Wildlife Session

Foraging Habits of Mallards and Wood Ducks in a Bottomland Hardwood Forest in Texas

L. Christopher Miller,[1] *U.S. Forest Service, Southern Research Station, Wildlife Habitat and Silviculture Laboratory, Nacogdoches, TX 75962*

R. Montague Whiting, Jr., *Arthur Temple College of Forestry, Stephen F. Austin State University, Nacogdoches, TX 75962*

Michael S. Fountain, *Arthur Temple College of Forestry, Stephen F. Austin State University, Nacogdoches, TX 75962*

Abstract: Although winter foods of mallards *(Anas platyrhyncos)* and wood ducks *(Aix sponsa)* have been documented in several studies, no such research has been conducted in natural bottomland hardwood forests in eastern Texas. We collected 40 mallards and 38 wood ducks and sampled available foods in eastern Texas during winters 1987–1988 and 1988–89 to study food habits and preferences. Acorns from four oak species comprised >89% and >99% of the diets of mallards and wood ducks, respectively. Nuttall oak *(Quercus texana)* acorns made up >67% of the diet of each species both years. Program PREFER indicated seeds of deciduous holly *(Ilex decidua)* and willow oak *(Q. phellos)* acorns were favored by mallards and wood ducks, respectively; preferences overlapped widely among potential foods, however. Although bottomland systems provide critical habitat for wintering waterfowl, their contributions can be enhanced by applying established silvicultural techniques to encourage desirable oak species.

Key words: acorns, food habits, food preferences, mallard, wood duck

Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 57:160–171.

Bottomland hardwood forests are important to wintering mallards and wood ducks, especially in the southeastern United States (Delnicki and Reinecke 1986, Fredrickson and Heitmeyer 1988, Barras et al. 1996, Combs and Fredrickson 1996). In eastern Texas, these habitats provide resources for over 100,000 wintering mallards and over 130,000 wintering and breeding wood ducks (Bellrose 1976). However, bottomland hardwoods in Texas and throughout the southeastern United States are subjected to losses from reservoir construction and stream and river channelization, diversion, and dredging. Although 640,000 ha of hardwood bottomlands remain in Texas, these habitats have decreased by more than 300,000 ha since 1935 (Lang and Bertelson 1987).

Food resources of bottomland hardwood forests are critical for the nutritional

1. Present address: PBS&J, 206 Wild Basin Road, Suite 300, Austin, TX 78746

needs of wintering mallards and wood ducks (Heitmeyer and Fredrickson 1981). Within these habitats, mast (primarily acorns) is the most important food (Wright 1961, Allen 1980, Delnicki and Reinecke 1986, Combs and Fredrickson 1996). Although food habits of mallards and wood ducks have been studied widely, only Allen (1980) assessed food habits of these species in forested bottomlands in eastern Texas and his data were collected in a managed greentree impoundment that contained food plots. Our objectives were to determine food habits, food availability, and food preferences of mallards and wood ducks wintering in a naturally flooded bottomland hardwood forest in eastern Texas.

Methods

This study was conducted in a 728-ha mature bottomland hardwood forest in the Stephen F. Austin Experimental Forest (SFAEF). The SFAEF is part of the Angelina River Basin and the bottomland portion of it is one of the few natural bottomland systems remaining in eastern Texas. The SFAEF is in the Pineywoods Vegetation Region and the Oak-Hickory-Pine Forest Subregion (U.S. Fish and Wildlife Service 1979). The area is subtropical and humid; average annual precipitation is about 115 cm and ranges 89 to 142 cm (Larkin and Bomar 1983). Normally, fall and winter rains inundate the entire SFAEF bottomland. The area was closed to waterfowl hunting, thus mallards and wood ducks were largely undisturbed except for collection efforts.

Collection of Ducks

We collected ducks during the day in winters 1987–88 and 1988–89. When possible, we observed ducks feeding prior to collection. In Mississippi, wood ducks collected in the evening had greater frequencies of food samples than those taken in the morning (Delnicki and Reinecke 1986). In this study, examination of mallards and wood ducks taken early in the first winter showed similar trends, thus collection efforts were concentrated later in the day. When a duck was collected, the location where it was feeding was flagged, and the bird's esophagus and proventriculus were removed, injected with a 10% formalin solution, placed in a labeled plastic bag, and frozen for subsequent analysis.

Collection of Food Availability Samples

We sampled food availability at feeding locations using the methods of Lind (1974). Potential food items were collected in both the water column and in the soil-leaf litter substrate using a 15-cm square Ekman dredge. The dredge had a #20 U.S. series screen fitted over the top to prevent potential food items suspended in the water column from passing through. We collected five subsamples (Longhurst 1959) at each location, one at the flagged point and four at subjectively selected adjacent points. No subsample was >20 m from the bird's presumed feeding location and >70% were within 10 m. Each subsample was transferred from the dredge into a bucket with a #30 U.S. series sieve on the bottom and washed to remove soil. The resulting material was placed in a plastic container and saturated with a solution of formalin, acetic acid, and alcohol. Each set of five subsamples was combined to form a single food availability sample.

Analyses of Digestive Tracts and Availability Samples

After thawing, contents of the esophagus and proventriculus of each duck were washed, sorted, and identified to the lowest possible taxa. Foods that could not be identified were classified as plant or animal. For each duck, food items from each taxon were placed in a separate vial containing 10% formalin. Thereafter, each vial was emptied and the contents were blotted dry and weighed. After obtaining wet weights, each taxon was dried to a constant weight. We used dry weight in all analyses (Reinecke and Owen 1980).

Each food availability sample was poured into a metal tray where litter and detritus were washed and removed. The remaining material was washed through a series of graded soil sieves to separate potential food items by size. All organisms and plant foods were removed, washed, sorted, and identified to the lowest possible taxa. Each sample was searched until no new food items were found. Weighing and calculation procedures were the same as for digestive tract samples.

Statistical Analyses

We used program PREFER (Johnson 1980, Frank 1985) to calculate food preferences of mallards and wood ducks by year. We selected PREFER because it used ranks rather than actual values, thus reducing effects of sampling error (Johnson 1980) and sensitivity of results to the inclusion or exclusion of food items (Thomas and Taylor 1990). This program tested the null hypothesis that available foods were equally preferred (Frank 1985) and ranked the food items that each duck consumed such that the item with the greatest weight received the highest rank; food availability items were likewise ranked. For each food item, the difference between the consumed and available ranks was a measure of the bird's preference for that item. These differences were then subjected to a Waller-Duncan comparison using a K-ratio of 100:1, which is analogous to an alpha level of 0.05 (Waller and Duncan 1969, Johnson 1980). Output from PREFER included a list of food items ranked in order of preference and results of the Waller-Duncan comparisons. For these tests, we included only food items recorded in both food consumption and availability samples.

Results

Foods Utilized

During 1987–88, bottomlands on the SFAEF flooded in early November and remained flooded throughout winter. Between 26 November and 4 February, we collected 30 mallards (19 males, 11 females) and 31 wood ducks (15 males, 16 females). In contrast, the bottomlands did not flood until late December in 1988–89. Thus, we collected only 10 mallards (five males, five females) and 7 wood ducks (five males, two females) between 27 December and 27 January.

Dry weights of digestive tract contents ranged 0.0015–24.5907 g (Miller

Table 1. Total dry weights of foods consumed by mallards and wood ducks collected in a flooded bottomland hardwood forest in eastern Texas, winters 1987–88 and 1988–89. Numbers of individuals that consumed each food item are also shown.

	Mallards				Wood ducks			
	1987–88 (*N* = 30)		1988–89 (*N* =10)		1987–88 (*N* = 31)		1988–89 (*N* = 7)	
Taxon	Weight (g)	*N* birds	Weight (g)	*N* birds	Weight (g)	*N* birds	Weight (g)	*N* birds
				Plant material				
Nuttall oak	52.3806	10	32.2244	4	64.4134	5	30.7549	3
Willow oak	8.4884	2	1.8848	1	5.9685	2	4.1302	1
Swamp laurel oak	3.9358	3	tr[a]	1	8.6104	3	2.7860	1
Water oak	1.7242	1	—	—	0.9772	1	—	—
Acorn fragments	2.6609	27	11.1406	10	7.2222	30	8.0768	7
Hawthorn (*Crataegus* spp.)	0.7617	1	—	—	—	—	—	—
Deciduous holly	0.1366	10	tr	2	tr	1	tr	1
Others	tr[b](7)[c]	n/a	tr(1)	n/a	tr(3)	n/a	tr(2)	n/a
Unidentified	0.3883	n/a	tr	n/a	tr	n/a	tr	n/a
Subtotal	70.5385		45.3110		87.3397		45.7744	
				Animal material				
Crawfish	1.0105	6	0.5091	5	tr	1	—	—
Aquatic sowbugs	0.6044	18	tr	3	tr	7	tr	4
Aquatic earthworms	0.1682	5	tr	3	—	—	tr	4
Clams	0.1554	8	tr	3	tr	1	tr	3
Scuds	0.1539	8	tr	1	tr	2	tr	2
Others	tr(3)	n/a	tr(1)	n/a	tr(2)	n/a	—	—
Unidentified	tr	n/a	tr	n/a	tr	n/a	tr	n/a
Subtotal	2.2817	—	0.5495	—	0.0915	n/a	0.0448	n/a
Grit	4.3170	23	tr	4	0.6164	7	tr	2
Total	77.1372	—	45.9030	—	88.0476	—	45.8316	—

a. Values < 0.1 g (except subtotals) are listed as trace (tr); see Miller (1992:34–35, 37–38) for complete data.

b. Total weight of taxa that occurred in trace amounts.

c. Number of taxa in the Others category.

1992:66–68). During winters 1987–88 and 1988–89, mallards used 21 and 11 identifiable food items, respectively, and wood ducks used 14 and 10 such items, respectively (Table 1). In 1987–88, 6 mallards (three males, three females) and 13 wood ducks (four males, nine females) contained food that could be identified only as plant or animal matter; however, all except a male mallard contained unidentified acorn fragments. Unidentified acorn fragments were recovered from 57 ducks collected that winter, and three of the remaining four birds contained identifiable food items. In 1988–89, identifiable food items were found in all but a female mallard and all birds contained unidentified acorn fragments.

Mallard digestive tract contents were dominated by plant foods each winter (Table 1). Acorns comprised 89.7% and 98.6% of total dry weight (including grit) in 1987–88 and 1988–89, respectively. Nuttall oak acorns made up the majority of foods used each year. Crawfish (order Decopoda) was the only animal food that comprised >1.0% of the diet either winter, and was the only animal found in greater than trace quantities (i.e., >0.1 %) in 1988–89. Unidentified plant and animal matter comprised minor proportions of the digestive tract contents each year (Table 1). Grit comprised 5.6% of the contents in 1987–88 but <0.1% in 1988–89.

Wood ducks used 14 identifiable food items (eight plant, six animal) during 1987–88 and 10 (six plant, four animal) during 1988–89 (Table 1). During both winters, acorns made up >99.0% of the total dry weight from digestive tract contents. In 1987–88, seeds of sugarberry *(Celtis laevigata)*, deciduous holly, and panic grass (*Panicum* spp.) were recorded in trace quantities as were seeds of deciduous holly, panic grass, and smartweed (*Polygonum* spp.) in 1988–89. Animal foods were present only in trace quantities each year (Table 1).

Food Availability

During 1987–88, we recorded 42 potential food items, 30 of which were plant matter (i.e., seeds and nuts). Plant matter comprised 98.7% of the dry weight of available foods and acorns contributed 94.8% of the total. Nuttall oak acorns were the dominant food item, but 10 additional plant foods were present in greater than trace proportions. We identified 12 animal taxa, comprising 1.3% of the total dry weight, in availability samples. Aquatic sowbugs (order Isopoda) represented the largest group in both weight and occurrence. Crawfish, freshwater clams (order Pelecypoda), scuds (order Amphipoda), and aquatic earthworms (class Oligochaeta) also were present in greater than trace amounts (Table 2).

During 1988–89, we identified 18 potential food items (Table 2); all were previously identified in 1987–88. The 11 plant foods comprised 99.7% of the total dry weight. Acorns made up 97.8% of the plant foods, and overcup oak *(Q. lyrata)* acorns dominated in both dry weight and occurrence (Table 2). Other than oaks, only water hickory *(Carya aquatica)* nuts were found in greater than trace amounts. Seven animal foods, representing only 0.3% of the total dry weight, were identified in food availability samples. Crawfish comprised the most important animal taxa in terms of dry weight, whereas aquatic sowbugs were most important in terms of occurrence (Table 2).

Food Preferences

Preference analyses separated mallard foods into three widely overlapping groups each winter (Table 3). In 1987–88, the highest-ranked food item was seeds of deciduous holly, which ranked significantly higher than only four items. The ranking of Nuttall oak acorns was not different from that of acorns of other oak species. Crawfish was the highest ranked animal food; snails (order Gastropoda) were the only other invertebrate that ranked higher for consumption than availability. Both taxa received significantly higher rankings than aquatic earthworms, which was the lowest-ranked food item (Table 3).

Results of preference analysis for mallards collected in 1988–89 must be viewed with caution because the number of food items consumed (11) barely exceeded the number of birds (10) collected (Frank 1985). However, similarities to the

Table 2. Total dry weights of potential plant and animal foods collected at feeding sites of mallards and wood ducks in a flooded bottomland hardwood forest in eastern Texas, winters 1987–88 and 1988–89. Numbers of samples in which each taxon was recorded are also shown.

	1987–88 ($N = 61$)		1988–89 ($N = 17$)	
Taxon	Weight (g)	*N* samples	Weight (g)	*N* samples
Nuttall oak	67.3859	18	31.7563	4
Swamp laurel oak	19.3520	9	2.0034	1
Overcup oak	17.6770	12	41.7786	11
Willow oak	6.9330	9	1.0004	1
Water oak	3.9004	4	0.9004	1
Water hickory	3.2764	2	1.6606	1
Muscadine grape (*Vitis rotundifolia*)	0.7014	1	—	—
Southern red oak (*Quercus falcata*)	0.5757	1	—	—
Deciduous holly	0.3958	8	tr[a]	3
Sugarberry	0.3017	2	—	—
Common rush (*Juncus effusus*)	0.1072	5	—	—
Others	0.1675[b](19)[c]	n/a	tr(4)	n/a
Plant material subtotal	120.7740	n/a	79.1789	n/a
Aquatic sowbugs	0.6645	52	tr	11
Crawfish	0.2823	12	0.1260	5
Clams	0.2495	27	tr	6
Scuds	0.1703	34	tr	5
Aquatic earthworms	0.1397	42	tr	10
Others	tr(7)	n/a	tr(2)	n/a
Animal material subtotal	1.5422	n/a	0.2566	n/a
Total	122.3162	n/a	79.4355	n/a

a. Values < 0.1 g are listed as trace (tr); see Miller (1992:30–31) for complete data.
b. Total weight of taxa that occurred in trace amounts.
c. Number of taxa in the Others category.

1987–88 rankings suggest that the results were reasonable (Table 3). As in 1987–88, Nuttall oak acorns ranked highest among acorns of oak species and crawfish ranked highest among invertebrates. However, in contrast to 1987–88, three of the five top-ranked taxa were invertebrates. Also, willow oak acorns and aquatic earthworms ranked higher and smartweed and aquatic sowbugs ranked lower in 1988–89 than in 1987–88.

For wood ducks, preference analyses created three groups in 1987–88 but only two in 1988–89 (Table 4). The top-ranked group in 1987–88 included 8 (six plant, two invertebrate) of the 13 food items, thus overlap among groups was less pronounced for wood ducks than for mallards. Willow oak, water oak *(Q. nigra)*, and swamp laurel oak *(Q. laurifolia)* acorns were in the top-ranked group, whereas Nuttall oak acorns were not; furthermore, the difference between willow oak and Nuttall oak acorns was significant. Invertebrates were generally ranked lower than plant foods. Beetles (order Coleoptera) and crawfish were in the top-ranked group. Clams,

Table 3. Mean differences in rankings of food use versus availability for mallards collected in a flooded bottomland hardwood forest in eastern Texas, winters 1987–88 and 1988–89. Food items are in order of preference.

1987–88 (N = 30)		1988–89 (N =10)	
Taxon	Difference[a]	Taxon	Difference[b]
Deciduous holly	2.1400A[c]	Nuttall oak	2.0000A
Nuttall oak	1.1400AB	Crawfish	1.6250A
Sedge (*Cyperus* spp.)	0.8000AB	Willow oak	0.8125AB
Smartweed	0.5400AB	Clams	0.5417AB
Crawfish	0.2000AB	Snails	0.1667ABC
Snails	0.1400AB	Deciduous holly	0.0833ABC
Water oak	0.1200AB	Swamp laurel oak	0.0625ABC
Swamp laurel oak	0.0800AB	Scuds	–0.2500ABC
Panicgrass	0.0460AB	Aquatic earthworms	–0.4167ABC
Knotgrass *(Paspalum distichum)*	0.0420AB	Smartweed	–1.2917BC
Hawthorn	0.0360AB	Aquatic sowbugs	–2.4583C
Clams	–0.1200AB		
Aquatic sowbugs	–0.2600ABC		
Scuds	–0.5400ABC		
Willow oak	–1.0200BC		
Blackgum *(Nyssa sylvatica)*	–1.4200BC		
Common rush	–1.4200BC		
Aquatic earthworms	–2.9000C		

a. Critical value for Waller-Duncan = 2.72.

b. Critical value for Waller-Duncan = 2.86.

c. Groups within columns with the same capital letters are not different ($P > 0.05$).

scuds, and aquatic sowbugs made up the lowest-ranked group; the latter two taxa ranked lower than other food items (Table 4).

As with mallards, the number of food items consumed by wood ducks in 1988–89 (10) was greater than the number of birds collected (7), thus the results should be viewed with caution. Also, as with mallards, preference rankings were similar between years. Acorns of willow oak were the top-ranked food item and were significantly preferred over two invertebrates. Smartweed, which was not identified in wood duck digestive tracts in 1987–88, ranked second in 1988–89. Also, clams, which ranked relatively low in 1987–88, ranked third in 1988–89. The change in rank for clams parallels that in mallards. Otherwise, there were only minor changes in the relative rank of food items found in wood duck digestive tracts between years (Table 4).

Discussion

Foods Consumed

During the two winters of this study, Nuttall oak acorns were the staple food of mallards and wood ducks in the SFAEF. Likewise, Nuttall oak acorns made up 55% of available plant food in the first winter and 40% in the second. No other study has

Table 4. Mean differences in rankings of food use versus availability for wood ducks collected in a flooded bottomland hardwood forest in eastern Texas, winters 1987–88 and 1988–89. Food items are in order of preference.

1987–88 (N = 31)		1988–89 (N = 7)	
Taxon	Difference[a]	Taxon	Difference[b]
Willow oak	2.5652A[c]	Willow oak	2.5714A
Water oak	1.9783AB	Smartweed	1.2646AB
Swamp laurel oak	0.9564AB	Clams	0.8333AB
Panicgrass	0.7826AB	Deciduous holly	0.6714AB
Sugarberry	0.7609AB	Swamp laurel oak	0.5714AB
Beetles	0.5870AB	Panicgrass	–0.0714AB
Deciduous holly	0.5000AB	Nuttall oak	–0.0833AB
Crawfish	0.4823AB	Aquatic sowbugs	–0.1667AB
Snails	0.2826B	Scuds	–0.3571B
Nuttall oak	–0.0217B	Aquatic earthworms	–0.5833B
Clams	–1.3044BC		
Scuds	–2.9348C		
Aquatic sowbugs	–3.7609C		

a. Critical value for Waller-Duncan = 2.17.

b. Critical value for Waller-Duncan = 2.74.

c. Groups within columns with the same capital letters are not different ($P > 0.05$).

documented extensive use of Nuttall oak acorns by mallards, and only two studies (Louisiana Department of Wildlife and Fisheries 1981, Delnicki and Reinecke 1986) recorded extensive use of Nuttall oak acorns by free-ranging wood ducks. In the Delnicki and Reinecke (1986) study, although Nuttall oak acorns were available, they were not consumed by mallards.

Overcup oak, which had an importance value more than twice that of Nuttall oak (Miller 1992:27), dominated the canopy of the study area. Although overcup oak acorns were available each winter (Table 2), none was identified in any duck digestive tract. Both duck species may have avoided overcup acorns because their husks completely cover the nuts, which could make ingestion and swallowing difficult. However, digestive tracts of all but four ducks contained unidentified acorn fragments. Gray squirrels *(Sciurus carolinensis)* were noted retrieving floating overcup acorns from the water, then husking and eating the acorns while perched on logs. Fragments dropped by squirrels were concentrated in water adjacent to the logs. Acorn fragments comprised larger proportions of diets of both duck species in the second winter (Table 1), when overcup oak acorns were the most abundant potential food item, than in the first winter, when they ranked third (Table 2).

Acorns of willow oak, water oak, and swamp laurel oak also constituted important parts of the diet of both species each year. Mallards collected on a greentree reservoir <30 km upriver from our study area used proportions of willow oak and water oak acorns similar to those we recorded (Allen 1980). However, wood ducks collected in that study consumed greater proportions of water oak and lower proportions of willow oak acorns than we recorded. Likewise, wood ducks collected in Arkansas and Mississippi used more water oak than willow oak acorns (Hall 1962, Delnicki and Reinecke 1986). In Hall's (1962) study, cherrybark oak acorns comprised the majority of the digestive tract contents of both mallards and wood ducks, and willow oak acorns were not recorded in mallard digestive tracts. Finally, the use of swamp laurel oak acorns by either mallards or wood ducks has not been documented in other studies.

The dense overstory canopy of the study area limited understory vegetation, thus the lack of seeds from understory woody plants, grasses, sedges, and annual forbs in duck digestive tracts is not surprising. The dense deciduous canopy did result in an abundance of leaf litter on the forest floor. When flooded, the resulting detritus provided habitat for invertebrates, an important source of protein necessary for successful nesting (Fredrickson 1980). However, this study and several others (Allen 1980, Delnicki and Reinecke 1986, Combs and Fredrickson 1996) indicated that animal matter makes up only small proportions of the diets of wintering mallards and wood ducks.

Food Preferences

Both mallards and wood ducks depend on foods in bottomland hardwood forests to meet energy requirements during winter (Fredrickson and Drobney 1979, Fredrickson 1980, Nichols et al. 1983, Delnicki and Reinecke 1986). Acorns are a high energy food available in such habitats. Although mallards and wood ducks examined in this study consumed acorns from the same oak species, our results suggest that differences in preference did occur (Tables 3 and 4). However, because of the low numbers of birds which consumed many of the identifiable food items, our findings must be viewed with caution.

Differential use of Nuttall oak acorns may have been due to size. Nuttall oak acorns, favored by mallards, are much larger than those of willow oaks (Delnicki and Reinecke 1986, Barras et al. 1996), which were favored by wood ducks. Low selectively of willow oak acorns by mallards supports the results of feeding trials by Hall (1962). However, he also reported low selectivity of willow oak acorns by wood ducks, which is contrary to our results and those of Barras et al. (1996). Because willow oak acorns have thinner shells, more nutrients, and lower tannin indices than Nuttall oak acorns (Barras et al. 1996), low use by mallards may be due to feeding strategy. In the SFAEF, mallards generally fed in specific locations for extended periods whereas wood ducks continuously swam as they fed (Clark and Whiting 1994). Mallards may have been concentrating on readily available Nuttall oak acorns whereas wood ducks were using more dispersed willow oak acorns (Table 2).

Selection of Wintering Habitats

Waterfowl use of and distribution in bottomland hardwood forests and availability of waterfowl food are largely dependent on winter precipitation and mast production (Nichols et al. 1983). Mallards and wood ducks seek flooded bottomlands and may remain in such areas throughout the winter if conditions remain favorable. However, upon arriving on the wintering grounds, lack of water may cause both species to seek alternate habitats (Fredrickson 1980).

In 1987–88, the study area was flooded by early November and remained flooded through March; both mallards and wood ducks were present throughout that period. However, in 1988–89, the area did not flood until late December and ducks were not present until after Christmas. Although the area was flooded, few ducks remained after late January. However, the average weight of potential foods in availability samples in 1987–88 (2.0051 g) was less than half that in 1988–89 (4.6727 g); furthermore, weights of Nuttall oak acorns averaged 1.1047 g in the first winter and 1.8680 g in the second. Finally, weights of food in digestive tracts averaged 2.7079 g in 1987–88 and 5.1532 g in 1988–89, thus food availability does not appear to have been limiting in 1988–89.

Management Recommendations

This study reiterates the importance of bottomland hardwood forests to wintering waterfowl. Although natural bottomland systems provide critical habitat, their overall contribution can be enhanced by applying silvicultural techniques that promote desirable mast-producing species. To do so, the ecology and phenology of these species must be considered. The four oak species that produced acorns consumed by ducks in the SFAEF are members of the red oak section *(Lobatae)*, and require two growing seasons for acorn maturation (Hardin et al. 2001). Therefore, it is important to provide a mix of these species in case one or more fail to produce acorns in a given year.

The four desired oak species are relatively intolerant of shading. Also, although all may live for >100 years, acorn production decreases with increasing age. Therefore, bottomland hardwood forests should be managed to maintain single-cohort stands which represent different age classes and species throughout the forest (Kellison and Young 1997). Successful regeneration of bottomland oaks depends on the presence of advance regeneration in the understory. Procedures to inventory advance regeneration are well documented (Hart et al. 1995). If sufficient advance regeneration is present in a stand scheduled for regeneration, it may be cleancut (i.e., cut all stems >5 cm dbh). This will allow new recruits to develop without competition from overtopping stems. The resultant vegetation may be very dense for 10–15 years but will rapidly progress to an oak-dominated stand. Species composition of the new stand will approximate the percentages that occurred in the advance regeneration.

If advance regeneration of desired oak species is not present, then a combined shelterwood seed cut and improvement operation should be applied, with undesirable species targeted for removal. In this operation, basal area of the overstory trees should be reduced to 10–12 m^2/ha to improve vigor and stimulate acorn production of the seed trees. Also, increased light reaching the forest floor will stimulate seedling establishment. A second regeneration inventory should be conducted in two to five years to evaluate the advance regeneration; if regeneration is adequate, then overstory removal may be conducted as a cleancut operation.

Acknowledgments

The U.S. Forest Service, Southern Research Station, Wildlife Habitat and Silviculture Laboratory, provided financial support and the study site. J. Neal of the U.S. Fish and Wildlife Service provided vehicles and support services. R. E. Thill and J. Walter provided technical assistance in food item identification. M. J. Chamberlain, W. C. Conway, B. Davis, J. R. Glenn, J. D. Laing, J. D. Taylor, II, and four anonymous reviewers provided valuable comments on the manuscript.

Literature Cited

Allen, C. E. 1980. Feeding habits of ducks in a green-tree reservoir in eastern Texas. Journal of Wildlife Management 44:232–236.

Barras, S. C., R. M. Kaminski, and L. A. Brennan. 1996. Acorn selection by female wood ducks. Journal of Wildlife Management 60:592–602.

Bellrose, F. C. 1976. Ducks, geese, and swans of North America. Stackpole Books, Harrisburg, Pennsylvania.

Clark, H. B. and R. M. Whiting, Jr. 1994. Time budgets of mallards and wood ducks wintering in a flooded bottomland hardwood forest. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 48:22–30.

Combs, D. L. and L. H. Fredrickson. 1996. Foods used by male mallards wintering in southeastern Missouri. Journal of Wildlife Management 60:603–610.

Delnicki, D. and K. J. Reinecke. 1986. Mid-winter food use and body weights of mallards and wood ducks in Mississippi. Journal of Wildlife Management 50:43–51.

Frank, A. M. 1985. PREFER-Preference assessment program. U.S. Fish and Wildlife Service, Ann Arbor, Michigan.

Fredrickson, L. H. 1980. Management of lowland hardwood wetlands for wildlife: problems and potential. Transactions of the North American Wildlife and Natural Resource Conference 45:376–386.

______ and R. D. Drobney. 1979. Habitat utilization by postbreeding waterfowl. Pages 119–129 *in* T. A. Bookout, editor. Waterfowl and wetlands: an integrated review. North Central Section, The Wildlife Society, Madison, Wisconsin.

______ and M. E. Heitmeyer. 1988. Waterfowl use of forested wetlands in the southern United States: an overview. Pages 307–323 *in* M. W. Weller, editor. Waterfowl in winter. University of Minnesota Press, Minneapolis.

Hall, D. L. 1962. Food utilization by waterfowl in green-tree reservoirs at Noxubee National Wildlife Refuge. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 16:184–199.

Hardin, J. W., D. J. Leopold, and F. M. White. 2001. Harlow and Harrar's textbook of dendrology. Ninth edition. McGraw-Hill, New York, New York.

Hart, C. P., J. D. Hodges, K. Belli, and J. Stanturf. 1995. Evaluating potential oak and ash regeneration on minor stream bottoms in the Southeast. Pages 434–442 *in* M. B. Edwards, compiler. Proceedings of the eighth biennial southern silviculture research conference. U.S. Forest Service, General Technical Report SRS-1.

Heitmeyer, M. E. and L. H. Fredrickson. 1981. Do wetland conditions in the Mississippi Delta hardwoods influence mallard recruitment? Transactions of the North American Wildlife and Natural Resource Conference 46:44–57.

Johnson, D. H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology 61:65–71.

Kellison, R. C. and M. J. Young. 1997. The bottomland hardwood forests of the southern United States. Forest Ecology and Management 90:101–115.

Lang, L. L. and D. F. Bertelson. 1987. Forest statistics for east Texas counties. U.S. Forest Service, Resource Bulletin SO-118.

Larkin, T. J. and G. W. Bomar. 1983. Climatic atlas of Texas. Texas Department of Water Resources, Austin.

Lind, O. T. 1974. Handbook of common methods in limnology. C. V. Mosby, St. Louis, Missouri.

Longhurst, A. B. 1959. The sampling problem in benthic ecology. Proceedings of the New Zealand Ecological Society 6:8–12.

Louisiana Department of Wildlife and Fisheries. 1981. Pesticide residue analysis of breast muscle tissue and a food habit study of wood ducks collected in Louisiana. Project W-29-R, Study II, Job 6, Louisiana Department of Wildlife and Fisheries, New Orleans.

Miller, L. C. 1992. Food habits, preferences, and dietary overlap of mallards and wood ducks wintering in a bottomland hardwood forest of east Texas. Master's thesis. Stephen F. Austin State University, Nacogdoches, Texas.

Nichols, J. D., K. J. Reinecke, and J. E. Hines. 1983. Factors affecting the distribution of mallards wintering in the Mississippi Alluvial Valley. Auk 100:932–946.

Reinecke, K. J. and R. B. Owen, Jr. 1980. Food use and nutrition of black ducks nesting in Maine. Journal of Wildlife Management 44:549–558.

Thomas, D. L. and E. J. Taylor. 1990. Study designs and tests for comparing resource use and availability. Journal of Wildlife Management 54:322–330.

United States Fish and Wildlife Service. 1979. Concept plan: unique wildlife ecosystems of Texas. U.S. Fish and Wildlife Service, Albuquerque, New Mexico.

Waller, R. A. and D. B. Duncan. 1969. A Bayes rule for the symmetric multiple comparison problem. Journal of the American Statistical Association 64:1484–1503.

Wright, T. W. 1961. Winter foods of mallards in Arkansas. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 13:291–296.