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Acorn Dispersal by the Blue Jay (*Cyanocitta cristata*)

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Summary. Blue jays transported and cached 133,000 acorns from a stand of *Quercus palustris* trees in Blacksburg, Virginia, representing 54% of the total mast crop. A further 20% (49,000) of the mast crop was eaten by jays at the collecting site. A large proportion of the nuts remaining beneath the collecting trees was parasitized by curculionid larvae. The number of nuts transported per caching trip ranged from 1–5 with a mean of 2.2. Mean distance between seed trees and caches was 1.1 km (range: 100 m–1.9 km). Jays appeared to choose species with small- to medium-sized nuts *(Quercus palustris, Q. phellos, Q. velutina, Fagus grandifolia)* and avoided the larger nuts of *Q. borealis* and *Q. alba*.

Nuts were cached singly within a few meters of each other and were always covered with debris. Covering may improve germination and early growth by protecting the nut and radicle from desiccation. The vegetation structure of most suburban caching sites was analogous to open, disturbed environments in more natural landscapes. The presence of numerous *Quercus* seedlings in jay caching sites and the tendency for jays to cache nuts in environments conducive to germination and early growth indicate that blue jays facilitate colonization of members of the Fagaceae.

Introduction

Ecologists generally attribute seed dispersal of the Fagaceae to mammals, particularly squirrels (Smith and Follmer 1972; Short 1976), although the importance of acorn dispersal by the European jay *(Garrulus glandarius)* has been documented (Chettleburgh 1952; Bossema 1979). The North American blue jay *(Cyanocitta cristata)* has been identified as a Fagaceae nut predator (Lay and Siegler 1937; Van Dersal 1940; Shaw 1971), but only anecdotal information exists regarding its role in seed dispersal and plant colonization. Our research indicates that the blue jay participates in long-distance dispersal (up to several kilometers) of large numbers of Fagaceae nuts, and that the process of nut caching appears to facilitate plant colonization. Its importance relative to local dispersers (e.g., squirrels) is probably greater in highly-fragmented landscapes where forests are isolated by agricultural and urban land.

Methods

The central study site was a stand of 11 seed-bearing pin oaks *(Quercus palustris* Muenchh.) on the campus of Virginia Polytechnic Institute and State University in Blacksburg, USA. The trees were open-grown with well-developed crowns and a mean dbh of 41 cm. The area surrounding the study site was a mosaic of residential neighborhoods, vacant lots, mature woodland, and old fields. Other species of the Fagaceae growing near the study site included American beech (*Fagus grandifolia* Ehrh.), willow oak (*Quercus phellos* L.), black oak (*Q. velutina* Lam.), northern red oak (*Q. borealis* Michx. f.) and white oak (*Q. alba* L.).

Nine jays foraging at the central study site were color-marked to determine transport time. Both marked and unmarked birds were used to estimate foraging and caching times. Numbers of acorns harvested, eaten at the collecting trees, and carried per individual per caching trip were determined during observations at the collecting trees at different periods during the day and on several different days. Caching sites were located by following birds as they left collecting trees.

Almost all acorns were removed from the trees and eaten immediately, dropped or transported. We estimated the size of the seed crop by determining the number of acorn caps remaining beneath trees and the number of caps attached to acorns carried away by jays. All caps were removed before consumption or transport except during the first half of the dispersal period when caps were difficult to remove. Cap removal presumably enables jays to carry more seeds in the esophagus.

To estimate the number of caps and acorns remaining beneath collecting trees, the area under the crown of each tree was divided into quadrants by 4 equidistant transects radiating from the trunk base. Compass direction of the first transect was randomly chosen. A transect with length equal to the crown radius was divided into thirds: inner-, mid-, and outer-crown segments. Two non-overlapping quadrats (each 0.25 m^2) were randomly placed within each segment along the transect line. Mature acorns were counted, classified according to whether or not they had been partially eaten, and superficially examined for fungal or insect infestation. The total number of caps and acorns remaining below each tree was obtained by averaging counts from the 24 quadrats and extrapolating to the area under the crown (less trunk area). The difference between the cap and acorn totals summed over all trees represented that portion of acorns dispersed by jays (excluding the fraction taken without removal of the cap). There was no evidence of use by other birds or mammals.

Results and Discussion

Foraging. Foraging initially concentrated in the upper crowns of trees with greatest mast. As the season progressed, acorns from the lower branches were taken and eventually fallen acorns were collected. The jay held the inverted acorn with its feet and hammered the cap with closed bill until it became loosened from the nut. The lower mandible was then used to pry the cap off. Upon removal of the cap, the acorn was either hammered open and eaten or swallowed whole and cached later. The last

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acorn taken before departure was always carried in the bill. This foraging behavior was observed in all jays.

An average of 4.1 min (SD=3.19, n=41) was spent eating and collecting acorns per feeding bout. Maximum feeding time was 30 min. The average number of acorns consumed per bird per caching trip was 0.41 (SD=0.67, n=30). In only 2 cases was more than one acorn eaten. The number of whole acorns swallowed for transport ranged from 1–5, with a mean of 2.2 (SD=1.0, n=37).

Nuts of other species taken by jays included willow oak, black oak and beech. Northern red oak and white oak were not utilized by jays, despite large nut crops. Overall, jays chose species with moderate to small nuts. Mean diameter (cm) and weight (g) were greatest for local red oak (1.86, 5.65, resp.) and least for willow oak (1.10, 0.74) and pin oak (1.19, 1.30) with black oak (1.67, 3.09) and commercially-obtained red oak (1.62, 2.59) intermediate. White oak may not have been chosen because its acorns had already germinated beneath seed trees, and local red oak acorns were perhaps too large to be swallowed.

Utilization and Transport. The number of mature acorns produced by the collecting trees was estimated from cap counts to be 221,000 acorns. An estimated 113,000 acorns remained beneath collecting trees. By subtraction, the total number of acorns removed by jays was 108,000. The number of acorns taken from the site with caps intact was determined in the following manner. One out of every 2.2 acorns carried per trip during the first half of the harvest had the cap attached. Assuming the removal of the 108,000 acorns was relatively uniform throughout the 28-d caching period, then the number of caps removed (r) was: $r=(c/n)\ (a\cdot t)$, where c is the number of caps carried per trip (1), n is the total number of acorns carried (2.2), a is the total number of acorns removed without caps (108,000), and t is the proportion of the dispersal period during which caps were carried (0.5). Thus, approximately 25,000 acorns were estimated to have been carried with caps giving a corrected total mast of 246,000. The adjusted number of acorns taken by jays was therefore 133,000 or 54 percent of the available mast.

Forty-three percent of the acorns (49,000) remaining beneath the collecting trees had been eaten by jays. Cursory examination for fungal and insect infestation of the other 57% showed that many acorns had holes characteristically made by curculionid larvae. Thus, the proportion of viable acorns remaining near the trees was small.

Average time required for a round trip by a single marked bird to a cache 1 km away was 15.1 min (SD=6.75, n=16). Distances between collecting trees and caches ranged from 100 m to 1.9 km. Of the 46 caches located, the average distance from the collecting trees was 1.1 km. Observation of jays in rural Wisconsin indicated maximum dispersal distances of 4–5 km (unpubl. data, W.C. Johnson and R.L. Paterson).

Caching. Upon arrival at a caching site acorns were usually disgorged and deposited on the ground in a pile. The jay selected an acorn and hopped or flew to a nearby caching spot. After caching the first acorn, the jay returned to the pile and repeated the procedure. However, some jays regurgitated single acorns as each nut was cached. Most acorns were deposited on the soil surface and covered with litter. In a few instances the acorn was dropped on bare soil, hammered into the ground, and then covered. Acorns were never left exposed and were always hidden singly within a few meters of each other.

Forty-two (91%) of the 46 caching sites were in lawns or bare soil. The remaining 4 caches were in relatively heavy undergrowth. On only one occasion did a jay cache seeds in a place totally unsuited for germination (i.e., among ivy on a brick wall). Unlike many dispersal agents which cache seeds where seedling establishment is improbable (e.g., tree cavities; Kilham 1963) jays consistently cached acorns in suburban sites which were structural analogues of sites suitable for oak colonization in more natural environments (Fowells 1965). For example, structural characteristics of most caching sites in suburban Blacksburg were analogous to edge habitat and early successional stages in more natural landscapes. Litter was shallow, vegetation height was generally less than 0.2 m, and most sites were fully insolated. In more natural environments, dispersal of nuts from forest to edges and to open, disturbed sites would increase the probability of seedling establishment and landscape persistence of shade-intolerant species. The process of covering acorns with debris or burying them may enhance germination and early growth by protecting the nut and radicle from desiccation.

Data on the utilization of caches by jays were not collected. However, we found numerous pin and black oak seedlings in jay caching sites in Blacksburg where squirrels were absent and seed sources distant. This is strong inferential evidence that utilization of caches by jays and other nut predators is less than complete and that blue jays facilitate colonization of the Fagaceae. Death of a bird, failure of birds to remember cache locations, surplus stores during mild winters and bumper nut crops are factors which would contribute to the colonization of oaks from jay caches. To draw firm conclusions regarding the importance of blue jays in the regeneration of the Fagaceae would require more detailed monitoring of germination and survivorship of cached nuts in natural as well as suburban environments. Blue jay dispersal would appear to be especially important to Fagaceae persistence in landscapes with high patch turnover rates where seed sources and "safe sites" (Smith 1975) have become isolated by deforestation.

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