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Abstract

Fruits continue to be recognized as an important food source for birds in temperate areas, particularly during the fall migration period. More than 20 species of plants producing fleshy fruits are found in the Arkansas Ozarks. However, only a few of these appear to be important resources for birds during the fall migration period (August - October). Among those are sassafras (*Sassafras albidum*), gray-backed grape (*Vitis cinerea*), black cherry (*Prunus serotina*), hercules club (*Aralia spinosa*) and pokeweed (*Phytolacca americana*). Over the past 4 years, we have documented the physical and nutritional characteristics of those fruits and taken observational data on the assemblages of birds eating them. It appears that avian species assemblages feeding on fruits are partially determined by the physical and nutritional contents of those fruits. Sassafras is extremely lipid-rich and higher in caloric content than the other species of fruits. It appears to be eaten almost exclusively by larger birds, perhaps be due to the large size of its fruits, which may exceed gape width of many smaller bird species. *Prunus* and *Vitis* are also eaten by a large number of avian species. *Phytolacca* was eaten only by a small number of primarily resident bird species and often persisted into the winter. Reasons for this pattern are not clear, as it was relatively similar to the other fruits in most characteristics. *Aralia* was seen being eaten by only a few species of birds but is less common than the other species, and its small fruits may not be as attractive as those of the other species. Compared to other places in the east, there appear to be a relatively low number of migratory frugivorous birds in northwestern Arkansas. Overall, there were very few species noted at any fruiting plants, and a large proportion of the total assemblage of birds was comprised of resident species.

Introduction

Researchers are increasingly recognizing the importance of fruit as a food resource for migratory birds. While it has long been recognized that many avian taxa, even those that are primarily insectivorous, eat fruits during migration, the extent and magnitude of that change in diets has only recently become apparent (Parrish, 1998). Therefore, information about distribution, abundance, and characteristics of different ftuit species is important, as those factors may affect resource availability to migratory, and perhaps also resident, bird species during the fall migration period (Parrish, 1998; Thompson & Willson, 1979; Johnson et al., 1979).

Many studies of frugivory by migratory birds have taken place during the fall migration period in the eastern United States (Stiles, 1980). Most of these studies have focused on species assemblages eating fiuits (Malmborg & Willson, 1988; Parrish, 1998), interactions among fruiting species and their avian dispersers (Baird, 1980; Malmborg & Willson, 1988; Thompson & Willson, 1979), or nutritional content of fruits (Johnson et al., 1979). All of these factors may have important consequences both to birds eating fruits and to fruiting plants that rely on birds for seed dispersal.

Despite this, little has been published about fruiting plants and the birds that eat their fruits in Arkansas. It has been noted that, compared to other places in the eastern U.S., fall migrants are relatively scarce in northwestern Arkansas (Neal and Mlodinow, 1986; pers. obs.). In addition, Smith and Riley (1990), noted that a pokeweed (*Phytolacca americana*) on which they monitored fruit crop and avian visitation, was only visited by a few species of resident birds. It was not clear from their study whether this is a general pattern in northwestern Arkansas, or limited to pokeweed. We present here some additional observational and analytical data on *Phytolacca* and other fruiting plants in northwestern Arkansas, some tentative conclusions about bird-plant interactions in this region, and some suggestions for future research.

Methods

Species Assemblages.--Species assemblages of birds utilizing different fruiting plants were determined using field notes taken by Prather and Mlodinow during the period from August through October in each year from 1995 through 1999. Additional data were obtained from fecal samples of birds captured while mist-netting at Lake Fayetteville, Washington County, during those same time periods.

Phenology and Persistance of Fruits.--Phenology of *Vitis* and *Sassafras* were determined by weekly counts of ripe and

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unripe fruits on fruiting plants taken by Smith and Riley between mid-August and late October 1984. Phenology and removal rates for fruits of *Prunus* were determined by weekly counts of ripe and unripe fruits taken by Prather between mid-August and late September 1997. Removal rates were also determined for *Sassafras* and *Vitus* using unpublished data taken by Smith and Riley every two days between mid-August and early November 1984. Removal rates for these three species were made with those of *Phytolacca* determined by Smith and Riley between mid-August and early November 1984 (Smith and Riley, 1990). No phenology was determined for *Aralia*. Persistence of fruits was determined from notes taken by Prather in the field during fall and winter of 1995 - 1999 and the phenological data taken above.

Nutritional Analysis.--Samples of each of the 4 species of fruits were collected and analyzed to determine nutritional content. Each sample was dried to constant weight in a vacuum oven at 100° C., and the following nutritional components were determined in the Nutritional Analysis Laboratory of the Department of Poultry Science at the University of Arkansas, Fayetteville: calories/gram dry weight, percent ash, percent crude protein, percent crude sugar and specific sugar content, percent crude fat and specific fatty-acid content, and percent indigestible fiber. Means and standard deviations were determined by running a minimum of 3 samples through each type of analysis. Unless otherwise noted, all analytical procedures are those found in the Center for Excellence in Poultry Science Laboratory Manual for Nutritional Analysis. Caloric content was determined using bomb calorimetry. Percent ash was determined by placing 500 mg samples in a muffle furnace at 500° C for 24 hours and reweighing the remaining material. Percent crude protein was determined by weighing 50 mg dry weight samples through a CE Elanotech elemental analyzer, in which the sample is fired at high temperature and the percent nitrogen in the resulting gas is measured. Percent protein was determined indirectly by multiplying percent nitrogen by a correction factor of 4.25 (Izhaki, 1990). Percent crude sugar was determined by hydrolyzing 500 mg dry weight samples in a 3/1 solution of 1% H_2PO_4 and methanol, removing the methanol under vacuum, and running the resultant solution through a High Pressure Liquid Chromatography (BPLC) reverse-phase column. Passage of specific sugars was detected using a Refractive Index Analyzer (RI). Percent crude fat was determined by running 500 mg dry weight samples through supercritical fluid extraction (SFE) with CO^2 as a solvent, washing the extract with benzene, and weighing the extract once the benzene evaporated. Specific fatty acids was determined by dissolving the extract in hexane, and running through a gas chromatograph (GC). Passage of specific fatty acids was detected with a Flame Ionization Detector (FID). Percent indigestible ("dietary") fiber (primarily cellulose) was determined by neutral detergent fiber (NDF) analysis (Goering and Van Soest, 1987). Five-hundred mg dry weight samples were dissolved in boiling saline and acid solution for one hour and filtered to extract all undigested elements. Those elements were dried to constant weight and reweighed to determine percent content.

The mean size of each fruit was determined by measuring the diameter of 100 fruits of each species, with the exception of sassafras, which had oblong fruits. A length and width of 50 fruits were measured for this species.

Energetics of Fat Deposition.--Cost of fat deposition, and amount of fat that could be generated was determined for birds eating 100 g of each fruit type. For purposes of this analysis, it was assumed that there was no uptake or energetic cost due to passage of the indigestible fiber and mineral (ash) components of the fruits. Uptake of all other groups of ""energy-bearing" compounds (proteins, carbohydrates, and lipids) was assumed to be 100%. To allow for direct comparison, final values of the energy budget based on each fruit were converted to grams of fat/kcal energy spent.

Since fatty acids are taken up from the digestive tract essentially unchanged (Klasing, 1998), and the fatty acids stored by birds often parallel those in their diet (Blem, 1990; Caldwell, 1972, Klasing, 1998), all fatty acids were assumed to be stored in the forms and ratios found in the initial food source. Additionally, it was assumed that there was no metabolic cost associated with storage of fatty acids.

Proteins were broken down into their component amino acids for analysis. Since insufficient amounts of sample were available for amino-acid analysis, amino acid profiles for fruits were taken from published literature (Izhaki, 1993). Fruits in the same or closely related families as those analyzed in this study were used. Each amino-acid was assumed to be deaminated and converted to acetyl-CoA through a standard pathway. Ketogenic amino-acids were assumed to enter directly into lipogenesis as either acetyl-CoA or acetoacetyl-CoA after deamination. Glucogenic amino acids were assumed to be converted to either pyruvate or the citric-acid cycle intermediates alpha-ketoglutarate or succinyl-CoA after deamination. All digestible carbohydrates (starches and simple sugars) were assumed to be taken up as glucose and converted to acetyl-CoA through glycolysis.

Results

Species Assemblages.--A total of 24 species of birds were observed feeding on fruits of these five species of plants between August and October (Table 1). *Prunus, Vitis,* and *Sassafras* were all eaten by 10 or more species, while only 5 species were observed eating *Phytolacca* and *Aralia.* Only 20% (1 of 5) of the species seen eating pokeweed were long-distance migrants, while 50-75% of the bird species seen eating each of the other fruits were long-distance migrants (Table 1). Only one small-bodied species (Red-eyed Vireo)

Table 1. Species assemblages of birds feeding on various fruits in northwestern Arkansas. Bold type indicates a long-distance migratory species.

Taxon	*Aralia spinosa*	*Phytolacca americana*	*Prunus serotina*	*Sassafras albidum*	*Vitis cinerea*
Downy Woodpecker (*Picoides pubescens*)			x		
Red-bellied Woodpecker (*Melanerpes carolinus*)			x		
Eastern Kingbird (*Tyrannus tyrannus*)			x	x	
Great-crested Flycatcher (*Myiarchus crinitus*)			x		x
Least Flycatcher (*Empidonax minimus*)	x			x	
Alder Flycatcher (*Empidonax alnorum*)	x				
Tufted Titmouse (*Baeolophus bicolor*)			x		
Northern Mockingbird (*Mimus polyglottus*)	x	x	x		
Brown Thrasher (*Toxostoma rufum*)	x	x			
Gray Catbird (*Dumatella carolinensis*)	x	x	x	x	x
American Robin (*Turdus migratorius*)		x	x	x	x
Wood Thrush (*Hylocichla mustelina*)				x	
European Starling (*Sternus vulgaris*)		x	x		
Red-eyed Vireo (*Vireo olivaceous*)			x	x	x
Warbling Vireo (*Vireo gilvus*)					x
Philadelphia Vireo (*Vireo philadelphicus*)					x
White-eyed Vireo (*Vireo griseus*)	x	x			
Orange-crowned Warbler (*Vermivora celata*)	x				
Baltimore Oriole (*Icturus galbula*)			x	x	
Common Grackle (*Ouiscalus quiscala*)			x		
Summer Tanager (*Piranga rubra*)			x	x	
Scarlet Tanager (*Piranga olivacca*)					x

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was observed eating *Sassafras*, while several small-bodied species were observed eating *Prunus, Vitis,* and *Aralia.*

Phenology and Persistence of Fruits.--Availability of ripe fruits of both *Sassafras* and *Prunus* peaked in early-mid September and ripe fruits rarely persisted after the end of that month (Figs. 1 and 2)[1]. Availability of ripe fruits of *Vitis* peaked in late September and early October, primarily because removal did not occur until later in October (Fig. 3). Ripe grapes were noted uncommonly after the end of October. Pokeweed had a much more prolonged ripening period (Riley and Smith, 1990), and commonly persisted into winter months. No data were taken on the peak fruiting period of *Aralia.* However, it was noted mainly in September and early October, and rarely seen outside those months.

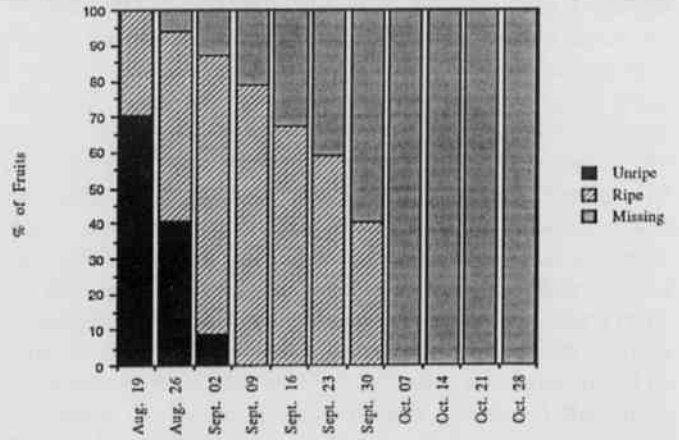

Fig. 1. Percent of ripe, unripe, and missing fruits of *Sassafras* over the study period. Data collected by Smith and Riley using weekly counts of fruits on marked branches during fall 1984.

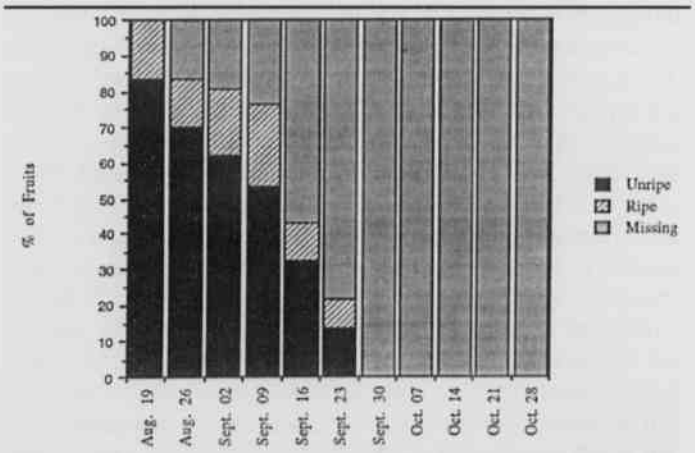

Fig. 2. Percent of ripe, unripe, and missing fruits of *Prunus* over the study period. Data collected by Prather using weekly counts of fruits on marked branches during fall 1997.

[1]Fruits of *Prunus* trees in other parts of Arkansas often ripen earlier in the summer. Thus, the phenology of the trees in this study appears to be atypical for this species.

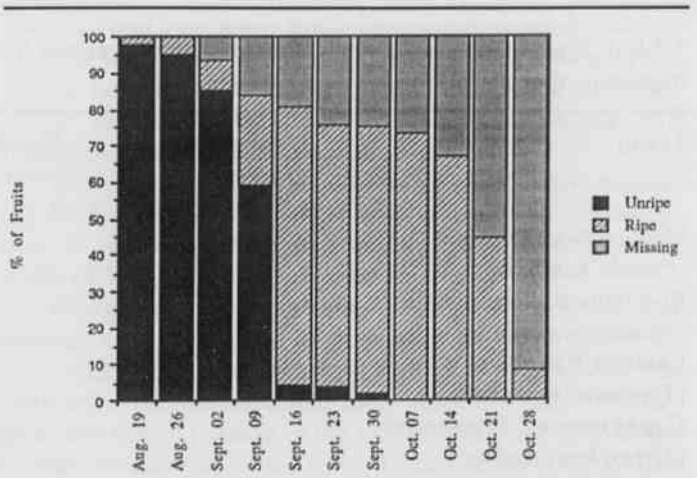

Fig. 3. Percent of ripe, unripe, and missing fruits of *Vitus* over the study period. Data collected by Smith and Riley using weekly counts of fruits on marked branches during fall 1984.

Physical and Nutritional Characteristics of Fruits.--*Sassafras* was outstanding among the fruits analyzed as having comparatively high lipid content and comparatively low sugar content (Table 2). *Sassafras* also had much higher caloric content (Table 3) than the other fruit species and a larger fruit (Table 4). The other four types of fruit were essentially similar in nutritional content (Table 2), caloric value (Table 3), and color (Table 4), although *Aralia* had a much smaller fruit than did the other species (Table 4). Sagsafras yielded higher amounts of fat per grain, and had a lower cost/gram fat deposited than did the other species (Table 3). The amount of fat deposited and the cost/gram of fat deposited was similar for the other fruit species (Table 3).

Discussion

The avian species assemblage observed eating fruits in northwestern Arkansas is relatively small compared to that of other areas in the east, e.g. Illinois (Malmborg & Willson, 1988) and Rhode Island (Parrish, 1998). Notably lacking in our observations are *Catharus* thrushes and northern-breeding warblers, which make up a large part of the species assemblage in these locations. These species are rare in northwestern Arkansas during fall migration (Neal & Mlodinow, 1986). Indeed, although 60% (15 of 25) of the species we noted were long-distance migrants, only 2 of these, the Red-eyed Vireo and the Gray Catbird were observed eating fruits on many occasions, and both of these breed locally. Besides these two species, the most commonly noted species at fruiting trees were Northern Cardinal, Northern Mockingbird, and American Robin, all of which are resident in northwestern Arkansas. At least for American Robins, juveniles appear to eat more fruit than

Table 2. Nutritional characteristics[a] of taxa of fruits eaten by birds in northwestern Arkansas.

Taxon	Nutritional Content % Starch	% Sugar	% Protein	% Lipid	% Indigestible Fiber	% Ash
Aralia	30.93 ± 2.78	36.78 ± 2.40	7.23 ± 1.19	03.14 ± 0.16	12.37 ± 1.71	5.61 ± 0.66
Phytolacca	29.08 ± 1.12	39.36 ± 2.21	5.37 ± 0.33	01.75 ± 0.24	17.86 ± 1.15	6.26 ± 0.42
Prunus	32.44 ± 1.80	42.54 ± 3.20	2.31 ± 0.19	01.24 ± 0.02	17.55 ± 3.77	3.92 ± 0.24
Vitus	45.02 ± 0.74	27.18 ± 1.19	3.12 ± 0.08	02.21 ± 0.17	15.72 ± 0.99	6.57 ± 0.65
Sassafras	04.88 ± 2.47	07.77 ± 1.30	4.32 ± 0.22	30.68 ± 0.15	50.34 ± 3.39	2.02 ± 0.06

[a] Mean ± standard deviation of % dry weight. All values based on 3 samples.

Table 3: Comparison of the efficiency of utilizing different food items eaten by migratory birds for building fat stores.

Taxon	Calories[a] / Gram	Digestible Components[b]	Energy Used (KJ)	Fat Produced	Cost / Gram (KJ)
Aralia	4748 ± 044	78.1%	80.6	25.9 g	3.11
Phytolacca	4476 ± 029	75.6%	78.3	24.3 g	3.23
Prunus	4324 ± 189	76.5%	80.0	25.1 g	3.19
Vitus	4252 ± 043	77.5%	78.5	25.4 g	3.09
Sassafras	7269 ± 166	47.6%	26.5	35.4 g	0.75

[a] Mean ± standard deviation.
[b] Percent dry weight of all protiens, lipids, sugars, and starches.

Table 4: Comparison of some characteristics of the fruits and fruit crops of plant species eaten by birds in northwest Arkansas.

Taxon	Fruit Size (mm) [a]	Ripe Fruit Color	Peak Fruit Availability	Persistance After Ripening
Aralia	5.21 ± 0.34	Purple-Black	September ?	Rare
Phytolacca	8.24 ± 0.43	Purple-Black	Aug. - Oct.	Common
Prunus	7.20 ± 0.51	Red-Black	August ?	Rare
Vitus	7.40 ± 0.94	Purple-Black	Sept. - Oct.	Uncommom
Sassafras	7.67 ± 0.63 X 9.94 ± 0.61	Blue-Black	Aug. - Sept.	Rare

[a] Mean ± standard deviation.

adults (Smith, pers. obs). The preponderance of resident species as fruit-eaters in northwestern Arkansas would make this an interesting area to study frugivory and seed dispersal.

The data suggest that several of the fall-fruiting plant species in northwestern Arkansas are quite similar in nutritional content and physical characteristics. *Sassafras* was larger and higher in energetic content than the other species, characteristics that should make it very attractive to migratory birds. Large numbers of Eastern Kingbirds, Gray Catbirds, and Baltimore Orioles have been noted in fruiting *Sassafras* trees in late August and early September (pers. obs.). Such large groups of birds were also noted occasionally at cherry trees.

Sassafras crops appear to be removed very rapidly (Fig. 1, Smith, pers. obs.), as were those of *Prunus* (Fig. 2). *Prunus* appeared to be the most favored food of migrants and was seen being consumed by the most species. The smaller fruits may make this species more attractive to small birds than

Sassafras. *Vitis* was more persistent after ripening, although the plants examined for phenology were stripped of fruits in late October. *Phytolacca* fruits ripened over a longer period of time than did fruits of the other species (Smith & Riley, 1990), and were very persistent after the end of the ripening period.

Fruit size appears to be an important factor influencing the avian species assemblage eating the various fruit species examined in this study. Of the birds observed eating *Sassafras*, only Red-eyed Vireo can be said to be relatively small-bodied, whereas several small-bodied species (*Empidonax* flycatchers, Tufted Titmouse, warblers, vireos, and Indigo Bunting) were seen eating *Prunus, Vitis,* and *Aralia*. *Aralia* was exceptional in being attended by three of the smallest species observed eating fruits: Least Flycatcher, White-eyed Vireo, and Orange-crowned Warbler. Small species may be able to swallow the fruits of *Aralia* more easily than those of other species. However, small fruits may not be attractive to larger birds able to eat larger-fruited species. It has been shown in other systems that frugivore assemblages can be affected by fruit size, especially if fruits are large and exceed the gape width of many species that could potentially feed on them (Wheelwright, 1985).

Pokeweed remains enigmatic among the fruiting plants of northwestern Arkansas in being attended almost exclusively by common resident bird species despite having no exceptional physical or nutritional characteristics. This pattern does not appear to be related to lack of observations, since most of the species seen eating *Phytolacca* have been noted doing so many times. Pokeweed is also quite common, and should be available in areas with a wide variety of bird species, making the pattern even more difficult to explain. Some additional evidence that *Phytolacca* is less favored by birds than other fruit species is that ripe fruits commonly persist well after the end of the normal fruiting period, a trait seen rarely in the other species discussed here. Finally, in a study in Illinois, pokeweed was noted as being eaten by relatively few species (Malmborg & Willson, 1988). It seems likely that *Phytolacca* is being avoided by many species of birds due to some unknown factor, perhaps toxic secondary compounds that make the fruits less palatable (Izhaki & Safriel, 1989). More research on this species is certainly warranted.

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