{TVol}}{0.005454 \times 24^2}$$

The same formula applies for other quantities pertaining to this tree, those quantities would simply be substituted for the volume. For basal area per acre, the formula simply reduces to the tree tally times the BAF.

Similarly, let LVol represent the volume of a log that is 12 feet long, calculated using Smalian's formula for example. The missing piece of information is the SLF mentioned earlier that is analo-

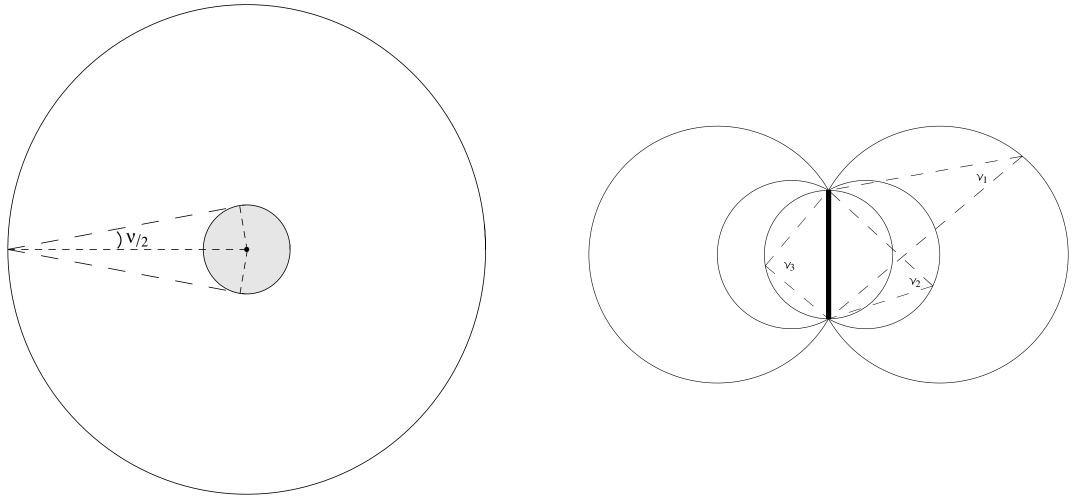

Figure 1: HPS (left) showing a tree-circle for an angle ν (minutes); and PRS (right) showing the "mitotic" log-circles for three different angles: $\nu_1 = 30°$, $\nu_2 = 60°$ and $\nu_3 = 90°$.

gous to the BAF. Assume that an angle of 28.07°was used to sample this log on a point. The SLF for this angle is given by Gove et al. [3] as 6,290.8 and is in square feet per acre, just like the BAF. The formula for calculating volume per acre represented by this log is very similar

$$\text{Vol/Ac} = \frac{6,290.8 \times \text{LVol}}{12^2}$$

The blowup factor for this log is the SLF divided by the log length squared. This log represents 6,290.8 square feet of squared length per acre based on the SLF. While this may seem an odd currency for foresters to work in, it really is not that strange. For example, basal area is simply a constant times the square of diameter. If the concept of basal area had not been developed, we would be speaking in terms of squared diameter factors instead of basal area factors. So while squared length may take a little getting used to, it is actually correlated with volume; therefore, the more logs sampled on a point, the more squared length (just the log tally times the SLF) and thus, the more volume. Again, since we know that basal area also correlates well with volume per acre, the analogy holds for PRS here too.

In HPS, trees can appear to be neither "in" nor "out;" such trees are termed borderline and the correct way to handle them is to measure a limiting distance to the tree. The limiting distance is compared to a table for that tree's dbh. Such tables are available for different BAFs, or are simple to generate on a spreadsheet program. In PRS, the same concept applies. If it is not possible to make a judgement as to whether a log is clearly "in" or "out" with the angle gauge, then the distances from the sample point to the ends of the log are measured and a "limiting length" is calculated to make the determination. The formula and a sample calculation is given in [3]. Checking the limiting length on borderline logs is important in PRS just as in HPS. It is not correct to simply sample every other borderline log, just as it is incorrect to sample every other borderline tree. This is a fact often forgotten in the woods; improperly rejecting or including borderline trees by such an ad hoc rule leads to biases in the estimates by both sampling methods.

As can be seen in Table 1, PRS shares two other characteristics in common with HPS: slope correction and boundary correction. Detailed treatment of the methods that should be used for

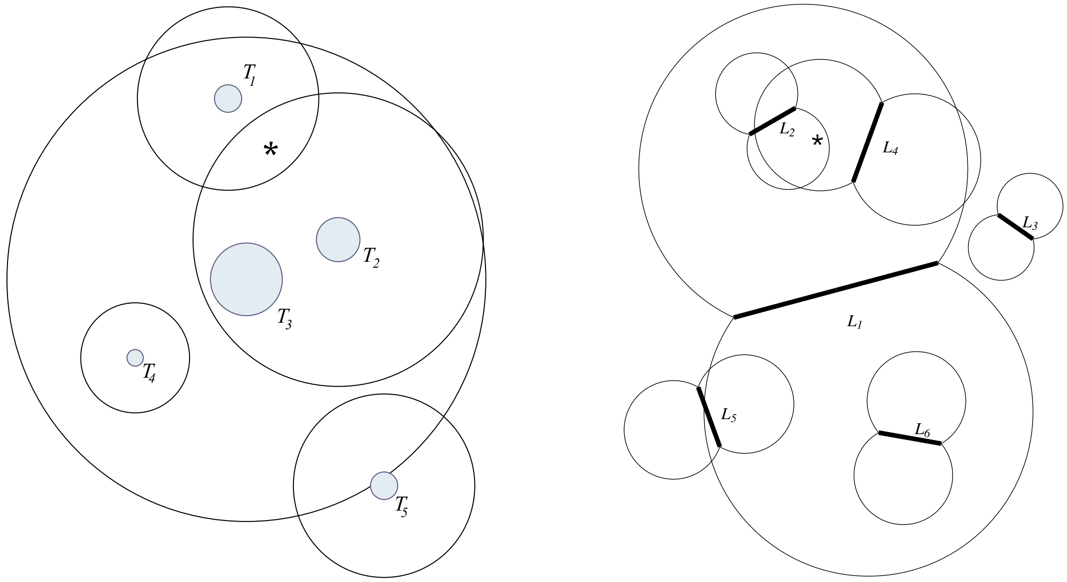

Figure 2: HPS (left) showing tree-circles and and PRS (right) showing the log-circles; the sample point has landed where the $\star$ is in both cases.

implementing both in the field are found in the associated references in Table 1. Suffice it to say that, for slopes in excess of 20%, slope correction is appropriate. In addition, the method that is recommended for boundary correction in PRS—namely the mirage (reflection) method—parallels closely it's implimentation in HPS, though an alternative procedure based on the mirage method my be more appropriate ([1], [2]).

Finally, when sampling an entire point with PRS, the same concepts apply operationally as in HPS. Figure 2 shows a contrived sample point in the field. In the left-hand figure, the sample point fell within the tree-circles of trees 1, 2 and 3; thus, these trees would be sampled with a prism from the point center. Similarly, in the right-hand figure, logs 1, 2 and 4 would be sampled on the PRS point since the point center falls within the log-circles for these logs. This figure also shows that the orientation of the log to the sample point does not matter, as long as the log length can be seen with the angle gauge, the cruiser can be on either side of the log. It is important to realize, however, that sighting on the log is supposed to be done on the same plane as the log itself, thus, if one is viewing the log end-on, the length would not be visible, so there is no chance of sampling a log in this case as illustrated by the log-circles. Detailed information may be found on PRS and related methods in the references.

References

[1] Ducey, M.J., Gove, J.H., and Valentine, H.T. 2002. A walkthrough solution to the boundary overlap problem. *Forest Science* (in review).

[2] Gove, J.H, Ringvall, A., Ståhl, G., and Ducey, M. J. 1999. Point relascope sampling of downed coarse woody debris. *Canadian Journal of Forest Research* 29:1718–1726.

[3] Gove, J.H., Ducey, M.J., Ståhl, G., and Ringvall, A. 2001. Point relascope sampling: A new way to assess doened coarse woody debris. *Journal of Forestry* 99(4):4–11.

[4] Ståhl, G. 1997. Transect relascope sampling—A method for the quantification of coarse woody debris. *Forest Science* 44(1):58–63.

[5] Ståhl, G., Ringvall, A., Gove, J.H., and Ducey, M.J. 2002. Bias due to slope in point and transect relascope sampling. *Forest Science* (in press).

Pre-Cruise Planning

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Introduction

The exact numbers a timber cruise gives are governed, in some measure, by chance. But a good cruise isn't an accident; good cruising happens by design. A good cruise takes into account chance events (what statisticians call *random variability*), and the tendency for fixed ways of doing things to skew the results (what statisticians call *bias*), reducing these in an appropriate balance with the expense of taking more and better data. What is that appropriate balance? That depends on the purpose of the cruise and the client at hand.

Here, I'll give a brief overview of four steps to planning a good cruise:

1. Saving your old cruise results
2. Knowing why you are cruising
3. Targeting appropriate accuracy
4. Selecting efficient tools and adequate intensity

A little bit of time spent on each of these four steps can save a lot of time in the woods. Time is money, and we could all use a little more of one or the other, or both. It can also help ensure you have the quality information you wanted to make good forest management decisions -not shaky cruise results that leave you out on a limb.

Saving Old Cruise Results

It may seem counterintuitive that a little time in the office will really help you do a better job in the woods, but it's true. The reason is fairly simple. If you've been spending much time at all doing forest inventories or stand exams, you probably have a treasure trove of information that will help you design better cruises. The trick is to recognize that information and save it so you can find it later.

What sort of information am I talking about here? Well, to jump ahead a bit, at some point you are going to find yourself asking how many points or plots to do in a cruise. Suppose your measure of accuracy for that cruise is related to the board feet per acre in a stand. If you look up the answer in a textbook, it will say you need to know either the *standard deviation* of the board foot estimates from the points, or the *coefficient of variation*. Both numbers express how much variability there will be between the individual prism points or plots. The difficulty is that you haven't done the cruise yet, and so the textbook will tell you to do a "pre-cruise" to estimate those numbers. There are two problems with that advice. The first is that with a small sample, your estimates of the standard deviation or the coefficient of variation are going to be lousy. The second is that unless it's a really big project, you can't afford to do a pre-cruise anyway.

But there is an alternative. I'll bet it's fairly unusual for you to cruise a stand that is so unique, it's not like anything you've ever cruised before. If you could only find those old computer printouts for similar stands, you could look up the standard deviations or coefficients of variation you wanted, and have a good idea in advance what the numbers might look like.

Another question you may find yourself asking is, "Am I happy with my past cruises?" Chances are you already have a sense for the answer. But to translate that into meaningful statistical terms, you'll want to look at just how those past cruises turned out. In particular, you may want to look at the "plus or minus" part of the confidence limits. If you want better performance, you should look at ways of designing your cruises to make those confidence limits narrower. If you feel like you are spending too much time and money cruising, and your old confidence limits are very tight (say, plus or minus 5% even for small tracts) you probably have some room to design *less* accurate cruises.

How to do this, without filling your office with cabinet after cabinet of old cruise results? Easy. Just set up a simple spreadsheet. Every time you work up the data for a new stand, grab the printout and make a new row in the spreadsheet containing a few key pieces of information, like the type/size/density class of the stand, how the stand was cruised (plot or prism), the BAF or plot size, and the number of points used. Then, add the statistical information: the estimates (averages), coefficient of variation, and confidence limit widths for trees per acre, basal area, and volume per acre (board feet, or cords, or both). Later, when you need to estimate those statistics for a new stand, you can use the "sort" function in the spreadsheet and scan through to find all the old stands like it.

I hate filing, and it sometimes seems hard to find the time to set things up right in a spreadsheet and keep up on the data entry. But remember, developing a good way to track your information will save you much more time down the line than it costs up front.

Why Are You Cruising?

This step seems so obvious that it is all too easy to skip. Many foresters have a "one size fits all" approach to cruising. Like "one size fits all" clothing, the results - both for accuracy and cost - are usually acceptable, but could often be improved. And sometimes what happens is awkward, or embarrassing, or just plain ugly.

The management decisions you will make, and the environment in which you have to defend those decisions, should determine what kind and accuracy of information you need. Is this cruise just to give you a rough sense of a tract? Will you base a silvicultural prescription on the data? Do you need rock-solid numbers for volume and value? Does this cruise have legal implications? Each of those situations demands different kinds of information and levels of effort. If you did a cruise that would stand up under hostile cross-examination from a good lawyer every time you did a stand exam, your boss or your clients would be right to go find a forester who could get the job done at a lower cost. On the other hand, if you take a cruise into court that was designed like you were doing a stand exam, that lawyer will make you wish your boss or your client *had* found somebody else.

Now, I'm not suggesting that you spend huge quantities of time navel-gazing over the existential meaning of each new cruising situation, or tailoring a new set of specs for every single cruise in every single stand. That's not practical, and it's not necessary. Most foresters can probably identify two or three categories (like sizes S, M, and L) that encompass 99% of their cruises. Most of the time, it is also fairly easy to see what category a particular client and their needs, or a particular tract and management situation, fits into. If you have good protocols for those categories, you will *save* time because you will not over-cruise when you don't need to (but will cruise intensely when you do need to), and you will get *better* answers because you will have solid numbers when you really need them (but won't waste your time when you don't need them). You'll also recognize fairly quickly when you have an oddball situation that doesn't fit - an XS that requires even less cruising than usual, or an XXL that really calls for a big, one-of-a-kind design.

Target Appropriate Accuracy

Once you know why you are cruising, you can target your efforts to achieve the accuracy you need. Too little accuracy means you will make bad forestry decisions, and both the woods and your clients will suffer. Too much accuracy hurts your bottom line: it means you spent money you didn't need to. Your job as a forester is to bear both of those factors in mind and find a happy medium.

Do I Need To Cruise?

On some jobs, an important question to ask is whether you need to cruise at all. Looking at your own operations, and the kind of recommendations being made in this workshop, you'll quickly realize that cruising effectively can cost real money. It can be tempting to take short-cuts: reduce the number of points, use a bigger BAF without using more points, eyeball things that really should be measured, and so on. But think about how you actually spend your time when you are cruising. Unless you are cruising with an exceptionally high intensity, most of your time is spend *walking between points.* So even if you are going to cruise shoddily, you still spend a lot of time and money! And a shoddy cruise often hurts you, or your client, or the woods, when you make decisions based on shoddy numbers. So you still make a big investment, but you get nothing back -or worse.

The alternative, of course, is a quick walk-through and qualitative examination of the stand. You make an educated guess about the board foot volume, the stand density, and the other things you need to make a sound decision. Field foresters with a lot of experience often guesstimate things with enough accuracy to make simple decisions correctly and reliably. If you can guesstimate better and cheaper than you can cruise, and if you don't need to back up your guesstimates with any hard data, don't cruise.

Another way of looking at this question uses all that old cruise data you just entered into a spreadsheet. If past cruises under similar circumstances to those you are contemplating now had very wide confidence limits (so wide that you could have made an educated guess and been within those limits), and you were still satisfied with the decisions you made, maybe you don't need to cruise.

Now, sometimes you're not cruising for your own needs, but just to make someone else (like a county forester or a sustainability auditor) happy. Maybe you just need to cruise to "veneer over" decisions that don't need much information. Then maybe a quickie cruise with ultra-wide confidence limits will do the trick, since you won't really use the numbers to make any decisions. But don't kid yourself that the numbers mean much. And don't be surprised if someday that "other party" gets wise and starts to expect more.

Is this a rough stand exam?

If you've decided you do need to cruise, perhaps the least demanding situation is a rough stand exam. The data themselves won't be used to drive a quantitative silvicultural prescription. They'll just being used to give a quantitative indication of the general features of a stand, and maybe to indicate roughly what some likely management strategies might be. Keeping costs down is often a high priority in this kind of cruise. But it's important to maintain reasonable standards, or that description won't necessarily resemble the stand very much.

If you're prism cruising with a BAF 10 in a reasonably homogenous stand, then 8-12 points per stand will probably give you the quality of answers you need. If you switch to a larger BAF, say a 15 or 20 (a switch I'll argue below is a smart one), you will need more points than that. It sounds like a lot, and in some ways it is. But a cruise with that intensity, based on the numbers I have on file, will give answers for total basal area or cordwood volume that are within about 20% of the true basal area or cordwood volume 95% of the time. For board foot volume, the numbers will be worse. You can, and should, use some numbers from stands you have cruised to see if I am out in left field. If I'm right, and you use fewer points, your answers will be somewhat worse. On the other hand, for a rough idea of a stand, do you need to do much better? Now bear in mind, those sorts of error ranges are for the *totals* in a stand. If you want to look at particular categories, like hardwoods or softwoods, or particular grades, or particular diameter classes, the accuracy is not likely to be there.

What will you actually do in the woods? The plot layout should be a simple, easy grid, and pacing between points will do just fine. (Some folks like gizmos that pay out string to measure distance; just remember that the factors that make pacing inaccurate, like steep terrain and heavy slash or understory, also throw off the string gizmo, because it assumes you were moving on a straight, level path.) A Biltmore stick will work fine for DBH; after all, exact diameter distributions aren't critical to a rough stand description. Heights can be crude -or maybe not even measured - because nothing you would do with a rough stand description depends on precise volume determination. Boundary correction and other esoteric details can be ignored (unless it's easier just to do them right automatically); the goal is a good "ball park" estimate, not a strictly unbiased one. On the other hand, some of the things that *seem* like a good idea (like moving plots around when they don't fall in "typical" areas) aren't really good ideas statistically (they introduce bias) *and* take time, so you'd still avoid those kinds of practices. A good stand exam cruise follows two simple rules: keep it simple, keep it quick.

Are legal issues at stake?

At the other end of the cruising spectrum are inventories supporting legal action. This is unfamiliar turf for some foresters but it's becoming all too common. It is important to recognize that "generally accepted practice" does not cut the mustard in a court of law - at least, not if you want your cruise data accepted as scientific evidence. The current legal standard for scientific evidence was established by the U.S. Supreme Court in *Daubert vs. Merrill-Dow Pharmaceutical*, and elements of that standard include the conformity of the method to peer-reviewed procedures, and the ability to calculate known error rates. In other words, your cruise should be good enough to satisfy an ivory-tower professor, and it must be statistically sound.

It's hard to say how many plots are enough for a cruise like this, but it will be a lot more than you would have done for an ordinary stand exam. You can afford to spend a couple of hours working out the sample size in advance using old cruise data as a guide -it will be nothing compared to the hours you should spend in the field, and no matter how much you hate math, it will be less miserable than a couple of hours on the witness stand. Once you've figured out your number of plots and grid spacing, you'll do your best job of locating the plots in the field. That may still mean pacing, but if you can scare up a second pair of hands, it might be time to get out a tape. No matter how you lay out the plots, you should never deviate from your pre-planned sampling locations. That grid is your claim to objectivity; if you bend it, it will break. Once you are on the plot, tape or caliper DBH to nearest 0.1" (Ducey 2000), and check your borderline trees exactly (Iles and Fall 1988). Far better in a cruise like this to be over-careful. If money is at issue, take accurate heights and spend the time to do the grading right -perhaps on a subsample of trees (point double-sampling and related methods can come in handy here). You absolutely have to be unbiased, so you should control for boundaries (Gregoire 1982) and sloping terrain using proven methods. When you are done, don't throw anything away, not one scrap of paper. Is this kind of cruising expensive? You bet, compared to ordinary cruising. Not at all, compared to what that lawyer is going to get as a billing rate.

The "stand exam" example I've given, and the legal example, are just that -examples. As a forester, you need to examine the situations you commonly cruise in, and bring to bear what you can from your own data. Many situations will fall close to the "stand exam" level, requiring decent numbers - decent enough to keep you from making a bad decision. In those cases, small biases may be acceptable, and it's important not to go overboard with an expensive "perfect" cruise. Silvicultural prescriptions are information intensive. You will probably need more plots than for a stand exam, and you'll need to gather and organize a lot of other information besides basal areas and volumes to do a good job. Financial situations can demand unbiased numbers, so you should modify your protocols to include correction for common biases such as boundary overlap. As other papers from this workshop show, many of those corrections are so quick and easy you may find yourself doing them even when they aren't strictly required. Legal situations demand accountability and known error rates. Your protocols must be razor-sharp. Finally, some situations are not critical. Trust your eye and your judgement to gather good qualitative information. If you know why you are cruising and where your cruising situation is in this spectrum, and have saved your data from past cruises to assist you with the design, you have everything you need to move on to the final step.

Choose Effective Tools and Adequate Intensity

Prism or Plot?

Not too long ago, this would have been a hotly debated question. But at this year's workshop, a show of hands indicated nearly everyone is using prism cruising. That's not really surprising, given the superiority of prism cruising for estimating things like basal area, cubic volume, and board foot volume.

Fixed-area plots do have their place. Many CFI designs use fixed-area plots, in part because they are old (and it's tough to change boats in mid-stream with CFI), and in part because the number-crunching is simpler. Small fixed-area plots may also be better if you are cruising uniformly small timber that isn't *too* dense (remember that in prism cruising, the "plot size" for small trees can be tiny!). But in most situations, prism cruising is simply far less time consuming, and gives you numbers that are just as good.

What BAF Should I Use?

So you've settled on prism cruising. What BAF should you use? I'll be up front here -I'm going to argue that in much of our timber, a BAF 10 is too small. A lot of people use it because that's what is in the standard undergraduate measurement textbooks. The problem is that a BAF 10 isn't in those textbooks because it's efficient for ordinary cruising, it's there because it's efficient for teaching. (10 is a nice round number; and you don't want students covering too much ground efficiently in a lab - the teacher spends too much time chasing after them.) Some folks choose a BAF 10 because of a rule of thumb out there that 6-10 trees per point, or something like it, is what you should aim for. Unfortunately, that rule of thumb hasn't been backed up by any data or any solid line of reasoning. You can do better.

A smart choice of BAF weighs the tradeoff between sampling variability (the standard deviation or CV of the points) and nonsampling errors (the mistakes that cause little creeping biases, or not-so-little biases). Sampling variability is directly related to BAF. Using a small BAF gives bigger "imaginary plots" for each tree than a large BAF does. So the CV of the points will be smaller with a small BAF, and you will need fewer points to get the same confidence limits width. That seems like a good thing. On the other hand, there are advantages in spreading your sampling effort over a larger number of locations in the woods - it makes you less susceptible to the variability represented by large-scale variations, like gaps, clumps, hemlock inclusions in hardwood stands, and so on. You're more likely to hit those features (but they really are out there), and more likely to hit them in about the right proportion.

A small BAF does have advantages if you suffer from "pushing the point" (Oderwald and Gregoire 1995). Remember that when you use a prism (not a stick or notch-type gauge), you are supposed to hold the prism over the point and move yourself around it. But inexperienced cruisers, or sometimes even experienced cruisers at the end of a long, hard day, can slip up and stand over the point, turning the prism around it. This effectively adds an arm's length to the "imaginary plot" radius of each tree, so you get an over-tally. It turns out the over-tally affects small trees more, and it is more of a problem when the BAF is large.

A more important problem in many forest types is non-detection (Wensel *et al.* 1980, Wiant *et al.* 1984). Non-detection occurs when you don't tally a tree you should have, either because you didn't see it at all, or because it was far away and borderline, and it was too much trouble to check it properly. This is much more of a problem with big (and valuable!) trees, because they can be farther away and still be "in" with the prism. Sampling with a larger BAF can solve the problem, though, because trees have to be closer to be tallied. For example, you have to be able to spot a 24" oak from 66' away if you are using a BAF 10. In poor light conditions, or a stand with much understory at all, or even a stand with very many trees, will you be able to see it and judge whether it is supposed to be tallied? Using a BAF 20, you only have to spot that tree from 46.7' or closer.

At this point, you are probably asking, "But if I switch from a BAF 10 to a 20, won't it take more time? I'll need to take more points." You're right that you will need more points - in typical conditions, almost twice as many (but not quite). But remember that you only tally half as many trees with a BAF 20. And they are all closer to the point, so it takes less time to walk over to each tree to get its DBH and check it for defects. Will you have to spend more time walking between points? No. For example, suppose you were going to do BAF 10's every 8 chains on lines 8 chains apart. Why not do BAF 20's every 4 chains on the same lines? It's the same amount of walking, you just stop twice as often for a faster look at what's around you. There is no rule that says your sampling "grid" has to be perfectly square -any reasonable rectangle will do.

Should you switch to a larger BAF without increasing the number of points? Probably not. Unless you thought you were already overcruising, you will need more points. And always keep a close eye on the results whenever you switch methods.

How Many Points? Really?

How many plots are enough? The formula is very simple. Whether you are doing point or plot sampling, the formula is

$$n=(t*CV/A)^2$$

with the symbols defined as:

n number of plots or points (not trees!); the statistical sample size

A the allowable error, in percent. For example, if you want to be within 20% of the answer you would get from a 100% tally, then A=20. You get to pick this, based on the client, the situation, and the objectives of the cruise.

CV coefficient of variation (%) - our familiar expression for how variable the data are. (This is the number you really want to get from past cruises in similar stands!)

t a number based on how sure you need to be, that the right answer is within A% of your cruise estimate. Now, you could look up t in a t-table (standard mensuration textbooks like Avery and Burkhart 2002 or Husch *et al.* 1982 include them), but here are some rough values:

To be right half of the time, use t=2/3.
To be right 2/3 of the time, use t=1.
To be right 90% of the time, use t=1 2/3.
To be right 95% of the time, use t=2.
To be right 100% of the time, scrap the formula. You need to tally every tree in the stand.

Here's a simple example: I'm cruising a typical mixedwood stand with a BAF 10 prism. I want to be 90% certain I am within 20% of the true board foot volume, so I set t=1.67 and A=20%. My records show a typical CV for board foot volume in this type is 40%. I calculate $n = (1.67*40/20)^2 = 11.1$ points. For higher certainty (such as 95% confidence) or tighter bounds (such as A=10%) I'm gonna need more points.

Now, a lot of foresters don't like this formula, because it tells them to do more work than they want to. That's tough. The equation doesn't lie. If it tells you to do a certain number of points, and you put in a lot less, your numbers just won't be as good as you want them to be, pure and simple. Sure, you can always increase A to crank down the number of points you need to do. Just be honest with yourself about what that means.

You'll have noticed, no doubt, that stand size never showed up in that equation. Some folks will tell you that means you should always put the same number of points in a two stands of the same time, even if one stand is 5 acres and the other is 50 acres. Strictly speaking, that's true, if you think your allowable error (A) is the same between the two stands. I don't know about you, but I'm much more concerned about a 20% error in my estimates for a 50 acre stand (or a 500 acre property!) than in just one 5 acre piece. So A may relate to stand size, and you probably do want to put more points in a bigger stand.

How does all this relate to percent cruise? It doesn't. A 10% cruise may be just right in a 50-acre stand. It will be way too much in a 500-acre tract. And nowhere near enough in a 5-acre tract. Besides, you can't get an honest percent cruise in advance for a prism cruise, anyway.

Random or Systematic Sampling?

If you know my job title, you know I am part statistician, so you may be expecting me to tell you to do strictly random sampling instead of sampling systematically with a grid or line-plot setup. It is true that most statistical formulas assume points are randomly located within each stand. How big a deal is it if you violate that assumption?

It turns out that it's not much of a big deal at all. In fact, sampling on a grid can be advantageous (although it's hard to prove it with the amount of data gathered in a typical cruise). Common sense tells you that a grid gives you guaranteed uniform coverage, and that should be good. There's some fancy-pants math that can prove it, too. The exception is when your grid spacing matches up to some pattern in your forest. Textbooks are full of pictures of regular ridge and valley patterns, and sad stories about foresters who always sampled on the ledge or in the swamp. A more realistic problem in the Northeast arises with modern mechanized harvesting. You set up a nice regular pattern of skid trails and ghost trails, making sure the logger always reaches out to just the optimum distance, and then the next time you come back to cruise... were you always in the skid trails, or always in the dense areas? Beating this sort of problem is really easy, especially if you've already had a look at your aerial photos. You just don't pick a plot spacing that could match up to the patterns you see.

There are some precautions you should take when you sample systematically. You should use a random start to get you to the first sample point, so you are not always starting right near the edge, or just as bad, always avoiding the edges. And don't move plot centers to avoid edges, stand boundaries, roads, gaps, and so on. It can distort your numbers and it's more work... not a good bargain. Don't believe me? Read on.

What About Points That Land In (Fill In The Blank)?

There's always something out there you didn't want to deal with - roads, swamps, you name it. But when a point falls there, what should you do? Not take the point? Move it nearby? Or put it in and take your lumps?

There are two correct answers, but each one requires a little bit of work. Which answer you choose depends on how you want to deal with the area of this "bad stuff."

Correct Answer #1: If the bad stuff is part of your calculated area for the stand or tract, put in the plot where it falls. If it is empty, enter it as an empty plot (remember an empty plot is different information than no plot!). Yes, it will affect your numbers. But if 2 of your 20 points on a tract fell in moose muck, it's a reasonable bet that about 10% of your tract area is in moose muck. That should be reflected in your numbers.

Correct Answer #2: You can always figure out how many acres of the bad stuff are in your stand or tract, and deduct them from the total. You don't have to do the plot in this case (especially helpful if the bad stuff is, say, a pond). But you should stay on grid and move on to the next point *as if* you had done the plot.

There are a whole bunch of incorrect answers, most of them arising from trying too hard to do the right thing. A common mistake is to throw out the plot, but then try to keep the total number of plots the same by putting in an extra plot somewhere near by. The problem is that areas *near* roads, *near* wetlands, and so on are often different from the run-of-the-woods. You also probably already sampled roughly the right number of these ecological edges using your grid. When you throw out the "bad" plot and put another in near the edge, you will bias your numbers to make the forest look more like edge. It's not a mistake that will destroy you, but it's a fair amount of work in the field, and for very little benefit. If you are worried about not having enough plots because of the "odd" areas in a woodlot, there's a simpler fix: just make the grid spacing slightly more dense when you plan the cruise, so you will have a few extra sample points and can afford to lose a couple.

Conclusions

A lot goes into making a good cruise, but a good cruise will give you reliable numbers. When your numbers are not good enough, you save money up front on cruising but pay for it later with bad decisions. It's also possible to cruise too well - wasting money on perfect numbers you just don't need. By making full use of your old cruises, understanding why you are cruising, targeting an appropriate accuracy level, and selecting efficient tools with an adequate intensity, you can count on numbers of the quality you need at the best possible cost.

References

Avery, T.E. and Burkhart, H.E. 2001. *Forest Measurements,* 5th ed. New York: McGraw-Hill. 456 pages.

Ducey, M. J. 2000. Prism cruising with diameter classes: theoretical considerations and practical recommendations. *Northern Journal of Applied Forestry* 17(3): 110-115.

Gregoire, T.G. 1982. The unbiasedness of the mirage correction procedure for boundary overlap. *Forest Science* 28: 504-508.

Husch, B., Miller, C.I., and Beers, T.W. 1982. *Forest Mensuration*, 3d ed. New York: Wiley.

Iles, K. and Fall, M. 1988. Can an angle gauge really evaluate “borderline trees” accurately in variable plot sampling? *Canadian Journal of Forest Research* 18: 768-773.

Oderwald, R.G. and Gregoire, T.G. 1995. Overstated volumes from pushing the point. *Southern Journal of Applied Forestry* 19:162-165.

Wensel, L.C., Levitan, J. and Barber, K. 1980. Selection of basal area factor in point sampling. *Journal of Forestry* 78: 83-84.

Wiant, H.V. Jr., Yandle, D.O. and Andreas, R. 1984. Is BAF 10 a good choice for point sampling? *Northern Journal of Applied Forestry* 2: 23-25.

Field Techniques

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Personal preferences and ingrained habits play a big role in the measurement tools and field techniques we regularly use. I suggest that we should be willing to reexamine those preferences and habits, correct our measurement techniques (if needed) and, experiment with new approaches we may not have used before. But first:

- Know the measurement objective! It influences the accuracy required, the sampling system employed, and the most suitable mix of measuring tools to do the job.
- Strive to avoid bias in all forms! Systematic distortions can arise from incorrect use of measurement tools, incorrect sampling methods, even bias in one's visual perceptions.
- Don't assume any mistakes you do make will be compensating! For example, cruisers will often tally every other borderline tree rather than measuring such stems. Why? Because its easier. HOGWASH! I've noted a common tendency among students to undercount stems at sample points. This means that borderline trees are also consistently undercounted. Not everyone views each potential borderline tree in the same way.
- Try to increase efficiency while on the point or plot by measuring and recording tree variables in a systematic fashion. Also, if working as a crew, divide up the work to be done at sampling locations so as to achieve maximum efficiency.
- Remember! The post-cruise statistics you or your computer program crunches do not take into consideration any technique errors you may have made. These errors add to and enlarge your calculated sampling error.

Tree diameters – Many cruisers prefer the Biltmore stick. It has no moving parts and can't get out of adjustment. Stick diameters will be correct if: (1) your stick <u>and</u> your eyes are at 4.5 ft. above ground on the tree's uphill side, (2) your eye is 25" from the tree, and (3) you do not move your head when taking the reading. Even if you are placing measured trees into broad diameter classes (such as 2-inch classes), if your technique is poor you may consistently be putting some stems into the wrong classes.

Tree/log heights – Heights are more difficult and time consuming to measure. Many of us rely on ocular estimates of the number of merchantable logs or log segments in trees and the grade or product designations in each. I suggest <u>measuring</u> one tree per plot or point before ocular estimating. At the very least, one ought to measure some stems first thing in the morning and again after lunch. Tree heights will vary greatly as you travel from type to type or up and down slopes. Don't estimate heights when standing near the base of the tree. Be willing to back off. Trees tend to look taller when you're standing directly beneath them. For good results use a 100 ft. base distance and a percent scale hypsometer to take height readings. A hypsometer with a topographic scale should be used at a base distance of 66 ft. You can vary the base horizontal distance from the tree as long as you adjust your height readings. For example, using a percent scale clinometer and standing at a horizontal distance of 85 feet from the tree one obtains a reading of –10% to the stump and +70% to the merchantable top diameter. Ignore the algebraic signs, add* the readings to obtain 80 and multiply by .85 to correct for not standing at the base distance of 100 feet. The final answer is 68 feet of merchantable stem length.

**Exception: subtract the lower from upper reading if a horizontal line from your eye is below the base of the tree*

One final tip for better height readings is not to move your head when taking readings to both the base and top of the tree. By first tilting your chin up you can achieve this and can take both readings by moving just your eyes.

Tree volumes – Regardless of whether your volumes are figured by your software program or by using volume tables you often must select an appropriate form class to use. A one percent change in Girard's form class creates a volume change of approximately 3 percent for most trees. Sampling form on standing trees is possible but a more convenient way is to measure trees being felled at an active logging job. A few minutes spent collecting actual form class data can make your volume estimates more reliable.

Defect deductions –Individual log scaling type deductions are time consuming to work out in the field. Fortunately, a cull percent factor can easily be applied to defective trees using tables which show average percentage of total tree volume by log or log segment. Dimensions of defective stems can also be reduced when entering them into the computer. A third option is to apply an overall species cull percent to the gross volume results you generate.

Cruise grid calculation – A systematic, square pattern grid is easily figured. Multiply the acres to be cruised by 43,560 and divide by the number of sample points. Take the square root of the result and you have your grid dimensions in feet. A random start for the first sample point on the cruise grid is highly recommended. Put the final grid on your cruise map and number the points.

Basal area sampling - While almost all foresters use point sampling the choice of tools varies. Wedge prisms are widely preferred but some cruisers are using angle gauges. Gauges include the Christmas tree gauge, the Cruiser's Crutch, and the Relaskop. When using any gauge the cruiser's eye must be over the point as this is where the sighting angle originates. With prisms, cruisers must carefully hold the prism directly over the point as the plot sweep is made.

Prisms should be held at right angles to the line of sight. Make a correction if slopes to dbh exceed 5 degrees. Measure slope along the line of sight to dbh with a clinometer. Next, put the prism on the flat edge of the clinometer, and with both held at right angles to the sight line, tilt the prism the appropriate degree of slope.

Correctly measuring borderline trees is important in obtaining good tree counts. Simply tallying every other borderline is not reliable for the reasons mentioned earlier. The plot radius factor multiplied by dbh gives one the horizontal limiting distance. To make the decision process less difficult, mark the back side of a 100' fiberglass tape with tree diameters at their limiting distances. This will speed up borderline decisions, especially when working alone. On most points the tape can easily be held horizontally. On very steep terrain multiply the cosine of the slope in degrees by the slope distance from the point to the tree to find actual horizontal distance.

Slopover – Sometimes a point on the cruise grid will fall close to the woodlot boundary and you instinctively know that the prism or angle gauge might easily pick up qualifying trees over the line. Options frequently applied in this situation are: (1) move the point back further into the cruise area or, (2) take a half point count and double the results. Neither of these methods does a good job of adequately representing edge trees in the woodlot. Edge trees may differ considerably in average diameter, quality and other characteristics compared to stems within the lot interior. Such trees need to be included in point tallies, especially where lots are small in size and have a high proportion of perimeter to acreage. The mirage method is recommended for dealing with slopover. First, tally qualifying trees within the tract from the point. Then, simply measure from the cruise point to the tract boundary and then extend that line the same distance to a correction point outside the cruise area. Any trees that qualify from the correction point are tallied twice. The mirage correction method can also be used with fixed area cruise plots.

Double check the tally at each point before leaving. Also mark and number each cruise point and tie in the ends of each cruise line. Add these details to the grid on your cruise map. Time and money will be saved if you or someone else needs to revisit the sample point afterwards. Try applying several of the recommended techniques. You'll get **more from your cruise** and **more from your crews!**

Reference:

Avery, T.E. & H. E. Burkhart, 2002, Forest Measurements, 5th Edition, McGraw-Hill, New York

What Do Your Cruise Results Mean?

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PART I – THEORY

At the conclusion of a timber cruise, three categories of numbers result, (1) the estimate, (2) the standard deviation and (3) the standard error. Here I will describe each statistic and why it is important to know it.

The Estimate

Usually the most important part of the timber cruise is the estimate. This statistic is our cruise result for the fundamental question of "how much?" For example, the cruise may be trying to determine how many cords of pulpwood are growing on a tract of land or how much is the timber worth in dollars.

Often the cruise may be conducted to diagnose the stocking of trees in which case we may want to know how many square feet of basal area per acre are growing in the stand, or what the average diameter at breast height is.

We would be kidding ourselves if we thought our estimate was the true value of our population. The estimate is no more than that, *an estimate*. We don't expect it to be the actual value of the population, but we do expect it to be within some pre-determined limit from the actual population mean.

When cruising with a prism, we really have 2 estimates for each value. For example, the estimated number of cords per acre is a combination of the mean VBAR[1] for cordwood and the mean basal area per acre. It is calculated by:

Mean VBAR x Mean Basal Area/Ac. = Mean Volume/Ac. {1}

<u>The Standard Deviation</u>

We often want to know how variable our data is. We can measure the variability by looking at how far each observation or cruise point is from the average. The difference is called a deviation.

To calculate the deviation we subtract the mean from each observation. It would be best to use the population mean, however, we will probably never know the real population mean. The best we can do is to use the sample mean, which, in the example (table 1), is 60.

Table 1			
Obs.	Mean	Deviation	Deviation²
60	60	0	0
80	60	20	400
40	60	-20	400
40	60	-20	400
100	60	40	1600
80	60	20	400
60	60	0	0
60	60	0	0
20	60	-40	1600
60	60	0	0

If we have done the math correctly, the deviations should sum up to zero. That's because the

[1] VBAR is the volume to basal area ratio calculated by dividing the volume by the basal area resulting in the mean volume per square foot of basal area.

observation values should lie evenly above and below the mean. The zero sum of the deviations doesn't help us much so we have to look for another way to quantify the deviations. We will use the quadratic mean, which is simply calculated by squaring each deviation (x) then summing them. We then divide by the number of observations (n) and take the square root of the result. However, here we use n-1 as a divisor because we used the sample mean instead of the population mean, which gives us 1 less degree of freedom.

Quadratic Mean (standard deviation)= S = sqrt [sum (x^2)/n-1] {2}

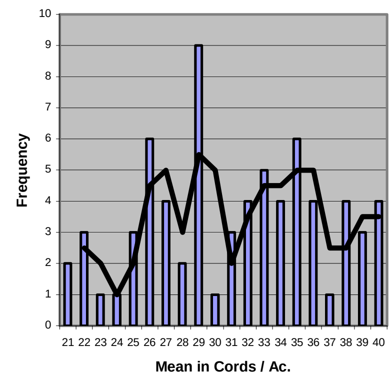
The value calculated in equation 2 is the average deviation of our observations from the mean. We know from more complex mathematics that if the population is normally distributed, about 68% of the observations fall within ±1 standard deviation from the sample mean. Conveniently, about 95% of the observations should fall within ±2 standard deviations from the sample mean.

If the population is not normally distributed, the standard deviation in itself has little meaning for us. However, even in non-normal distributions the standard deviation is useful because it is used to calculate the standard error.

If the standard deviation is divided by the mean we get the coefficient of variation, or the standard deviation expressed in a percentage form. This equation is simply:

Coefficient of Variation = CV = S/mean {3}

Figure 1. Sampling Results (Means n=5)

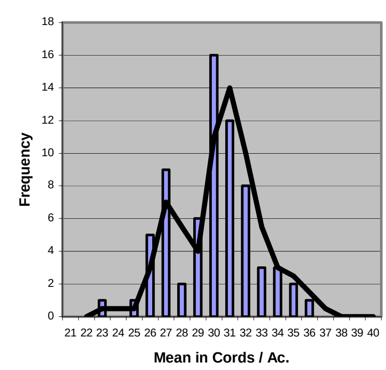


<u>The Standard Error of the Mean</u>

The standard deviation is a helpful indicator of the central tendency of the cruise data around the mean. However, it is more useful in calculating the standard error of the mean, which we generally just call the standard error.

The standard error is a very useful tool for determining how close our sample mean is to the real population mean. Just as about 68% of the observations in a normal population are within ±1 standard deviation of the sample mean, if we cruised the same stand many times, about 68% of the sample means would fall within ±1 standard error of the real population mean. Approximately 95% of the sample means would fall within ±2 standard errors of the real mean. The distance on each side of the sample mean where the true population mean is expected to fall is called the confidence limit, … the limits where we are confident the population mean will be.

Figure 2. Sampling Results (Means n=30)



Calculated in the same units as the estimate:

Standard Error (SE) = S/sqrt (n) {4}

Confidence Limits (CL) = t x SE {5}

where "t" is the number of standard errors required for the particular application.

Or calculated as a percent (%) of the estimate:

Standard Error as a % (SE%) = CV/sqrt (n) {6}

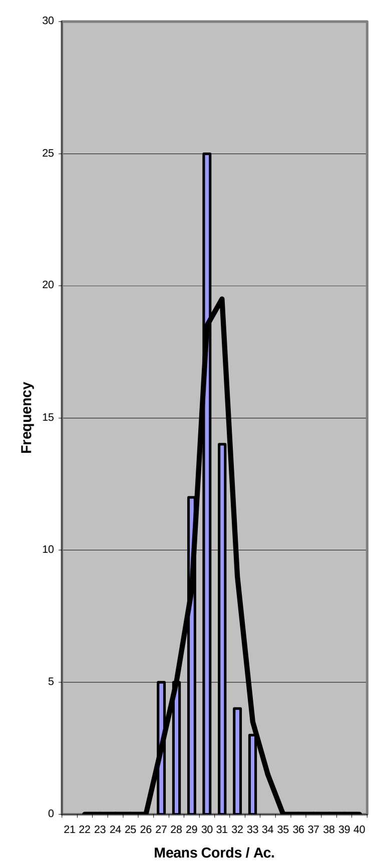
Confidence Limits (CL) = t x SE% {7}

Because we are using sample data to calculate the confidence limits, we need to use "t" instead of the number of standard errors required for our application. Tables are available for "t" values. These values can be greatly affected by sample size. For example, 95% of the sample estimates actually fall within ± 1.96 standard errors of the true population mean, however since our calculated standard error is based on a sample, we must use "t" to adjust for sample size. In samples such as these the degrees of freedom (df) will be n-1. For a 95% degree of confidence and a sample size of 5, "t" = 2.776 for 4 df; for the same degree of confidence but a sample size of 30, "t" = 2.045 for 29 df; and for a sample size of 90, "t" = 1.986 for 89 df. As you can see as sample size increases "t" approaches the true number of standard errors for a degree of confidence (in this case 95%).

What if your population isn't normally distributed? The central limit theorem helps us here. The theorem simply states that if the population is normally distributed, the means of all the possible samples (cruises) will be normally distributed. If the population isn't normally distributed, the means approach a normal distribution as sample size increases. So if we have put in enough cruise points, our mean should be predictable. Figure 1 shows the results from 60 different 5 point cruises of the same simulated forest stand. The vertical axis shows the number of cruises estimating a certain number of cords per acre (X axis). It is easy to see that there is no strong pattern of agreement between the cruises, leaving us with little certainty of what the actual population mean is. If we calculated the standard error for each of these cruises, we would expect a large standard error, often ± more than 100% of the mean.

Figure 2 shows 60 cruises of the same simulated forest stand but with 30 points each instead of only 5. Notice that the distribution of the cruise estimates is more normal-like and symmetrical. Also, it seems more probable that the population mean is actually around 30 or 31 cords per acre. Calculating the standard error for these cruises should result in a smaller number in most cases. We should get a narrower confidence limit than we would expect from a cruise of only 5 points.

Figure 3. Sampling Results (n = 90)



Finally, figure 3 shows 60 cruises from the same stand, however this time we took 90 points during each cruise. This distribution shows the cruises in good agreement around 30 cords per acre. Notice that these cruises form the most normal-like distribution even though the population is not normally distributed.

The standard errors from these cruises should be lower than the cruises that only contained 30 points. Generally, these cruises would yield on the whole, the narrowest confidence limits of the 3 sample sizes that we have looked at, or the best amount of confidence in our estimate. This graph has been stretched out vertically so that the values of the Y-axis are similar to those in figure 2.

The actual population mean for this stand is 30.4 cords per acre.

PART II – APPLICATION

In Part I of this paper we saw that sample size is important for determining estimates with generally small standard errors and confidence limits. Samples (cruises) with 90 observations (points) seem to result in much better (smaller) confidence limits and more symmetrical distributions than samples with only 30 observations. Like-wise, 30 observations seem to result in smaller confidence limits and more symmetrical distributions than only 5 observations. The problem in applying these principles is that taking 30 to 90 observations within a single stand during a cruise is very time consuming and costly.

One approach to improving the efficiency of a cruise is to break down the cruise estimate into its 2 simplest parts. Remember in equation 1 that the estimate is the mean VBAR times the mean basal area. The confidence limit from a standard cruise includes the confidence limit of the mean VBAR and the confidence limit of the mean basal area. In a cruise, these two confidence limits are simultaneously computed as one number. However, the confidence limits can be calculated separately and this gives us our clues to more efficient cruises.

If we are using a small basal area factor such as 10 BAF we may be tallying 10 to 15 trees per point. So, for each *point* basal area we measure 10 to 15 VBARs. From 10 cruise points we would get 100 to 150 VBAR observations but only 10 point basal areas. To increase the sample size of basal areas we need more points. It seems wasteful to take more VBARs just to get more basal areas. What we need are more basal areas not more VBARs!

The simplest way to correct the problem is to measure the same number of trees over more points (i.e. fewer trees per point). This will yield more point basal areas (one per point), while keeping the number of trees to be measured for VBARs approximately the same. Increasing the basal area factor of the prism will accomplish this. Instead of using a 10 BAF prism, choosing a 20 or 40 BAF prism will yield about 2 to 4 times more point basal areas respectively, for approximately the same number of VBARs. For nearly the same time resources, a much more efficient cruise can be conducted by increasing the number of points but maintaining or reducing the total number of trees (VBARs) measured through the use of the larger BAF prism.

It would be most efficient to balance out the CV’s of the VBARs and the basal areas. The CV’s are used because they express variation in percent, which makes comparisons possible between basal areas and VBARs. If the VBARs contain the greatest variation (a higher CV), then the VBARs should be sampled more intensively than the basal area. If the basal area has a higher CV then the basal areas should be sampled more intensively. Generally, I have found that the basal area will be more variable because VBAR is based heavily on merchantable height, and similar species will have similar heights (and similar VBARs). Stands that are species pure or close to species pure will usually have the lowest CV’s for VBARS. Mixed species stands will usually require more trees to be measured per point.

Researchers have had great success cruising stands with 2 prisms simultaneously. A very large factor angle gauge (BAF 80 – 110 is suggested for the northeast) is used to determine which trees to measure for volume, and a smaller factor prism (BAF 20 – 40) is used to count trees for point basal area. This method is usually referred to as *Big BAF* cruising (Iles – personal communication, Burk – personal communication). In this method, the mean VBAR and its standard error in percent are calculated as well as the mean basal area and its standard error in percent. The estimate is calculated using equation 1 and the standard error is calculated as a percent by using Bruce's (1961) equation:

$$\text{Combined Standard Error\%} = SE\%iii = \text{sqrt}\,(SE\%i^2+SE\%ii^2) \qquad \{8\}$$

Where sqrt is the square root, SE%iii is the combined standard error %, SE%i is the standard error % of the VBARs and SE%ii is the standard error % of the point basal areas.

Equation 8 shows some interesting facts about cruise efficiency. If SE%i is 10 and SE%ii is 40, the combined SE%iii will be about 41.2, so it serves no purpose to sample more of element i, since it has little impact on the final result. However, if element ii can be sampled more intensively so that SE%ii is reduced to only 20, the combined SE% will be reduced to 22.4, which is a substantial reduction in the error of the estimate. If element ii is basal area, then we have reduced our SE% quite dramatically by only taking more basal areas. Basal area can be measured quickly and efficiently with a prism or angle gauge resulting in a more efficient cruise.

A smaller BAF prism is used for basal area measurement because smaller BAFs tend to have lower standard errors since a larger area (less variable) of the tract is sampled. However, I suggest using a 20 to 40 BAF prism in most cases, especially if the basal area is 100 ft² or more. A BAF of 10 or less may lead to under-estimates of basal area (Wiant et al 1984, Barrett and Carter 1968, Husch 1955) probably due to trees that are missed while taking the point.

A forester need not begin this sampling method from scratch. As in traditional prism cruising, experience can be gained by looking at past cruises and calculating the standard errors for basal area and VBARs and using these statistics for future cruise designs.

Table 2		
Statistic	VBAR	Basal Area
Mean	185.3	31.0
CV	39.4	70.0
SE	14.6	6.9
SE%	7.9	22.3

Example:

During a recent cruise 25 white pine stems were tallied from 10 basal area points. Using equation 8, the SE%iii would be the square root of $7.9^2 + 22.3^2$ to equal 23.7% (see table 2). If we increased our sample so that the error in the VBAR were cut in half the SE%iii would only drop to 22.6% However, if we took more basal area points and cut the error in the basal area in half, the SE%iii would drop to 13.7%. How many additional *trees* must be measured to drop the SE%iii to the 13.7% achieved by increasing the sample on basal area? Since the SE%ii (22.3%) dominates the calculation tallying more VBAR trees shouldn't achieve our goal.

Double Sampling

A third alternative would be to measure trees at every nth point and record only basal area at each point between measure points. For example trees are measured at every 5th point and only basal areas taken on the remaining points. This method has been with us for many years and is often referred to as *double sampling*. A drawback to double sampling is that the measure trees are clustered around only a few points and may not be representative of the stand, or because of the patchy nature of many species within stands several species VBARs may not be measured.

CONCLUSION

Cruising forest stands yields estimates, standard deviations and standard errors. These three statistics are important in evaluating the success of the cruise in delivering important management information. The stand's variation and the sample size of the cruise work together to determine these cruise statistics. Foresters can increase sample size by conducting more efficient cruises. Efficiency can be achieved by balancing the CVs of the VBARs and point basal areas. Three field techniques can be suggested; (1) increasing the BAF of the prism used (generally to 20 or 40 BAF); or (2) using a large BAF for determining which trees to measure for VBARs and using a smaller prism for tree counts (Big BAF); or (3) measuring VBARs on every nth point and recording tree counts on every point (Double sampling). Foresters should evaluate and choose the method that provides the best estimates, narrowest confidence limits and best time efficiency when planning a cruise.

CITATIONS

Barrett, James P and Carter, James F. 1968 **Comparing methods of sampling a white pine stand.** Society of American Foresters, Journal of Forestry November 1968, pages 861-863.

Bruce, Donald 1961 **Prism cruising in the western United States and volume tables for use within.** Mason, Bruce and Girard. Portland, Oregon. As cited in Dilworth, J.R. and Bell, J.F. 1977 **Variable Probability Sampling – Variable plot and Three-P.** OSU Book Stores, Inc. Corvallis, Oregon.

Burk, Thomas – personal communication.

Husch, B. 1955 **Results of an investigation of the variable plot method of cruising.** Society of American Foresters, Journal of Forestry, August, 1955 pages 570 - 574.

Iles, Kim 1999 personal communication and website **www.island.net/~kiles/**

Wiant, Harry V. Jr.; Yandle, David O. and Andreas, Richard 1984 **Is BAF 10 a good choice for point sampling?** Northern Journal of Applied Forestry, June 1984, Society of American Foresters.

Writing Integrated Prescriptions from Your Cruise Results – or How Do I Recognize and Treat Wildlife Habitat Elements

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Writing an integrated forest and wildlife habitat management prescription is a several step process. Landowners first need to articulate their habitat and economic goals for the property. Forest and wildlife habitat managers can then manipulate habitat conditions at the landscape, stand, and within-stand scales to meet those goals, if they have the habitat information upon which to base a set of prescriptions. The described process can be found in DeGraaf et al. (1992).

Getting landowners to express their level of interest in wildlife habitat is the first step. Do their interests include a general wildlife diversity theme or are they particularly interested in certain species-groups: traditional game species (e.g. deer, moose, rabbit/hare, bear, grouse, woodcock, turkey, and waterfowl) or species of special interest or importance (e.g. threatened and endangered). A landowner may also be generally interested in particular wildlife taxa (e.g. amphibians (salamanders and frogs), reptiles (turtles and snakes), birds (neotropical migrants and residents), and mammals (bats, small mammals, and furbearers). Numerous habitat guidelines are available to landowners interested in game-species habitat; and forest stewardship and sustainability considerations (Williamson 1993; Elliott 1988; Sepik et al. 1981; VT Fish and Wildlife 1986).

Try to get a sense of habitat opportunity class across a larger landscape scale (Table 1). Current FIA statistics (Frieswyk and Widman 2000) indicate that most NH counties now (except Strafford) are at least 70 percent forested. Lands outside the Gulf of Maine coastal subsections still exceed 80 percent forested with the northern three counties ranging from 86 to 96 percent forested. Most properties typically managed by NH consulting foresters are still embedded in a predominantly forested landscape. Caution must be used when using this prescription process on predominantly upland and wetland nonforest landscapes, where forested stands are the less common features.

Consider using a 10-factor multiplier of the subject acreage to determine a rough composition of the area encompassing the subject property and surrounding neighborhood. Is the area almost totally forested (>90 percent) or mostly forested (70 to 90 percent)? How much aquatic habitat is available (<5 or >5 percent)? With this visual assessment of landscape composition, a consulting forester can begin assessing the current condition of the area against the generalized habitat composition goals presented in Table 1. These goals have been developed to present a broad range of habitat conditions over time for a variety of wildlife species.

Combining the surrounding area information with detailed current acreage or percentages of cover type, size, and stand density information gives the consultant a chance to assess the current condition (cover-type and size-class distributions) of the subject property against these habitat composition goals. Identifying the within-stand features (Table 2) in the inventory process completes the information needed to construct a set of integrated prescriptions. Integrated prescriptions evolve from the answers to questions like:

- Is there enough or too much hardwood or softwood acreage (a conversion potential)?
- Is there enough or too little aspen-birch acreage?
- Is there enough or too little hard and soft mast present?
- Is there enough 0-10 year age class acreage in this management period?
- Is there enough large-sawtimber class acreage?
- Are there sufficient amounts of large coarse woody debris and larger-diameter cavity trees across the property?
- What is the potential for vernal pools, seeps, and riparian habitat across the property?
- Are there known woodland raptor nest sites, heron rookeries, bald eagle or osprey nest sites, bald eagle winter roost sites, peregrine falcon aeries, and wintering deer areas on the property?
- What other special habitat elements are present on this property and how important are they to the landowner (apple trees, upland openings, beaver-created openings, uncut or old-growth patches, rare plants and natural communities)?

Those stands subsequently treated in the current management period are the stands with prescriptions deemed most important. These stands could be high value stands, high-risk stands, esthetic-driven treatments, market-driven treatments or wildlife habitat-driven treatments. Some stand prescriptions may be less commercially operable; and may need to be paired with more saleable stand prescriptions. Some stand prescriptions may be more appropriately treated through a cost-share program. There will probably be some stands with a hands-off prescription.

Most of the answers to the questions presented require more information than just the quality and quantity of available growing stock. The good news is that most of the structural information can be gathered in a comprehensive vegetative inventory. Putting this information in context with the surrounding lands composition will require some additional effort. Ascertaining the current status of special habitat elements and features requires on-the-ground knowledge and periodic contact with Natural Heritage Inventory for any new rare or uncommon occurrences in the surrounding area. Doing these things will greatly improve the development and implementation of integrated management prescriptions.

Table 1. Habitat opportunity and composition goals by percent (DeGraaf et al. 1992).

Composition	I	II	III	IV
Habitat breadth:				
Forest Nonforest Water	> 90 0-10 < 5	> 90 < 5 > 5	70-90 5-30 < 5	70-90 5-30 > 5
Size-class distribution:				
Regeneration Sapling-pole Sawtimber Large sawtimber	5-15 30-40 40-50 < 10	5-15 30-40 40-50 < 10	5-10 25-35 55--65 < 10	5-15 30-40 40-50 < 10
Cover-type distribution:				
Deciduous (not oak)				
Short rotation Long rotation	5-15 20-35	10-25 15-30	5-10 20-40	5-20 10-20
Hard mast - oak	1-5	1-5	5-25	1-15
Coniferous	35-50	35-60	10-35	25-50
Nonforest				
Upland openings Wetlands	3-5 1-3	3-5 1-3	15-30 1-3	5-10 3-5

Table 2. Within-stand features provided through integrated prescriptions (DeGraaf et al. 1992).

Within-stand feature	Clearcut	Shelterwood	Group/patch	Single-tree	Thinning
Canopy closure	Open	Partial	Partial	Closed	Closed – partial
Exposed perches	X	X	X		
Inclusions	X	X	X	X	X
Large cavity trees	X	X	X	X	X
Hard mast	Possible	X		X	X
Soft mast	X	X	X		
Midstory	Not immediate	Not immediate	Not immediate	X	X
Shrub layer	X	X	X		
Herb layer	X	X	X		
Coarse woody debris	X	X	X	X	X

Literature Cited

DeGraaf, R.M., M. Yamasaki, W.B. Leak, and J.W. Lanier. 1992. New England Wildlife: management of forested habitats. USDA For. Serv. Gen. Tech. Report NE-144. 271 p.

Elliott, C.A. (ed.). 1988. A forester's guide to managing wildlife habitats in Maine. University of Maine Cooperative Extension. 46 p. + appendices.

Frieswyk, T. and R. Widmann. 2000. Forest statistics for New Hampshire: 1983 and 1997. USDA For. Serv. Res. Bull. NE-146. 130 p.

New Hampshire Division of Forests and Lands, DRED, and Society for the Protection of New Hampshire Forests (compilers). 1997. Good Forestry in the Granite State: Recommended voluntary forest management practices for New Hampshire. Tilton, NH: SPNHF and Sant Bani Press. 140 p + appendices.

Sepik, G.F., R.B. Owen, Jr., M.W. Coulter. 1981. A landowner's guide to woodcock management in the Northeast. Orono, ME: Maine Agric. Exp. Station Misc. Rep. 253. 23 p.

Tubbs, C.H., R.M. DeGraaf, M. Yamasaki, and W.M. Healy. 1987. Guide to wildlife tree management in New England northern hardwoods. USDA For. Serv. Gen. Tech. Report NE-118. 30 p.

Vermont Fish and Wildlife Department. 1986. Model habitat management guidelines for deer, bear, hare, grouse, turkey, woodcock and non-game wildlife. Montpelier, VT: Leahy Press. 64 p.

Williamson, S.J. 1993. Forester's guide to wildlife habitat improvement. 2nd edition. Durham, NH: University of New Hampshire Cooperative Extension. 41 p.

Stand-level Inventory Needs for Silvicultural Prescriptions

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Some inventories are conducted for the purpose of developing silvicultural prescriptions. In many cases, however, prescriptions are developed by visually assessing stand conditions. In either case, it is important to recognize certain factors (Table 1).

Maturity: The proportion of trees that are mature or high-risk is critical in developing an appropriate prescription. One rule of thumb is that if the stand has over 50% of the basal area in mature and high-risk trees, the stand is ready for an evenaged regeneration harvest. This simply implies that there is insufficient immature material to continue managing the existing stand. High-risk trees are merchantable stems that will not last until the next entry – they might be called pathologically mature. One useful definition of maturity is financial maturity. As a general rule, a tree that has reached its peak of grade or product improvement, as defined by local markets, has reached financial maturity.

Quality: When assessing the remaining immature trees (those that are not mature or high risk), it is useful to know whether they have the future potential to make sawlog material (AGS – acceptable growing stock) or not (UGS – unacceptable growing stock). If the AGS basal area is less than the C-line as defined by appropriate stocking guides, the usual conclusion is that the stand should be regenerated. If the AGS is above the C-line, the stand should be maintained and managed by either evenaged or unevenaged methods. (The stocking guides apply to evenaged stands, but this general rule should work.)

Understory: Understory conditions (generally trees/regeneration below 4.5 inches dbh) are critical in developing appropriate prescriptions. If the understory is dominated by undesirable species (possibly striped maple, hobblebush, beech, red maple, etc.), this needs to be dealt with in developing the prescription. Where the understory is mixed and variable, it might be prudent to conduct a regeneration survey to assess the availability of acceptable stems. For example, the presence of 50-100 free-to-grow red oak or white pine stems per acre would be worth knowing. This could be determined by taking a series of 1/1000 to 1/500-acre plots and simply tallying the one or two most dominant stems. In general, undesirable understories are dealt with through harvesting systems causing heavy disturbance – groups, patches, clearcuts. Acceptable understories can be released through shelterwoods, overstory group removals, individual-tree selection, and the like.

Diameter Distribution: In assessing the possibilities for single-tree selection, the diameter distribution (trees/acre over dbh class) is of some concern. The usual goal is something approaching a J-shaped or slightly S-shaped distribution. Of particular concern is a diameter distribution that is somewhat level in the small diameter classes, especially when only the desirable species are included. This implies the need for some serious attention to regeneration, establishment, and small-stem development – possibly using groups or small patches to encourage prolific regeneration.

Patchiness: In assessing the possibilities of uniform silvicultural treatments (single-tree selection, uniform thinning, shelterwood) as contrasted with non-uniform operations (specifically group/patch selection), some assessment of horizontal structure or patchiness is useful. While this could be done through analysis of inventory plot data, the more usual approach (and possibly most realistic) is through a visual assessment.

Average Dbh: The usual statistic is the dbh of the tree of average basal area as determined by dividing basal area by numbers of trees and converting back to dbh. This is a standard entry in the available stocking guides.

Stocking: Using average dbh and basal area per acre as entries into the stocking charts, assessments can be made of total stocking and stocking of AGS in relation to the A-line (maximum stocking), B-line (target residual stocking), and C-line (minimum adequate stocking) levels. In general, stands nearer to the A-line than the B-line could be scheduled for some form of evenaged or unevenaged partial cutting (again, applying the stocking guides to the unevenaged condition).

Operational Things: Total volumes and volumes per acre available for harvest reflect the feasibility of a proposed silvicultural operation.

Other factors also influence the choice and details of a silvicultural prescription: current markets, wildlife habitat needs, and esthetic objectives. These concerns need to be factored in with the inventory items listed above to arrive at a final prescription.

Table 1.—Inventory measures used in developing silvicultural prescriptions. X provides a very general guide to the appropriate types of prescription, or to the prescription most related to the inventory measure.

Measure	Level	Clearcut	Shelter wood	Group/Patch	Single-tree	Thinning/ Improvement Cut
Mature/ Risky	Over 50%	X	X			
	Under 50%			X	X	X
Quality	AGS>C line			X	X	X
	AGS<C line	X	X			
Understory	Good		X	(Group Release)	X	NA
	Bad	X		X		
Dbh Distribution				X	X	
Patchiness	Patchy			X		
	Uniform		X		X	X
Mean Dbh						
Stocking	Near A-Line			X	X	X
	Near B-line or below					

Log Rule Tools and Timber Tools - Modern, Easy to Use and Inexpensive

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Introduction

Log Rule Tools and *Timber Tools* are programs written to address the practical needs of people involved with the management and harvesting of forest products. Log Rule Tools is a utility for calculating log volumes in multiple rules and comparing prices. Timber Tools is a timber cruising program intended for those who buy, sell or value timber. Both install like stand-alone programs in Windows 95, 98, NT, 2000 or XP, but require Microsoft Excel (version 97 or higher). Each of these program is explained here in turn.

Log Rule Tools

Log Rule Tools is used for accurate conversion of log volumes and prices between log rules. So-called "rule of thumb" conversions can be inaccurate because they fail to account for the variation in the differences among the rules, based on log size. This program allows you to rapidly enter a log tally and automatically calculates the log volumes in Doyle, Scribner, International, Maine, Roy and Vermont log rules. You can even add a seventh log rule customized to your own sawmill, based on kerf size and trim.

The purpose for converting log volumes from one to another is often to compare prices. Once you have entered a log tally, *Log Rule Tools* allows you to easily calculate equivalent prices in each rule. Enter a known price in one rule and the equivalent prices in the other rules are shown automatically. Prices from different mill specification sheets may be compared, even if you do not have a log tally to go with them. This comparison is made by entering a representative log tally (based on size specifications) and then entering the corresponding price.

One of the most appealing features of *Log Rule Tools* is that is free. It has been distributed to people in the Forest Products industry throughout the northeastern United State. Free copies of *Log Rule Tools* may be downloaded at the Northeast Forests web site (www.northeastforests.com). *Log Rule Tools* contains a partially working demonstration of *Timber Tools* software for making estimates of timber volumes.

Timber Tools

Timber Tools software is used in making estimates of timber volumes from field measurements. It is similar in look and layout to *Log Rule Tools*. This program was assembled to fit the budget and meet the needs of people who want to measure timber for the purposes of buying, selling or valuation. It offers user-friendly features and an innovative approach calculating timber volumes. Input from nearly 1,000 timber cruising workshop participants in 8 northeastern states was used in *Timber Tools*' design. This group included loggers, procurement foresters, consulting foresters, landowners, realtors, and public agency foresters. The result is an easy-to-use web page like interface that gets you information you can understand and use.

The user-friendly interface allows rapid data entry. Choose from straightforward calculations of total volume by species for 100%, plot and strip cruises or point sampling calculations of species volume per acre. Click on a region and then a species and you are ready to enter your field tally. Volumes are updated automatically in Doyle, Scribner, and International rules all at once. Special worksheets for spruce and fir timber give volumes in International and Maine rules.

Unlike some of the older and more cumbersome DOS-based timber cruising programs, *Timber Tools* allows data entry in one inch DBH intervals for ten different form classes. Conventional tree heights (1, 1-1/2, 2, 2-1/2 etc.) have been expanded to include volumes for new tree heights you will not find anywhere else - 1/2, 3/4, 1-1/4, & 1-3/4 logs. These new heights are particularly useful in accurately estimating the volume in valuable veneer trees.

This software is primarily based on Mesavage and Girard's classic *Tables for Estimating Board-foot Volume of Timber*. These tables were created for the USDA Forest Service in 1946 and remain a reliable source of information to this day. The tables themselves were updated slightly by the addition of the new height classes mentioned earlier. These new heights more accurately address the hardwood resource in some parts of the country. Default form classes used for various species in this software come directly from those reported by Mesavage and Girard. Users may opt to define their own form classes for each species. Nearly all of the Volume-Basal Area Ratio tables incorporated in *Timber Tools* were derived from the form class volume tables.

One flaw in *Tables for Estimating Board-foot Volume of Timber* that Mesavage and Girard recognized is that the tables will overestimate when use for northern conifers. The merchantable height of both spruce and fir takes very small top diameters (5") into account. Instead of using Mesavage and Girard's form class tables for these species, *Timber Tools* uses Maine rule tables from Young's *Additional Volume Tables for Maine* (University of Maine, 1971) and International rule tables composed in a similar fashion. Hardwood and hemlock pulpwood volume tables are referenced from Young's *Volume Tables for Maine*.

Affordability, reliability and ease of use have made *Timber Tools* a popular choice among consulting and procurement foresters throughout the country. *Timber Tools* is available through Forestry Suppliers catalog or through their web site at www.forestry-suppliers.com.

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(603) 968-9544 or 786-9544
Fax (603) 968-8544
we4hahns@yahoo.com

MULTICRUISE is a very flexible inventory processing program. Portions are based on the INVENT program developed by the University of New Hampshire in 1979. Computer Forest Consultants rewrote the INVENT program using Microsoft ® Fortran to run on microcomputers, and added many enhancements. The following summarizes the features of MULTICRUISE.

- Processes variable plot, fixed plot, strip, or 100% tally data
- Accepts data and produces summaries and statistics for one timber stand or many timber stands within a single processing job.
- Accepts data and produces summaries and statistics for up to five different sub-samples or "Levels". Common uses for Levels includes Cut/Leave tree tallies or Acceptable/Unacceptable growing stock tallies. The user defines the Levels to be used, allowing maximum flexibility.
- DBH (Diameter Breast Height) measurements in either 1 inch or 2 inch diameter classes.
- User defined Confidence Interval for determination of statistical sampling error.
- Allows up to 21 user defined tree species for each processing job.
- Allows up to 6 user defined products for each processing job. Each tree is measured by 8 foot long bole sections, each section is tallied by product code. Volumes can be calculated using either the International ¼", Scribner, or Doyle log rules, Cords, or Cubic Feet.
- Top diameter of each tree can be tallied; a default top diameter for each processing job can be selected.
- Output summaries can include the following tables:
  -Species stocking tables by Level, DBH class, Basal Area per Acre, Tree per Acre, and Volumes per acre for each product.
  -Same information for All Hardwoods, All Softwoods, and All Species.
  -Same information listed by Species but expressed as a percent of the total.
  -Volumes per acre listed by species and Product.
  -Total Volumes expanded by acreage, listed by species and Product.
- Output Options can be selected depending upon the amount of inventory detail desired:
  -Each species/diameter table, with summaries for each stand and the total job.
  -Summaries only for each stand and the total job.
  -Job summaries only, with or without species/diameter detail.
  -Output can be directed to a printer, screen or a disk file.

System requirements: IBM (R) PC or compatible, 256K RAM, MS or PC-DOS 2.0 or later.
Price: $300; $500 with Fortran Source Code; User's Guide only - $20.

Two Dog Forest Inventory Software

Jeff Underhill
FORESTERS INCORPORATED
LAND MANAGEMENT- INFORMATION SYSTEMS
P.O. Box 11750
Blacksburg, VA 24062-1750
(540) 951-2094
http://www.foresters-inc.com

Two Dog software provides a complete forest inventory solution for field and desktop computers that will increase your accuracy and productivity in the field and office.

First developed in 1993, Two Dog is an established application with a large user base. The latest release, Version 2.1, is the most comprehensive forest inventory application ever and will work for any user in all forest types. Two Dog is a platform with a future, created by a private company dedicated to its support and development.

OFFICE DOG SOFTWARE - *Inventory setup, data analysis and report generation*

Office Dog will process your field data quickly and accurately, providing volumes, values, and comprehensive reports.

CUSTOM INVENTORY
Using the **Method Manager**, Office Dog allows you to customize your inventory style, parameters and calculations.

RESULTS
Upload **Field Dog** files with a simple "point and click" or enter data straight from tally cards. Reports may be printed in a variety of formats from the simplest to the most complex.

VERSATILITY
Export reports to word-processing or spreadsheet programs. Link Two Dog data files directly with ArcView, MapInfo or other GIS platforms for **GIS/GPS compatibility**.

- Tree Grading and Multiple-Products per tree
- For: Plots, Points, 100%, Strip, %Mark and Tally
- Multi-Resource: Trees, Plants, Wildlife, and More
- Double-Point Sampling and Height Sub-Sampling
- Stump Cruising for Timber Trespass
- Customizable screens and user-defined Pick-Lists for prompts
- Volume tables by Species and Product
- All Standard Volume-Tables & Custom Volume-Table entry
- Extensive Reports with Complete Statistics

- Phone, web and email support from manufacturer (*1st hour free*)
- Professional, On-Site Training Available
- Software and Techniques Support 3rd Party Forest Certification

Platforms: Windows 95, 98, ME, NT, 2000 & XP

FIELD DOG SOFTWARE - *Data entry on handheld field computers*

FAST

Field Dog software is designed for rugged handheld computers such as Husky. Designed to increase productivity and accuracy, Field Dog software provides fast field data-entry with a user-defined interface. Field Dog is now more comprehensive and yet more flexible - turn menu items and features on & off to keep the interface simple to use in the field. Fully supports all the required information for certification.

SECURE

Data is automatically saved into fail safe memory so you can have peace of mind knowing that a day's worth of data can't be lost due to power loss or harsh field conditions.

FEATURES

- Point, Plot, and 100% inventories
- Double-point sampling
- Sub-sampling of merchantable or total height
- Tree grading and multiple products in a tree
- Up to 99 species and 40 products
- Multi-resource inventories – wildlife and plants
- Stratification by Stand – in the woods or office
- Stump-diameter cruising for timber trespass
- Up-to-Now statistics on volume, # trees, basal area and value in the field.
- Sample reliability and suggested sample size.
- User-defined pick-lists and on-screen help
- Positional information at the Tract, Stand and Point Level

Platforms: **Husky** FS/MP series, **CMT** PC5 series & **Juniper Systems** Allegro FPC

Handheld Field Computers

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What they can do for you…

Get out of the woods sooner – Faster point or plot sampling can be achieved due to the sleek and ergonomic design of modern day handheld field computers. One-handed operation provides for quick and efficient data entry and leaves the other hand free for other tasks. Inventory points are sampled at an improved rate, much faster than with a traditional tally card.

The forest at your fingertips – Rather than dealing with sloppy tally sheets, turning or flipping pages on a clipboard or notebook, a keystroke is all that's needed to collect point data and information such as ownership, location, accessibility, wildlife and all other critical non-timber values from a management standpoint.

Time is on your side – No need to spend hours re-entering the tally card data into your spreadsheet or database. All your inventory data is stored on the handheld unit and transfers directly to your PC or laptop in seconds. Calculations take no more than a few minutes and stand summaries and several other reports are a simple mouse click away.

Assume an hour of data entry time saved for each cruise and apply that hour over a week, a month or even a year. Imagine the time savings you could have. And time is money.

Coupled with Field Dog…

Improved Accuracy – Due to rigorous error checking and data validation, your calculated volumes, basal areas, trees per acre and other figures are more reliable than ever before.

Up-to-Now Results – the field forester now has the ability to make management decisions in the field. With Field Dog running on a handheld computer, you may calculate volumes, basal areas, trees per acre and dollar values along with the statistics for each, right there in the woods! This powerful feature gives the user the opportunity to present key information to a landowner on the spot and allows for close-up analysis without going back to the office.

What To Look For In a Handheld Field Computer

<u>Durability</u> – You want a machine that can repeatedly withstand drops, bangs, bashes, thunderstorms, submersions and all other hazards that a typical timber cruise can deliver. All the machines we sell and support meet or exceed industry standards for durability and data retention.

Ergonomic Design – What good is a bombproof unit if you have to hunt and peck keys to enter data? You need to be as fast or faster than a pencil and tally card, so a unit that lends itself to easy, one-handed data entry is desirable.

Performance – Clock speed and memory are crucial. You don't want to wait for several seconds while the computer processes your last keystroke. More so, you need a unit with enough disk space to store at least a day's worth of field data. In technical terms, processor speeds range from 8 MHz to over 100 MHz. Disk space ranges from 2 to 32 MB.

Battery Life – A sleek and rugged field computer is also of no use if it can't stay powered on for a full day in the woods. Most units today boast 40+ hour battery life on a single charge. Depending on your use for any given timber cruise, a more likely figure is in the neighborhood of 12 – 20 hours. All models we support will perform all day with options for AA alkaline replacement and lithium ion emergency backup.

Rugged Handheld Field Computers vs. Palm/Pocket PC Handsets

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Today's market is flooded with many state-of-the-art handheld PC's (also known as Palm, Pocket PC and PDA). These modern palm sized units are easily obtained by a short drive to the mall or with a simple mouse click. The potential is there to better organize daily activities not only related to business, but to personal, family and other areas as well. Versatility of these relatively inexpensive Palm sized units is ever increasing with features allowing for email, Internet, navigation, entertainment and other mobile communications on the go.

Considering all the apparent benefits of a PDA, it would seem that they would be ideal for taking to the woods for a day or weeks worth of inventory. And taking the average price into consideration, one would think it the obvious choice over (or successor to) the larger, heavier and more expensive handheld data collectors that have been tromping through the woods for over a decade. A closer comparison of the two types will show that this is not the case and may persuade you to reconsider your investment.

Rugged handheld field computers (RHFC) manufactured by companies such as Itronix-Husky, Juniper Systems and DAP Technologies are built with data collection in mind. In the area of forest inventory, these units are intended solely for the purpose of getting you out of woods sooner with safe, sound and accurate data.

Field Worthiness: Rugged handheld field computers are ready for abuse. One look at a Husky FS series model and you'll see why. We're not sitting in a coffee shop, strolling on a city street or tilted back in our first-class seating accommodation, we're in the woods. Limbs, branches, rocks, deadfalls, streams, swamps and bogs eagerly await us in most instances and therefore, we need a unit that can stomp through it all with us. There isn't a single PDA tough enough to withstand repeated bashes, bangs, drops and inundations that a field forester is likely to deliver. Almost all rugged handhelds today are shockproof and waterproof (submersible) to military specifications.

Ergonomics: One of the nicest features offered today in rugged handhelds is the ergonomic shape that lends itself to user efficiency. Keyboards are arranged in a fashion that allows for one-handed data entry and frees up the other hand for other tasks such as a prism or Biltmore stick. With a PDA, users most use the pen stylus to enter data on the screen, thus, a two-handed operation.

Screen Properties: Although screen size isn't vastly different between rugged handhelds and PDA's, durability and readability are key issues here. Rugged handheld displays are designed to absorb impact and resist scratching while providing for maximum readability under conditions where the screen is covered with rain, snow, ice or even pollen. The PDA touchscreen falls well short of this standard. One well-placed (of course, unintentional) blow to a Palm style screen can and will send you back to the truck for tally sheets.

Processing Speed and Performance: Several of the most powerful PDAs operate on a Windows CE platform. This essentially is a stripped down pocket version of Windows as we've been using it for years. Although this provides for a familiar interface in the woods, at the same time, it has the potential to undermine your productivity. Since most PDAs don't have a full keyboard, data entry relies on touch screen interaction via drop-down lists or scrolling functions. This touch screen process is much slower than typing data straight into a DOS interface on a unit that displays a full alphanumeric keyboard designed for one-handed entry. You can find several Windows CE units that offer full keyboard access, yet very few are designed for efficient one-handed entry. Either the keys are too small or the keys are spread out in a non-productive fashion. Another productivity concern is that of the operating system itself. Due to the complexity and nature of the Windows environment, processes that go on in the background take a heavy toll on the next subject.

Battery Life: Due to improvements in battery technology and system power monitors, one can expect their unit to last at least an 8 hour field day. Most of today's field computers can easily sport a 30 plus hour battery life. However, there are several unit features, such as a screen backlight, that can rapidly drain your battery of power and there is nothing which drains batteries faster than a windows program running at top clock speed. Many reviews of top name Windows CE units have criticized the poor battery life experienced even under light loads. Should you run out of power in the field, your only options are either a backup battery or an alternative power source such as AA alkaline batteries. The majority of PDAs don't offer this capability, but are standard features on most rugged handheld field computers.

Price: One of the greatest advantages of the PDA is the price. For the same amount you'd pay on a Juniper Systems Allegro, you could have 10 Palm units. Unfortunately, many individuals shopping for a data collector base their decision solely on this factor and ignore other important considerations. The point here is that you're likely to go through 10 PDAs in the same amount of time as one rugged handheld.

Data Transfer: Clearly the one advantage PDAs have over rugged handhelds is the ease of transferring data to and from a PC. For most Palm units, the process involves the user simply placing the unit in a cradle and walking away. This functionality is made possible through the use of USB ports and a plethora of well-supported software. The majority of rugged handhelds depend on correctly configured serial ports and a quality null modem cable. The handshaking process here can often prove to be a highly frustrating task.

Inevitably, we will begin to see field worthy and efficient versions of the multi-functional PDA, but until that technology evolves, the higher priced rugged handheld is still the best tool for the field

NED software for forest management: much more than cruising[1]

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Abstract

The term NED describes a set of computer programs intended to help resource managers and landowners develop goals, assess current and potential conditions, and produce sustainable management plans for forest properties. NED-1 helps analyze forest inventory data from the perspective of various forest resources for management areas up to several thousand acres. The electronic data collection program NEDDC interfaces directly with NED-1 to facilitate use of field data recorders. Programs such as the Forest Stewardship Planning Guide and NEWILD allow people with an interest in managing their forests but lacking detailed data to improve their understanding of various management activities and their effects on the forest. StewPlan, the latest release, is a form-generating program that helps prepare stewardship plans that meet the requirements of the USDA Forest Service Stewardship program. The resources NED addresses include visual quality, ecology, forest health, timber, water, and wildlife, allowing a user to evaluate the degree to which individual stands or a management unit as a whole may provide the conditions required to accomplish specific goals. Users can select from a variety of reports including tabular data summaries, general narrative reports, and goal-specific analyses. An extensive hypertext system provides information on resource goals, the desired conditions that support achieving those goals, and related data used to analyze the actual condition of the forest, as well as detailed information about the program itself and the rules and formulas used to produce the analyses. Further development, currently known as NED-2, will enhance that capability of the software to incorporate cutting treatments and simulate development of forests through time and allow data collection with inexpensive handheld computers. The programs are being developed by the USDA Forest Service's Northeastern and Southern Research Stations in cooperation with many other organizations and individuals.

Introduction

Deciding how to manage forest property can be complex and sometimes difficult, especially if many goals need to be met in one area. Keeping track of lots of information and making many calculations are things that computers do very well. NED is a family of computer programs designed to provide prescriptions and analysis for managing forests for multiple values on a landscape scale. Some of these programs are in wide use by a variety of forestry professionals throughout the Northeastern United States, and others are being used by

[1] The use of trade or firm names in this article is for reader information and does not imply endorsement by the U. S. Department of Agriculture of any product or service.

landowners, educators, and school children interested in what makes up their forests and how various activities may affect the landscape.

Each program associated with NED addresses a different need in the process of deciding what to do to manage forested lands. Some NED products help create stewardship plans and help professional foresters develop management strategies. Other NED products help do outreach and education to students and owners of nonindustrial private forests (NIPF). NED includes the best tools available to illustrate to NIPF landowners why and how they should manage their lands to achieve their stewardship goals without telling anyone what the right thing to do may be. This emphasis on supporting the decisions of the landowner or manager through analysis and expert advice means that we do not allow NED to come up with "the right answer". Instead, we try to provide users of the software with a general understanding of their situation while using data collected from their woods to help analyze specific questions. The key is that through this approach we are able to help people consider multiple benefits and the tradeoffs among them.

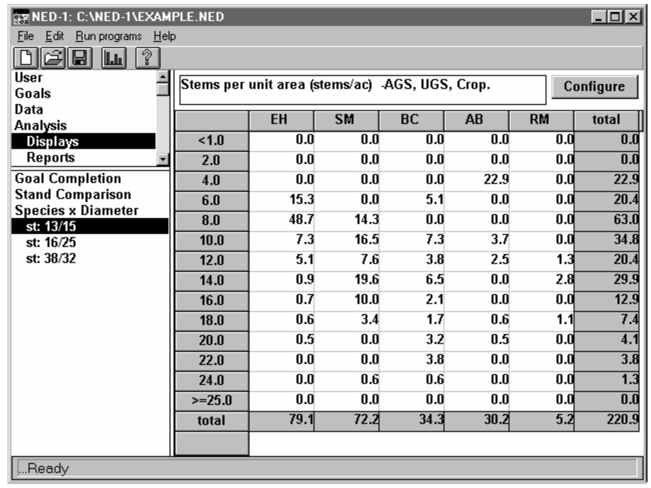
The intended users of NED include all who are interested in management of forest land, principally those responsible for the individual management decisions on specific units of land. Current capability of the program focuses on the northeastern United States but is being expanded. The NED system will facilitate translation of general goals into specific and compatible goals. NED will then be able to conduct specific analyses of management recommendations for units of land with these goals. Silviculture often heads the list of tools used by resource managers to achieve their goals. In its broadest sense, silviculture includes both direct and indirect manipulation of forest vegetation. The most direct and most traditional method familiar to foresters is cutting trees, but planting, burning, and other activities are also part of silviculture. NED attempts to provide as much information as possible to a user regarding possible management goals for a particular property, the conditions necessary to meet those goals, and possible silvicultural activities that can help move conditions in the forest closer to the desired ones. Thus, the two primary groups of users envisioned are consulting foresters, either private or service foresters, and public forest resource managers such as district-level managers on state or national forests. Private landowners without training in resource management can use parts of the system without assistance but are not expected to utilize NED's full capabilities. Training in the use of some of the programs is likely to be helpful even to professional natural resource management practitioners.

NED software is being developed by researchers in the USDA Forest Service affiliated with the Northeastern Research Station and the Southern Research Station, in cooperation with many other forestry experts. The term NED originally stood for "North East Decision model", but since the programs have begun to address issues outside the Northeast, we no longer consider it an acronym, but merely the name of a friendly assistant, like Fred or Ted or Ed.

Available Programs

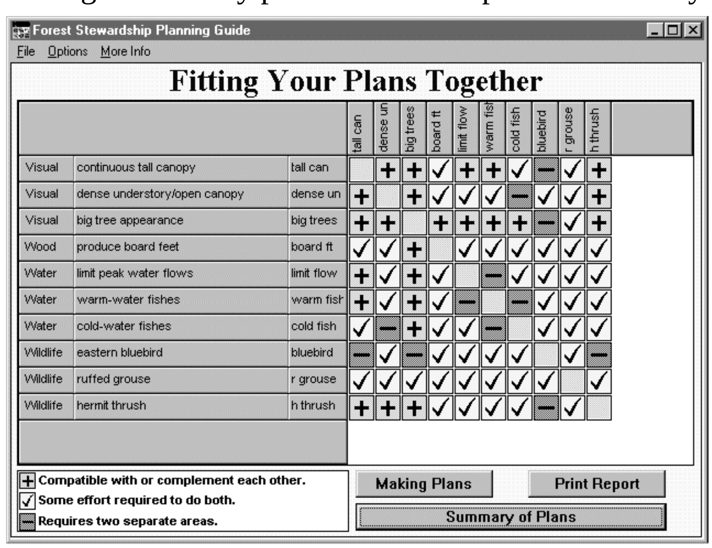
To facilitate useful input from potential users in the design of the system, NED's developers have chosen to release independent software programs in stages. The initial freestanding programs such as NED/SIPS (Simpson *et al.* 1995), NEWILD (Thomasma *et al.* 1998), and the Forest Stewardship Planning Guide (Alban *et al.* 1995) have a large body of users, have generated considerable comment, and have influenced the design of additional software. These programs are available for downloading at http://www.fs.fed.us/ne/burlington/ned. StewPlan is still in its testing phase, but it is also available at the NED web site.

NED-1 is a Windows® program that emphasizes the analysis of forest-inventory data from the perspectives of various forest resources (Twery *et al*. 2000). The resources it addresses include visual quality, ecology, forest health, timber, water, and wildlife. The primary function of NED-1 is to evaluate the degree to which individual stands, or the management unit as a whole, provide the conditions required to accomplish specific goals. An extensive help system provides the user with information about user-identified resource goals, the desired conditions that support achieving those goals, and related data used to analyze the actual condition of the forest. NED-1 is designed to begin to integrate the pieces from the initial programs into a single interface. It includes the multiple-resource, multiple-value goal sets defined within the Forest Stewardship Planning Guide, the evaluation of wildlife habitat as represented in NEWILD, and much of the timber inventory summary and economic analysis provided in NED/SIPS. NED-1 adds the complexity of a multiple-stand management unit and provides analysis for an entire management unit as well as the individual stands separately, so the user can evaluate conditions across the entire property.



The inventory and data entry system for NED-1 is extremely flexible. It includes many variables not generally inventoried by traditional foresters, including a variety of understory and ground layer characteristics, so that the inventory may be evaluated for visual resources and wildlife habitat. However, if a user is interested only in some characteristics, the data entry forms can be modified to match the variables collected. A data collection and transfer program, NEDDC, is available to facilitate use of NED-1 with portable data recorders that run the DOS® operating system.

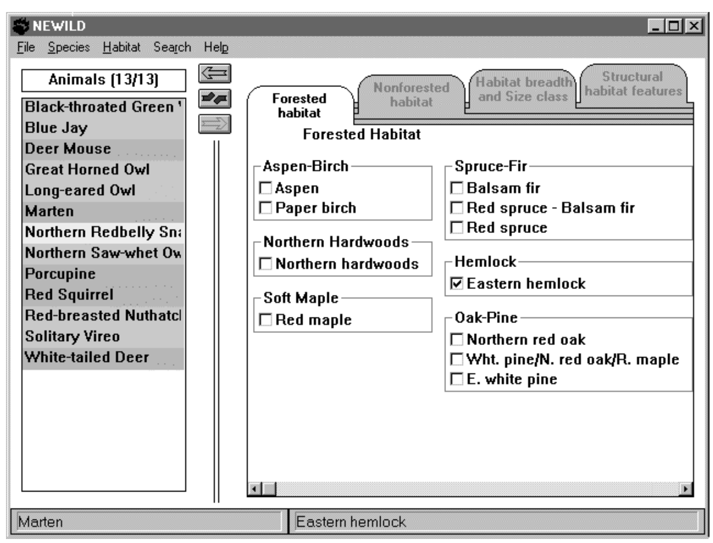
The Forest Stewardship Planning Guide (Alban *et al.* 1995) is designed to provide people with exposure to and explanations of a wide range of forestry practices used to produce a variety of benefits from forests. The program begins by giving a user extensive background information on forests in general, then attempts to elicit the landowner's goals for the forest. The Windows®-based program guides the user through a process of selecting forest stewardship goals. This program makes limited recommendations on managing a forest for specific goals and describes the conditions that must be created or enhanced to accomplish them. Many landowners in New York,



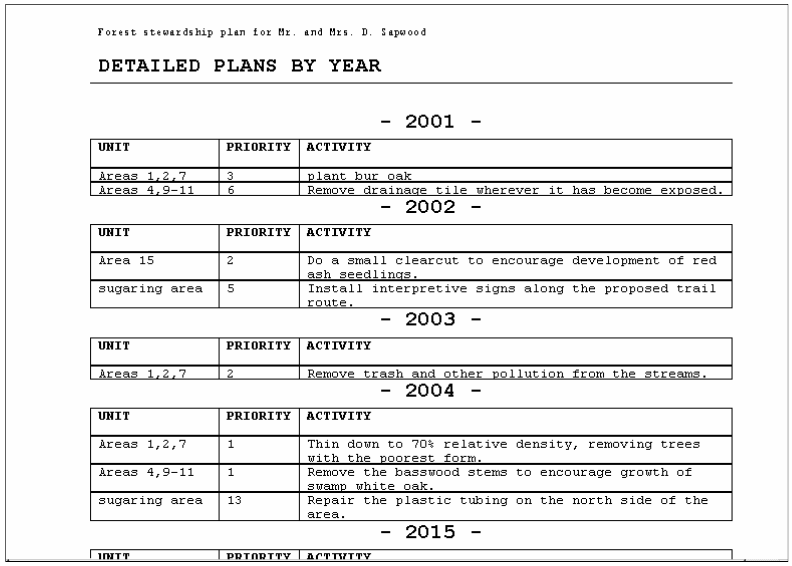
Pennsylvania, and elsewhere have found this a very helpful introduction to the possibilities available to them as they contemplate doing things in the forest. Many people have found it most useful in the way it allows them to compare and contrast the compatibility of various management goals. Successful workshops for landowners have been held in several northeastern states using this software. Numerous private consulting foresters use this program to introduce forest management topics to new clients. The Planning Guide requires no actual forest inventory or data from the woods, so it is easy to use in a classroom setting and has been adopted by several high schools and colleges as part of their curriculum.

NED/SIPS (Simpson *et al.* 1995), a program subtitled Stand Inventory Processor and Simulator (SIPS), provides a means of creating, managing, and analyzing forest-inventory records at the stand level. Its interface simplifies entering and editing stand-inventory data. Once data are entered, many analytical tools are available to help understand and evaluate the data. A variety of reports can be generated to describe the vegetation structure, timber value, and economics of the stand. Users can apply any of a set of standard treatments to the stand or design a customized cutting scheme, and use one of the four incorporated stand-growth simulators (NE TWIGS, SILVAH, OAKSIM, and FIBER) to show what the stand may look like in the future. NED/SIPS runs in DOS and is subject to difficulties inherent to that system, but it is reasonably robust and has proved useful to many foresters over the past 5 years. The NED/SIPS interface features pull-down menus and context-sensitive help, access to four growth-and-yield simulators using the same data file format, overstory summary tables for common measures of stand characteristics (such as density, species, and volume), and economic analyses of incomes and expenses over time.

NEWILD, published in 1998 (Thomasma *et al*. 1998), is designed to provide access to and evaluation of information on species-habitat relationships for 338 terrestrial vertebrate species in New England. This program is based on publications by DeGraaf and Rudis (1986) and DeGraaf *et al.* (1992) that describe the habitat conditions used or preferred by these species of birds, mammals, reptiles, and amphibians. A portion of the text from these publications has been incorporated into the HELP portion of NEWILD. A user can provide NEWILD with a habitat description and determine what species might be likely to use the area, or ask the program to identify the habitat preferences of a particular species of interest. Most of the species addressed in NEWILD are present in Pennsylvania, and most have equivalent habitat requirements. There are some exceptions, such as the white-tailed deer rarely needing a protected wintering area in Pennsylvania, but the vast majority of requirements are the same. The wildlife habitat analyses in NED-1 are based on the same sources as in NEWILD, but have been adapted to Pennsylvania conditions.



StewPlan, a program just released for testing in the summer of 2001, is available from the NED web site. (Knopp and Twery, http://www.fs.fed.us/ne/burlington/ned). This software provides a standardized format for preparing a stewardship plan in conformance with all current guidelines for the Forest Stewardship program as administered by the USDA Forest Service, State and Private Forestry. StewPlan is designed to be used by consulting foresters and service foresters charged with the responsibility of preparing stewardship plans, but it is simple enough to use so that typical landowners familiar with computers could use it as well, provided they had the necessary resource expertise. Using a typical Windows-style interface, StewPlan facilitates entry of data for identification and description of a forest property, detailed descriptions of existing conditions, management goals, and specifications of anticipated activity for the duration of a plan. It provides a convenient summary in printed form as its primary output.


Forest stewardship plan for Mr. and Mrs. D. Sapwood

DETAILED PLANS BY YEAR

- 2001 -

UNIT	PRIORITY	ACTIVITY
Areas 1,2,7	3	plant bur oak
Areas 4,9-11	6	Remove drainage tile wherever it has become exposed.

- 2002 -

UNIT	PRIORITY	ACTIVITY
Area 15	2	Do a small clearcut to encourage development of red ash seedlings.
sugaring area	5	Install interpretive signs along the proposed trail route.

- 2003 -

UNIT	PRIORITY	ACTIVITY
Areas 1,2,7	2	Remove trash and other pollution from the streams.

- 2004 -

UNIT	PRIORITY	ACTIVITY
Areas 1,2,7	1	Thin down to 70% relative density, removing trees with the poorest form.
Areas 4,9-11	1	Remove the basswood stems to encourage growth of swamp white oak.
sugaring area	13	Repair the plastic tubing on the north side of the area.

- 2015 -

UNIT	PRIORITY	ACTIVITY

Acknowledgments

Many more than 100 people have contributed to the development of NED software through participation on committees, testing of preliminary versions, or providing financial or moral support. Suffice it to say that without their hard work and dedication, NED and NED-1 would not have been possible. We are most indebted to David A. Marquis, whose vision and energy conceived the project and sustained its early development.

References

Alban, L.M., Thomasma, S.A. and Twery, M.J. 1995. Forest stewardship planning guide user's manual (Version 1.10) [Computer program]. Gen. Tech. Rep. NE-203. Radnor, PA.: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 15 p. [Computer disk].

DeGraaf, R.M. and Rudis, D.D. 1986. New England wildlife: habitat, natural history, and distribution. Gen. Tech. Rep. NE-108. Broomall, PA.: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 491 p.

DeGraaf, R.M., Yamasaki, M., Leak, W.B. and Lanier, J.W. 1992. New England wildlife: management of forested habitats. Gen. Tech. Rep. NE-144. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 271 p.

Simpson, B.T., Kollasch, R.P., Twery, M.J. and Schuler, T.M. 1995. NED/SIPS user's manual:

Northeast decision model stand inventory processor and simulator (Version 1.11) [Computer program]. Gen. Tech. Rep. NE-205. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 103 p.

Thomasma, S.A., Thomasma, L.E. and Twery, M.J. (1998) NEWILD (version 1.0) user's manual.[Computer program] Gen. Tech. Rep. NE-242. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station. 28 p. [1 computer disk; user's manual].

Twery, M. J., H. M. Rauscher, D. J. Bennett, S. A. Thomasma, S. L. Stout, J. F. Palmer, R. E. Hoffman, D. S. deCalesta, E. Gustafson, H. Cleveland, J. M. Grove, D. Nute, G. Kim, R. P. Kollasch. 2000. NED-1: integrated analyses for forest stewardship decisions, Computers And Electronics In Agriculture 27(1-3): 167-193.

The Society for the Protection of New Hampshire Forest's
Bio-Timber Inventory (BTI)

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The Society for the Protection of New Hampshire Forest's Bio-Timber Inventory (BTI) is a complete land management system, designed to give foresters and land managers the tools they need to practice eco-system based forest management. The product of more than 6 years of research and development, the BTI has benefited greatly from the input and ideas of many natural resource professionals, including; foresters, ecologists, wildlife biologists, botanists, statisticians, and computer programmers.

The BTI system consists of three primary components. First, the BTI Field Method has been fully coded and programmed for use with electronic data loggers (users without data loggers can fill out paper field forms and transfer the data to a PC afterwards). Second, a software program named Sylvester processes field and non-field data and exports user-chosen reports to a management plan template. Third, Sylvia (a suite of custom-built ArcView extensions) converts field and non-field data into ArcView maps, using three separate applications (BTI-Grid, BTI-Path and BTI-Map).

In the field, the BTI augments established timber cruising practices with targeted ecological data collection, providing foresters with a practical way of performing comprehensive inventories. In the office, a suite of new software programs is used to process BTI field data, automatically converting it into a variety of powerful tables, graphs, queries and ArcView (GIS) maps. Property features that are not sampled in the field (such as deeds, taxes, bound status, gates, signs, trails, soils, stratified drift aquifers, etc.) are also automatically converted into tables and maps by the software. All told, the software automates the production of more than 60 reports (tables, graphs, queries and maps) from both field and non-field sources. Users then have the option of automatically exporting any or all of these reports directly into a management plan template, greatly expediting the often tedious job of forest management plan production. The end result is a comprehensive forest management plan that integrates timber information with ecological attributes and processes (in keeping with Green Certification guidelines), for a fraction of the time that a "regular" plan would have taken to produce.

Ecological elements sampled and processed by the BTI system include:

- ✓ Vertical profiles of vegetation layers and their respective densities, facilitating wildlife habitat modeling
- ✓ Disturbance mapping; whether biotic (animals, insects and/or diseases), abiotic (ice damage, blowdown, etc.), or human (prior forest management activities and/or other land uses)
- ✓ Age class distribution (even or uneven-aged classification of stands)
- ✓ Aspect and slope
- ✓ Maps of landscape-scale features, such as stratified drift aquifers, watersheds, surface waters,

wellhead protection areas, land type associations (LTA's), etc.

- ✓ Extensive New Hampshire soils information (derived from published soils manuals and other sources), including soil attribute tables and maps. For users outside of New Hampshire, the system will support the substitution of NH soils data with soils information for other states
- ✓ Per acre estimates of snags (dead standing trees) and downed logs, important habitat features for wildlife
- ✓ Hydrologic features, including seeps, streams, etc.
- ✓ Locative maps of wildlife sign and special habitats, including tracks, scat, bear-clawed trees, vernal pools, deer yards, etc.
- ✓ Probable natural forested plant communities (as interpreted from the New Hampshire Natural Heritage classification system)
- ✓ Unusual, rare, threatened, endangered, and/or invasive alien plant occurrences, both woody and non-woody (herbaceous)
- ✓ A master list of all woody and non-woody plant species identified during the inventory
- ✓ Maps of recreational and cultural features, such as trails, vistas, stonewalls, wells, cellar holes, orchards, old roads, etc.

Silvicultural information of value in forest management includes:

- ✓ Stand delineation and mapping
- ✓ Per-acre timber volumes (board-foot, cord, ton, cubic-foot or cunit) by user-assigned product class (e.g., veneer, sawlog, pulpwood, etc.) - by species, by stand, and property-wide
- ✓ Stand and stock tables - by species, diameter and trees per acre
- ✓ Quantified and proportional estimates of overstory vs. understory and acceptable vs. unacceptable growing stock trees - by species, by stand and property-wide
- ✓ Relative densities by species and by stand
- ✓ Cut and leave basal area and board foot estimates
- ✓ Proportional estimates of damaged trees by stand (also of use in wildlife habitat assessments)
- ✓ Regeneration stocking estimates by species and by stand
- ✓ Silvicultural prescriptions, by sample point and by stand
- ✓ Operability maps showing the types and locations of areas with operating limitations (slope, terrain, wet, etc.)
- ✓ User-defined value estimates of cut/leave and/or all standing timber, by species and by stand
- ✓ Site index tables (derived from published soil manuals)
- ✓ Soil maps showing relative timber productivity (derived from published soil manuals and other sources)
- ✓ Statistical confidence limits, associated to a variety of quantifiable estimates (both commercial and non-commercial)