SEED DISPERSAL IN *JUNIPERUS*: A REVIEW

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ABSTRACT

The dispersal of *Juniperus* seeds is reviewed. Although birds are the major dispersal agents, mammals can be significant, but even harvester ants have been found to carry berries up to 15 m to their nests, then remove the pulp and deposit the seeds outside their mounds. *Phytologia 92(3): 424-434 (December 1, 2010).*

KEY WORDS: Seed dispersal, *Juniperus*, birds, mammals, harvester ants, germination.

The seminal paper in juniper seed dispersal was by Phillips (1910). His oft-cited paper was based on six years of field observations and interviews with naturalists concerning the dispersal of seeds of several *Juniperus* species. Phillips noted that because many juniper species' berries (female cones) mature in the fall and stay on the tree until spring, these present birds with a high energy food source when other seeds may be in short supply. In addition, the berries are often blue with a white bloom that makes them discernible even at considerable distances (Phillips 1910, Adams 2008). Phillips (1910) notes that E. A. Mears fed caged Bohemian waxwings (*Ampelis garrulous*) berries of *J. scopulorum* Sarg. and observed that over 900 berries passed through the birds in 5 hours. Clearly, these birds can consume and rapidly spread juniper seed. Phillips noted that a flock of 50 robins consumed all of the fruits on a juniper tree in a single day!

He also noted the occurrence of 'fence row' junipers that were presumably 'planted' by birds resting on fences.

Phillips (1910) compiled a list of birds that had been found to consume juniper berries (Table 1). In addition, he reported that in Texas, the feces of raccoons, foxes, wildcats and chipmunks contained large amounts of juniper seeds from November to March. But he concluded that mammals are of rather minor importance in juniper-seed dispersal, compared to birds. Phillips also gave an interesting account of a Texas cattle herd that was driven to Kansas and grazed a few days on the treeless prairie, that later gave rise to a small juniper population.

Table 1. Birds that have been found to consume juniper berries (Phillips, 1910).

***Juniperus* species**
Canachites canadensis - Canada Grouse
Corvus brachyrhynchos - Common Crow
Empidonax trailli - Traill Flycatcher
Oreortyx p. plumiferus - Plumed Quail
Pedioecetes phasianellus - Sharp-tailed Grouse

Juniperus communis
Merula migratoria - Robin
Parus atricapillus - Black-capped Chickadee

Juniperus sabina
Tyrannus tyrannus - Eastern Kingbird

Juniperus scopulorum
Ampelis garrulous - Bohemian Waxwing

Juniperus utahensis (J. osteosperma)
Meleagris gallopavo - Wild Turkey

Juniperus virginiana
Ampelis cedrorum - Cedar Waxwing
Carpodacus purpureus - Purple Finch
Corvus brachyrhynchos - Common Crow
Colaptes auratus - Yellow-shafter Flicker
Dendroica coronata - Myrtle Warbler
Dryobates pubescens - Downy Woodpecker
Hesperiphona vespertina - Evening Grosbeak
Hylocichla guttala -Hermit Thrush
Lagopus leucurus - White-tailed Ptarmigan
Merula migratoria - Robin
Mimus polyglottos - Mockingbird
Passerella iliaca - Fox Sparrow
Pinicola enucleator - Pine Grosbeak
Sayornis phoebe - Say's Phoebe
Sialia sialis - Bluebird
Sphyrapicus varius - Yellow-bellied Sapsucker
Tyrannus tyrannus - Kingbird

McAtee (1947) published an exhaustive annotated bibliography of papers dealing with the distribution of seeds by birds and noted that shade-tolerant cedars often develop under "perch trees."

Abbott and Belig (1961) found that red squirrels fed on *J. communis* berries during the winter, but avoided the prickly foliage of common juniper.

Poddar and Lederer (1982) reported that Townsend's solitaires feed exclusively on berries of *J. occidentalis* during the winter. They analyzed the nutritional content and found 4% protein, 16 % lipid and 46% carbohydrate and concluded that *J. occidentalis* berries provide sufficient nutrients and energy to sustain solitaires during the winter.

One of the most detailed studies of the fate of juniper berries was conducted by Holthuijzen and colleagues (overview and references in Holthuijzen, Sharik and Fraser, 1987). Figure 1 shows a summary of their results. Noteworthy is that 65.5% of the berries were dispersed

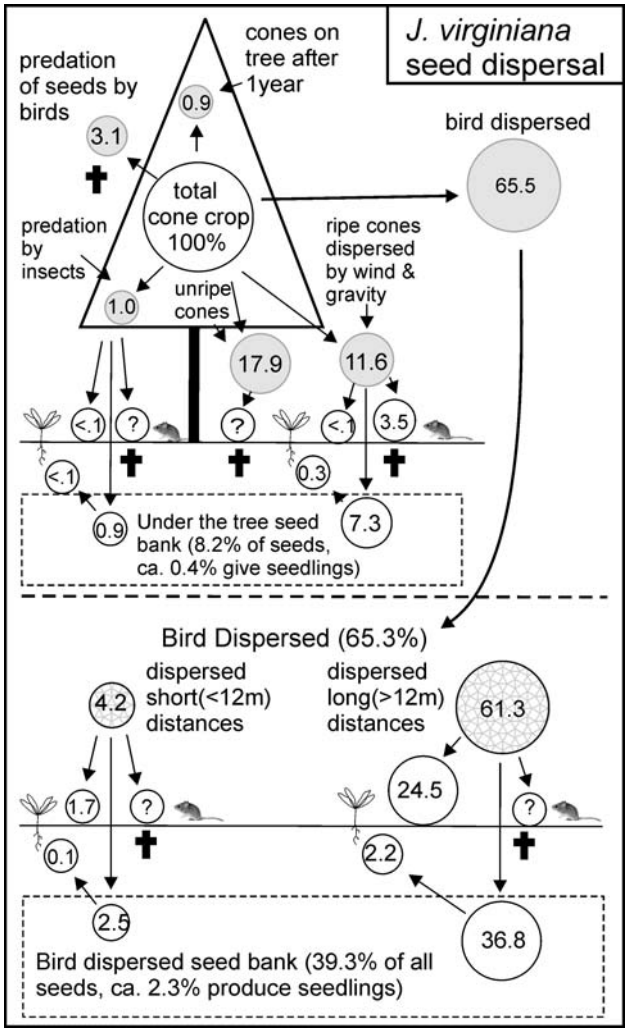

Figure 1. Dispersal of seeds in *Juniperus virginiana* (adapted from Holthuijzen et al. 1987).

by birds (Fig. 1). In addition, a large proportion (17.9%) of the cone-crop fell as unripe cones. This appears to be a common situation as I (RPA) have observed many unripe berries under various juniper species. However, very few of the seeds deposited under the tree canopy produce seedlings (ca. 0.4% of the seed crop, Holthuijzen et al. 1987). This seems to imply that the allelopathic nature of juniper foliage may inhibit seed germination under the canopy. Of course, shading and competition for moisture are additional factors.

Of the 65.5% berries dispersed by birds, about 93.6% were dispersed greater than 12 m from the tree. Of the 2.7% that produce seedlings, about 85% of these arose from long distance dispersal of seeds. Of course, a considerable number of seeds are deposited on the soil surface (1.7%, 24.5%) and these may germinate in favorable years.

Holthuijzen and Sharik (1985) showed that seed dispersal and seedling patterns in *J. monosperma* had very definite effects under the tree canopies (Fig. 2). The great majority of seeds fall under the tree, whereas, the majority of the seedlings are near, but outside the canopy of the tree (Fig. 2). Again, this may reflect allelopathy and/ or the shade and moisture constraints under the tree canopy.

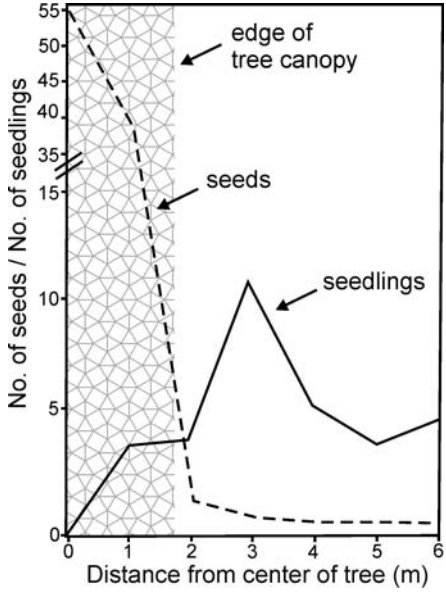

Figure 2. Number of seeds (per 0.1 m^2) vs. seedlings (adapted from Holthuijzen and Sharik 1985).

The passage of juniper seeds through the digestive tract of Cedar Waxwings was examined by Holthuijzen and Adkisson (1984) who reported an average residence time of only 12 mins. At the rate of feeding, they estimated that a Cedar Waxwing would eat about 53 berries per hour. So it is easy to see that Cedar Waxwings feeding in a large *J. virginiana* tree could deposit many of the seeds under the tree canopy, as shown in Fig. 2.

Holthuijzen and Sharik (1985) found that seeds collected from the feces of warbler and waxwing germinate at a rate of 55.0% and 27.6%, compared to the control (16.1%) germination tests. It is thought that the passage through the digestive tract scarifies the seeds making it easier to absorb water. However, Salomonson (1978) fed *J. monosperma berries* to Townsend's solitaires and then germinated the seeds and got mixed results. Berries collected in March, 1974 and fed to the birds had a germination rate of 24% vs. the control germination rate of 18%. In contrast, berries collected in March, 1974, then stored in dry, dark boxes at 21ºC until November, 1974 (6 mos.) displayed the reverse pattern: those fed germinated at 35% vs. 45% for the control.

Johnsen (1962) examined the effects of seed passage through various animals and germination for *J. monosperma* seeds. Table 2 shows that digestion by animals speeds up the germination, but did not appear to increase the percentage of germination. It is assumed that the control germination seeds were kept moist for the entire 10 weeks. In northern Arizona, it would be very unlikely that soils might be kept moist for 10 weeks, so rapid germination following a rain would appear to be favored (i.e., favoring animal excreted seeds).

In the Canary Islands, *Juniperus cedrus* is dispersed by thrushes, ravens and lizards (B. Rumeu, pers. comm.). Control germination reached about 21% (after 200 days), whereas seeds passed by ravens and thrush attained about 33% germination. In contrast, seeds passed through the digestion tract of lizards showed reduced germination of about 10% (B. Rumeu, pers. comm.). Rumeu et al. (2009) reported that during the winter, they obtain about 98% of their diet from *J. cedrus* berries.

Table 2. Effects of passage through the digestive tracts of various animals on the germination of *J. monosperma*. Data from Johnsen (1962).

	cumulative % germination by weeks									
animal	1	2	3	4	5	6	7	8	9	10
none (control)	0	1	6	16	29	29	36	41	44	44
bird	11	15	20	39	43	43	44	44	44	44
coyote or fox	2	10	28	37	40	44	45	45	45	45
packrat	8	14	22	40	44	44	45	45	45	45
jackrabbit	7	13	25	45	50	51	51	51	51	51
sheep	3	12	31	42	45	46	46	46	46	46

Schupp et al. (1997) examined feces of Nuttall's cottontail rabbits, mule deer, elk and coyotes for the presence of *J. occidentalis* seeds. Table 3 shows that, in general, these mammals do not consume vast quantities of juniper berries, except for coyotes that have a significant amount of seeds in some scats. We have observed *J. osteosperma* seeds in coyote scat in Arizona (Fig. 3), where it makes up the major portion of the scat.

Figure 3. *Juniperus osteosperma* seeds in coyote scat (near Cottonwood, AZ)

Table 3. Numbers and frequency of *J. occidentalis* seeds in defecations of 4 mammals.

	# pellets or scats	# with seeds	total # seeds
cottontail	2046 pellets	8	8
mule deer	19,414 pellets	6	6
elk	562 pellets	0	0
coyote	29 scats	4	437

Horncastle and Hellgren (2004) reported opossums and deer mice removed *J. virginiana* berries from beneath trees. They remarked that rodents appear to be seed predators and are not effective in dispersal.

Chavez-Ramirez and Slack (1993) analyzed scat from four carnivores (raccoon, ringtail, and brown and gray foxes. They found that during the winter months when *J. ashei* fruits are plentiful, all of these carnivores consumed considerable amounts of the berries. Because these carnivores have large home ranges (3.2 km to 10.4 km) they might be effective in long range dispersal. However, Chavez-Ramirez and Slack (1993) noted that, in at least 15 cases, rodents had consumed as much as 50% of the *J. ashei* seeds in mammal feces.

Harvester ants (*Pogonomyrmex* sp.) are well known to collect seeds and plant materials (Rissing, 1988). In a study at the Desert Botanica Garden, Phoenix, the latter workers found that the diet of *P. rugosus* diet consisted of 87% seeds from three annual plant species. The harvester ant's range varied from 12.7 to 22.1 m (avg. +/- 4 m, 1 SD) over a 3 year period. The larger range (22.1 m) occurred in 1984 when a drought restricted the growth of the favored annual species.

Recently we (DT) observed harvester ants carrying berries of *J. arizonica* from a tree about 15 m from their nest/ mound (Fig. 4). A few cleaned seeds were found next to the mound and one clean seed was found in the nest (fig. 5).

Figure 4. Harvester ant carrying a juniper fruit to its nest/ mound.

Figure 5. (top) cleaned *J .arizonica* seed taken from nest.
(bottom) Fungal farm in ant nest.

In our situation the ants generally become active in the morning, forming only a single marching column about eight inches wide to the juniper tree. They harvested the berries from the ground only, and returned at a rate of one berry every two minutes. This continued all day (~8 hr) for a week. At such a rate as many as 1600 berries may have been carried to their nest. During this period, the column from the juniper tree to the nest carried only juniper seeds. A few ants, not in this column, cut up leaves from a *Penstemon* near the hole. On another occasion, an ant column was harvesting only bird seed in a bird feeding area. When juniper berries were place along the 'bird seed' column, the ants refused to pick up any berries. It appears that the ants just harvest one kind of material at a time.

In summary, it appears that harvester ants bring juniper berries into their nest, eat off the pulp and then carry the seeds out to the edge of their mound.

This is not the first report of harvester ants collecting juniper berries. Willard and Crowell (1965) reported that *Pogonomyrmex owyheei* carried juniper (*J. occidentalis*) twigs and berries to their nests.

Although harvester ants may play a role in the dispersal of *J. arizonica* seeds, there is little doubt that birds are the main dispersal agents of seeds of that taxon as well as nearly all *Juniperus* species (Holthuijzen et al. 1987). In fact, Santos et al. (1999) found that birds were about 30 times as effective as mammals in the dispersal of *J. thurifera* seeds in Spain.

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LITERATURE CITED

Abbott, H. G. and W. H. Belig. 1961. Juniper seed: A winter food for red squirrels in Massachusetts. J. Mammalogy 42: 240-244.

Adams, R. P. 2008. Junipers of the world: The genus *Juniperus*. 2nd Ed., Trafford Publ., Vancouver, B.C., Canada.

Chavez-Ramirez, F. and R. D. Slack. 1993. Carnivore fruit-use and seed dispersal of two selected plant species of the Edwards Plateau, Texas. Southwestern Natl. 38: 141-145.

Holthuijzen, A. M. A. and C. S. Adkisson. 1984. Passage rates, energetics, and utilization efficiency of the cedar waxwing. Wilson Bull. 96: 680-684.

Holthuijzen, A. M. A. and T. L. Sharik. 1985. The avian seed dispersal system of eastern red cedar (*Juniperus virginiana*). Can. J. Bot. 63: 1508-1515.

Holthuijzen, A. M. A., T. L. Sharik and J. D. Fraser. 1987. Dispersal of eastern red cedar (*Juniperus virginiana*) into pastures: an overview. Can. J. Bot. 65: 1092-1095.

Horncastle, V. J. and E. C. Hellgren. 2004. Differential consumption of eastern red cedar (*Juniperus virginiana*) by avian and mammalian guilds: Implications for tree invasion. Amer. Midl. Nat. 152: 255-267.

Johnsen, T. N. 1962. One-seed juniper invasion of northern Arizona grasslands. Ecol. Monog. 32: 187-206.

McAtee, W. L. 1947. Distribution of seed by birds.

Phillips, F. J. 1910. The dissemination of Junipers by birds. Forest Quarterly 8: 11-16.

Poddar, S. and R. J. Lederer. 1982. Juniper berries as an exclusive winter forage for Townsend's solitaires. Amer. Midl. Nat. 108:34-40.

Rissing, S. W. Dietary similarity and foraging range of two seed-harvester ants during resource fluctuations. Oecologia 75: 362-366.

Rumeu, B., D. P. Padilla and M. Nogales. The key role of a Ring Ouzel Turdus torquatus wintering population in seed dispersal of the endangered endemic *Juniperus cedrus* in an insular environment. Acta Ornithologia 44: 199-204.

Salomonson, M. G. 1978. Adaptations for animal dispersal of one-seed juniper seeds. Oecologia 32: 333-339.

Santos, T., J. L. Telleria and E. Virgos. 1999. Dispersal of Spanish juniper *Juniperus thurifera* by birds and mammals in a fragmented landscape. Ecography 22: 193-204.

Schupp, E. W., J. M. Gomez, J. E. Jimenez and M. Fuentes. 1997. Dispersal of *Juniperus occidentalis* (western juniper) seeds by frugivorous mammals on Juniper Mountain, southeaster Oregon. Great Basin Naturalist 57: 74-78.

Willard, J. R. and H. H. Crowell. 1965. Biological activities of the harvester ant, *Pogonomyrmex owyheei*, in central Oregon. J. Econ. Entomology 58: 484-489.