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CONIFER SEED SURVIVAL IN A WESTERN OREGON CLEARCUT

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Abstract. A study of the survival of naturally disseminated tree seed was made in a clearcut area on the H. J. Andrews Experimental Forest in the Cascade Range of western Oregon during 1955–60. From start of seed fall until the end of germination in late spring the following year, 12% of the Douglas-fir (*Pseudotsuga menziesii*) seed survived. Ground-feeding birds and small mammals caused 63% of the seed loss and other agents 25%. Thirty-one per cent of the seed of western hemlock (*Tsuga heterophylla*) lived from the start of seed fall until the end of germination. Of the amount lost, birds and mammals took 16% and all other factors 53%. A large proportion (65%) of western redcedar (*Thuja plicata*) seed survived during the same period. The entire loss was attributed to causes such as nonviable filled seeds, disease, invertebrates, and others. Ground-feeding birds and small mammals showed a definite preference for Douglas-fir seeds. Only about 25% as many hemlock seeds were taken, and redcedar was not consumed in appreciable amounts. Most of the seed depredations by birds and mammals occurred from start of seed fall to start of germination; other factors took heaviest toll during the germination period.

INTRODUCTION

Prompt regeneration of new forests after logging is a major problem in the Douglas-fir region of western Oregon and Washington. An important deterrent to forest regeneration in this area is considered to be destruction of seed by small mammals (Moore 1940, 1942, Kangur 1954, Hooven 1958). Birds, insects, molds, and other factors also take a toll of seed (Isaac 1943, Hagar 1960, Lawrence and Rediske 1962). Some seed, of course, survives to produce new trees, as attested by the eventual restocking of most deforested areas. However, prompt regeneration is desired by today's intensive forest management.

The principal aim of a study conducted from 1955 to 1960 was to determine the percentage of fallen tree seed that survived. Specific questions were: (1) What proportion of filled seed survives, and what proportion of the mortality can be attributed to bird and small mammal depredations and other losses (nonviable filled seeds, invertebrates, disease, etc.) (a) from start of seed fall until start of germination; (b) from start of seed fall until end of germination; and (c) during the germination period; and (2) Are seed losses related to (a) kinds and numbers of small mammals; (b) size of seed crop; and (c) tree species.

The study was made on the H. J. Andrews Experimental Forest[1] in the Cascade Range of western Oregon. This forest includes almost the entire watershed of Lookout Creek, a tributary of Blue River, where elevations range from 1,400 to 5,250 ft.

The 41-acre study area was clearcut in 1953 and the logging slash burned the same fall. A total of 3,940,440 board feet of sound timber was removed—81% Douglas-fir (*Pseudotsuga menziesii*), 12% western hemlock (*Tsuga heterophylla*) and true firs (*Abies* spp.), and 7% western redcedar (*Thuja plicata*). Elevation of the south-facing unit ranged from 2,500 to 2,750 ft, and its

[1] Maintained and operated by U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station, with headquarters at Portland, and the Willamette National Forest with offices at Eugene, Oregon.

average slope of 11% was more gentle than much of the surrounding terrain.

Methods of Study

Animal populations

In addition to general observations of bird numbers, small mammal populations were estimated on a trapping grid where 100 traps were spaced 50 ft apart. Sherman-type live traps (3 by 3 by 10 inches) were baited with chicken scratch feed in cold weather and whole oats during warmer periods. Traps were set for 6 consecutive nights following snow melt in either April or May and again in September each year. Each animal was ear-tagged and released at the capture site. The population of each small mammal species was estimated by the "Lincoln Index" (Dice 1952). The last three daily computations of each trapping period were averaged for the final estimate. 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 equal to one-half of the average adjusted range length was then added to the exterior of the grid to delineate effective area covered by the traps.

Seed survival

Seed traps and ground samples.—Seed survival was measured directly by comparing numbers of filled seeds recovered from seed traps and ground samples (Squillace and Adams 1950, Davis 1959). Trapped seeds were assumed to be protected against loss to animals and other agencies, while ground samples were exposed to all types of mortality. Difference in numbers of filled seeds per unit area collected from traps and ground samples gave an estimate of fallen seed percentage prior to germination.

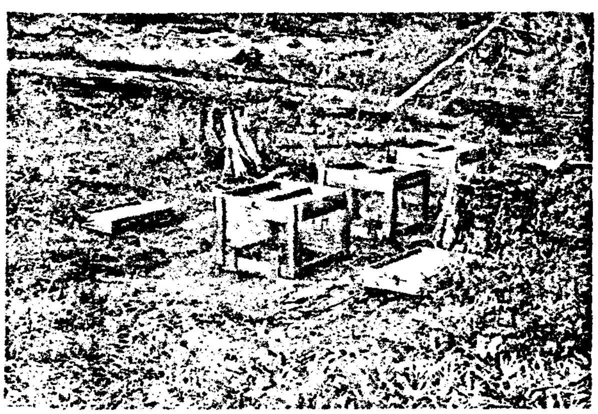

Fig. 1. Seed traps (right and left) used to estimate seed fall and exclosures (center) used to estimate seed fall survival by seedling indices. Some trampling occurred outside the units, although plots themselves were essentially undisturbed.

Seed traps measured 2 by 3 ft and had an effective surface area of 5.7 ft^2 (Fig. 1). Trap bottoms were made of 14- by 18-mesh window screen and tops of ⅜-inch mesh hardware cloth.

Sixteen seed traps were used during 1955 and 24 during 1956–60. One trap was placed on each side of each set of randomly located exclosures. Seeds were collected from traps once a month, except when snow or other conditions interfered, and were cut for ocular appraisal to determine if the endosperm filled the coat. However, all filled seeds are not viable. Toumey and Korstian (1931) state, "A large percentage of the seed that appears good under ocular examination fails to grow when subjected to germination tests."

One-square-foot ground samples were taken in duplicate near each seed trap to recover seeds from sites exposed to all kinds of mortality from seed fall to germination. Large pieces of litter in the samples were closely examined for seeds, then discarded. The remaining litter was removed down to mineral soil and placed in bags. Where sampling points fell on rotted logs, the surface was carefully removed and examined for seeds. Bags of moist soil and debris were dried and stored until seeds could be recovered by personnel of the Oregon Cooperative Seed Laboratory. These seeds were also cut to determine the number filled.

A record was kept of seed remains found in the ground samples from 1957 to 1959. All remains are considered to be from filled seeds. While remains supply a clue to the amount of the various seeds utilized by wildlife, this method has deficiencies. For example, seed remains from tree-feeders may blow into a cutting; entire seeds are sometimes eaten by animals; remains are frequently broken into small pieces, making difficult their detection as well as identification of the animal responsible. Identity of the cause of mortality from the 1959 seed remains was attempted by methods described by Moore (1940), Kangur (1954), and Lawrence and Rediske (1962).

Exclosures and quadrats.—The number of freshly germinated seedlings was also used as an index of seed survival. Agents responsible for seed losses and their relative influence were determined by seedling checks (twice weekly during most of the germination period) within small exclosures and open quadrats. Seeds were considered to become seedlings when the radicle penetrated the soil and the plant became partially erect. By using the estimated number of filled seeds trapped per acre as a base for all computations, the exclosures permitted estimates of seed survival or loss from start of seed fall through the germination period.

Exclosure frames, 2 ft high and 3 ft square, were constructed of 1- by 4-inch redcedar lumber and were covered on the top and sides with ⅜-inch mesh hardware cloth (Fig. 1). The mesh was small enough to exclude birds and small mammals but large enough to permit winged seeds, most insects, and other invertebrates to enter. The upper surface of a wooden frame of 1- by 4-inch lumber was set flush with the ground surface to serve as a base for each exclosure and to prevent entry of birds and mammals when desired. In very loose soil additional precautions would need to be taken to exclude small mammals, especially *Microtus*. Godman and Krefting (1960) used similar exclosures in Upper Michigan.

Three exclosure frames and one open quadrat of the same area were included in each set of sampling units. Exclosures are referred to as "closed," "open-closed," and "open." The closed exclosure was made bird- and mammal-proof when set out. The open-closed exclosure had its base set 4 inches above ground surface from the time of seed fall until just prior to germination, when it was lowered and made bird- and mammal-proof. The open exclosure was permanently set 4 inches above ground, and the open quadrat was marked only by wire stakes at each corner.

Exclosures and quadrats were randomly located within three belts from timber edge. Number of sets in each belt, with distances from the edge, was as follows:

Year	50–100 ft	200–250 ft	350–400 ft
1955	5	3	0
1956–60	6	4	2

Data were analyzed by the chi-square (χ^2) differences for mortality. The 1% level was selected as a criterion of significance.

Results and Discussion

Animal populations

Birds.—The most common ground-frequenting summer residents on the cutting were juncos (*Junco oreganus*), song sparrows (*Melospiza melodia*), and white-crowned sparrows (*Zonotrichia leucophrys*). Small numbers of pine siskins (*Spinus pinus*), which sometimes feed on the ground, were observed mostly in flight or in trees in summer. In the fall, summer residents were joined or replaced by members of their species plus golden-crowned sparrows (*Zonotrichia coronata*) and other less abundant ground-feeding birds. Length of the fall migration seems to be closely associated with weather conditions; consequently, times of arrival and departure vary. Small numbers of juncos, song sparrows, and sometimes rather large flocks of siskins and red crossbills (*Loxia curvirostra*) frequented the cutting after peak migration. The ground-feeders apparently move to lower elevations during winter and flocks congregate along the McKenzie River. In early spring, even when patches of snow still remain, birds start moving to higher elevations. Spring migration often reaches a peak when most seeds are germinating. Large numbers of birds are generally evident for only a short time; later, only the breeding population and lesser numbers of later migrants remain. The fall migration often occurs when new seed is falling and consequently available to ground-feeders.

In his studies in the Douglas-fir region of northwestern California, Hagar (1960) found the largest bird populations on cutover areas 3–7 years old. He reported an average of about 2.6 birds of all species per acre during the breeding season. Of this number, juncos comprised nearly 1 bird per acre. The study fell within Hagar's period of high bird population.

Small mammals.—Estimated deer mouse (*Peromyscus maniculatus rubidus*) populations fluctuated widely between spring and fall (Fig. 2). Spring levels ranged from 0.5–2.7 mice per acre and fall numbers from 2.0–11.5. Regardless of size of the fall population, however, spring numbers always were low and, with the exception of 1959, reasonably uniform. This suggests that the winter conditions impose a population limit on deer mice.

Overwinter survival of *Peromyscus* might be expected to be correlated with current tree seed production, yet in 1956–57, when seed fall was heavy, spring 1957 deer mouse numbers were low. This single observation could imply that abundant tree seed alone does not insure a high overwintering deer mouse population. Other factors, such as weather, cover, and predation—singly or together, seem to be more important than tree seed abundance to winter survival in cuttings. Movement may also influence the size of the population to a considerable degree.

Fall deer mouse populations fluctuated widely (Fig. 2). The tree seed crop was moderate in 1954–55 and good in 1956–57, and relatively high populations of deer mice followed in the fall of 1955 and 1957 respectively. Thus there appeared to be a relationship between tree seed abundance and size of deer mouse population the next fall (Gashwiler 1965).

Townsend's chipmunks (*Eutamias townsendii cooperi*) were also present on the trapping grid. Spring trapping was done as soon as most of the snow melted, although patches were often present in the timber and along the forest edge and weather was frequently cold, with wet snow, sleet, and rain. Such conditions were apparently conducive to

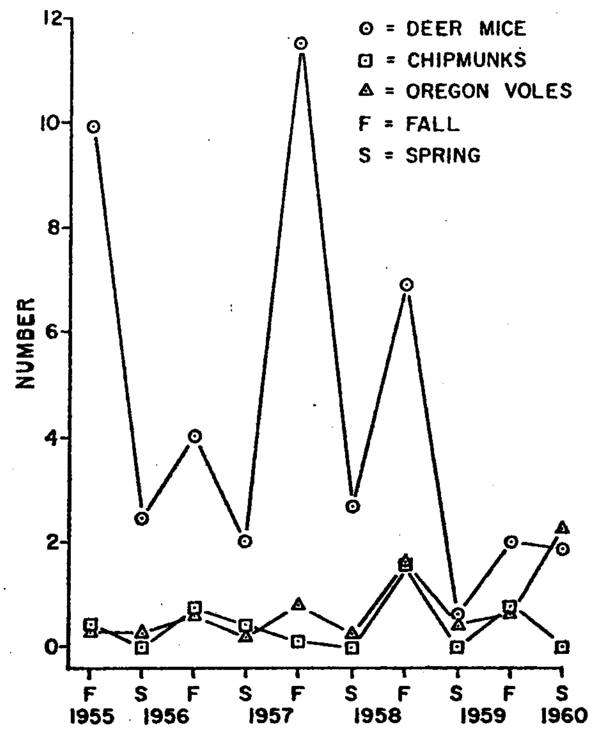

FIG. 2. Estimated number of small mammals per acre by season and year.

continued hibernation, for no chipmunks were captured during the springs of 1955, 1957, and 1958 and only a few in 1956 and 1959. Fall chipmunk populations were also low, although Fig. 2 does show a slight upward trend from spring data. Apparently several years are required for a logged area to develop into prime chipmunk habitat. Bailey (1936) indicated these animals are mainly forest dwellers but also frequent brushy habitat.

Populations of Oregon voles (*Microtus oregoni oregoni*) were relatively low during the study, but there seemed to be a slight upward trend in the fall of 1958 and spring of 1959. Vegetation on the cutover area consisted mainly of forbs and woody plants which are considered to be marginal vole habitat. Dalquest (1948) found the largest Oregon vole populations in fields of short or dry grass.

Other small mammals captured during the study included seven ermines (*Mustela erminea*), three Trowbridge shrews (*Sorex trowbridgii*), one vagrant shrew (*Sorex vagrans*), and one bushy-tailed wood rat (*Neotoma cinerea*).

Seed survival

Seed crops were good in 1956–57 and 1959–60 (Table 1). The estimated crop in 1956–57 was about 526,000 filled seeds per acre, comprised of 70% redcedar, 16% Douglas-fir, and 14% hemlock. In 1959–60 the crop was estimated to be 423,000 filled seeds per acre. About 42% were hemlock, 40% Douglas-fir, and 18% redcedar. Thus the 1956–57 crop was primarily redcedar while the 1959–60 crop was primarily hemlock and Douglas-fir. Average seed fall for the 2 years was 475,000 filled seeds per acre, consisting of

TABLE 1. Number of filled seeds in seed traps and ground samples and number of seedlings in exclosures and open quadrats

Sample type	1956–57	1959–60	Total	Estimated average per acre
Douglas-fir				
Seeds				
Seed traps				
To start of germination	261	518	779	124,000
To end of germination	268	530	798	127,000
Ground samples	22	64	86	39,000
Seedlings				
Closed exclosures	155	315	470	95,000
Open exclosures	42	31	73	15,000
Open-closed exclosures	46	35	81	16,000
Open quadrats	23	48	71	14,000
Hemlock				
Seeds				
Seed traps				
To start of germination	226	537	763	122,000
To end of germination	230	562	792	126,000
Ground samples	24	137	161	73,000
Seedlings				
Closed exclosures	101	190	291	59,000
Open exclosures	84	107	191	39,000
Open-closed exclosures	91	107	198	40,000
Open quadrats	24	88	112	23,000
Redcedar				
Seeds				
Seed traps				
To start of germination	1,090	224	1,314	210,000
To end of germination	1,154	238	1,392	222,000
Ground samples	324	97	421	191,000
Seedlings				
Closed exclosures	597	81	678	137,000
Open exclosures	657	62	719	145,000
Open-closed exclosures	622	54	676	136,000
Open quadrats	132	32	164	33,000

47% redcedar, 27% Douglas-fir, and 26% hemlock.

The survival or loss percentage of seeds is based on the seed fall as measured by seed traps. Seed fall was not complete at the start of germination so the total number per acre is greater (Table 1). It should be kept in mind that trapped seeds represent the total number of filled seeds whereas the number of germinated seeds in the exclosures was influenced by other factors, among which were nonviable filled seeds, birds and mammals, invertebrates, and disease.

Seeds and seedlings were so few in the poor seed years that no significant results were obtained and the data are omitted from this report. In 1955–56, 16 seed traps caught 5 filled seeds; 24 traps in 1957–58 and 1958–59 had 27 and 47 filled seeds respectively. Only 2 seedlings were found in 8 sets of exclosures and quadrats in 1955–56, 29 were found in 12 sets in 1957–58, and 22 were found in 12 sets in 1958–59. In the combined total for the 3 years, all species in each treatment—except hemlock in the open quadrats—were more abundant than in the closed exclosures. Although the samples are very small, the data suggest that seed loss attributable to animals may be lower during poor seed years because the law of diminishing returns came into operation.

Numbers of Douglas-fir seedlings were nearly the same in all plots exposed to birds and small mammals (Table 1). This indicated that the animals visited each treatment freely and were neither attracted nor repelled by the wire-covered frames. This evidence of uniform usage gives added confidence to conclusions drawn from the study. The situation differed with hemlock and redcedar, however. Here, numbers of germinating seedlings within the open quadrats were substantially less than in the open exclosures (about 30% for hemlock and 79% for redcedar). The explanation probably lies in size of seed which in turn affects seedling vigor and its ability to withstand heat and drought. Douglas-fir has the largest seed, redcedar the smallest. Exclosures probably produce a more favorable microclimate for the germination of seeds. Fowells and Arnold (1939) reported that small wire-mesh seed-spot covers reduced soil temperatures an average of 12.2°F in California. Hemlock and redcedar are more tolerant of shade and their seedlings more delicate than those of Douglas-fir. It seems possible, therefore, that many of their seeds either failed to germinate in the open plots or died in the initial stages of germination owing to unfavorable microclimate. Because of this, and possibly other exclosure influences, the open quadrats were not included in computations of seed losses.

Douglas-fir.—The average number of filled Douglas-fir seeds per acre for the good seed years was 124,000 (estimated from seed traps) and the average number remaining at the start of germination (estimated from ground samples) was 39,000 (Table 1). Consequently, 31% (39,000/124,000) of the seeds survived all forms of mortality and 69% were lost (Table 2). Bird and mammal depredations accounted for 62% [(95,000–16,000)/127,000] of this loss, and other agents for the remaining 7%. The high overwinter seed loss to birds and mammals is of particular interest. Although no supporting data are available, it seems logical to expect heavy losses during late fall or early winter soon after the start of seed fall when the bird and deer mouse populations are high. Another high-usage period might be early spring just prior to germination (after the ground becomes bare and before seedlings appear) when birds are often numerous and animal food resources are at a lower level. The relatively light seed losses (7%) to factors other than birds and mammals during winter are reasonable since invertebrates and agents of disease probably are comparatively inactive then. Douglas-fir seeds are liable to mortality during the relatively short sprouting period. In 1960 a sample of 95 randomly selected sprouting Douglas-fir seeds were marked in the exclosures and quadrats and their fate followed. These seeds were developing a radicle but were still too small to be classed as seedlings. The percentage of loss was similar in the different exclosures. Of these sprouting seeds, 76% reached the seedling stage.

Seed survival in the closed exclosures by the end of germination was 75% (95,000/127,000). This percentage of filled seeds germinated under complete protection from birds and small mammals. The 25% failing to germinate included nonviable filled seeds and losses to invertebrates and diseases. Seed survival in the open units for the same period was 12% (15,000/127,000) or a mortality of 88% (Table 2). These seeds were not protected and were subject to mortality from many causes. Depredations by birds and mammals amounted to 63% [(95,000–15,000)/127,000]. This was only slightly above the percentage at the start of germination. Other causes of loss increased to 25% (88%–63%). Roughly two-thirds are lost to birds and mammals and one-quarter to other causes. However, the 12% which did germinate represents a large number of seedlings (15,000 per acre). At 200 crop trees per acre only 1 in 75 would need to survive to provide adequate stocking. Seedling mortality is often very high, however, and large numbers are needed

TABLE 2. Mortality percentages of filled seeds for two periods: from seed fall to start of germination, and during germination

Species	Seed fall to start of germination			During germination			Combined total		
	Birds and mammals	Other factors	Total	Birds and mammals	Other factors	Total	Birds and mammals	Other factors	Total
Douglas-fir.......	62*	7	69	1*	18	19	63	25	88
Hemlock.........	15*	25	40	1*	28	29	16	53	69
Redcedar........	0*	9	9	0*	26	26	0	35	35

*Chi-square differences for seed mortality between birds and mammals and other factors are significant (P < .01) as determined from actual numbers of seed.

to insure adequate stocking of well-distributed crop trees.

During the germination period bird and mammal losses (Table 2) were only 1% (63%–62%). At the same time other causes of mortality accounted for 18% (25%–7%). Although bird and mammal seed destruction was low during the germination period, other evidence suggests they may be seeking very young seedlings. Birds and small mammals readily harvest the seed coat and encased cotyledons of such seedlings. These items, being held a short distance above the ground, would seem to be vulnerable to depredations. The data also show that seed losses to other causes during the germination period amounted to 18% compared to only 7% overwinter.

Hemlock.—The seed trap–ground sample data (Table 1) indicated a hemlock seed survival of 60% (73,000/122,000) from seed fall to germination. It was nearly double that of Douglas-fir. Birds and mammals accounted for 15% [(59,000–40,000)/126,000] of the 40% loss (Table 2). The remaining 25% was due to other factors. Overwinter Douglas-fir seed losses to birds and mammals were significantly greater than those of hemlock ($\chi^2 = 281.6$; $P < .01$). On the other hand, Douglas-fir seed mortality from other factors was significantly less than that of hemlock ($\chi^2 = 71.9$; $P < .01$). Total Douglas-fir seed loss from seed fall to germination was significantly greater than that of hemlock ($\chi^2 = 64.1$; $P < .01$).

Seed survival through germination in the closed exclosures was 47% (59,000/126,000) and the loss 53% (Table 2). Thirty-one per cent (39,000/126,000) lived in the open exclosures. Survival of hemlock seeds was about 2½ times greater than for Douglas-fir (31% vs. 12%). Of the 69% seed loss, birds and mammals destroyed 16% [(59,000–39,000)/126,000] and all other mortality factors 53%.

Twenty-nine per cent (69%–40%) of the seed died during the germination period (Table 2). Birds and mammals took 1% [(40,000–39,000)/126,000] and other factors accounted for 28% (53%–25%). Of the 39,000 seeds surviving in the open exclosures only 1 in 195 would need to survive to provide adequate stocking. Hemlock and Douglas-fir seed losses to birds and mammals were both 1% during the germination period. However, hemlock mortality to other causes was about one-half greater than Douglas-fir (28% vs. 18%). In 1960 a small random sample of 43 sprouting hemlock seeds was marked in the exclosures and quadrats, and 72% survived to the seedling stage. This was only slightly lower than for Douglas-fir (76%).

Redcedar.—The average survival of filled redcedar seeds (Table 1) was estimated from seed traps and ground samples to be 91% (191,000/210,000). The 9% (100%–91%) loss was much lower than for Douglas-fir and hemlock (Table 2). Numbers of tiny seedlings in the closed and open-closed exclosures were so nearly the same that the bird and animal depredations for the period were considered nil. Hence, the 9% loss was entirely the result of nonviable filled seeds, disease, invertebrates, etc.

An estimated 137,000 seedlings per acre developed in the closed exclosures (Table 1). Consequently, 62% (137,000/222,000) of the filled seeds germinated and 38% were lost to factors other than birds and mammals. Similar computations for the open exclosures, where the seeds were vulnerable to all forms of mortality, revealed a survival of 65% (145,000/222,000). This was 3% more than the survival where birds and mammals were excluded, indicating that birds and small mammals took few if any fallen redcedar seeds. The 35% loss was due to factors other than birds and mammals (Table 2). For 200 crop trees per acre only about 1 in 700 seedlings would need to survive to provide adequate stocking.

During germination 26% (35%–9%) of the seeds was lost to non-bird and non-mammal causes (Table 2). There was no statistically significant difference between this and losses for hemlock (28%) and Douglas-fir (18%). A small random sample of 28 sprouting redcedar seeds was marked in the units in 1960. Of these, only 64% formed seedlings. Thus, 36% succumbed during the relatively short sprouting season, an appreciably higher loss than for either Douglas-fir or hemlock. The period of sprouting may be a weak point in the life of redcedar.

Other relationships.—The influence of birds, voles, and chipmunks on seed survival was considered to be either uniform or negligible. Yearly bird populations were considered nearly constant so their consumption of seed was probably uniform during good seed years. Voles, thought to be light or non-tree seed eaters, were present only in low numbers (Fig. 2). Chipmunks were also present in low numbers, and while they do take tree seed (Broadbooks 1958) their overall influence is believed light on small scattered seed since they do not seem to spend much time "gleaning." In addition, they hibernate during winter.

Deer mice, proven tree seed eaters (Jameson 1952), were the most abundant small mammals although their numbers were low during both good seed years (Fig. 2). Seed trap-ground sample results (Table 1) indicate lower seed survival for all tree species during the 1956–57 seed year when the deer mouse population was larger, and higher seed survival during 1959–60 when the population was smaller— a pattern one might logically expect. However, the exclosure-quadrat study shows the opposite for open exclosures. These apparently conflicting findings are probably due to small samples and sampling variation. Even though the 1956 fall deer mouse population was twice as great as 1959, it only amounted to two additional animals per acre.

Ground-feeding birds and small mammals showed a definite preference for Douglas-fir seeds taking 66% of those eaten compared to [illegible] for hemlock and none for redcedar. Most ground-feeding birds and small mammals apparently do not like redcedar seeds. Moore (1940) found, in controlled feeding tests, that Douglas-fir and hemlock seeds were equally acceptable to deer mice while redcedar was only lightly taken.

Reasons why one species of tree seed is eaten and others avoided have not been determined. Size of seed may be a factor: Douglas-fir seeds are larger than those of hemlock and redcedar and thus may be easier for birds and mammals to find. They would also represent a larger quantity of food and consequently be more desirable. Palatability may also play a part—in addition to being small, redcedar seeds have a pungent odor which may be repulsive to most birds and small mammals.

Most of the seed loss to birds and small mammals occurred prior to germination. Losses to other factors were greatest during the germination period.

Seed-remains data for 1959–60 are shown in Table 3. These remains were found in ground samples and were not sufficiently numerous to justify statistical analysis. Positive identification of causes of seed loss from remains of small tree seeds is difficult; therefore, the data are only roughly approximate. Nearly two-thirds of the seed remains were left by mammals, one-third by birds, and only a few by insects.

Data for the 2 good seed years reveal that many of the shed tree seeds are lost to bird and small mammal depredations. Douglas-fir seeds suffer the greatest loss with hemlock and redcedar following in order. Reduction of this loss should help natural regeneration by increasing the number of viable seeds and thus increasing the chances for more to fall in suitable environmental sites. However, the data also show that relatively large numbers of seeds germinate even when exposed to all forms of natural mortality. Consequently, efforts to aid natural regeneration should be directed not only at the seed fall but also toward assisting the tiny seedlings. Methods of helping the small seedlings were not explored, this would seem to be an important field for additional investigation.

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Table 3. Animal factors causing seed mortality as revealed by seed remains recovered from ground samples (1959-60 seed year)

Factor	Douglas-fir		Hemlock		Total	
	Number	Percentage	Number	Percentage	Number	Percentage
Mammals	96	67	1	17	97	64
Birds	36	25	0	0	36	24
Insects	1	1	0	0	1	1
Unidentified	11	7	5	83	16	11
Total	144	100	6	100	150	100

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