Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

ING SEED STORED IN SEROTINOUS CONES OF LODGEPOLE PINE

James E. Lotan and Chester E. Jensen

USDA Forest Service Research Paper INT-83, 1970
Intermountain Forest and Range Experiment Station
Ogden, Utah 84401

THE AUTHORS

JAMES E. LOTAN has been Project Leader of the Intermountain Station's Lodgepole Pine Silviculture research work unit, located in Bozeman, Montana, since 1965. He has been a member of this unit since 1961 and has published a number of articles on lodgepole pine management.

CHESTER E. JENSEN is Principal Statistician for the Intermountain Forest and Range Experiment Station. Previously, he held the same position at the Northeastern and Central States Forest Experiment Stations. Mr. Jensen, who holds a master of forestry degree from Michigan State University, received his training in graduate statistics at Iowa State University.

USDA Forest Service
Research Paper INT-83
1970

ESTIMATING SEED STORED IN SEROTINOUS CONES OF LODGEPOLE PINE

James E. Lotan and Chester E. Jensen

INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
Forest Service
U.S. Department of Agriculture
Ogden, Utah 84401
Joseph F. Pechanec, Director

CONTENTS

Page

INTRODUCTION	1
ESTIMATING THE NUMBER OF VIABLE SEED FOR THE AREA OF INTEREST	1
A. Number of Serotinous Cones Per Acre	1
Method 1	1
Method 2	2
B. Number of Seed Per Acre	6
C. Number of Viable Seed Per Acre	6
SAMPLE APPLICATION--NUMBER OF VIABLE SEED FOR THE AREA OF INTEREST	7
A. Number of Serotinous Cones Per Acre	7
Method 1	7
Method 2	8
B. Number of Seed Per Acre	8
C. Number of Viable Seed Per Acre	8
LIMITATIONS OF EQUATIONS (1) AND (2)	8
SIGNIFICANCE OF STORED SEED PER ACRE	9
REFERENCES	10

ABSTRACT

Two interim formulas for estimating the number of serotinous cones in lodgepole pine stands are presented. One formula requires a 25-limb sample count of serotinous cones on felled trees for which total tree estimates are desired together with tree d.b.h., crown ratio, and age; although this formula is more dependable, it is also more costly in application. The second formula requires only a count of trees bearing serotinous cones on each plot plus average d.b.h. and average age for trees on each plot.

Methods are also presented for expanding these estimates to number of viable seeds per acre, for the area of interest.

INTRODUCTION

Many stands of Rocky Mountain lodgepole pine (*Pinus contorta* Dougl.) bear an abundance of serotinous cones containing viable seed. These unopened cones remain on the trees up to 40 years and may provide most of the seed for regenerating burned or logged areas. However, the number of serotinous cones differs considerably from tree to tree within stands; also, the same is true for the proportion of closed-cone-type trees between stands (Crossley 1956; Lotan 1967, 1968).

When the closed-cone habit prevails, the species has the ability to store seed from year to year, accumulating literally millions of seed per acre, and if the forest manager is aware of the seed potential, he can secure natural regeneration through appropriate scheduling of cultural treatments.

It is equally important that the forest manager recognize a lack of stored seed in areas to be clearcut so that he can plan for artificial regeneration well in advance of cutting. Seed dispersed annually from surrounding uncut stands cannot be expected to reach more than 200 feet into cutover areas (Boe 1956; Tackle 1964).

It is clear that in lodgepole pine management there is need for evaluation of seed potential for both ecological and silvicultural purposes. The first step is to estimate the biotic potential for restocking, using an estimate of the number of viable seed per acre (as shown in this paper) as a base.

Previously, Lotan (1963) published a simple linear formula using a 25-limb count of serotinous cones on felled sample trees as the basis for estimating the total number of serotinous cones per tree. Since then, these data have been supplemented and more dependable multivariable formulas have been developed for use in the application of two estimating methods, one involving measurements on felled trees and the other on standing trees.

ESTIMATING THE NUMBER OF VIABLE SEED FOR THE AREA OF INTEREST

This process is described below in three steps.

A. Number of Serotinous Cones Per Acre

Method 1

The first method for estimating the number of serotinous cones is likely to be the most dependable of the two considered here, but is costly to apply because of the need to fell plot trees. This method would perhaps be most appropriate for research applications in the area from which the study data originated and where higher estimating precision is required. It includes use of an equation (shown below) to estimate number of cones per tree for trees on sample plots. Plot totals are then converted to per-acre values and are averaged.

$$Y = (0.0807 \text{ d.b.h.}^2 + 60.3 \text{ cr} - 58.7 \text{ cr}^2 - 0.0754 \text{ age} + 0.1585 \text{ count} - 3.45)^2 \quad (1)$$

where Y = Total serotinous cones per tree,
 D.b.h. = Diameter at breast height in inches,
 Cr = Live crown ratio,
 Age = Age of tree at stump height in years,
 Count = Total number of serotinous cones on the 25-branch segments.

The coefficient of multiple determination, or R^2 , was 0.834; i.e., these variables account for 83 percent of the variance in Y. The standard error of the estimate is 40 cones per tree, with an average of 965. The half-confidence interval is approximately 120 cones.

How to collect data:--Assuming the application of conventional sampling techniques, plot size should be large enough to include at least 4 to 6 trees of cone-producing size. The required data include:

1. D.b.h. in inches,
2. Total height in feet,
3. Crown length in feet,
4. Tree age at stump height in years,
5. The 25-limb sample count of serotinous cones.

For the 25-limb sample, all trees of cone-producing size must be felled prior to sampling. Count the serotinous cones on 25 outer-one-foot segments of main branches only. Start sampling at the top and work downward around the tree until 25 samples are collected. Record the total number of cones on the 25-limb samples. Use equation (1) and compute the estimated number of serotinous cones per tree. The cones-per-tree values can then be summed for each plot, expanded to per-acre values, and these averaged over plots.

A preliminary sample of plots can be used to determine the coefficient of variation of plot values. These in turn can be used to determine sample size, as is done for other sampling problems. Our samples had means from about 60,000 to 200,000 cones per acre and coefficients of variation that varied from 148 percent for the lower means to 77 percent for the higher means. The standard deviation will usually be about one-quarter to one-third of the range of data.

Method 2

This second method has a potential for rough estimates only, but all required measurements are relatively easy to make and it seems to be the most reasonable alternative available for obtaining stored-cone information.

The equation is:

$$Y = (1.925 \text{ d.b.h.}^2 - 1.371 \text{ age} + 3.411 \text{ tpa} - 0.00615 \text{ tpa}^2 + 46.2)^2 \quad (2)$$

where Y = Serotinous cones per acre,
 D.b.h. = Mean plot d.b.h. in inches,
 Age = Mean plot age in years,
 Tpa = The number of serotinous-cone-type trees per acre.

Figure 1.--On a tree classified as "serotinous," 90 percent or more of the cones it bears are closed. Note the characteristic fusiform shape of the cones indicated by the arrows.

The R^2 for equation (2) is 0.703. But the "Y" values used as input for this equation were, themselves, derived from "smoothed" tree estimates using equation (1) so that the R^2 of 0.703 contains upward bias and the standard error of estimate (13.4 thousand cones per acre) is biased downward. These two biases are thought to be relatively small.

How to collect data:--The plot data required for Method 2 are little more than normally obtained for inventory purposes, and trees do not have to be felled. The data required are:

1. Mean plot d.b.h. in inches (merchantable trees only),
2. Mean plot age in years (merchantable trees only),
3. Number of serotinous-cone types of trees per acre.

Compute the average plot d.b.h. and age. Examine each tree in the plot to determine if it is of the serotinous-cone type. Use good quality binoculars of 6 or 7 power and determine the tree's cone habit. Trees included in the formula should definitely bear 90 percent, or more, serotinous cones (figure 1). Current-year, immature cones are not to be included. Trees not counted are those having 90 percent, or more, open cones (classified as "open-coned," figure 2), and those having between 10 and 90 percent serotinous cones (classified as "intermediate," figure 3). These data should not be collected in wet weather when open cones are closed by hygroscopic swelling (figures 4, 5, and 6). However, observations can be made in the winter when snow is on the ground if relative humidities are low. Field crews should be supervised for accuracy concerning cone determination.

Using equation (2), compute the estimated number of serotinous cones per acre for each plot. Then the average across all plots will be the estimated number of cones per acre. Values from preliminary samples can be used to determine the coefficient of variation and required sampling intensity as mentioned in Method 1.

Figure 2.--On a tree classified as "open-coned," 90 percent or more of the cones it bears are open. Note the characteristic globose shape of the cones indicated by the arrows.

Figure 3.--On a tree classified as "intermediate," between about 10 and 90 percent of its cones are serotinous. It is intermediate in cone habit.

Figure 4.--Serotinous cones.

Figure 5.--Open cones.

Figure 6.--Open cones closed due to moisture and hygroscopic swelling.

B. Number of Seed Per Acre

The number of cones per acre can be multiplied by an estimated number of seed per cone to arrive at number of seed per acre for the area of interest. A direct seed count from sample cones collected on or near the study plots is recommended.

Although direct seed counts are apt to be more reliable, average cone length can be used as a basis for estimating number of seed per cone. See Thompson's formula (1969) presented below:

$$Y = 10.3X - 25.3 \quad (3)$$

where Y = Number of seed per cone,
 X = Cone length in cm. and $X \geq 2.5$ cm.

But the r^2 value (0.38) in Thompson's data was rather low, and there is no guarantee against bias in application.

C. Number of Viable Seed Per Acre

Either cutting or germination tests should be conducted on seed from the sample cones to obtain the percentage of viable seed; this value can then be multiplied by the total seed estimated for the area to arrive at total viable seed.

The viability of seed from serotinous cones varies substantially between areas and from year to year (from 10 to 90 percent, in our experience).

SAMPLE APPLICATION—NUMBER OF VIABLE SEED FOR THE AREA OF INTEREST

Assume that we have a 1,000-acre area for which we are estimating number of viable seed.

A. Number of Serotinous Cones Per Acre

Method 1

Assume the following measurements of three felled trees on a 1/50-acre plot:

Table 1.--Measurements of three felled trees

Tree number	D.b.h.	Total height	Crown length	Age	Serotinous cones on 25 limbs
	<i>Inches</i>	<i>Feet</i>		<i>Years</i>	<i>Number</i>
1	9	90	85	100	250
2	10	80	70	100	210
3	11	90	90	102	230

Table 2.--Values of variables to be entered in equation (1)

Tree number	D.b.h. ²	Cr	Cr ²	Age	Serotinous cones on 25 limbs
1	81	0.944	0.891	100	250
2	100	.875	.766	100	210
3	121	1.000	1.000	102	230

Multiplying each of these by the appropriate coefficient (from page 2) and adding the constant (-3.45), we have:

Table 3.--Computations using equation (1)

Tree number	0.0807 (d.b.h.)	60.3 (Cr)	-58.7 (Cr) ²	-0.0754 (age)	0.1585 (count)	Constant	Sum	(Sum) ² or cones per tree
1	6.54	56.92	-52.30	-7.54	39.62	-3.45	39.79	1,583
2	8.07	52.76	-44.96	-7.54	33.28	-3.45	38.16	1,456
3	9.76	60.30	-58.70	-7.69	36.46	-3.45	36.68	1,345
Plot sum								4,384

Therefore, the estimate for this 1/50-acre plot is 4,384 serotinous cones. Assume that we had estimates totalling approximately 110,000 cones from twenty-five such plots distributed over the 1,000-acre tract. Then, since our total acres sampled would be 25 (1/50 acre) = 0.5 acre, we can convert the 110,000 cones to a per-acre figure and we have:

$$110,000 (1.0 \text{ acre}/0.5 \text{ acre}) = 220,000 \text{ cones per acre.}$$

Method 2

Assuming existence of the following data:

1. Mean plot d.b.h. in inches = 10,
2. Mean plot age in years = 100,
3. Number of serotinous-cone type of trees per acre = 150.

Then using the proper formula (see page 2) we would have:

$$1.925(10)^2 - 1.371(100) + 3.411(150) - 0.00615(150)^2 + 46.2 = 474.9$$

The square of 474.9 or 225,530 is the estimate of number of cones per acre, or approximately 226,000.

B. Number of Seed Per Acre

Either make a direct seed count per cone or obtain length measurements and use Thompson's formula. Then, assume a sample cone estimate of 10 seed per cone. Using Method 1 we would estimate:

$$220,000 \times 10 = 2,200,000 \text{ seed/acre.}$$

Using Method 2 we would estimate:

$$226,000 \times 10 = 2,260,000 \text{ seed/acre.}$$

C. Number of Viable Seed Per Acre

Assume that either cutting or germination tests on seed from sample cones resulted in viability estimates of 80 percent. Then we would estimate viable seed per acre as being:

$$\begin{aligned} 2,200,000(0.8) &= 1,760,000, \text{ using Method 1} \\ \text{or, } 2,260,000(0.8) &= 1,808,000, \text{ using Method 2.} \end{aligned}$$

LIMITATIONS OF EQUATIONS (1) AND (2)

Equations (1) and (2) are interim and are most applicable to the largely mature and overmature stands sampled in this study near West Yellowstone, Montana, and Island Park, Idaho (Lotan 1967, 1968). The characteristics of these stands are shown in table 4. It is believed that these two equations will also be representative for the vast acreages of these types of stands in the northern Rocky Mountain and Intermountain Regions (Idaho, Montana, Wyoming, and Utah) not sampled here.

A positive coefficient might be expected for age in equations (1) and (2) for stands up to about 60 years old. However, in older stands such as those studied here, the trees gradually, with increased age, lose their capacity for cone production. Thus, we have a negative coefficient for age.

Table 4.--*Characteristics of stands in serotinous cone survey,
Gallatin National Forest, 1963, and Targhee National
Forest, 1964*

Study area	Average age	Average d.b.h.	Average total height
	<i>Years</i>	<i>Inches</i>	<i>Feet</i>
West Yellowstone Flat	111	8.3	49.2
Madison Plateau Front (old burn)	88	6.7	53.0
Island Park Flat	117	10.0	66.0
Moose Creek Plateau	191	12.5	61.0

SIGNIFICANCE OF STORED SEED PER ACRE

Seed per acre, stored in closed cones, give an estimate of the biotic potential of the previous stand to regenerate the disturbed area. If one knows the probability of a seedling becoming established (probable seed-seedling ratio) at a specific age (1 year old, 3 years old, etc.) for a given seedbed condition, habitat type, climate, and aspect, he can then estimate the number of seedlings per acre that can be expected at the age specified.

Throughout its range, lodgepole pine regeneration tends to vary. Stored seed per acre can vary from a few thousand to a few million and considering this wide range an estimator need only be concerned with large differences in stocking potential; that is, whether one might expect stocking on the order of a few hundred stems per acre or tens of thousands per acre.

After harvesting lodgepole pine in central Montana foresters can expect 20,000 seedlings per acre. Elsewhere, as in some parts of Wyoming, an absence of the serotinous cone habit in lodgepole pine requires an artificial means of regenerating the stand. However, in many areas, regeneration by natural means is variable. One of the important factors in this variability is the number of seed stored in serotinous cones of the species. An estimate of seed per acre is the first factor to consider in predicting success or failure of the natural regeneration process in lodgepole pine.

We can now see a number of opportunities to regulate stocking through manipulation of either the estimated seed supply or the environment. It is possible to secure adequate stocking on areas where experience-based seed-seedling ratios and stored seed estimates indicate probable understocking. This can be accomplished by any one of the following: intensifying site preparation; treating slash to assure maximum seed release; treating the area to reduce seed loss to rodents; or by using a combination of these treatments to gain maximum benefits from stored seed. Conversely, expected overstocking may be reduced by: limiting site preparation; reducing disturbance of the soil surface during logging; or by treating the slash to destroy a portion of the stored seed. During preparation of cutting plans, it is important to fully realize the potential for natural regeneration. This information will be useful in preparing stand prescriptions for future treatments; these treatments may involve major thinning operations or the gathering of seed and growing of seedlings at a nursery.

REFERENCES

- Boe, Kenneth N.
1956. Regeneration and slash disposal in lodgepole pine cuttings. Northwest Sci. 30(1): 1-11, illus.
- Crossley, D. I.
1956. Fruiting habits of lodgepole pine. Can. Dep. Northern Aff. and Nat. Resources, Forest Res. Div. Tech. Note 35, 32 p., illus.
- Lotan, James E.
1963. Sampling serotinous cones in lodgepole pine. Mont. Acad. Sci. Proc. 23: 20-24, illus.
- _____
1967. Cone serotiny of lodgepole pine near West Yellowstone, Montana. Forest Sci. 13(1): 55-59, illus.
- _____
1968. Cone serotiny of lodgepole pine near Island Park, Idaho. U.S. Forest Serv. Res. Pap. INT-52, 6 p., illus.
- Tackle, David
1964. Regenerating lodgepole pine in central Montana following clear cutting. U.S. Forest Serv. Res. Note INT-17, 7 p., illus.
- Thompson, Ronald E.
1969. Relationship of seed yield and viability to the age of cones of lodgepole pine. Unpub. master's thesis, Univ. of Mass., Amherst.

LOTAN JAMES E. and JENSEN CHESTER E.

1970. Estimating seed stored in serotinous cones of lodgepole pine, USDA Forest Serv. Res. Pap. INT-83, 10 p., illus.

Two interim formulas for estimating the number of serotinous cones in lodgepole pine stands are presented. One formula requires a 25-limb sample count of serotinous cones on felled trees for which total tree estimates are desired together with tree d.b.h., crown ratio, and age; although this formula is more dependable, it is also more costly in application. The second formula requires only a count of trees bearing serotinous cones on each plot plus average d.b.h. and average age for trees on each plot. Methods are also presented for expanding these estimates to number of viable seeds per acre, for the area of interest.

LOTAN JAMES E. and JENSEN CHESTER E.

1970. Estimating seed stored in serotinous cones of lodgepole pine, USDA Forest Serv. Res. Pap. INT-83, 10 p., illus.

Two interim formulas for estimating the number of serotinous cones in lodgepole pine stands are presented. One formula requires a 25-limb sample count of serotinous cones on felled trees for which total tree estimates are desired together with tree d.b.h., crown ratio, and age; although this formula is more dependable, it is also more costly in application. The second formula requires only a count of trees bearing serotinous cones on each plot plus average d.b.h. and average age for trees on each plot. Methods are also presented for expanding these estimates to number of viable seeds per acre, for the area of interest.

LOTAN JAMES E. and JENSEN CHESTER E.

1970. Estimating seed stored in serotinous cones of lodgepole pine, USDA Forest Serv. Res. Pap. INT-83, 10 p., illus.

Two interim formulas for estimating the number of serotinous cones in lodgepole pine stands are presented. One formula requires a 25-limb sample count of serotinous cones on felled trees for which total tree estimates are desired together with tree d.b.h., crown ratio, and age; although this formula is more dependable, it is also more costly in application. The second formula requires only a count of trees bearing serotinous cones on each plot plus average d.b.h. and average age for trees on each plot. Methods are also presented for expanding these estimates to number of viable seeds per acre, for the area of interest.

LOTAN JAMES E. and JENSEN CHESTER E.

1970. Estimating seed stored in serotinous cones of lodgepole pine, USDA Forest Serv. Res. Pap. INT-83, 10 p., illus.

Two interim formulas for estimating the number of serotinous cones in lodgepole pine stands are presented. One formula requires a 25-limb sample count of serotinous cones on felled trees for which total tree estimates are desired together with tree d.b.h., crown ratio, and age; although this formula is more dependable, it is also more costly in application. The second formula requires only a count of trees bearing serotinous cones on each plot plus average d.b.h. and average age for trees on each plot. Methods are also presented for expanding these estimates to number of viable seeds per acre, for the area of interest.

Headquarters for the Intermountain Forest and
Range Experiment Station are in Ogden, Utah.
Field Research Work Units are maintained in:

Boise, Idaho
Bozeman, Montana (in cooperation with
Montana State University)
Logan, Utah (in cooperation with Utah
State University)
Missoula, Montana (in cooperation with
University of Montana)
Moscow, Idaho (in cooperation with the
University of Idaho)
Provo, Utah (in cooperation with
Brigham Young University)

NATIONAL AGRICULTURAL LIBRARY

1022966184