Evaluating and Scheduling WHITE-PINE WEEVIL CONTROL in the Northeast

by Robert Marty and D. Gordon Mott

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A FORMIDABLE LOSS

ALTHOUGH it is not eye-catching to the casual observer, damage done by the white-pine weevil is widespread and serious on white pine trees in the Northeast. Weevil injury may be costing Northeastern woodland owners and lumber producers as much as 7 million dollars each year, due for the most part to the lumber degrade that weevil injury causes.

The direct economic losses are indeed formidable. Yet the indirect influence of this forest pest is perhaps of even greater consequence. Uncontrolled weeviling limits the usefulness of timber-management activities, often to such an extent that no cultural practices can be undertaken profitably. Uncontrolled weeviling reduces the quality of some pine stands so much that they drop below the commercially operable margin, stripping owners of not only a part, but of all income from these stands. Finally, uncontrolled weeviling has resulted in a region-wide pine resource of such increasingly poor quality that it cannot support profitable processing enterprises.

Weevil injury is not the only problem faced by pine growers and processors. But is it the most pressing one for many, and it is a problem that can be solved. Weevil injury can be controlled—effectively and profitably—in many stands.

The purpose of this report, addressed to all those interested in pine management and pest control, is to develop an economic evaluation procedure that can help in deciding *where* to practice weevil control, and to provide information about weevil injury

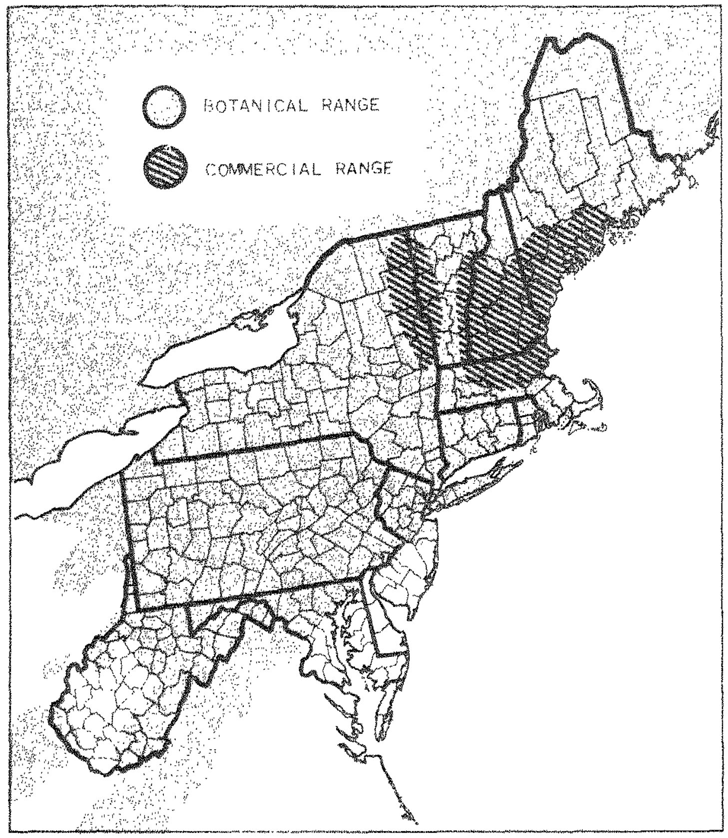


Figure 1.—The botanical and commercial ranges of eastern white pine (*Pinus strobus* L.) in the northeastern United States.

buildup that can help in deciding *when* to begin control treatments. This report does not cover in detail the various control methods and techniques. Other publications are available that deal with *how* to control the weevil.

No attempt has been made to acknowledge every scientific contribution to this subject; only a few sources are cited. More than 100 scientists have published studies on the white-pine weevil or on related problems. Each has added something to our present understanding, and it is the sum of these contributions that makes this report possible.

CONTROL INFORMATION

THE BIOLOGY OF WEEVIL INJURY

The Tree

Eastern white pine (*Pinus strobus*, L.) is a widely distributed and commercially important conifer that is native to the Northeastern United States. The natural botanical range of the species includes southeastern Canada, the Lake States, the Northeast, and the Appalachian Mountains as far south as Georgia (fig. 1). In the Northeast it is commercially important and is a predominant feature of the landscape in southwestern Maine, southern New Hampshire, northeastern Massachusetts, and in the northern drainage of the Hudson River in New York.

Though found on a variety of sites, white pine is likely to predominate permanently only where the competition offered by more tolerant species is not great. This tree is capable of high rates of growth, and it tends to maintain growth longer in life then most other conifers. In the Northeast, white pine is found in virtually pure stands; as the major component of stands that also contain significant quantities of hemlock, or of red oak and white ash; and as a moderate to minor component of many spruce-fir, northern hardwood, and central hardwood stands.

The Insect

The white-pine weevil (*Pissodes strobi* (Peck)) (fig. 2) is found throughout the botanical range of white pine. This small brown snout beetle attacks many conifers, both native and exotic (Craighead 1950), but white pine is its principal host.

Figure 2.—The white-pine weevil (*Pissodes strobi* (Peck)).

Adult weevils hibernate during winter in the pine duff of the forest floor. They emerge the next spring, usually some time between March and May. Emergence has been shown to be correlated with warming air temperatures expressed as cumulative degree-days (Godwin and Bean 1956). Mating may occur in the fall, but typically takes place after emergence in the spring (Jaynes 1958).

Soon after emergence, the weevils move toward the terminal growth of pine trees to feed and lay eggs. Weevils tend to move away from the ground and toward light during this period (Sullivan 1959); and they are strong flyers, so their movement is not limited to crawling. Female weevils may deposit several eggs per day for 2 months or more during May, June, and July. The eggs are inserted in small cavities chewed by the adult female in the bark of the previous year's terminal growth. Larvae hatch from these eggs in a week or 10 days, feed in the inner bark of the leader, pupate, and emerge as adults in the late summer.

Rather little is known about white-pine weevil population dynamics except that the general pattern is one of establishment, build-up, and continuation at a more or less high level of abundance.

Susceptibility of Pine

Not all pine trees are equally apt to be attacked by the white-pine weevil. Weevils tend to prefer vigorous pine trees with thick-barked leaders, and trees that are tall in relation to their neighbors (Kriebel 1954). This preference helps to explain why dominant and co-dominant pines are attacked more frequently than pines that are suppressed or overtopped. Weevils require coniferous duff for an overwintering site, and a scarcity of duff may limit weevil abundance; so this may explain in part why pines intermixed with hardwoods are not attacked so frequently as pines in pure stands.

There is some evidence that genetically controlled differences in susceptibility exist among eastern white pine trees. Provenance tests indicate that certain geographic ecotypes of pine may have a genetic resistance to weevil attack (Wright and Gabriel 1959). However, genetic differences appear to be small in comparison with environmental effects.

Figure 3.—Symptoms of weevil injury. A, terminal growth drooping after weevil larvae have attacked the internode below. B, weevil-caused crooking in young pine. C, crooking and forking in pole-size pine. D, an enclosed weevil-killed leader stub on a mature pine, sometimes the only evidence of injury that remains.


A
B
C
D

Response to Attack

The first evidence of weevil attack are small drops of resin that form on the leaders after the weevils have begun feeding and egg-laying. The weevil larvae, developing in and feeding on the leader, girdle the shoot and kill the growth above. This portion of the terminal growth gradually droops and turns brown, providing a positive symptom of injury (fig. 3).

The length of stem destroyed by the weevil varies. The last year's terminal growth (the site of egg-laying) and the current year's terminal growth are always destroyed by a successful attack. Occasionally 3 and even 4 years' growth is destroyed when larvae progress further down the stem than usual.

The lateral whorl below the lowest dead terminal continues the tree's height development, and the branches of this lateral whorl compete for the dominant position. New growth on the branches in this whorl tends to turn upward. Usually one branch soon outstrips the others and becomes the tree's terminal shoot. Generally the successful lateral is one of the largest ones with its base in the upper part of the whorl (Rhodes 1963). Not infrequently, however, growth is so evenly matched among competing lateral branches that forking of the main stem results. Actually, early dominance and forking are two extremes in response, and all gradations between can be found. Typically, competition persists long enough so that the branches that lose the race for the dominant position later appear to be attached at an unusually acute angle, and they may be unusually large if competition persists for any length of time.

The degree of injury may be significantly conditioned by environment. Dense, even-aged stands on good sites seem to show quicker and more complete recovery than is typical of other stand conditions.

THE INCIDENCE OF INJURY

Factors Related to the Incidence of Injury

The average incidence of weevil injury has been found to vary from year to year and from place to place. It also seems to be correlated with stand height, at first increasing and then declining as the stand grows taller. Within groups of young trees, taller individuals are injured more frequently than their shorter neighbors. Trees that have been weeviled before also seem to be injured somewhat more frequently than those that have not.

Variations from Year to Year and from Place to Place

A recent survey of weevil injury to northeastern pine plantations provides some indication of the regionwide average variation in injury incidence from year to year[1]. This cooperative survey was initiated by the Bureau of Entomology and Plant Quarantine in 1951, and was later transferred to the Division of Forest Insect Research of the Northeastern Forest Experiment Station, and was carried on annually in most states until 1957.

Each year, selected white pine plantations in eight northeastern states were re-examined for weevil injury. The average percent of trees currently injured in all stands examined varied from 2.7 percent in 1952 to 7.4 percent in 1955. The trend is generally upward in this group of young stands because weevil populations are still building up. Stands were also grouped by total height, and an average injury rate was computed for each height class and each year. The change in average rate from year to year for stands of a particular height class gives a better indication of general yearly variations in insect activity. The general level of weevil injury, as indicated by this measure, does vary to some extent from year to year (fig. 4).

[1] Lowe, J. H. Jr., and W. E. Waters. SURVEY OF WHITE-PINE WEEVIL DAMAGE IN PLANTATIONS IN THE NORTHEAST, 1951-57. Unpublished report. U.S. Forest Service. Northeast. Forest Expt. Sta., 8 pp., 1959.

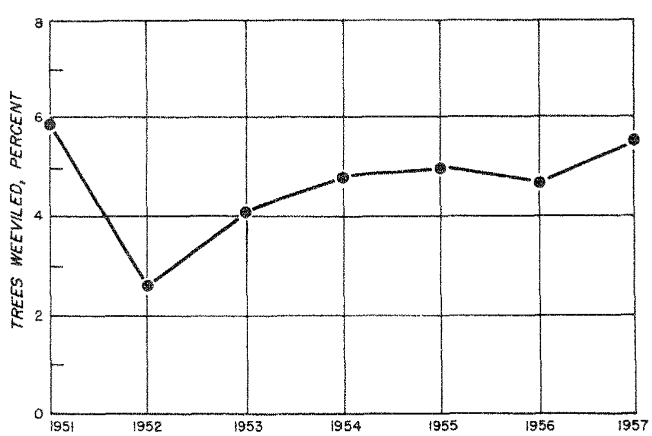


Figure 4.—Variation in current weevil injury from year to year in 4.5- to 6.4-foot-tall pine plantations in the Northeast, 1951-57.

Differences in the incidence of cumulative injury from place to place seem to be greater than year-to-year differences. A study of weevil-caused volume loss in New Hampshire (Marty 1959) showed that the average number of injuries discernible in the first 40 feet of bole of standing sawlog-size pines varied from 2 to 4½ among 12 small groups of pines within a 2-county area. Marked differences in the incidence of injury from place to place for young stands also have been noted (MacAloney 1930).

The existence of place-to-place differences in injury incidence raises the possibility of rating areas according to the general or long-term weeviling hazard they have shown. Foresters are often able to pinpoint areas of particularly high or low hazard on the basis of general observation alone. Further experience, coupled with sampling of injury rates, may suffice to establish generalized hazard zones, which could be of value in guiding control activities.

Variations Related to Absolute Tree Height

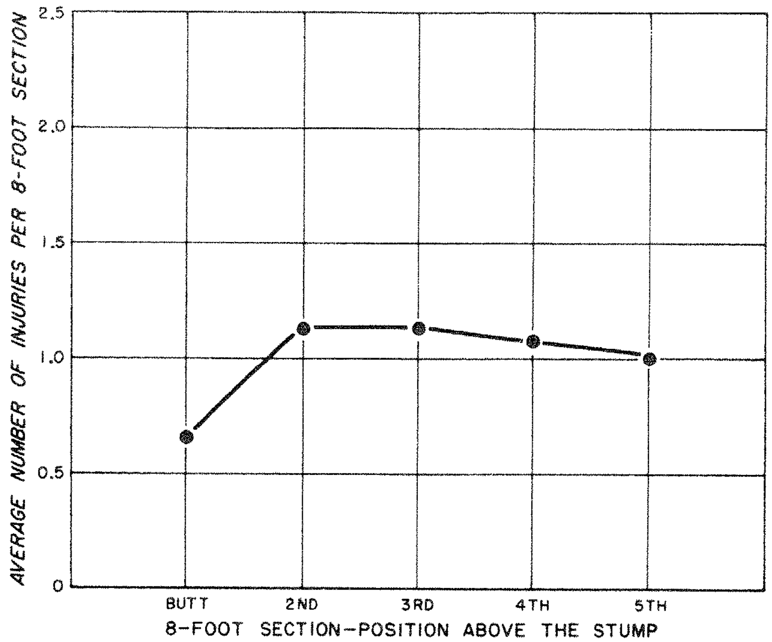
The New Hampshire volume-loss study also disclosed a difference in the average number of injuries in various sections of the bole. For these stands, discernible bole injury was generally light in the first 4 to 8 feet of the bole, then increased in the next 16 feet, but decreased in the logs above (fig. 5). This same pattern has been found in other studies as well (Connola and Wixson 1963).

Lowe and Waters[1] have suggested that the eventual decline in bole injury may be due to the increasing proportion of injuries that are diverted to the extra leaders produced by weevil injury (leaders that eventually become unmerchantable stems or branchs) rather than to the merchantable bole (to which the injury count was restricted in the aforementioned study). There may also be other changes in stand characteristics and weevil-population characteristics that take place as the trees grow in height, which contribute to this effect.

The Amount of Crop Tree Injury That Can Be Prevented by Control

Very little information about injury incidence in sawtimber trees is available, yet some estimate of the average number of injuries to anticipate under different conditions of weevil hazard is needed. Butt-log injuries averaged 1¾ per tree for the sample plots of sawlog-sized pines studied in New Hampshire and subsequently

Figure 5.—Weevil injury at different heights in the boles of sawtimber pines in New Hampshire.



in other northeastern states. Plot averages for butt-log injuries ranged from ¾ per tree to more than 3 per tree. Plot averages for second-log injury ranged from 1½ to 3, with a mean of 2¼.

In areas of high hazard, weevil injury usually begins earlier, develops faster, and reaches greater intensity than in areas of lower hazard. In areas of high hazard, then, butt-log injury may be much more serious than elsewhere. Differences in the amount of injury in the second log are probably less pronounced, although still significant.

All injury is not preventable with today's control techniques. There is likely to be some injury of treated trees, especially where weevil hazard is high. However, this unpreventable injury should not be great where control is properly done.

Estimates of the number of bole injuries that will be prevented by control are given in table 1 for three levels of hazard, in the butt log and the second log. Table 1 should be looked at as a definition of three levels of hazard. There is reason to believe that many white pine plantations will be subject to high hazard rates of injury, as these are defined in table 1. Many natural stands are subject to lower injury rates. Most stands, planted or natural, will be subject to an injury rate somewhere within the range of this table. However, it is not known how prevalent the various hazard levels are throughout the Northeast. Specifically, it would be improper to assume that the medium hazard level of table 1 is the most frequently occurring hazard level.

Table 1.—Definitions of three levels of weevil hazard based on the number of injuries per log

Weevil hazard	Number of preventable injuries			
	Butt log		Second log	
	Average	Range	Average	Range
Low	½	0-1	1¼	0 -1½
Medium	1½	1-2	2	1½-2½
High	2¾	2+	2¾	2½+

The Distribution of Attacks Within Stands

Careful evaluation of injury patterns in the white pine plantations examined in the plantation survey has provided evidence of the importance of relative height and past injury on the distribution of current injury within these stands of pine. When little injury occurs in a pine plantation, most of it occurs in the tallest trees. As injury rates increase, a greater proportion of trees of lower heights are injured, but the greatest proportion of injuries still occurs in the taller trees (fig. 6).

The plantation survey also showed that trees that have never been weeviled before suffer less than their share of current injury. For example, when one-half of the trees in a plantation have never been weeviled, these never-weeviled trees suffer only 37 percent of the current injury, on the average. Sixty-three percent of the new injury occurs on the half that has already been injured. The distribution of attacks is thus related to the proportion of trees still unweeviled (fig. 7).

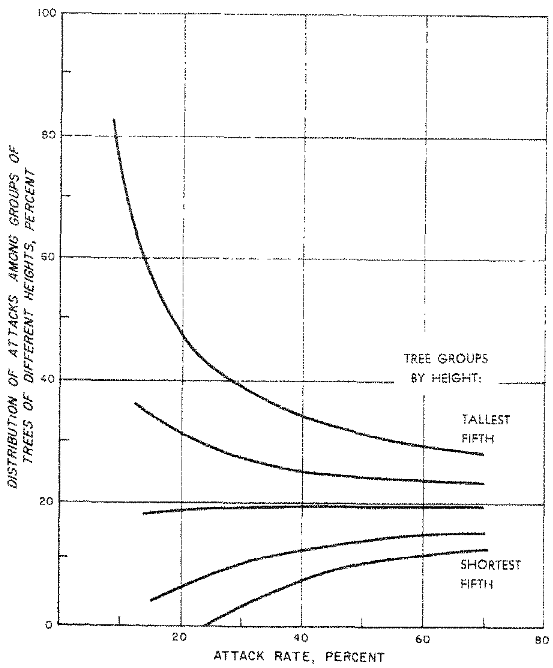


Figure 6.—The relation between attack rate (proportion of all trees in a plantation that are currently attacked) and the proportion of the attacks occurring on trees in five relative height classes.

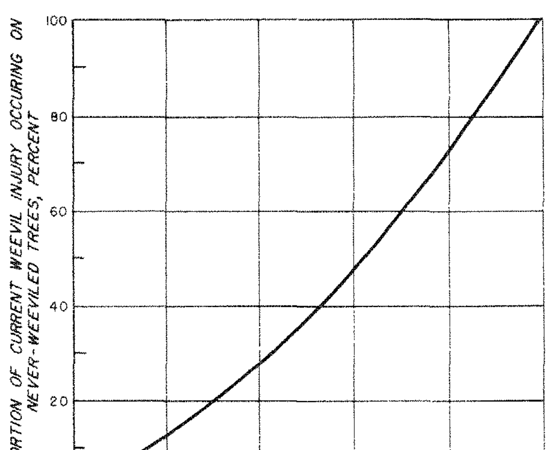


Figure 7.—The relation between the proportion of all trees in a plantation that have never been weeviled and the proportion of attacks that occur on these never-weeviled trees.

The Pattern of Injury Buildup

The first weevil attacks that occur in a young stand are caused by insects that have immigrated from surrounding areas. If the new stand provides suitable conditions, such as adequate duff for overwintering and not too much overstory shade to discourage egg-laying, gradual buildup of a resident weevil population takes place. This population buildup is accompanied by a coincident buildup in injury.

The typical trend in injury buildup is not perfectly regular or smooth; rather, rapid increases alternate with more modest increases and sometimes temporary declines. However, an average pattern has been observed in the plantation survey. This reveals that when the rate of attack is low, as when the weevil population is just becoming established, the increase in the rate of attack the following year is apt to be relatively great. When the attack rate is high, on the other hand, the increase in attack rate the following year is apt to be small.

These relations describe a typical pattern of injury buildup. At first the injury rate increases rapidly from one year to the next; then it increases more and more slowly until it is fluctuating about

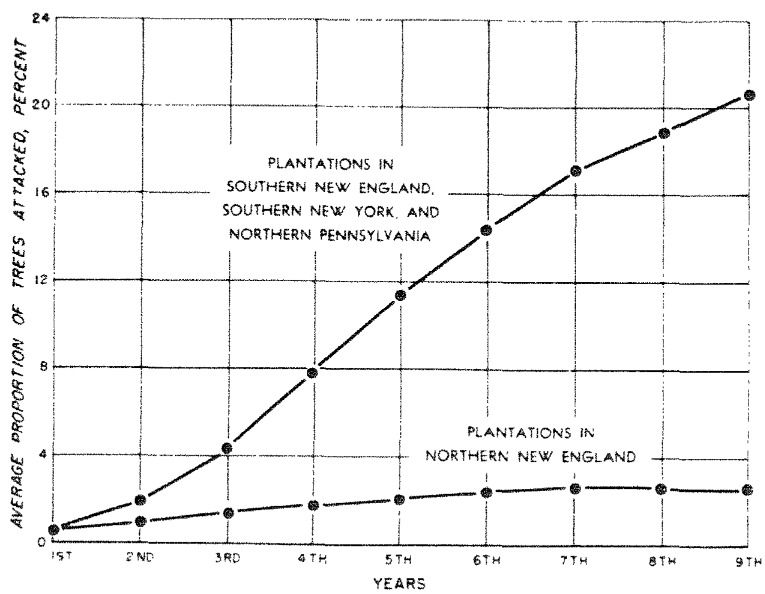


Figure 8.—Two average patterns of injury-rate buildup found among northeastern pine plantations.

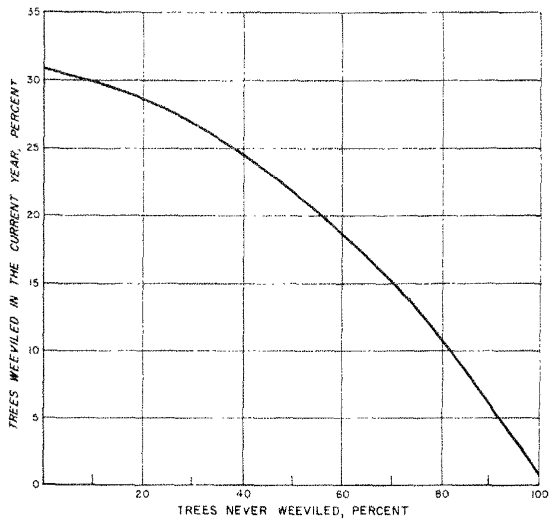


Figure 9.—The average relationship between the percent of trees currently injured, and the percent of trees that have never been weeviled, in northeastern pine plantations.

a rather stable and continuing rate that differs from stand to stand, from place to place, and from year to year. We believe that this equilibrium injury rate probably reflects the maximum weevil-population density that the area can support, and is another measure of hazard. Two curves (fig. 8) depict the injury-rate buildup in two quite different conditions: rapid buildup to a high equilibrium rate, typical of plantations in southern New England, northern Pennsylvania, and southern New York; and a more gradual buildup toward a low equilibrium rate typical of northern New England pine plantations.

In the plantations surveyed, as the injury rate increased in successive years, the number of never-weeviled trees declined. Consequently there is a relationship between the current rate of attack and the proportion of trees never-weeviled at any point in time (fig. 9).

These data from plantation pine 16 feet and shorter do not show the eventual decline above 20 feet in injury rate, discerned in studies of larger trees.

Other Causes of Terminal Injury

Other agents can cause terminal injury in pine. Frost damage, whipping by hardwood saplings, and attack by various animals and birds may all be important sources of terminal injury in particular localities, and will be present to some degree in most stands. For these reasons even elimination of the white-pine weevil will not completely eliminate terminal injury. It is important to be sure that the weevil is the major cause of injury before weevil control is prescribed.

VOLUME LOSS

The Region as a Whole

Weevil injury has continued unchecked for as long as we know, and in many cases the most heavily damaged trees and stands have been left uncut. For example, in 1952 the New Hampshire sawlog inventory was only 60 percent of what it could have been if there had been no weevil injury (Waters et al 1955). Two billion board feet of timber, made unmerchantable by weevil injury, were occupying valuable growing space. Volume loss continues today wherever pine owners fail to control weevil injury. Annual losses for the Northeast as a whole may be 50 to 100 million board feet per year, with a total value of perhaps a million dollars.

How Injury Affects Recoverable Volume

In 1952 Waters and others (1955) made a careful appraisal of more than 100 sample plots located in New Hampshire white pine stands. Some of the stands sampled were of poletimber size; others held sawtimber. By comparing weeviled pines with pines free of weevil injury, it was possible to determine average levels of loss due to weevil injury, and to determine the way that injury affected recoverable volume.

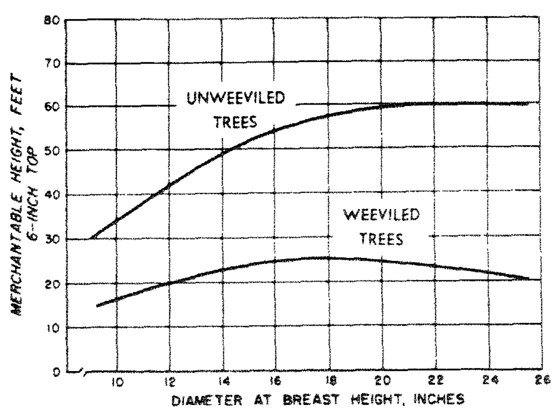


Figure 10.—Average merchantable height of weeviled and unweeviled white pine in New Hampshire, 1952. (After Waters et al, 1955.)

The most striking influence of weevil injury was the reduction in merchantable height that it caused (fig. 10). Loss in merchantable height caused all the volume loss noted in pole-size trees, and most of the volume loss in sawtimber trees. Injury also caused sweep and crook within merchantable length, which accounted for the remaining volume loss in sawtimber trees. Average volume losses for the pines sampled in New Hampshire were 13 percent in pole-size trees, 40 percent in the sawlog portions of sawtimber trees, and 70 percent in those portions of sawtimber trees above sawlog limits.

Injury Intensity and Volume Loss

The number and position of weevil injuries are important in determining volume losses. In general, the more frequently the tree is injured, the greater the volume loss will be. The position of an injury on the bole is also important. Injuries above normal merchantable height cause no loss. Injuries in the top logs cause relativel' little loss because they affect only a small portion of the tree s volume. Injuries located in the butt log are often the most serious because they are in the section of the tree that has the greatest volume.

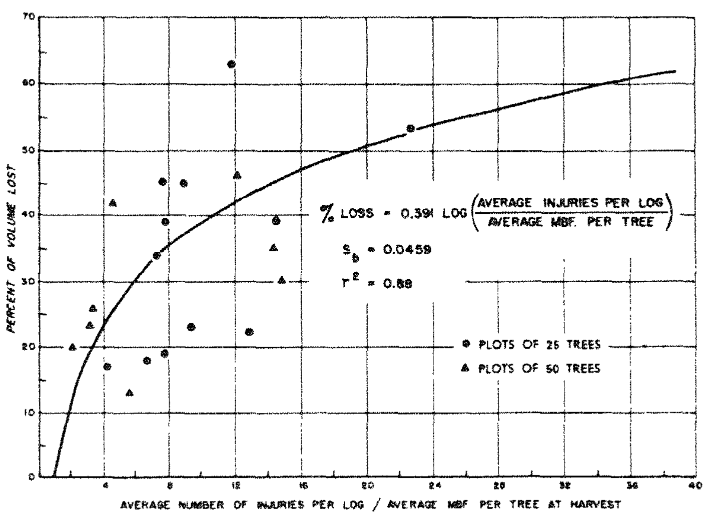


Figure 11.—A relationship between volume loss, injury intensity, and tree size.

Two studies of sawtimber pine stands have been made in an attempt to determine the relationship between the incidence of bole injury and volume loss. The initial study has been mentioned above and is reported elsewhere (Marty 1959). The second study confirmed the results of the first and led to a somewhat better way of expressing the relationship (fig. 11).

In these studies, 20 plots of sawlog-size pines, scattered throughout the Northeast, were examined. Plots were made up of either 25 or 50 trees. All 20 plots had been affected by weevil injury, and volume loss for individual plots varied from 22 percent to 63 percent. Such limited research cannot give exact estimates of effects, but analysis did show that both the average number of injuries per log and tree size at harvest were significantly correlated with volume loss. Other factors, both intrinsic and extrinsic, also influence loss importantly, but these factors have not yet been studied quantitatively.

Average Volume Saved

The volume-loss relationship can be used to predict the amount of volume that can be saved by control under different conditions of weevil hazard, as these are defined in table 1. Table 2 shows the average board-foot volume saved per tree by control in the first and second logs for each level of weevil hazard, and for a number of different harvest diameters (d.b.h.). Notice that the volume

Table 2.—Estimates of the volume saved by control under different hazard conditions[1] for trees of various harvest d.b.h., in board feet

Tree d.b.h., inches	Butt log				Second log			
	Normal volume[2]	Volume saved when hazard is—			Normal volume[2]	Volume saved when hazard is—		
		Low	Medium	High		Low	Medium	High
10	36	16	21	24	20	9	12	13
12	56	19	27	31	32	14	15	18
14	78	20	32	37	46	20	19	22
16	106	21	36	45	62	12	21	26
18	136	19	39	49	81	11	23	29
20	171	14	38	53	104	8	23	32

[1] Hazard conditions are defined as to expected incidence of preventable injury according to ratings in table 1.

[2] Normal volumes, taken from Bickford (1951) for a form class of 78, assume no weevil injury.

that can be saved by control usually increases with harvest d.b.h., but not as rapidly as normal volume increases. This reflects the fact that for any given level of injury, the percent of normal volume lost declines as normal volume increases. Given the number of crop-trees per acre and their harvest d.b.h., per-acre volume savings can be determined from table 2.

LUMBER DEGRADE

Comparative Importance

Weevil injury causes two important forms of economic loss. The first, discussed above, is loss in merchantable volume, which is easy to see in most injured stands. The second type of loss is a reduction of the quality in the portion of the injured tree that still is merchantable. Loss in quality becomes apparent only after the tree is cut and sawed. Its effect is to lower the grade of some of the lumber recovered from the injured tree.

Although lumber degrade cannot be seen in standing trees, it is much more important economically than is volume loss. Ostrander and Stoltenberg (1957) concluded that reduction in lumber quality due to weevil-caused defect is substantial. They found losses of $2 to $34 per thousand board feet, depending on the number of injuries per log.

The average rate of weevil injury for trees now being harvested in the Northeast is probably between 1 and 2 injuries per 16 feet of merchantable bole. Our studies indicate that this means an average decrease in quality index[2] of somewhere between 6 and 14 points. At 1961 prices—and assuming that the changes in the supply of the various grades if no weeviling had occurred would not affect their prices—this constitutes an average loss of $10 to $24 per thousand board feet of white pine produced. With rates of production for the Northeast averaging 600 to 700 million board feet per year (1946-56), the economic loss from weevil-caused lumber degrade may be more than $6 million each year.

[2] Quality index (QI) is an expression of lumber grade yield. The higher the QI, the better the grade yield of lumber. QI is derived by determining for each lumber grade its price expressed as a percentage of the average price of No. 1 and 2 Common lumber, and multiplying these relative values by the volumes of lumber in each grade forthcoming from a tree, a log, or a run of logs. QI is usually expressed as a percent. For example, a QI of 127 percent indicates that a grade mix of lumber on the average was worth 127 percent as much as an equal volume of No. 1 and 2 Common lumber.

How Injury Affects Timber Quality

Lumber-recovery studies have shown that several lumber defects are caused by weevil injury. Among these are cross-grain, red rot, large branch knots, and loose knots (Ostrander and Foster 1957). These defects arise from the heavier and more acutely angled branching that follows weevil injury, and from a gradual enclosing of the dead weeviled leader (fig. 12).

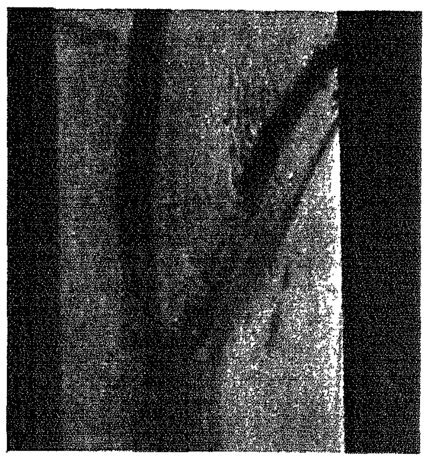


Figure 12.—Weevil-caused lumber defects.

Generally, weeviling defects have been found in mill studies to reduce board quality by one grade. However, in some cases weeviling may cause no degrading defects: or it may cause enough defect to reduce lumber quality as much as three grades.

The Influence of Number of Injuries on Quality Loss

An examination of 248 logs processed at one mill in Maine showed that the average loss in quality index due to weevil injury increased significantly with the number of injuries per log (fig. 13). Quality index declined an average of 7½ points for logs with a single weevil injury, about 12 points for 2 injuries, 15½ points for 3 injuries, and 18 points for 4 injuries.

These data indicate that as the number of injuries increases there is a somewhat less than proportional decline in quality index. The study did not disclose any marked differences in loss for logs of different sizes.

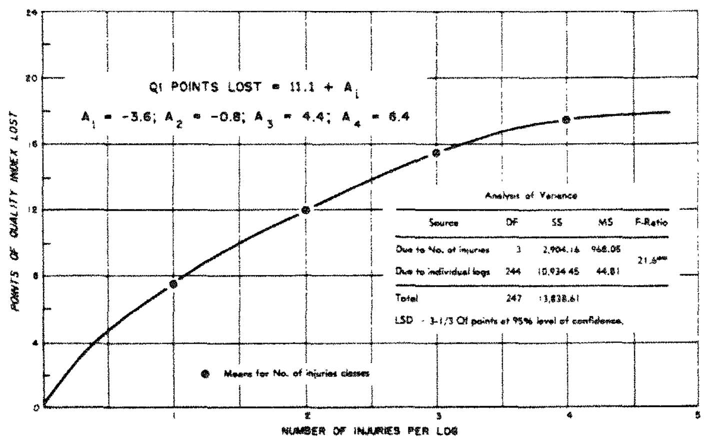


Figure 13.—A relationship between number of injuries and lumber degrade. Class means are connected by a freehand curve.

The Improvement in Grade Recovery Due to Weevil Control

It is possible to construct estimates of the average quality index increase due to control that would occur given the three levels of weevil injury assumed in table 1. Table 3 shows the average increase for the first and second log in each hazard class. Remember that these increases in quality index apply to the entire volume of protected logs, not only to the volume that would otherwise be lost. The volume that would have been recovered even without control is also raised to the new quality level.

Table 3.—Estimated increases in lumber quality due to weevil control, for three levels of hazard

Weevil hazard[1]	Average increase in lumber grade recovery due to control in the—	
	Butt log	Second log
	Quality index	*Quality index*
Low	4.5	9.0
Medium	10.0	12.0
High	14.5	14.5

[1] Injury rates assumed are given in table 1.

THE VALUE OF CONTROL

How White Pine is Used

The value of weevil-caused losses—and hence the potential value of weevil control—depends upon the value of white pine timber. The value of pine timber, in turn, depends upon the demand for it at any given time, and the supply made available by landowners and managers.

Most eastern white pine is converted into lumber; but some pine is pulped, and small amounts are used in other ways (U.S. Forest Service 1954). Eastern white pine lumber has three major uses: construction, containers, and manufactured specialty products. It is used as sheathing, subflooring, and other structural elements in light construction; for packaging and crating of various sorts; and to make patterns and flasks, millwork, furniture and fixtures, boot and shoe findings, matches, toys, athletic equipment, and other specialty products.

These uses take different grades of white pine lumber. The lower grades are generally suitable only for construction and containers. Manufactured products require higher quality lumber. The competition faced by white pine lumber producers in the Northeast also varies from one grade to another. The lower common grades of white pine can be replaced readily in construction and containers by other species of lumber and by plywood and nonwood products such as gypsum board. On the other hand, the better grades of white pine lumber are a preferred material that commands premium prices for many manufacturing uses. Competition in the higher grades comes from eastern white pine produced in the Lake States and western white pine and sugar pine from the Western States.

Stumpage Markets in the Future

Market prospects are considerably more favorable for good-quality than for poor-quality stumpage (King et al 1960, Holland 1960). The ease with which poor common lumber can be replaced by other materials severely limits market outlets and depresses prices for these grades, and so for poor-quality stumpage as well.

The average lumber grade mix currently produced by the white pine industry of the Northeast is: Selects 3 percent, No. 1 and No. 2 Common 12 percent, No. 3 Common 35 percent, and No. 4 Common 50 percent. Trees harvested in the Northeast average about 12 inches in diameter. Published projections (Holland 1960, King and others 1960) for this run-of-the-woods stumpage foretell a 50-to-75-percent increase in stumpage prices over the next 40 to 60 years, based on likely trends in population, per-capita lumber consumption, construction activity, lumber-production costs, and stumpage supplies. According to these projections, stumpage of the current average quality and size, which sells now for about $15 or $20 per thousand board feet, may be worth approximately $25 to $35 per thousand board feet when stands now suitable for weevil control become mature.

Influence of Average Tree Size and Quality

In the future, owners who sell stumpage that is of better-than-average quality and of larger-than-average size may be able to sell their stands at a premium. How much more than the going price they receive will depend on competitive conditions in their stumpage market when they sell, and on how much better their stumpage is than the average.

Logging and milling studies (Dowdle 1962) carried on at the Northeastern Station indicate that it now costs about $13 more per thousand board feet to process logs from pine trees 10 inches d.b.h. than from 20-inch trees. Large trees will probably continue to be cheaper to log and mill than small ones, and the differences in cost may be even greater in future years. Because of these differences in processing cost, stumpage made up predominately of trees 16 inches d.b.h. and larger may be worth $10 more per thousand board feet than will the more usual 10-to 14-inch stumpage.

Those who practice weevil control are more likely to produce stumpage of better than average quality. Weevil control in the butt log is quite likely to increase a pine stand's average lumber grade yield by 5 points on the quality index. If pine lumber prices increase somewhat in the future, an added point of quality could easily be worth $2 per thousand board feet to the processor.

In areas where the competition for stumpage remains slight, stumpage prices may stay at virtually the same relative level as today. Pine owners will not be offered much of a premium for superior stands in these areas. But for the major pine-producing areas, where the processing industry is concentrated, and where there is likely to be brisk competition for better-than-average stumpage, the picture should be brighter.

Future Price Assumptions

Two different assumptions about future prices are used here because prices and pricing policies may vary so much from one area to the next. You can use the price assumption that you feel will be closest to the mark for your area.

The first assumption is that the stumpage market will stay much the same as it is today. Run-of-the-woods stumpage will sell for $20 per thousand board feet, and one-quarter of the additional value of better-than-average size and quality will be paid to stumpage sellers. The second assumption is that the general level of stumpage prices will increase by 50 percent, and that the pine owner will receive one-half of the additional value of better-than-average stumpage. Table 4 shows prices and differentials in dollar terms for these future market assumptions.

Table 4 also shows the total value of control. Total values are appropriate for the public investor who counts all returns to weevil control regardless of to whom they accrue. Stumpage prices are appropriate for the private pine grower who can expect to be paid only a part of the value he adds by weevil control.

Now it is possible to calculate the dollar stumpage returns added by control, for each hazard class, harvest d.b.h. and future price level, and for both butt-log and second-log control. These are shown, on a per-crop-tree basis, in table 5. This assessment of the value of control ignores the increased volume and quantity of thinnings in protected stands that will receive commercial thinning, and it somewhat understates control returns in these cases.

Table 4.—Stumpage value and price assumptions

Value elements	Stable markets[1]		Rising markets[1]	
	Total value per 1,000 bd. ft.[2]	Stumpage price per 1,000 bd. ft.[2]	Total value per 1,000 bd. ft.[2]	Stumpage price per 1,000 bd. ft.[2]
Base price	$20.00	$20.00	$30.00	$30.00
Add for stumpage of 16-inch d.b.h.	10.00	2.50	10.00	5.00
Add for each QI point saved	2.00	0.50	2.00	1.00

[1] Stable markets assume going prices like those of today with one-fourth of the size and quality differentials being passed on to the stumpage seller in the form of higher stumpage prices. Rising markets assume 50-percent increase in going prices and a doubling of the proportion of the size and quality differentials that are passed on to the stumpage seller.

[2] Total values are appropriate for public investors who count all returns regardless of to whom they accrue. Stumpage prices are appropriate for the private nonintegrated stumpage producer who can expect to be paid only a part of the value he adds by weevil control.

Table 5.—Estimated returns per crop tree for weevil control

Weevil hazard class	Crop-tree d.b.h. at harvest (inches)	Returns from butt-log control: Stable markets[1]		Returns from butt-log control: Rising markets[1]		Returns from second-log control: Stable markets		Returns from second-log control: Rising markets	
		Total value added[2]	After-tax return[2]	Total value added[2]	After-tax return[2]	Total value added[2]	After-tax return[2]	Total value added[2]	After-tax return[2]
Low	10	$0.64	$0.30	$0.80	$0.48	$0.54	$0.20	$0.63	$0.34
	12	.89	.37	1.08	.62	.86	.32	1.00	.53
	14	1.10	.43	1.30	.71	1.22	.45	1.42	.76
	16	1.58	.53	1.80	.91	1.48	.41	1.60	.74
	18	1.79	.55	1.98	.96	1.79	.46	1.90	.84
	20	1.95	.53	2.10	.95	2.12	.48	2.20	.92
Medium	10	1.14	.45	1.35	.74	.72	.27	.84	.45
	12	1.66	.62	1.93	1.03	1.06	.37	1.21	.62
	14	2.20	.77	2.52	1.31	1.48	.49	1.67	.84
	16	3.20	1.01	3.56	1.74	2.11	.63	2.32	1.11
	18	3.89	1.17	4.28	2.05	2.63	.75	2.86	1.34
	20	4.56	1.28	4.94	2.28	3.19	.86	3.42	1.55
High	10	1.52	.56	1.76	.93	.84	.31	.97	.51
	12	2.24	.77	2.54	1.31	1.28	.44	1.46	.75
	14	3.00	.98	3.37	1.68	1.78	.58	2.00	1.00
	16	4.42	1.34	4.88	2.34	2.58	.78	2.84	1.36
	18	5.41	1.56	5.90	2.77	3.23	.93	3.52	1.65
	20	6.55	1.82	7.08	3.26	3.98	1.12	4.30	1.97

[1] Stable and rising market conditions are defined in table 4.

[2] Total value added counts all returns regardless of to whom they may accrue, and is not reduced for income-tax liabilities. After-tax return reflects only the addition to stumpage income a private grower might expect under each market condition, less 25 percent to reflect a typical level of income-tax liability.

Returns are not difficult to calculate from the estimates already presented. For example, a tree that was protected from weevil injury while its butt log was formed, is in an area of medium hazard, will be harvested when it is 14 inches d.b.h., and will be sold in a stable market, will have 32 board feet more volume than it otherwise would have had (table 2); and the quality index of the butt log will have been increased by 10 points (table 3). The stumpage value of the volume saved is $20 per thousand board feet, and the quality added by control has a total value of $2 per quality point per thousand board feet (table 4).

The added stumpage value per tree can be calculated in two steps:

1. (Volume saved) (unit value of volume saved)
   (32 board feet) ($0.020)=$0.64
2. (Total volume) (QI increase) (unit value of quality)
   (78 board feet) (10 points QI) ($.002)=$1.56

The sum of these two elements gives a total value of $2.20 in this case.

The Effect of Taxes

Private investors must give up some of their added income in the form of taxes. Table 5 shows the added stumpage return per tree after this income is decreased by 25 percent for taxes.

CONTROL METHODS AND COSTS

Methods of Control

Weevil control means reducing the amount or severity of injury caused by the weevil. A number of techniques and prescriptions for control have been suggested and developed during the last 25 years. These techniques fall into three main categories: cultural, biotic, and chemical. A brief review of these may serve to underline the great variety of techniques available, and the diversity of control principles involved.

Cultural Control

A number of silvicultural prescriptions were early suggested, aimed at creating or maintaining conditions that lessen weevil attack or promote post-injury recovery (Pierson 1922). These were based on (1) obtaining partial shading of the pines with a hardwood overstory to reduce the frequency of attack, or (2) maintaining high density of pines to cause injured trees to straighten more quickly. These prescriptions are less than ideal because pine growing under an overstory or at high density develops merchantable volume more slowly than pines that have adequate growing room. So these control techniques can lead to loss of growth, just as weeviling does.

Another cultural method that has been suggested takes advantage of natural differences in tree condition in reclaiming weeviled pine stands (Cline and MacAloney 1931). This technique, developed for severely injured plantations, calls for selecting the least severely injured pines for crop-trees with due regard for spacing, and treating surrounding trees to free these crop-trees for rapid growth and development. In plantations the least-injured trees are often found in the lower crown classes. Pruning of all but one of the laterals in the topmost whorl of live branches will reduce crook and eliminate forking (Rhodes 1963).

Finally, a sanitation technique—removal and burning newly weeviled leaders—has been used in young pine stands to control infestation. This method is at least partially effective, but it is costly as compared with chemical control.

Biotic Control

Recently much interest has been shown in using other organisms to control insects. Micro-organisms such as viruses, bacteria, protozoa, and fungi are all being tried as controlling agents for various insects. Natural insect parasites and predators are also being studied. If it is possible to find a biotic vector that is effective in controlling the weevil, that is easily propagated, and that can be successfully distributed in selected locations, then weeviling could be controlled effectively, cheaply, and with little or no danger to other forms of life.

Genetic manipulation of the weevil itself is a different sort of biotic technique, and this holds considerable promise. One such technique involves sterilizing and releasing male weevils which then compete with normal males in mating, and thus reduce the population in the next generation. Effectiveness depends on the ratio of sterilized males to normal males and to females, and the success of sterilized males in competing with normal males.

Chemical Control

At present the most successful and widely used techniques are those that employ chemical insecticides to kill adult weevils. In most chemical techniques, liquid insecticide is applied to pine foliage. Applications of granular insecticide to ground litter have also been made to control weevil populations during hibernation.

Four ways of making foliar application have been developed: (1) drenching of leaders by means of portable compressed-air sprayers, (2) broadcast treatment of upper crowns with portable mist blowers, (3) with truck mounted mist blowers, and (4) with aircraft (Potts et al 1942, Crosby 1958, Connola et al 1955, and Hastings and Risley 1962).

In addition to these different methods of application, there are many different insecticides, carriers, spreaders and extenders, toxicant concentrations, rates of application, and timings of treatment. All these factors—and weather too—influence control success and the degree of danger to other organisms.

Finding the Cost of Control

No attempt is made here to analyze the costs of different control techniques that are now operational. At this writing, most people would probably choose as equipment a compressed-air sprayer (for control jobs involving less than 50 acres of young pine) or a mist blower (for larger ownerships and for contractors), and use aqueous solutions of DDT or lindane applied at 2- to 5-year intervals. But conditions from one ownership to another vary so much, and control techniques are developing so rapidly, that any analysis of these techniques would not apply generally, and would soon be out of date. If there is any question about the best technique in your particular case, you can decide on the basis of three factors that you will want to know in any case:

1. The per-acre cost of a treatment.
2. The number of treatments required.
3. Side effects of the control technique.

The cost per treatment is quite an individual affair; and it can vary widely from one manager or organization to the next, even when all employ similar techniques. Wage rates and subsidies are probably the most important cost factors. It is proper to include overhead expenses as well as direct costs in the cost estimate, and to deduct from the estimate any cost-sharing or subsidy payment (for example, ACP payments) anticipated. Cost-sharing and subsidy payments are available to the private investor, but not to the public investor; so the real cost of control will often be lower to the private investor. This tends to offset the private investor's tax load to a considerable degree. Cost per treatment for chemical weevil control in the Northeast usually has varied between $1 and $5 per acre.

The second cost factor—number of treatments—depends on such factors as the length of time you decide to maintain protection, and on how frequently the stand must be re-treated to hold injury to an acceptable level. You can estimate the number of treatments easily enough if you estimate four things: (1) the stand's average height when you plan to begin control, (2) the stand's average height when you plan to stop control, (3) the average rate of height growth, and (4) the treatment interval required for your control technique and the hazard condition. So far, re-treatment usually has been required every 2 to 5 years in the Northeast. You can use table 6 to find the number of years it will be necessary to continue protection for the various combinations of rate of height growth and average stand height when protection begins and ends.

The final factor—side effects—can be treated only as a matter of judgment. Occasions do arise when one technique is less costly, but more dangerous, than another. You can obtain a good idea of the extra cost involved in choosing the safer technique by estimat-

Table 6.—Number of years during which protection against the weevil must be maintained[1]

Present average height of pine (feet)	Number of years protection must be maintained when the average rate of height growth in feet per year is—					
	1.0	1.2	1.4	1.6	1.8	2.0
			BUTT-LOG PROTECTION			
2	17	14	12	11	10	9
4	15	13	11	10	9	8
6	13	11	10	9	8	7
8	11	9	8	7	7	6
10	9	8	7	6	5	5
12	7	6	5	4	4	4
			TWO-LOG PROTECTION			
2	33	28	24	21	19	17
4	31	26	22	20	18	16
6	29	24	21	19	17	15
8	27	23	20	17	15	14
10	25	21	18	16	14	13
12	23	19	17	15	13	12

[1] Control is assumed to continue 1 year beyond the season in which crop-trees average 18 feet in total height for butt-log protection, and 1 year beyond the season that crop-trees average 34 feet for 2-log protection.

ing the cost per treatment and number of treatments for each as outlined above. You must then make a judgment about whether the added safety is worth the added cost.

Control Schedule Assumption

At this point it is necessary to distinguish between two kinds of control procedure. The first procedure involves choosing a number of pine trees per acre that are to be maintained in an unweeviled condition, and from which crop trees will later be chosen.

Treatments are timed so that control maintains at least this many trees unweeviled, but there is no decision about which particular trees these will be. In practice, these trees will probably be the slower growing ones, since short trees are usually among the last to be attacked (fig. 6). Thus the crop trees probably will not be the fastest growing pines in the stand, and they may not be the best individuals in other respects as well. This may have a long-term influence on the genetic character of subsequent reproduction, which should be kept in mind.

The second procedure would involve choosing crop-trees before control began, and timing treatments so that all or some proportion of these trees were maintained weevil-free. This is probably not a very workable system because it would be difficult to choose crop-trees when the stand may be no more than 5 or 6 years old; and

Table 7.—Assumed average control schedules for stands subject to three levels of weevil hazard[1]

Weevil hazard	Stand height when control begins	Treatment interval	Treatments
	Feet	*Years*	*No.*
	BUTT-LOG CONTROL		
Low	11	4	2
Medium	8	3	4
High	5	2	6
	SECOND-LOG CONTROL		
Low	18	5	3
Medium	18	4	4
High	18	3	5

[1] An average rate of height growth of 1.2 feet per year is assumed. Weevil hazard is as defined in table 1.

because it would require many more treatments to protect fast-growing, more susceptible pines from injury. Both the profit analysis and the scheduling analysis assume the first control procedure, although other procedures are possible.

A later section of this report covers in detail the problem of scheduling control in individual stands. However, it is necessary to make some guesses here about the average control schedule for stands subject to each of the three levels of weevil hazard, in order to determine average levels of profitability. It is assumed here that on the average, treatment will begin sooner and will be repeated more frequently where weevil hazard is high than where it is low. Table 7 shows these assumed average control schedules for each hazard zone.

CONTROL DECISIONS

The first section of this report has presented background information necessary to an understanding of weevil injury and its effects. A series of assumptions and estimates have been drawn from these data about injury rates, volume and quality losses, and control schedules. The next step is to build on these estimates and assumptions to develop specific scheduling and evaluation guides.

CHOOSING CONTROL SITES

Control Criteria

From the economist's point of view, young pine plantations and areas of natural pine reproduction should meet each of four criteria before weevil control is undertaken in them:

- Sawlog production should be one of the objectives of stand management.
- The intensity of weevil injury should have reached a point where control is needed to assure the desired number of damage-free crop trees at target height.
- There must be sufficient funds and manpower available to undertake control.
- Weevil control ought to be a reasonably profitable use of these funds and manpower.

The first criterion is important because weevil control probably pays off adequately only in stands that will be harvested for sawtimber. Pine pulpwood yields are reduced by weevil injury to some extent, but probably not enough to warrant control. Pines grown for Christmas trees might benefit considerably from weevil control, but this is not considered in this report.

The second and third criteria involve matters of timing. It does not seem wise to begin control sooner than is necessary, and it is not possible to undertake control if you lack the needed time and money. Ideally, control should be timed so that adequate funds and manpower are available, and so that control is neither premature or delayed.

The final criterion is profitability. From the economist's point of view, one should not invest in weevil control except in stands where it is reasonably profitable. Weevil control should promise about as good a return as could be expected for investing in some other management practice, in a non-forest activity, or in securities. People differ about what is reasonably profitable for them. Some demand very high returns; others are satisfied with lower ones. Like treatment costs, acceptable return is an individual matter that each must decide for himself on the basis of his own investment opportunities.

The purpose of what follows is to develop and present estimates of the profitability of control in many different circumstances. By using this information you can rank young pine stands in order of their profitability for weevil control and concentrate your control efforts in the ones that offer returns that you judge to be adequate.

The Factors that Determine Control Profitability

Here is a summary of the factors that influence the costs and returns to weevil control:

■ Factors that determine stumpage value added:

1. *Weevil hazard.*—This determines the number of injuries that can be prevented (table 1) and the degree to which lumber grade yield can be improved by control (table 3).

2. *Target d.b.h. for crop trees.*—This, together with hazard, determines the average volume per crop tree that can be saved by control (table 2).

3. *Number of crop trees per acre.*—This converts crop-tree volume and quality savings to a per-acre basis.

4. *Future stumpage price or value.*—This determines the stumpage income or value added by control (table 5).

- Factors that determine control cost:

1. *Weevil hazard.*—This determines (for the purposes of this profit analysis) both the stand height when control begins and the average interval of time between treatments (table 7).

2. *Control period.*—This is defined by the stand's age when control begins and ceases (table 7).

3. *Treatment cost.*—This, with the other cost factors, determines the dollar amount and timing of control outlays.

A final factor, not mentioned before, must be taken into consideration in order to estimate rate of return to control.

- The factor that relates control cost and stumpage value added: *Investment period.*—This is given by rotation age less stand age at first treatment, and it determines the length of time that you must wait for returns.

Computing Profitability

If a value for each one of these factors is known or can be estimated for a young pine stand, then the amount and timing of each of the control costs and the amount of the control return can be estimated. These, in turn, can be used to determine the profitability of control as measured by a compound interest rate.

For example, a young pine stand subject to a medium weevil hazard, grown by a private owner who expects rising stumpage prices, under a management program that anticipates 200 twelve-inch d.b.h. crop-trees per acre at 60 years, is being considered for butt-log weevil control, with an estimated cost per treatment of $3 per acre. If the stand is growing on an average site, it will probably require about four treatments to protect the butt-log, the first one at about 6 years, followed by three more at 3-year intervals (table 7). The return for these expenditures will accrue when the stand is 60 years old and will amount to about $1.03 per crop-tree (table 5) or $206 per acre, which means about $10 to $12 per thousand board feet more than would have been received without control. Here is a compound interest formula that balances the series of costs with the return:

$$\$3\ (1.0p)^{54}+\$3\ (1.0p)^{51}+\$3\ (1.0p)^{48}+\$3\ (1.0p)^{45}=\$206$$

The unknown factor is p, the interest rate that just balances costs and returns. In this case it is about 6.0 percent, and this is the rate of return that such a control investment would earn under the conditions assumed.

The Importance of Profit Factors

A rate of return like this one was determined for more than 1,500 control situations, each different from all the others with respect to one or more of the profit-determining factors. The rates of return for these many situations were then compared to see how important each of the factors was.

First, changes in the level of weevil hazard did not change the rate of return when other factors were held constant. The reason for this is that, as hazard increases, both control costs and control returns increase, and one almost exactly offsets the other. This means that although it may be very expensive to control weeviling under high-hazard conditions, control is just as good an investment as under less severe conditions because so much more is saved.

Second, control in the second log seemed just as profitable as control in the butt log, under similar conditions. It is true that less volume and quality are saved in the second log, and that control outlays are not too much different. But costs do not have to be carried forward so far to harvest, and this reduction in the waiting period makes second-log control equally as profitable as butt-log control.

Third, two of the remaining factors, crop-tree d.b.h. and number of crop trees per acre, can be replaced by a single factor, butt-log volume per acre at harvest, with little error.

Profit curves are presented in figure 14 for various price assumptions, rotation ages, and treatment costs, each curve showing the rate of return for various per-acre butt-log volumes at harvest. Rotation age and harvest volume are the most important profit determinants. Profit estimates are within 1 percent of computed value in most cases.

The individual manager, who may have the same price expectation, treatment cost, and planned rotation age for all his stands, will find that per-acre butt-log volume is his major determinant of profitability. Weevil control is most profitable in his well-stocked stands on good sites, least profitable on his poor sites in sparsely stocked stands. However, if he is contemplating a long rotation, there may be little difference in control profitability from one stand to the next—returns may be uniformly poor. Returns are much better when rotations are short simply because costs are not

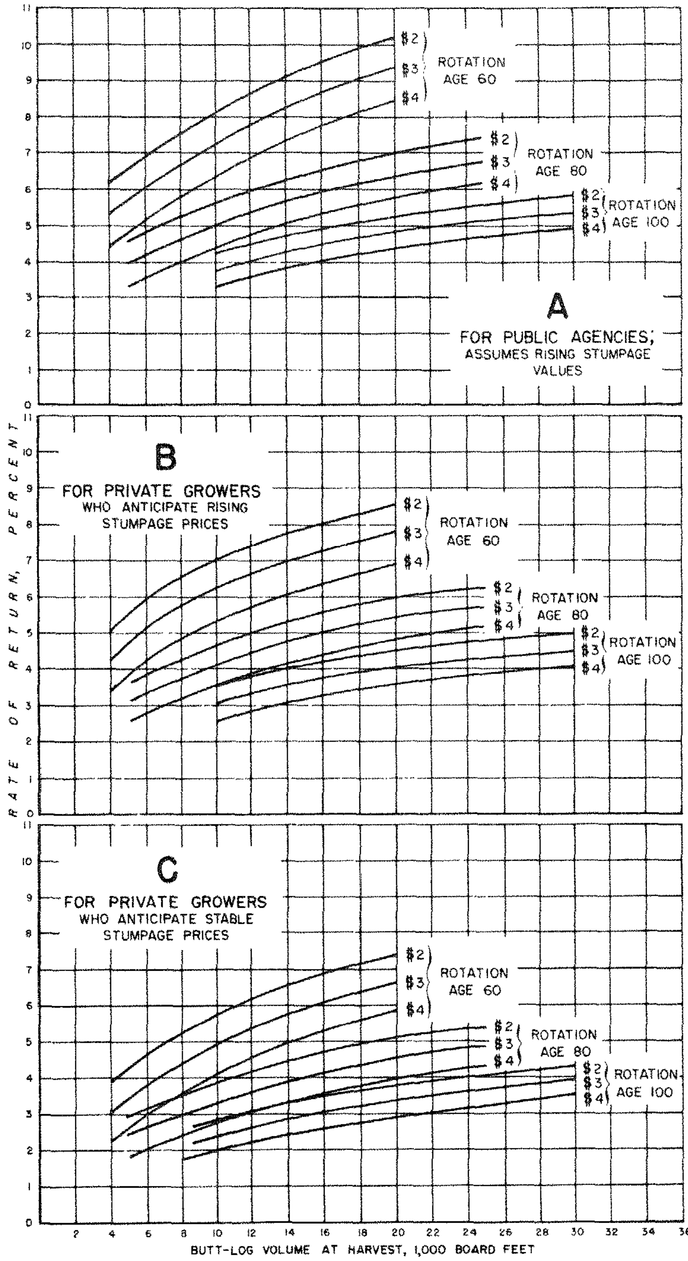


Figure 14.—Estimates of the profitability of weevil control.

Table 8.—Estimates of the rate of return from weevil control in well-stocked stands

Rotation age	Site Index[1]	Approximate butt-log volume per acre	Public agencies, Assuming rising stumpage prices and treatment cost per acre of—			Private growers: Assuming rising stumpage prices and treatment cost per acre of—			Private growers: Assuming stable stumpage prices and treatment cost per acre of—		
			$ 2	$ 3	$ 4	$ 2	$ 3	$ 4	$ 2	$ 3	$ 4
Years	*Feet*	*Mbf.*	%	%	%	%	%	%	%	%	%
60	60-80	5	6.5	5.6	4.8	5.6	4.7	3.9	4.3	3.5	2.8
	90-100	10	8.1	7.2	6.3	7.0	6.2	5.4	5.8	5.0	4.2
80	40	5	4.5	3.9	3.3	3.7	3.1	2.6	3.1	2.5	1.9
	50	10	5.6	4.9	4.3	4.7	4.2	3.7	3.9	3.4	2.8
	60-70	15	6.3	5.7	5.1	5.5	4.9	4.3	4.6	4.0	3.5
	80-100	20	6.9	6.3	5.7	5.9	5.4	4.8	5.1	4.5	4.0
100	40	10	4.2	3.7	3.3	3.6	3.1	2.6	2.9	2.4	2.1
	50-60	15	4.7	4.3	3.9	4.1	3.7	3.2	3.4	3.0	2.6
	70-80	20	5.2	4.7	4.3	4.5	4.0	3.6	3.8	3.4	3.0
	90-100	25	5.5	5.1	4.6	4.8	4.3	3.9	4.1	3.7	3.3

[1] Use this column when there is no better basis for estimating butt-log volume at harvest. Well-stocked stands of the indicated site index and rotation age have the approximate butt-log volumes shown.

tied up so long at compound interest, and there is also likely to be a greater range in profitability, depending on site, stocking, and intermediate management when rotations are short.

Public pest-control program administrators may choose control sites from among many ownerships with differing rotation-age objectives. In addition to the site and stocking considerations that determine butt-log volumes at harvest, expected rotation age will greatly influence profits. Public weevil control might well concentrate on ownership classes where rotations are typically short. Here the government funds invested in control will generate returns in the shortest time and at the highest rates.

The data of figure 13 are summarized by table 8 in a form that may be somewhat easier to use. This table shows rates of return to control given rotation age, butt-log volume per acre at harvest, market outlook, and treatment cost per acre. An additional column for site index is given to show what site index must be for well-stocked stands to yield the indicated butt-log volumes at the indicated rotation age. Site index can be used instead of butt-log volume when there is no adequate basis for estimating volume. *Well-stocked* means that at least 75 percent of the stand area is occupied by pine trees spaced not further apart than 15 feet. Reduce butt-log volume one step for stands 50-to 75-percent stocked.

Ranking Control Opportunities

Estimates of profitability provide a criterion for ranking pine stands and so establishing control priorities. This can be done by:

- Listing all stands of young pine reproduction that are to be managed for pine sawlog production, with their acreages, from management records, maps, etc.
- Estimating butt-log volume per acre at harvest for each stand by projecting number of crop-trees per acre at harvest along with their average d.b.h.; or by using the site-index method.
- Determining the rate of return to control from table 8 for the market expectation, planned rotation age, treatment cost, and butt-log volume.
- Arranging stands in descending order of profitability.

A hypothetical array of eight stands, with the information called for above, is shown in table 9. This listing ranks stands in order of profitability as best this can be judged. Thus it establishes a priority of available control opportunities. The manager can choose any rate of return that seems appropriate as his minimum acceptable rate, and then needs to consider only those stands that

Table 9.—A hypothetical priority ranking of white-pine weevil control sites

Stand Designation	Size	Planned rotation age	Estimated crop-tree volume at harvest	Rate of return to control[1]
	Acres	*Years*	*M bd. ft.*	*Percent*
14C	20	60	16	7.2
8B	5	60	12	6.6
27B	63	60	10	6.2
12B	12	60	10	6.2
32	12	80	24	5.7
107	44	80	18	5.2
63A	130	100	30	4.5
42C	83	100	22	4.1

[1] Rates of return, assuming a treatment cost of $3 per acre and a rising stumpage price for a private grower, are taken from figure 18 rather than table 8.

promise an equal or greater return. The acceptable rate of return in table 9 is 5 percent; this is represented by a dashed line dividing the upper, acceptable stands from the lower, unacceptable ones. A ranking of this sort can help in deciding where to practice control by identifying the stands where control is likely to be sufficiently profitable.

SCHEDULING CONTROL

The Importance of Timing

After control sites have been selected, several questions involving the timing of control treatments remain to be decided. It is very important to initiate and repeat control treatments in individual stands at the proper time. Treatments ought to be neither too soon nor too late if control is to be maintained at least cost over a rotation.

Many stands of pine reproduction, both planted and natural, have a thousand trees or more per acre. In these stands weevil injury can proceed, perhaps for some time, and still leave an adequate number of uninjured pines from which to choose well-spaced crop trees. In sparsely-stocked stands, particularly where weevil hazard is high, very early treatment may be needed to preserve even a minimum number of uninjured straight pines. Similarly, there will be substantial differences from one stand to the next in the length of time before re-treatment is necessary, depending on weevil hazard conditions, stocking density, average tree height, crop tree objectives, and the treatment used.

A particular pattern of treatment has been assumed in computing the rates of return to anticipate for control under various circumstances. These patterns assume a particular stand age at first treatment and a particular treatment interval, for each hazard condition (table 7). In practice the actual schedule of treatments may be somewhat different from those assumed, and it should be varied from one stand to the next to take into account local differences in the rate of weevil population buildup, stand density, and other such factors. Each control site, because it is to some degree unique, must be examined periodically so that the next control treatment can be scheduled when it is needed.

There has been too little experience with control to determine the optimum pattern for timing of treatments. At what weevil population level should control be initiated and repeated to reduce weevil injury to an acceptable level with the least control expenditure? Is population level best measured by injury rate, or is there some better measure? These are several of the questions that arise in control scheduling; there are many others.

There may be several benefits to initiating control before the number of never-weeviled trees has declined to the target number. First, early treatment provides a margin of safety in the form of extra undamaged trees in case weevil injury is greater than anticipated in later years, or in case subsequent treatments must be postponed for one reason or another. These additional trees may also mean that there will be a larger number of undamaged trees from which to choose crop trees, and so a better chance of including more of the faster growing trees in the final crop. Then too, early treatments probably have a better chance of being highly effective than when treatment is delayed until weevil population levels are high. These potential benefits of early treatment must be weighed against the possibility of added cost. Early treatment may be more costly either because it adds extra treatments, or because it increases the average length of time between treatment and harvest and so increases interest charges.

Forecasting the Decline in Never-Weeviled Trees

It is possible to predict, with a known degree of precision, the rate at which the number of never-weeviled trees in a young pine stand will decline without control, using the information presented earlier. First, there are definite relationships between the percent of trees in a young stand that have never been weeviled before current attack occurs (this percent can be estimated by examining the plantation) and both the current rate of attack and the percent of these new attacks that occur on trees never before weeviled (figs. 7 and 9).

These relationships are used to forecast the decline in the number of never-weeviled trees as follows. Suppose examination shows that 80 percent of the trees in a young plantation have never been weeviled. If the weevil hazard for this stand is about average for the Northeast, 12 percent of the trees will be weeviled in the next attack period (fig. 9); and 72 percent of these new attacks will be on trees never weeviled before (fig. 7). This means that the percent of trees never weeviled will decline by (.72 x .12) or about 8.6 percent, leaving 71.4 percent of the trees injury-free after the next attack period. The attack rate in the subsequent attack period, and the way in which these attacks will be distributed, can be calculated in the same way from the value 71.4 percent, and so on for additional periods.

In this example the average rate of decline in percent of never-weeviled trees was assumed. However, it is apparent that some plantations experience faster-than-average rates of decline and others slower rates. This has been taken into account in preparing table 10, wherein the percentage of the trees that will remain free of injury in 1, 2, 3, 4, and 5 years is predicted for average conditions (part A) and for two other rates of decline: slower than average (part B), and faster than average (part C).

In part A of table 10 there is an equal probability of observed values being higher or lower than the table values. Parts B and C of table 10 are constructed so that there are 3 chances out of 4 of having at least the proportion of injury-free trees indicated. The table is based on information from pine plantations and some uniform natural stands from many areas in the Northeast. It is not known whether it applies to more heterogeneous natural stands.

Table 10 can be used to determine whether and when treatment will be necessary during the next 5 years to maintain a given number of trees per acre in a never-weeviled condition. First, it is necessary to decide how many injury-free trees per acre are to be maintained. More than the planned number of crop trees should be maintained because some never-weeviled pines will be too close together for all to be crop trees, and because more than 5 years may be required to produce the desired length of injury-free bole. If twice the number of pines needed for crop trees is maintained in a never-weeviled condition by the initial treatment, this will be enough to provide for some loss between subsequent treatments and still leave enough to provide well-spaced crop trees. At this point one must also decide how high to extend control—one log, two logs, or some intermediate height.

Next, examine the trees on the tentative control site to determine: (1) the current percent of trees that have never been weeviled, (2) the percent of trees that were never weeviled until the last attack period, (3) the stand's present average height, (4) the average number of pines per acre, and (5) the average rate of height growth. This can be done by examining and measuring the pines on small plots appropriately located throughout the control site. Suitable sampling procedures should be developed to fit individual circumstances. Use table 6 to estimate the number of years remaining during which protection must be maintained. Table 6 gives the number of years for one-and two-log protection depending on present average height of pines and the average rate of height growth.

The pines on the sample plots are to be recorded in three categories: pines that have never been weeviled, pines that were first weeviled during the last attack period, and pines that were weeviled before the last attack period. The first category will indicate the present proportion of never-weeviled pines. The second category, added to the first category, will indicate the propor-

Table 10.—Predictions of the decline in proportion of pine never weeviled if control is not begun

A: THE AVERAGE RATE OF DECLINE

Use this part of the table only to determine whether weevil hazard is higher or lower than average in the stand or plantation. Estimates of percent never weeviled in this part of the table are constructed so that there is an equal probability of observations being above or below the estimate.

Percentage of pine observed to have been never weeviled in the first year of record	Percentage of pine expected to be never weeviled under average conditions—				
	1 year later	2 years later	3 years later	4 years later	5 years later
100	99	98	96	93	89
99	98	96	93	89	83
98	96	93	90	84	78
97	95	91	87	81	73
96	93	89	84	77	69
95	92	87	81	74	66
94	90	85	79	71	62
93	89	84	77	68	60
92	88	82	74	66	57
91	86	80	72	64	55
90	85	78	70	62	53
89	84	77	69	60	51
88	82	75	67	58	49
87	81	74	65	56	48
86	80	72	63	54	46
85	78	71	62	53	45
84	77	69	60	51	43
83	76	68	59	50	42
82	75	66	57	49	41
81	74	65	56	48	40
80	72	64	55	46	39
79	71	63	54	45	38
78	70	61	52	44	37
77	69	60	51	43	36
76	68	59	50	42	35
75	67	58	49	41	34
74	66	57	48	40	33
73	64	56	47	39	33
72	63	54	46	38	32
71	62	53	45	38	31
70	61	52	44	37	31
69	60	51	43	36	30
68	59	50	42	35	29

CONTINUED

Table 10.—Continued

Percentage of pine observed to have been never weeviled in the first year of record	Percentage of pine expected to be never weeviled under average conditions—				
	1 year later	2 years later	3 years later	4 years later	5 years later
67	58	49	41	34	29
66	57	48	41	34	28
65	56	48	40	33	27
64	55	47	39	32	27
63	54	46	38	32	26
62	53	45	37	31	26
61	52	44	37	30	25
60	51	43	36	30	25
59	50	42	35	29	24
58	49	41	34	29	24
57	48	40	34	28	23
56	47	40	33	27	23
55	46	39	32	27	22
54	46	38	32	26	22
53	45	37	31	26	21
52	44	36	30	25	21
51	43	36	30	25	20
50	42	35	29	24	20
49	41	34	28	24	20
48	40	33	28	23	19
47	39	33	27	23	19
46	38	32	26	22	18
45	38	31	26	22	18
44	37	30	25	21	18
43	36	30	25	21	17
42	35	29	24	20	17
41	34	28	24	20	16
40	33	28	23	19	16
39	32	27	22	19	16
38	32	26	22	18	15
37	31	26	21	18	15
36	30	25	21	17	14
35	29	24	20	17	14
34	28	23	19	16	14
33	27	23	19	16	13
32	27	22	18	15	13
31	26	21	18	15	12
30	25	21	17	14	12
29	24	20	17	14	12
28	23	19	16	13	11

CONTINUED

Table 10.—Continued

Percentage of pine observed to have been never weeviled in the first year of record	Percentage of pine expected to be never weeviled under average conditions—				
	1 year later	2 years later	3 years later	4 years later	5 years later
27	22	19	16	13	11
26	22	18	15	13	11
25	21	17	14	12	10
24	20	17	14	12	10
23	19	16	13	11	9
22	18	15	13	11	9
21	17	15	12	10	9
20	17	14	12	10	8
19	16	13	11	9	8
18	15	13	11	9	7
17	14	12	10	8	7
16	13	11	9	8	7
15	13	11	9	7	6
14	12	10	8	7	6
13	11	9	8	7	6
12	10	8	7	6	5
11	9	8	7	6	5
10	8	7	6	5	4
9	8	6	5	5	4
8	7	6	5	4	3
7	6	5	4	4	3
6	5	4	4	3	3
5	4	4	3	3	2
4	3	3	2	2	2
3	3	2	2	2	1
2	2	1	1	1	1
1	1	1	1	1	0

CONTINUED

Table 10.—Continued

B: THE RATE OF DECLINE WHEN HAZARD IS LOWER THAN AVERAGE

Use this part of the table only after having determined that weevil hazard is lower than average, by comparing injury history with Part A of this table. Estimates in this part of the table are constructed so as to give 3 chances in 4 of having at least as many weevil-free trees as indicated.

Percentage of pine now never weeviled	Percentage of pine expected to be never-weeviled in—				
	1 year	2 years	3 years	4 years	5 years
100	99	99	98	97	95
99	98	97	95	93	89
98	96	94	92	88	84
97	95	92	89	85	79
96	93	90	86	81	75
95	92	88	83	78	72
94	90	86	81	75	68
93	89	85	79	72	66
92	88	83	76	70	63
91	86	81	74	68	61
90	85	79	72	66	59
89	84	78	71	64	57
88	82	76	69	62	55
87	81	75	67	60	54
86	80	73	65	58	52
85	78	72	64	57	51
84	77	70	62	55	49
83	76	69	61	54	48
82	75	67	59	53	47
81	74	66	58	52	46
80	72	65	57	50	45
79	71	64	56	49	44
78	70	62	54	48	43
77	69	61	53	47	42
76	68	60	52	46	41
75	67	59	51	45	40
74	66	58	50	44	39
73	64	57	49	43	39
72	63	55	48	42	38
71	62	54	47	42	37
70	61	53	46	41	37
69	60	52	45	40	36
68	59	51	44	39	35

CONTINUED

Table 10.—Continued

Percentage of pine now never weeviled	Percentage of pine expected to be never-weeviled in—				
	1 year	2 years	3 years	4 years	5 years
67	58	50	43	38	35
66	57	49	43	38	34
65	56	49	42	37	33
64	55	48	41	36	33
63	54	47	40	36	32
62	53	46	39	35	32
61	52	45	39	34	31
60	51	44	38	34	31
59	50	43	37	33	30
58	49	42	36	33	30
57	48	41	36	32	29
56	47	41	35	31	29
55	46	40	34	31	28
54	46	39	34	30	28
53	45	38	33	30	27
52	44	37	32	29	27
51	43	37	32	29	26
50	42	36	31	28	26
49	41	35	30	28	26
48	40	34	30	27	25
47	39	34	29	27	25
46	38	33	28	26	24
45	38	32	28	26	24
44	37	31	27	25	24
43	36	31	27	25	23
42	35	30	26	24	23
41	34	29	26	24	22
40	33	29	25	23	22
39	32	28	24	23	22
38	32	27	24	22	21
37	31	27	23	22	21
36	30	26	23	21	20
35	29	25	22	21	20
34	28	24	21	20	20
33	27	24	21	20	19
32	27	23	20	19	19
31	26	22	20	19	18
30	25	22	19	18	18
29	24	21	19	18	18
28	23	20	18	17	17
27	22	20	18	17	17

CONTINUED

Table 10.—Continued

Percentage of pine now never weeviled	Percentage of pine expected to be never-weeviled in—				
	1 year	2 years	3 years	4 years	5 years
26	22	19	17	17	17
25	21	18	16	16	16
24	20	18	16	16	16
23	19	17	15	15	15
22	18	16	15	15	15
21	17	16	14	14	15
20	17	15	14	14	14

C: THE RATE OF DECLINE WHEN HAZARD IS HIGHER THAN AVERAGE

Use this part of the table only after having determined that weevil hazard is higher than average, by comparing injury history with Part A of this table. The estimates in this part of the table are constructed so as to give 3 chances in 4 of having at least as many weevil-free trees as indicated.

Percentage of pine now never weeviled	Percentage of pine expected to be never-weeviled in—				
	1 year	2 years	3 years	4 years	5 years
100	91	80	76	61	49
99	90	78	73	57	43
98	88	75	70	52	38
97	87	73	67	49	33
96	85	71	64	45	29
95	84	69	61	42	26
94	82	67	59	39	22
93	81	66	57	36	20
92	80	64	54	34	17
91	78	62	52	32	15
90	77	60	50	30	13
89	76	59	49	28	11
88	74	57	47	26	9
87	73	56	45	24	8
86	72	54	43	22	6
85	70	53	42	21	5
84	69	51	40	19	3
83	68	50	39	18	2
82	67	48	37	17	1
81	66	47	36	16	0

CONTINUED

Table 10.—Continued

Percentage of pine now never weeviled	Percentage of pine expected to be never-weeviled in—				
	1 year	2 years	3 years	4 years	5 years
80	64	46	35	14	—
79	63	45	34	13	—
78	62	43	32	12	—
77	61	42	31	11	—
76	60	41	30	10	—
75	59	40	29	9	—
74	58	39	28	8	—
73	56	38	27	7	—
72	55	36	26	6	—
71	54	35	25	6	—
70	53	34	24	5	—
69	52	33	23	4	—
68	51	32	22	3	—
67	50	31	21	2	—
66	49	30	21	2	—
65	48	30	20	1	—
64	47	29	19	0	—
63	46	28	18	—	—
62	45	27	17	—	—
61	44	26	17	—	—
60	43	25	16	—	—
59	42	24	15	—	—
58	41	23	14	—	—
57	40	22	14	—	—
56	39	22	13	—	—
55	38	21	12	—	—
54	38	20	12	—	—
53	37	19	11	—	—
52	36	18	10	—	—
51	35	18	10	—	—
50	34	17	9	—	—
49	33	16	8	—	—
48	32	15	8	—	—
47	31	15	7	—	—
46	30	14	6	—	—
45	30	13	6	—	—
44	29	12	5	—	—
43	28	12	5	—	—
42	27	11	4	—	—
41	26	10	4	—	—

CONTINUED

Table 10.—Continued

Percentage of pine now never weeviled	Percentage of pine expected to be never-weeviled in—				
	1 year	2 years	3 years	4 years	5 years
40	25	10	3	—	—
39	24	9	2	—	—
38	24	8	2	—	—
37	23	8	1	—	—
36	22	7	1	—	—
35	21	6	0	—	—
34	20	5	—	—	—
33	19	5	—	—	—
32	19	4	—	—	—
31	18	3	—	—	—
30	17	3	—	—	—
29	16	2	—	—	—
28	15	1	—	—	—
27	14	1	—	—	—
26	14	0	—	—	—
25	13	—	—	—	—
24	12	—	—	—	—
23	11	—	—	—	—
22	10	—	—	—	—
21	9	—	—	—	—
20	9	—	—	—	—

tion of never-weeviled pines that existed before the last attack period. Use this latter proportion, the percent of trees unweeviled before the last attack period, to enter part A of table 10, and find the expected percent never weeviled now in the *1 year later* column.

For example, if 71 percent of the pines were unweeviled before the last attack period, part A of table 10 indicates that 62 percent should now be in the never-weeviled category. Compare this expected percent with the actual percent now never weeviled as observed on your sample plots. If your observed percent is higher than the expected percent, it means that weeviling has been less severe than average, and you should use part B of table 10 to project the future decline in percent never weeviled. If your observed percent is equal to or lower than the expected percent, then weeviling is proceeding faster than average and you should use part C of table 10.

Part A of table 10, then, is used only to determine whether the stand's weevil hazard is less than average or more than average. This determination is not very reliable when using estimates of percent of trees never weeviled for only 2 years. Better estimates are possible if data for additional past years are reconstructed or if estimates from the first examination of a stand are retained and compared with subsequent injury rates found upon later examination. It is possible that generalized hazard maps will be constructed as weeviling records are accumulated. It is clear from present data that there are geographic differences, but they cannot be delineated as yet.

Use the percent now never weeviled to enter the appropriate line of the table (parts B or C) to estimate future declines in the percent of pines never weeviled. In using the table, the predictions of the proportion of the stand that will remain injury-free are read for each year in the future (up to 5 years) on the row corresponding to the present proportion never weeviled.

Find out (1) whether the percent of never-weeviled trees will decline below the percent you want to maintain during the next 5 years, and if it will, (2) how many years from now this will occur. This will give a date by which you should plan to have completed the first control treatment. If this date is several years from now you will have an opportunity to examine the stand next year and refine your estimate of when initial control will be necessary.

Scheduling Initial Control

You can develop a schedule for initial control by conducting this examining and forecasting procedure for each chosen control site. Table 11 illustrates the result of an examination for the hypothetical control sites shown in table 9. Remember that six of the original eight control sites were tentatively chosen for treatment because these six all promised more than a 5-percent return. Two were discarded because control would probably not be profitable enough for this owner on those sites. The initial control schedule (table 11) reveals that one of the six selected stands will not need treatment before the first log is formed. This stand can be dropped from the control schedule. The remaining stands will require the initial treatment at various dates in the future: two this year, one next year, and two 5 years hence.

Table 11.—A hypothetical scheduling computation for butt-log control

Stand designation	Rate of return to control	Pine density, in trees per acre	Desired number of never-weeviled trees per acre	Target proportion of never-weeviled trees	Proportion never-weeviled before last attack period	Proportion now never-weeviled	Weevil hazard	Time to target proportion	Present stand height	Rate of height growth per year	Time until butt-log is formed	Control needed within—
	%	*No.*	*No.*	*%*	*%*	*%*	*Class*	*Years*	*Feet*	*Feet*	*Years*	*Years*
14C	7.2	1,000	300	30	100	97	Above aver.	5+	12	1.8	4	(2)
8B	6.6	800	400	50	96	95	Below aver.	5+	4	1.4	11	5
27B	6.2	1,000	400	40	63	50	Above aver.	1	4	1.4	11	1
12B	6.2	600	400	67	85	75	Above aver.	1	6	1.4	10	1
32	5.7	800	300	38	80	65	Above aver.	2	8	1.6	7	2
107	5.2	600	300	50	88	85	Below aver.	5	2	1.2	14	5
63A	4.5	(1)	—	—	—	—	—	—	—	—	—	—
42C	4.1	(1)	—	—	—	—	—	—	—	—	—	—

[1] Dropped because rate of return is less than the acceptable rate of 5 percent (see table 9).
[2] Dropped because the butt log will have formed before the proportion of never-weeviled pines declines below the target proportion.

Allocating Control Effort

Data from examinations of areas slated for control will enable you to tentatively schedule treatment for particular areas several years in advance. For large properties or public control programs, much more treatment work may be needed in some years than in others, because of unequal areas of pine in different age classes, and because of differences in the rate of injury buildup. In peak years a strain is placed on available funds, personnel, and equipment; in slack years other tasks must be found for these funds, men, and equipment. One way of avoiding these ups and downs is to do the same amount of treatment every year. This will mean treating some stands before they need it in slack years and delaying treatment in some stands when the control load is heavier than average. But a fixed amount of treatment each year does allow efficient employing, training, and equipping of control personnel.

There is a middle path, between doing the needed control each year regardless of how large or how small, and doing a fixed amount of treatment each year regardless of needs, that is better than either extreme. The main idea is to provide some flexibility in the amount of treatment done each year. Some flexibility is needed because treatment opportunities fluctuate, and also because the funds available for treatment may change from year to year. Complete flexibility, however, is wasteful because it is difficult and inefficient to change the level of treatment operations markedly and repeatedly.

On most properties weevil control is probably one more incidental management task to be handled among a host of others. In most years the amount of treatment needed will not exceed what can be accomplished by regular personnel in the normal course of management. In peak years a decision must be made whether to employ, equip, and supervise temporary personnel, to contract the overload, or to delay treatment in some stands.

SUMMARY- A PLANNING GUIDE

This report has presented many different sorts of information about white pine and the white-pine weevil, and these data have been used to develop guides for evaluating and scheduling weevil control. This final section contains a weevil-control planning guide.

This planning guide outlines the questions to be answered and the data needed in setting up a control project or program. It is adaptable, with little modification, to both private and public ownerships and programs, since the planning sequence and data needs are the same regardless of whose program it is. The guide is also meant to serve as a summary of this report, to organize and put into perspective the various sorts of information and analyses presented.

Step 1: Basic Considerations

Examine your young pine plantations and areas of natural reproduction for weevil injury. Figure 3 will help you to recognize terminal injury caused by the weevil, and to distinguish it from similar injuries caused by other agents. If weeviling is prevalent in some young stands, it may be profitable to do control work, and so planning may be needed. However, consider this opportunity in the light of available funds and other opportunities. Some owners and public agencies, even though they have a weevil problem do not have the time or funds to do control work, or can use available time and funds to better advantage in other ways.

Step 2: Choose a Control Method

If you decide to go ahead, the next step is to gain some knowledge and experience of various control techniques. Some of the literature references given will introduce you to several different control methods that have been tested in the field. Next, try to talk with others in your area who have done weevil control, and watch actual operations in progress. Dealers are sometimes willing to demonstrate their spray equipment, or to lend it for a trial. In any case you will want to look over the various sorts of spray equipment available and determine their costs. Check on insecticide prices too. If you can borrow equipment, or if you decide to go ahead and purchase it at this point, make some trial runs with it. This will give you a chance to estimate your per-acre treatment cost, and to try different insecticide formulations for their effectiveness.

Step 3:
Decide on Control Objectives

There are four factors that must be considered at this point in the planning process. They can all be adjusted later if it seems necessary. Together these four factors determine your control objectives.

- The desired or target number of never-weeviled trees per acre.
- The target height to which control will be carried.
- The minimum acceptable rate of return to control.
- The maximum amount of control work you will be able to do during the first year.

The number of trees to aim at protecting depends on the number of crop trees needed. Generally, 150 to 200 crop trees per acre are needed to fully utilize most sites. Plan to protect about twice this many young pines in order to have some leeway in selecting crop trees later. Target height may be limited by the treatment technique you have chosen. Plan to protect second logs as well as butt logs if your control method allows. Decide on the lowest rate of return that will satisfy you, and try to estimate the maximum amount of control you can do in the first year.

Step 4:
Survey Young Pine Stands

Now you are ready to examine each young stand in detail to estimate control return and determine if and when treatment will be needed. Examine young pine stands that will be managed for sawlogs and that have not yet reached target height. You will need at least these data for each stand examined:

- Stand designation or location.
- Acreage.
- Anticipated rotation age.
- Site index.
- Number of pines per acre.
- Present average height.
- Rate of height growth.

- Proportion of pines now never weeviled.
- Proportion of pines first weeviled during the last attack season.

Make these estimates by sampling small groups of pines throughout each stand. Tables 8 and 10 will give you a return rate estimate and an estimate of the number of years to first treatment for each stand examined.

Step 5: Ignore Stands Where Control is not Warranted

You can ignore the stands that have rates of return below your minimum. Also ignore any stands that will reach target height before they will require treatment. Follow the procedures like those given in tables 9 and 11 to do this in an orderly fashion.

Step 6: Schedule the First Year's Control

The only stands you must make a decision on immediately are those that require control now. Single these out from the others and list them in descending order according to rate of return. Estimate the total control cost for each by multiplying the acreage by your per-acre treatment cost estimate. Add a cumulative cost column to the listing as well. This will tell you how far down the list of stands you can go with available funds. These stands will constitute your control program for the first year. Each offers adequate returns, needs control now, and can be treated with available funds.

Step 7: Begin Now to Plan for Subsequent Years

Make similar listings for 1 or 2 years in advance, showing the stands not scheduled for the first year. Plan now to re-examine next year's batch to make a final decision on whether to include them or not. This pre-planning will also allow you to plan for a change in the amount of control for the next year if this seems desirable.

A Last Thought

This report is meant to be a summary of current knowledge on two aspects of white-pine weevil control. It does not represent the final word on these subjects. Research continues, and new field experience is constantly being accumulated. These will lead to improved scheduling and evaluation guides as time goes on.

But it is important to begin now to take advantage of more weevil control opportunities. Effective control techniques are available, and current knowledge is sufficient to suggest a sound basis for control planning, to encourage more persons to examine their weevil-control opportunities, and to act on them.

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