Gashwiler

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FURTHER STUDY OF CONIFER SEED SURVIVAL IN A WESTERN OREGON CLEARCUT[1]

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Abstract. The survival of naturally disseminated, filled, seed of Douglas-fir (*Pseudotsuga menziesii*), western hemlock (*Tsuga heterophylla*), and western redcedar (*Thuja plicata*) was studied from 1960 to 1967. Ten per cent of the Douglas-fir seed survived from the start of seed fall until the end of germination the following year. Mice and shrews, mostly deer mice (*Peromyscus maniculatus*), destroyed an estimated 41% of the seed; birds and chipmunks (mostly birds) took 24%; and other factors (nonviability of filled seeds, invertebrates, disease, and others) accounted for 25%. Western hemlock seed survival was 22%. Mice and shrews (mostly deer mice) destroyed an estimated 22% of the seed, birds and chipmunks (mostly birds) 3%, and other agents 53%. The sample of western redcedar seed was too small to be reliable. Douglas-fir seeds were preferred by ground-feeding birds and small mammals—less than half as many hemlock were taken. Most Douglas-fir and hemlock seed mortality occurred before the start of germination.

INTRODUCTION

Prompt forest regeneration is necessary to sustain maximum timber production in the Pacific Northwest. Although artificial seeding and planting are common practices, natural regeneration still accounts for much reproduction. Considerable effort to favor natural regeneration is justified because of its potential economy and genetic adaptation to site. Knowledge of the factors destroying seed and their importance is essential to development of practices encouraging regeneration.

A cooperative study was conducted by the Bureau of Sport Fisheries and Wildlife, Willamette National Forest, and the Pacific Northwest Forest and Range Experiment Station from 1960 to 1967. It was designed to measure the loss to wildlife of naturally disseminated tree seed on a clearcut. Points investigated were: (1) the percentage of seed surviving all factors (a) between the start of seed fall and the start of germination, (b) between the start of seed fall and the end of germination, and (c) during the germination period; (2) the percentage of seed taken between start of seed fall and end of germination by (a) mice and shrews, (b) birds and chipmunks, and (c) other factors; and (3) the difference in seed losses between tree species.

This investigation continued the work for 1955–60 reported by Gashwiler (1967), but to secure more specific data large seed-survival units were used instead of small units of subplot size as in the former study. The study area was on the H. J. Andrews Experimental Forest in the Cascade Mountains of western Oregon. This forest includes the Lookout Creek watershed, a tributary of the Blue and McKenzie rivers, and ranges in elevation from 1,400 to 5,250 ft. The 25-acre study area was clearcut in the spring of 1959 and slash burned in September. An average of 80,720 bd ft/acre of sound timber was removed—79% Douglas-fir, 11% western redcedar, and 10% western hemlock and others. This clearcut faces south, its elevation ranges from 1,980 to 2,250 ft, and its slope averages about 14%.

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METHODS OF STUDY

Animal populations

Birds.—Only general observations were made of the bird life from 1960 to 1963, but in 1964 a permanent census line about 3,175 ft long was established and censuses were made twice weekly from early spring until winter. During winter, when ground-feeding birds were absent or very scarce, only general observations were made at irregular times. The census was made by walking slowly along the line with frequent stops and generally took about 1 hr. Observed birds were recorded, and their perpendicular distances from the line estimated (Breckenridge 1935). Biweekly censuses (generally four) were averaged to give two monthly population figures, and the average perpendicular distance for each species was doubled to estimate the width of strip censused (Kendeigh 1944). This permitted calculation of the area covered and an estimation of the number of each species per acre. When only large flocks of a single species were present, counts of birds in these flocks were considered the total for the clearcut (Hagar 1960).

Small mammals.—A permanent, square grid of 100 live traps spaced 50 by 50 ft was used to obtain small mammal population estimates. Sherman-type live traps (3 by 3 by 10 inches) were baited with mixed grain. They were set for 6 consecutive nights in April and September. Each animal was ear-tagged and released at the capture site. The population of each species was calculated by the "Lincoln Index" method, with the last three daily estimates averaged. Average adjusted range length (Stickel 1954) was based on three or more captures with not over one on the edge of the grid. A strip one-half the average adjusted range length was added to the exterior of the grid to delineate the effective trapping area.

Seed survival

Seed traps and ground samples.—Seed loss was measured by comparing the number of filled seeds found in traps and in ground samples (Squillace and Adams 1950). Only filled seeds are considered in this paper and hereafter will be referred to as seed.

Trapped seeds were considered to represent the total crop, whereas ground-sample seeds were exposed to all forms of mortality. Differences between the number found in traps and ground samples were indicative of fallen seed losses prior to germination.

Seed traps measured 2 by 3 ft with an effective catch area of 5.7 square ft. Trap bottoms were wire window screen and tops were 3/8-inch mesh hardware cloth. Twenty-four traps were used to sample the clearcut each year except 1964 when water washed one away. Single traps were randomly placed in three concentric belts from the forest edge as follows: 50- to 100-ft belt, 12 traps; 200- to 250-ft, eight traps; and 350- to 400-ft, four traps. Seeds were collected in April just prior to germination and in late August just before seed fall. Each seed was cut to determine if the endosperm filled the seed coat. This is only a general indication of viability, however, since all filled seeds do not germinate (U. S. Forest Service 1948).

Two, 1-ft^2 ground samples were taken near each trap to determine the number of seeds surviving from seed fall to germination. The samples were dried and stored until the seeds could be recovered by personnel of the Oregon Cooperative Seed Laboratory.

Seed-survival units.—The study units were exclosures and open quadrats designed to measure seed survival under different kinds of animal use. The number of freshly germinated seedlings in the study units was used as an index of seed sur-

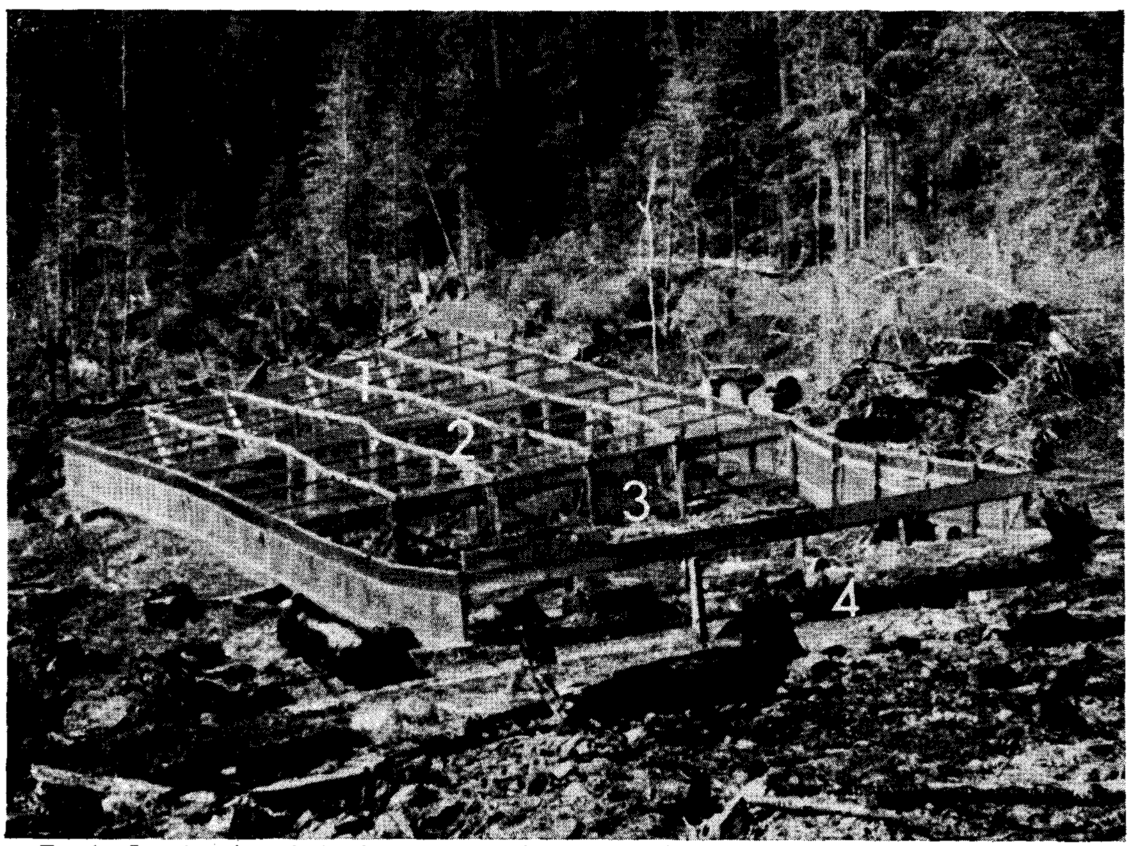

FIG. 1. Set of seed-survival units used to regulate access of birds and mammals to fallen conifer seed: (1) closed unit which excluded birds and mammals; (2) mammal unit which permitted only mouse and shrew entry; (3) bird unit which permitted only bird entry; and (4) open unit which allowed unrestricted entry.

vival. Four units were included in each set, and each set was replicated three times (Fig. 1). The four treatments per set were: (1) mammal unit—only mice and shrews could enter; (2) bird unit—only birds could enter; (3) closed unit—birds and mammals excluded; and (4) open unit—unrestricted animal use. By comparing the number of seedlings in each treatment with the number of seeds in the respective traps, the percentage of seed survival from the start of seed fall through the germination period was obtained.

Each survival unit was 35 ft². The wooden frames were approximately 60 inches high, with a 14-inch-wide strip of aluminum flashing at the top and a 36-inch strip of ⅜-inch-mesh hardware cloth below this. The bottom skirt, which reached approximately 10 inches to the ground surface, was ¾-inch-mesh hardware cloth on the mammal unit and ⅜-inch-mesh hardware cloth on the others (Fig. 1). The bird and closed units had the ⅜-inch-mesh wire extended into the ground 12 inches or more with an outward underhang at the bottom of approximately 12 inches. Bird exclosures had 1-inch, hexagonal mesh wire on top. The open units had only posts at each corner except where they joined the exclosures. Nine, 3-ft² subplots were located in each unit. Corners of these plots were marked with wire stakes and a cord was run around each to delineate size. These study units were roughly similar to those described by Wagg (1964).

The site of each set of study units was selected near a reasonably uniform stand of timber, a fairly straight cutting edge, and a gentle topography with similar soil and cover conditions. The location of each unit within each set was randomly selected. Two seed traps were located in each unit to measure the crop and were tended in spring and fall.

Despite intensive control measures, small mammals gained entrance to the bird and closed units and compromised the data. However, their activities had no adverse effect on the mammal and the open units, and these data were available for use. In a few instances, single birds got into the mammal units. The circumstances surrounding these entries indicated that little, if any, seed losses resulted, and they have been ignored in interpreting data.

Differences in mortality between species were compared by the chi-square method at the 95% confidence level.

Animal Populations

Birds

From 1964 to 1966, 58 species of birds were noted on or adjacent to the clearcut. The major ground-frequenting, seed-eating birds on the clearcut were juncos (*Junco oreganus*), varied thrushes (*Ixoreus naevius*), song sparrows (*Melospiza melodia*), fox sparrows (*Passerella iliaca*), white-crowned sparrows (*Zonotrichia leucophrys*), and golden-crowned sparrows (*Z. coronata*). Peak numbers were reached during late September; by the latter part of October, populations had dropped below one bird per acre and continued falling until the last of December (Fig. 2). None of these birds were noted in January and February, but a few reappeared in March. A comparison of ground-feeding bird populations and seed-fall data (Gashwiler 1969) showed that the peak bird population in the fall had only about 20% of the annual seed crop available for food. The bird population declined rapidly while the seeds increased. The impact of birds on the seed during fall and winter must have been light. In spring, however, the situation was different; a relatively large bird population was present to eat the available seeds and germinants (seedlings with the seed coat on the cotyledons). Spring appeared to be a period of relatively high loss of seeds and germinants to birds on the study area. Toumey and Korstian (1931) reported that most bird damage in nurseries occurred when the germinating seed was raised and the seed coat was still attached to the cotyledons.

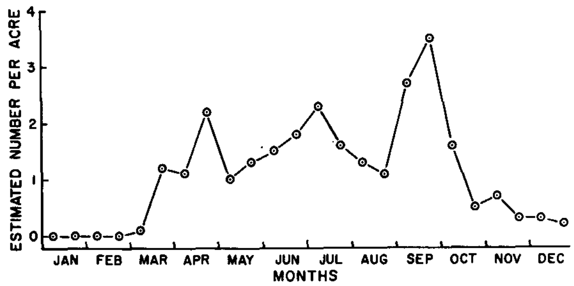

FIG. 2. Average estimated number of ground-feeding, tree-seed-eating birds per acre of study area for 1964 to 1966 (juncos, varied thrushes, and song, fox, white-crowned, and golden-crowned sparrows).

Small mammals

Estimated deer mouse populations ranged from 0.4 to 4.3 mice per acre in spring and from 2.4 to 8.6 in fall (Fig. 3). Spring numbers were always lower than those of the preceding fall and were roughly uniform except in 1963. Controls apparently limit deer mouse populations regardless of the fall numbers (Gashwiler 1965).

Fall deer mouse populations were more variable than spring populations. They were also uniformly higher from 1960 to 1963 than from 1964 to 1966 (Fig. 3). Reasons for this difference are

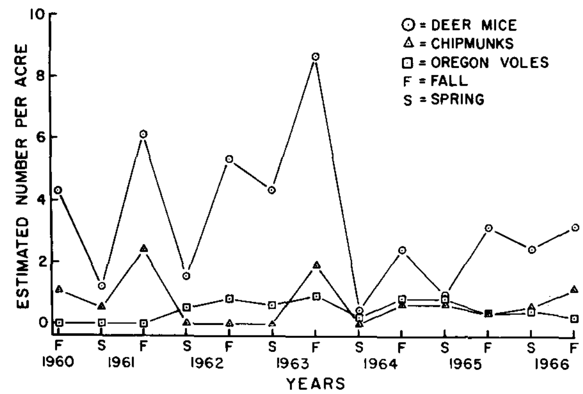

FIG. 3. Estimated number of small mammals per acre by season and year.

not known. Perhaps ground-plant cover had some influence on the populations; it ranged from 9% to 44%, but became stabilized at 41–44% in 1963.

In 1962 the combined Douglas-fir and hemlock seed crop was over 0.9 lb./acre. During the fall of 1963 the deer mice apparently responded to this food supply by increasing to 8.6 animals per acre (Fig. 3). This response was in accord with earlier data (Gashwiler 1965). However, the much heavier 1965 seed crop of 2.2 lb. of Douglas-fir and hemlock per acre did not cause a similar response in the fall of 1966. Reasons for this variation are not apparent; several interacting factors, besides size of seed crop, probably influence the number of deer mice per acre.

Smaller populations of Townsend's chipmunks (*Eutamias townsendii*) were also present. In general, numbers tended to be lower in spring than in the fall. However, only a trace were caught in the spring and fall of 1962 and the spring of 1963; none were captured in the spring of 1964. Catches in early spring may be poor because animals are still in hibernation. Many of the chipmunks caught in the clearing may actually have been timber-dwelling animals ranging into the logged area. Townsend's chipmunks seem to prefer an open forest or heavy brush-like habitat.

Oregon voles (*Microtus oregoni*) were not captured on the clearcut until the spring of 1962, about 2 years after burning. They were apparently present only in low numbers.

During the study, several other small mammals were captured: 16 vagrant shrews (*Sorex vagrans*), 11 Trowbridge's shrews (*Sorex trowbridgii*), 10 jumping mice (*Zapus trinotatus*), three red-backed voles (*Clethrionomys occidentalis*), one ermine (*Mustela erminea*), one California ground squirrel (*Citellus beecheyi*), and one bushy-tailed wood rat (*Neotoma cinerea*). The capture of red-backed voles 3 and 6 years after the burn was of particular interest. Other studies in the Andrews Forest have indicated a much longer period before redbacks reoccupy burned clearcut habitat. The animals were caught in cool sites in dense fireweed and blackberry cover near the forest edge.

Seed Survival

The size of the annual seed crops varied widely during the study (Table 1). Three yearly seed crops were less than 50,000 seeds/acre, two were between 75,000 and 100,000, and one over 225,000. Total seed fall for the 6 years was about 451,000 averaging 75,000 per year. Hemlock seed crops were the most uniform, producing 60–90% of the annual seed fall; Douglas-fir crops ranged from 4% to 40%. Redcedar seed production was generally low and erratic and varied from 0% to 24%.

Seed-survival percentage was calculated for two periods: (1) overwinter—from the start of seed fall to the start of germination (clearcut ground-sample seeds per acre divided by clearcut trapped seeds per acre); and (2) total—from the start of seed fall to the end of germination (open-unit seedlings per acre divided by open-unit trapped seeds per acre).

Douglas-fir

Overwinter survival of Douglas-fir seed was 20% (3,800 ÷ 18,800) and 80% was lost to all factors (Table 2). This survival was approximately one-third less than previously reported (Gashwiler 1967) and may have resulted from higher proportionate mortality of the smaller seed crops.

Total seed survival to the end of germination was only 10% (1,400 ÷ 14,800); 90% were destroyed or were nonviable (Table 2). These figures correspond closely with the 12% survival of Douglas-fir in the earlier study (Gashwiler 1967).

In the mammal unit 34% (4,100 ÷ 12,000) of the total Douglas-fir seeds survived; 66% was lost from mouse, shrew, and invertebrate use and from disease and nonviability (Table 2). Estimates of mouse and shrew use of Douglas-fir seed can be obtained by subtracting the 25% loss from "other factors" (insects, disease, unidentified, and nonviability) given by Gashwiler (1967). On this basis, 41% of the seed was destroyed by mice and shrews. Most of this mortality was probably caused by deer mice, which are heavy tree-seed eaters and were most abundant (Fig. 3).

Actual seed mortality attributable to birds and chipmunks is estimated at 24% (34% minus 10%). Birds were probably more responsible, since general observations suggest that chipmunks do not seriously "glean" the relatively small con-

TABLE 1. Yearly number and percentage of filled seeds trapped by species and total estimated number per acre (based on 24 seed traps)—1960–65

Seed year	Douglas-fir		Hemlock		Redcedar		Total	
	Number	Percentage	Number	Percentage	Number	Percentage	Number	Estimated number per acre
1960	1	4	23	85	3	11	27	8,600
1961	24	10	202	82	20	8	246	78,300
1962	97	40	148	60	0	0	245	78,000
1963	2	5	33	92	1	3	36	11,500
1964[a]	22	15	91	61	35	24	148	49,200
1965	225	32	436	62	46	6	707	225,100
Total	371	26	933	66	105	8	1,409	450,700

[a]23 traps in sample

TABLE 2. Average of estimated number of filled seeds in seed traps and ground samples and number of seedlings in open and mammal units, 1960–65

Sample type	Average of estimated number per acre			
	Douglas-fir	Hemlock	Redcedar	Total
Seeds				
Seed traps sampling clearcut to start of germination	18,800	47,600	5,200	71,600
Ground samples in clearcut to start of germination	3,800	11,200	3,000	18,000
Seed traps sampling units to end of germination				
Open units	14,800	19,900	2,500	37,200
Mammal units	12,000	23,700	2,300	38,000
Seedlings in units to end of germination				
Open units	1,400	4,300	200	5,900
Mammal units	4,100	5,900	300	10,300

ifer seeds from the heavy ground cover and litter, and populations were generally low and were hibernating during winter and early spring.

Hemlock

Overwinter survival of hemlock seed was 24% (Table 2). The 76% overwinter mortality included all causes plus nonviability. This survival was less than half that found earlier (Gashwiler 1967). Hemlock seed survival for this period was 1.2 times as great as for Douglas-fir (24% vs. 20%), but the difference was not statistically significant. In the prior study, hemlock seed survival was nearly double that of Douglas-fir.

From seed fall until the end of germination in the open units, total hemlock seed survival was 22%; 78% was lost to all forms of mortality plus nonviability. This survival was 2.2 times as great as for Douglas-fir (22% vs. 10%), but this difference was not statistically significant. Hemlock seed losses were 2% for all factors during the germination period. This is much lower than the 29% for the same period in the previous study (Gashwiler 1967). High pre-germination mortality may have reduced the small seed crop so much that it was no longer a sought-after food item.

The mammal units showed that 25% of the hemlock seed survived; 75% suffered mortality from mice, shrews, invertebrates, and disease, plus nonviability (Table 2). An approximate figure for loss of hemlock seeds to mice and shrews can be obtained by using the 53% given for "other factors" by Gashwiler (1967). Consequently, 22% (75% minus 53%) of the seed loss was the result of mouse and shrew activity. As with Douglas-fir, most of the loss was probably due to deer mice. Birds and chipmunks took only 3% (25% minus 22%) of the crop. Again most of this was probably taken by birds.

Redcedar

Since the redcedar sample was small, the results should be accepted with reservations. These results vary considerably from those reported earlier (Gashwiler 1967). From seed fall until the start of germination, 58% of the seeds survived, and 42% were lost to all causes (Table 2). Redcedar mortality was significantly lower than Douglas-fir and hemlock, but was over four times as high as redcedar mortality in the previous study (Gashwiler 1967). By the end of germination, 8% of the seeds in the open units were surviving, and 92% were lost to all causes; this percentage of loss was also roughly four times that reported previously. Mortality during the germination period amounted to 50% (92% minus 42%). Mice, shrews, invertebrates, and disease, plus nonviability, were responsible for 87% (100% minus 300 ÷ 2,300) of the total mortality. By using the 35% for "other factors" from Gashwiler (1967), mortality from mice and shrews was estimated as 52% (87% minus 35%). Birds and chipmunks accounted for the remaining 5% (13% minus 8%).

Other relationships

As previously reported, ground-feeding birds and small mammals showed a preference for Douglas-fir seeds. If the percentage of "other factors" from Gashwiler (1967) can be accepted for adjusting the values, mice, shrews, birds, and chipmunks accounted for 65% (41% + 24%) of the Douglas-fir seed mortality, but only 25% (22% + 3%) of that for hemlock and 57% (52% + 5%) for redcedar. These percentages are all higher than previously given and may reflect the reduced seed crops that were apparently too small to favor a large survival, but were still large enough in most instances to make seed gathering by animals worthwhile. A high percentage (78%) of the Douglas-fir and hemlock seed losses occurred prior to germination. Redcedar losses for the period before and during germination were roughly equal.

During the study plant ground cover ranged from 9% to 44%; small mammals, primarily deer mice, and birds were present in moderate to good numbers. Under these conditions the conifer seed crops, which averaged 75,000 seeds per acre, suffered relatively heavy mortality. Most of the Douglas-fir seeds were considered to have been lost to birds and small mammals (primarily deer mice); about one-fourth of the hemlock and redcedar seeds were destroyed by birds and mammals and one-half were destroyed by other agents. Reduction in seed mortality should aid regeneration by increasing the numbers of seeds available for seedling establishment. Until satisfactory operational methods are devised to increase both seed and seedling survival, large numbers of seeds are needed for adequate restocking.

Acknowledgments

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