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Avian removal of fruits from a pokeweed in northwestern Arkansas.—Pokeweed (*Phytolacca americana*), a common herb in disturbed areas of eastern North America, produces bird-disseminated fruits in late summer and fall (Armesto et al. 1983). Flowers are borne on green racemes of varying length and fruits (several mm in diameter) are initially green, becoming pink and finally dark purple when ripe (Armesto et al. 1983, McDonnell et al. 1984). As fruits ripen, racemes also change color to a deep pink, which may aid in fruit removal (Willson and Melampy 1983). Pokeweed fruits ripen asynchronously, a trait associated with temperate plants that fruit in summer (Thompson and Willson 1978, Stapanian 1982, McDonnell et al. 1984). However, pokeweed fruits are typical "low-quality" (Stiles 1980) fall fruits (Johnson et al. 1985).

Waves of migratory fruit-eating birds (primarily catharid thrushes) consume pokeweed fruits in fall in eastern United States as birds move down the Atlantic coast (e.g., Skeate 1987). However, almost no fall migration of frugivorous passerines occurs in the western Ozarks (James and Neal 1986); most fall fruits are eaten by permanent residents, particularly locally produced juvenile American Robins (*Turdus migratorius*) (unpubl. data). Thus, we conducted a study in which ripening and disappearance rates of individual fruits were monitored on a large pokeweed plant from August through October in northwest Arkansas to investigate removal rates of fall pokeweed fruits in the Ozarks in the absence of waves of migratory passerines.

Study area and methods.—Our study focused on fruits on two main stalks of a single large pokeweed plant located along a roadside ditch in a suburban setting one block west of the University of Arkansas, Fayetteville (Washington Co.) campus. This particular plant was chosen because of its size (>3 m tall) and isolation from other pokeweed plants (nearest pokeweed plant = 50 m). We began censusing fruits near mid-day on 18 August 1984, when ripe fruits first appeared and continued mid-day censuses at two-day intervals until 25 October. During each census, numbers of green, pink, purple, and missing fruits were counted on each raceme. Due to alternate branching symmetry of pokeweed plants, each raceme was identified by a unique code, which was written directly on the plant with black indelible ink, based on alternating letters and numbers for branches from the main stalk to the terminal branch, then sequentially numbering racemes on the terminal branch. Numbers of fruits on the ground under the plant also were recorded. A total of 33 censuses were performed; two censuses had to be postponed one day and one census skipped (26 September) due to heavy rains. Casual observations of birds on the pokeweed plant were made throughout the study period.

Results.—A total of 175 racemes was present on the two main stalks, with a mean of 32.3 fruits per raceme (range = 2–67 fruits). Development of green fruits from flowers after censusing began resulted in a peak of 4943 fruits present on 23 August (Fig. 1); only 240 fruits remained when censusing ceased on 25 October. The vast majority of fruits on the plant during August were unripe green fruits, which are not removed by birds (pers. obs.). The number of green fruits present steadily declined as fruits ripened during September and October. Average daily ripening rates generally increased from August through mid-September, meaning that average number of green fruits per raceme generally declined during that period, and ripening rates decreased in late September and most of October (Fig. 2A). (A sharp increase in ripening occurred 1 October following heavy rain and near freezing temperatures the last three days of September.)

Total number of purple fruits present on any given census was relatively low and remarkably constant throughout the study (Fig. 1). Average daily removal rates were highest in late August, but relatively constant through September and early October (Fig. 2B). Few

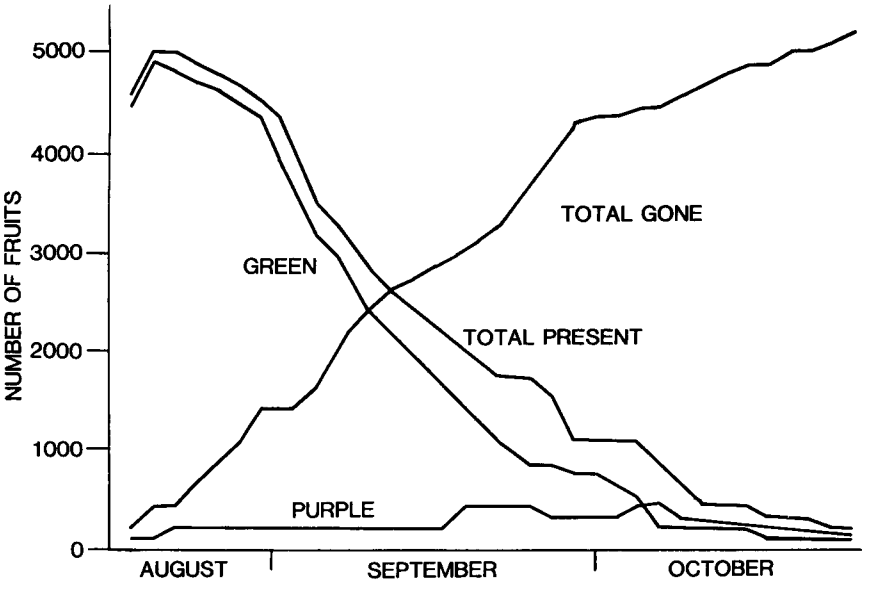

FIG. 1. Number of green, purple, total present, and total missing fruits on the pokeweed plant during the study based on censuses conducted at two-day intervals.

fruits were removed during the late September rain storm, and removal rates were lower in October than during August and September. A significant positive relationship existed between number of fruits removed each day and total number of fruits ($r = 0.56$, $P = 0.001$). The peak number of purple fruits present was 547 on 6 October, which represented 55% of all fruits present that day, and more purple fruits were present than were green fruits throughout most of October. Because of the relatively constant number of ripe fruits, total number of pink and purple fruits removed increased in a linear manner throughout the study (Fig. 1), and a significant negative correlation existed between percent of fruits removed each day and total number of fruits ($r = -0.63$, $P = 0.001$). Ripe fruits were usually missing on from 30–60 racemes between each census.

The only animals observed removing fruits were three species of birds, all of which are permanent residents in northwestern Arkansas. On four occasions, Northern Cardinals (*Cardinalis cardinalis*) were observed eating fruits on the plant, and an American Robin was seen once on the plant. In late August, when removal rates were highest (Fig. 2B), three Northern Mockingbirds (*Mimus polyglottos*) were seen together in early morning on two days removing fruits, and many aggressive interactions were observed among those birds. After that, a single mockingbird (based on characteristic notes in its song) defended the pokeweed plant as a fall feeding territory (e.g., Breitwisch et al. 1986, Logan 1987). That mockingbird often was seen removing fruits during early morning throughout September and October. During the day, it launched aerial attacks against conspecifics and other species of birds from a nearby perch where its view of the plant was unobstructed (see also Logan 1987). We were attacked on two occasions by the mockingbird while we censused fruits. Removal and dispersal of fruits away from the parent plant by birds was very efficient. Nearly 5600 fruits disappeared from the plant during the study, yet we found only six fruits

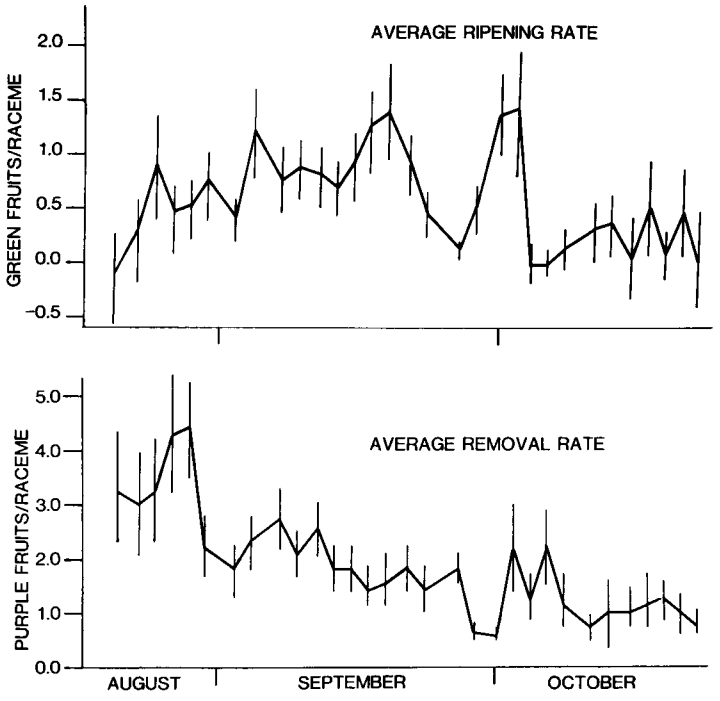

FIG. 2. A. Average daily ripening rate (i.e., average number of green fruits that ripened to pink or purple between censuses) for all racemes that had green fruits on the previous census. B. Average daily removal rate (i.e., average number of purple fruits missing between censuses) for all racemes from which fruits were missing. Bars represent ±2 SE.

on the ground under the plant during censuses. Repeated observations of those six fruits suggest that animals were not removing fruits from the ground between censuses.

Discussion.—Although based on only one large plant, our results suggest that asynchronous ripening of fruits can be a profitable reproductive strategy for seed dispersal during fall at lower latitudes (see Thompson and Willson 1979). Permanent resident birds were attracted to such displays, and nearly all fruits were removed and dispersed over the two-month fruiting period. In addition to the main hypotheses concerning ripening asynchrony as an adaptation for increased reproductive success reviewed by Gorchov (1985), we suggest that an asynchronously ripening fruit crop may attract a territorial frugivore which would ensure an orderly dispersal of fruits.

Avian defense of fruiting plants is uncommon, primarily because fruits usually provide a superabundant food supply that is difficult to defend (e.g., Howe and De Steven 1979, Pratt 1984). Mockingbirds have trouble defending large fruit crops against flocks of frugivores such as American Robins, European Starlings (*Sturnus vulgaris*), and Cedar Waxwings (*Bombycilla cedrorum*) (Moore 1977; K. G. Smith pers. obs). However, mockingbirds (Moore 1977, Logan 1987) and American Robins (Pietz and Pietz 1987) are able to defend fruit crops from individuals and small groups of birds. By removing most ripe fruits on a daily basis, a mockingbird might have greater success at defending an asynchronously ripening

plant such as pokeweed because the majority of the remaining fruits on the plant will be unattractive green fruits that will not attract large numbers of birds.

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