Winter Movements and Habitat Use by Wood Ducks in South Carolina

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Abstract: Ten wood ducks (*Aix sponsa*) were radio-tracked during the wintering period on Steel Creek, Savannah River Plant, South Carolina. Home range size, daily movement and habitat use were determined from 1,140 radio-locations. Data collected during approximately 21 to 28 days of intensive radio-tracking were sufficient for delineating individual wintering wood duck home range size.. Males had significantly larger home ranges than females (42 ha vs 12 ha) and exhibited greater diurnal movements. Females made 0.5 to 3-day excursions ($N = 10$) to locations outside their home ranges throughout the entire tracking period. Wood ducks generally preferred emergent wetland habitat over scrub-shrub, forested, and open-water habitats. Emergent wetland habitat exhibited a more open canopy and greater herbaceous understory development than did other types. Preferred nocturnal roosting sites were located adjacent to feeding and loafing areas and were characterized by dense overhead and lateral cover. Some ducks made short flights (< 150 m) to roosting sites, but others did not. No radio-equipped birds used communal roosts located on the study area.

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The wood duck has been the subject of many investigations concerning different aspects of its reproductive ecology (Leopold 1951, Bellrose et al. 1964, Grice and Rogers 1965, Odum 1970, Strange et al. 1971), food habits (Conrad 1965, McGilvrey 1966*a, b;* Landers et al. 1977), and habitat use (Hardester et al. 1963, Gilmer 1971, Ball 1973, Hepp 1977, Parr et al. 1979). No studies, however, have described wood duck home range size, daily movement, or habitat use during the wintering period. Some researchers feel that the wintering grounds often are critical in determining population sizes of migratory species (Lack 1968, Fretwell 1972). The objectives of this study were to document and compare sex-specific wood duck home range size, daily movement, and habitat use during the wintering period in South Carolina.

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Methods

The study was conducted on Steel Creek, a Coastal Plain stream located on the Department of Energy's 81,000-ha Savannah River Plant (SRP) near Aiken, South Carolina. Steel Creek originates in the Aiken Plateau and flows southeasterly 19.3 km across the SRP before entering the Savannah River Swamp. At this point water velocity is reduced and suspended particulates settle out, creating a 33-ha, fan-shaped delta. Steel Creek then flows southeasterly across the swamp for 2.4 km and drains into the Savannah River (Langley and Marter 1973). Steel Creek received varying amounts of thermal effluent from nuclear production reactors from 1954 through 1968. The effluent increased the creek's water volume and temperature, and had a devastating effect on the vegetation. The original flora was completely destroyed in the creek's floodplain and delta, leaving an overstory of hundreds of dead trees. Steel Creek is currently undergoing recovery from thermal discharge and contains a large number of herbaceous species characteristic of disturbed areas without a canopy (Sharitz et al. 1974, Landers et al. 1977). In addition to thermal loading, Steel Creek received 267 curies of cesium-137 in discharge water from 2 reactor fuel storage and disassembly basins from 1961 through 1973 (Marter 1974).

Wood ducks were radio-tracked on 2 separate areas of the Steel Creek drainage. The majority was monitored in the Steel Creek delta and its surrounding area (67 ha), hereafter referred to as the delta system. A beaver pond system in the Steel Creek flood plain approximately 2 km upstream from the delta system also was used by several radio-equipped birds. The beaver pond system (17 ha) encompasses 2 beaver ponds, their associated wetlands, and the adjacent Steel Creek floodplain.

Migratory wood ducks begin to arrive on Steel Creek during the second week in October and nesting may be initiated as early as the first week in February (Fendley 1978). Thus, the wintering period in this area extends from 1 November to 15 January. Beginning in early November, wood ducks were captured in 1.25 m^2 funnel and drop door traps (Addy 1956) baited with whole corn or diced sweet potatoes. Captured wood ducks were removed from traps and taken to the Savannah River Ecology Laboratory to determine cesium-137 whole body concentrations. Birds with cesium-137 concentrations in equilibrium with environmental levels had probably been on the study area for at least 2 weeks (Fendley et al. 1977) and would be more likely to have selected the area as a wintering site. Birds with equilibrium cesium-137 concentrations were fitted with radio-transmitters of 163 to 164 Mh_z weighing 20 to 30 g (4% of total body weight). Transmitters were mounted on the birds with an elastic harness (Brander 1968). Radio-equipped birds were released at their capture site within 24 hours of initial capture.

Two permanent receiving towers equipped with single, 8-element, yagi antennas were erected 0.4 km apart on the uplands adjacent to the Steel Creek delta to locate ducks using the delta system. Receiving stations for locating beaver pond birds were located at intersections of roads, creeks, railroads, and other geographical features readily recognized on SRP maps. A hand-held, 4-element, yagi antenna was used for signal reception at these stations. Directional bearings were taken at all stations with a hand-held compass.

Triangulation between 2 or more stations was used to calculate all locations, except when a bird was sighted visually. Bearings were estimated to be within $\pm 2°$ of the true direction at a distance normally 0.3 km. During intensive tracking, each individual was located every 2 hours from 1 hour before sunrise to 1 hour after sunset. Three-day periods of such intensive tracking were alternated with 2-day periods of 1 to 2 locations per day.

Home range calculations were determined with a computer program developed by Silvy et al. (1979) based on the minimum area method (Mohr 1947). Cumulative home ranges were computed by 7-day intervals after the method of Odum and Kuenzler (1955) to determine when sufficient data were available for making valid home range estimates. An index to linearity (Ables 1969) was calculated for each duck and provided a quantitative value for the shape of the home range. Diurnal movement was calculated by summing the 4 linear distances between 5 sequential locations separated by 2-hour intervals between 0800 and 1600 hours. To detect temporal trends in site selection, radio locations for each individual were grouped according to the following periods: before sunrise, sunrise to 0900 hours, 0900 to 1200 hours, 1200 to 1500 hours, 1500 hours to sunset, and after sunset.

Habitat types were delineated from aerial photographs and classified by ground observation into 4 major types on the basis of water depth, species composition and percent canopy cover. Although the study area was created as a result of past reactor effluent discharges, the site can be best described as mid-to-old-aged beaver ponds having emergent wetland, scrub-shrub, open water, and forested wetland habitat types as defined by Cowardin et al.

(1979). A detailed description of the study area has been given by Costanzo (1980).

Analysis of variance for unequal sample sizes was used to test for significant differences between means. Chi-square goodness of fit tests were used to determine random and non-random use of habitat types based on areal availability.

Results

Home Range

Seventeen wood ducks were equipped with radio-transmitters during the study. Seven ducks were monitored for <10 days each and were not included in data analysis. The remaining 10 radio-equipped wood ducks (5 males and 5 females) were located 1,140 times over 375 tracking days (Table 1). Cumulative home range curves plotted by 7-day intervals revealed that home range estimates stabilized after 21 to 28 days of radio-tracking under the monitoring regime of the study.

The average home range of males was significantly larger (3.5 times) than that observed for females ($F = 514.9$; $P < 0.05$) (Table 1). Although female home ranges were, on the average, decidedly more linear than those of males (Table 1), their shapes were not significantly different from that of

Table 1. Number of days monitored and locations and size and shape of home ranges of wintering wood ducks radio-tracked on the DOE-SRP Steel Creek study area.

Duck number	Days located	*N* locations	Home range (ha)	Index to linearity[a]
Males				
500	64	144	52.6	1.46
536	30	122	34.5	1.42
572	38	117	39.1	1.45
579	43	123	42.8	1.21
600	10	33	[b]	[b]
Mean	37	108	42.3 ± 7.7[c]	1.39 ± 0.12
Females[d]				
571	57	140	5.6	3.66
633	33	98	8.6	1.94
712	31	103	21.4	2.06
511	31	134	14.5	1.37
586	38	126	9.9	1.92
Mean	38	120	12.0 ± 5.5	2.19 ± 0.78
Total	375	1,140	25.4 ± 11.5	1.83 ± 0.49

[a] After Ables (1969).
[b] Insufficient locations for calculating home range size.
[c] Two standard errors.
[d] Females 511 and 586 were the only monitored birds that inhabited the beaver pond system.

males. Home range sizes of delta system and beaver pond system females were similar ($F = 0.004$; $P > 0.05$).

The 5 male wood ducks were never known to be outside of their estimated home ranges during the study period. Females, however, made infrequent excursions ($N = 10$) to locations outside the boundaries of their delineated home ranges. In all but 1 instance, these excursions lasted 0.5 to 3 days. Hens were intensively searched for during all known excursions, but were found in only 2 instances when hens moved 2.5 km from their area of normal activity to either the delta or beaver pond portion of the study area.

Some wood ducks monitored at the same time had overlapping home ranges. Overlap ranged from <5% to almost 100%. The home range of hen 571 was almost entirely within the area used by male 579. The greatest overlap between any 2 male home ranges was about 45%. No 2 radio-equipped ducks were observed in close proximity; however, radio-equipped birds were observed in the company of 2–5 other wood ducks.

Diurnal Movements

Several diel tracking periods conducted during the early part of the study indicated that wood duck movements during nocturnal periods were minimal. Consistent with the differences in home range sizes, males exhibited a significantly larger mean diurnal (1 hour after daylight to 1 hour before dark) movement than females ($F = 30.01$; $P < 0.05$) (Table 2). There were also significant differences between individual males in diurnal movement

Table 2. Average daylight movements for wintering wood ducks radio-tracked on the DOE-SRP Steel Creek study area.

Duck number	N[a] diurnal periods	Diurnal movement $\bar{X} \pm 2$ SE (m)	Range (m)
Males			
500	9	1,039 ± 226	711–1,788
536	13	731 ± 108	409–1,177
572	10	619 ± 176	193–1,063
579	11	812 ± 168	363–1,288
600	4	1,198 ± 560	520–1,896
Mean		880 ± 248	439–1,442
Females			
511	13	332 ± 60	221–552
571	10	119 ± 66	90–445
586	12	232 ± 108	65–593
633	11	331 ± 106	118–579
712	8	322 ± 78	160–513
Mean		283 ± 84	131–536

[a] A diurnal period consists of 1 location every 2 hours from 1 hour before sunrise to 1 hour after sunset.

($F = 4.08$; $P > 0.05$), but no such difference existed between females ($F = 2.05$; $P > 0.05$).

Examination of each individual's locations according to time of day revealed no temporal concentration of locations around some favored site (such as a loafing or feeding site) during diurnal periods. However, there was a trend toward selection of specific sites during nocturnal periods. These sites were generally characterized by dense lateral and overhead cover. Some monitored birds made short flights (generally <150 m) to roosting sites but others did not. Delta-system ducks did not use the large communal roost sites located on the delta which accommodated 50 to 1,000 ducks, whereas, the activity areas of beaver-pond ducks included a communal roost site which accommodated 0 to 350 ducks.

Habitat Use

Delta ducks.—Ninety-three percent of the radio-locations for the wood ducks using the delta system were in emergent wetland, scrub-shrub, and open-water habitats. The remaining 7% (60 locations) were in the mature, forested wetland. Thirty-two of these locations were recorded for 1 individual that used narrow, island margins where the hardwood overstory had been destroyed by an increase in mean, low, swamp water level due to past reactor effluent discharges. The increased penetration of sunlight has resulted in the development of a herbaceous understory along these island margins similar to that found in the other habitat types. Wood ducks monitored in this study never were observed more than 100 m into the forested wetland, apparently avoiding this mature, cypress-tupelo swamp. This unaltered habitat occurred as a continuous stand of more than 500 ha, whereas the other 3 types totaled only 67 ha. Therefore, the forested wetland habitat-type and all radio-locations within it were deleted from further analysis of habitat use based on areal availability.

If wood ducks utilized all 3 remaining habitats randomly, the percentage of locations in each habitat type should be similar to the respective habitat area percentages. In the delta system, 6 of 8 ducks were located more often than expected in emergent wetland, and 2 of 8 were located more often than expected in scrub-shrub and open water (Table 3). The locations in open-water habitat might be misleading because this type usually was quite narrow (<25 m) and boundary locations could actually have been in adjacent scrub-shrub and emergent, wetland habitat-types. This trend of nonrandom use of habitats was supported statistically when locations for all delta system ducks were combined and tested by Chi^2 ($\chi^2 = 9.21$; $P < 0.01$). Overall, there was a greater than expected use of emergent wetland, less than expected use of scrub-shrub, and close to random use of open water.

Beaver pond ducks.—Habitat use by beaver-pond ducks was analyzed separately from the delta-system ducks because of its smaller size (17 ha), and difference in number of habitat types available. There was no extensive

Table 3. Habitat use by wintering wood ducks on the DOE-SRP Steel Creek study area.

Duck number	*N* locations	% locations: Emergent wetland	Scrub-shrub	Open water	Forested wetland
Delta system		(50)[a]	(43)	(7)	
Males					
500	137	63	28	9	
536	90	3	49	48	
572	111	86	11	3	
579	123	99	0	1	
600	28	25	71	4	
Females					
571	140	91	7	2	
633	98	75	18	7	
712	92	58	42	0	
Total	819	69	22	9	
Beaver pond system		(43)	(44)	(5)	(8)
Females					
511	134	83	2	0	15
586	126	45	41	5	9
Total	260	64	21	3	12

[a] Numbers in parentheses indicate percentage of area occupied by that habitat type.

forested wetland type as was the case for the delta system so this type was not deleted from analysis.

The overall trend in use of emergent wetland, scrub-shrub, and open-water habitats by beaver pond ducks was similar to that found for delta ducks. However, this use pattern was the result of 1 duck, whereas the other duck used all habitats in proportion to their availability (Table 3). The overall use of the limited, forested wetland was close to random, although 1 bird used this type more than expected. As was the case for delta birds, a Chi^2 test of the combined location data of beaver-pond ducks showed a statistically nonrandom use of habitat types ($\chi^2 = 11.30$; $P < 0.01$) with a greater than expected use of emergent wetland, less than expected use of scrub-shrub, and close to random use of open water.

Discussion

Home Range and Diurnal Movement

Home ranges of wintering wood ducks stabilized, on the average, after about 21 days of radio-tracking and except for a shift in activity area by 1 female, there were no major changes in size and shape. No noticeable change in home range size and shape was consistent with the findings of Parr et al. (1979) for wood ducks monitored in Illinois during the fall. However, these data were for single seasons when reproductive activity was minimal. Other studies have shown regular changes in home range size and shape in relation to changes in waterfowl breeding activity (Dzubin 1955, Coulter and Miller 1968, Gilmer 1971).

Wood ducks wintering on Steel Creek had substantially smaller home ranges than those reported for wood ducks during spring, summer, and fall in other geographic areas. The average, fall home range for radio-tracked wood ducks in Illinois was 91 ha (Parr et al. 1979); and the average spring/early summer home range for Minnesota wood duck pairs was 200 ha (Gilmer 1971). These averages are almost 4 and 8 times larger, respectively, than the average in this study.

Although no direct comparisons of daily distance moved could be made with results of other studies because of differences in method of data collection, it is apparent that wood ducks in this study rarely moved the extreme distances recorded in other studies. Parr et al. (1979) found that, although most ducks were never found more than 2.2 km from their roost, some birds made long flights (10 km) from roosting to feeding areas. Similarly, Gilmer (1971) observed frequent moves of over 2.5 km and in some cases much greater. In this study, only females during their infrequent excursions (10) were known to move distances >1 km at a time.

Differences in home range sizes and daily distances moved between these different studies can probably be attributed to 2 factors: 1) differences in distribution of resources between study areas and 2) effect of different seasons on distribution and use of those resources. Resources required by wintering wood ducks include suitable food, cover, loafing and roosting sites. Autumn season requirements may additionally include resources needed for migration, whereas pre-nesting and post-nesting wood ducks also would require suitable resources for breeding, nesting, and moulting. Wood ducks may require more extensive activity areas to meet the larger resource demands of the fall and spring-early summer seasons.

The more uniform use of the Steel Creek study area probably reflects a more even distribution of needed resources than did either the Minnesota or southern Illinois study areas. Areas used by wood ducks in Minnesota (Gilmer 1971) consisted of small ponds (<1 ha) widely scattered throughout the study area. These small scattered use areas were connected by narrow travel lanes. In contrast, wood ducks radio-tracked in this study exhibited a uniform use of the Steel Creek study area. Wood ducks in the southern Illinois study (Parr et al. 1979) also exhibited greater variability in home range size and traveled greater distances than Steel Creek wood ducks. Movements during the fall also may be significantly influenced by behavioral differences related to aggregation and migration.

Differential home range size and daily movement between the sexes as found in this study are not uncommon. Although Parr et al. (1979) reported no differences in the size of male and female home ranges during the autumn season, other researchers have reported that home ranges of males were larger than those of females or those of pairs during the breeding season (Dzubin 1955, Gilmer 1971).

An interesting phenomenon, however, was the infrequent excursions made by all females and no males to sites outside the boundaries of delineated home ranges. Neither Parr et al. (1979) nor Gilmer (1971) observed such movement by female wood ducks during their studies. Based on data gathered, no explanation can be proposed for this unusual behavior; but, the phenomenon certainly needs additional study.

In contrast to the apparent uniform use of activity areas during diurnal periods on the Steel Creek area, the concentration of nocturnal radio-locations at specific sites within each duck's respective activity area suggests that the number of suitable nocturnal and roosting areas was limited. These areas were characterized by dense, overhead and concealing lateral cover. Parr et al. (1979) and Hein and Haugen (1966) also reported roost sites having dense, overhead cover. Little movement was noted at night in this study, and in that of Parr et al. (1979), suggesting that wood ducks feed mostly during diurnal periods. Although Thornburg (1973) and Tamister (1974) reported nocturnal feeding for some waterfowl species, many cases were attributed to human disturbances during diurnal periods.

Large communal wood duck roosts existed on the study area. However, no radio-equipped birds were known to frequent these sites. Birds using these communal roosts were probably transient wood ducks stopping on the area for short periods of time, because the number of ducks using communal roosts was observed to fluctuate considerably (50 to 500 individuals) during 2- to 3-week periods. This assumption was supported by the findings of Parr et al. (1979) who observed similar large communal wood duck roosts in southern Illinois during fall prior to southward migration.

Habitat Use

Parr et al. (1979) found a much greater use of buttonbush swamps than other available habitats by wood ducks in autumn in southern Illinois. Of the 3 habitat types available, wood ducks were found in the buttonbush swamp 88% of the time, flooded timber 12% of the time and not at all in open water. Characteristics of the buttonbush swamp described in their study were similar to those of the emergent wetland habitat used most often by Steel Creek wood ducks. Apparent selection for the emergent wetland habitat found in this study suggests that wood ducks wintering in South Carolina preferred early successional areas to adjacent unaltered mature, forested wetland (cypress-tupelo swamp) habitats. Landers et al. (1977), on the basis of food items utilized between October and February, also felt that wood ducks on the SRP used swamp habitat that had been altered by reactor operations more than undisturbed habitats. Low use of forested wetland in this study contradicts the findings of other investigators (Coulter 1957, Brakhage 1966, McGilvrey 1966*a, b*). Parr et al. (1979) reported large open water areas were of little value to wood ducks during the autumn season, and Gilmer (1971) observed that wood ducks made little use of large open wetlands. On the Steel Creek study site, open-water areas were relatively small, so wood ducks recorded as being in the open-water habitats may have been located on the periphery of these areas.

Conclusions

The relatively small home ranges and restricted daily movements in this study indicate that the development of small sites to meet all the needs of wintering wood ducks is a distinct possibility.

Although the wood duck's use of forested habitat has been documented by other investigators, it seems inadvisable to develop wintering sites in such habitats (greentree reservoirs) because they may provide an inconsistent source of food and be devoid of other required resources. Our data indicate a preference for habitat characterized by an interspersion of diverse, emergent forage and cover species, water-tolerant, protective shrubs, and small patches of open water for accessibility containing stumps and logs for loafing. Such a site would closely resemble a 5- to 10-year-old beaver pond.

Construction of such sites could follow the procedure outlines by the Atlantic Waterfowl Council (1972) for a drawn-down, waterfowl impoundment. The major difference would involve development of sufficient cover and manipulation of the water level during the flooded stage to insure proper cover density and food availability. Small impoundments could be developed in areas of greater elevation (Piedmont) for year-round wood duck use which would also be beneficial to other species of waterfowl.

Literature Cited

Ables, E. D. 1969. Home range studies of red foxes (*Vulpes vulpes*). J. Mammal. 50:108–120.

Addy, C. E. 1956. Guide to waterfowl banding. U.S. Dep. Int. Fish and Wildl. Serv., Laurel, Md. 164pp.

Atlantic Waterfowl Council. 1972. Techniques handbook of waterfowl habitat development and management. 2nd ed. Atlantic Waterfowl Council, Bethany Beach, Del. 218pp.

Ball, I. J. 1973. Ecology of duck broods in a forested region of north-central Minnesota. Ph.D. thesis. Univ. of Minn., St. Paul. 67pp.

Barr, A. J., J. H. Goodnight, J. P. Sall, and J. T. Helwig. 1976. A user's guide to SAS-76. Sparks Press, Raleigh, N.C. 329pp.

Bellrose, F. C., K. L. Johnson, and T. U. Meyers. 1964. Relative value of natural cavities and nesting houses for wood ducks. J. Wildl. Manage. 28:661–676.

Brakhage, G. K. 1966. Management of mast crops for wood ducks. Pages 78–80 *in* J. B. Trefethen, ed. Wood duck management and research: a symposium. Wildl. Manage. Inst., Washington, D.C. 212pp.

Brander, R. B. 1968. A radio-package harness for game birds. J. Wildl. Manage. 32:630–632.

Conrad, W. B., Jr. 1965. A food habits study of ducks wintering on the Lower Pee Dee and Waccamaw Rivers, Georgetown, South Carolina. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm. 19:93–98.

Costanzo, G. R. 1980. Movements and habitat use of wood ducks wintering in the Upper Coastal Plain of South Carolina. M.S. Thesis. Clemson University, Clemson, S.C. 54pp.

Coulter, M. W. 1957. Food of wood ducks in Maine. J. Wildl. Manage. 21:235–236.

——— and W. Miller. 1968. Nesting biology of black ducks and mallards in northern New England. Vt. Fish and Game Dept. Bul. 68–2. 73pp.

Cowardin, L. M., N. Carter, F. C. Golet, and E. T. LaRoe. 1979. Classification of wetland and deepwater habitats of the United States. U.S. Dep. Int., Fish and Wildl. Serv, Off. Biol. Serv., Washington, D.C. 103pp.

Dzubin, A. 1955. Some evidence of home range in waterfowl. Trans. North Am. Wildl. Conf. 20:278–298.

Fendley, T. T. 1978. The ecology of wood ducks (*Aix sponsa*) utilizing a nuclear production reactor effluent system. Ph.D. Thesis. Utah State Univ., Logan. 145pp.

———, M. N. Manlove, and I. L. Brisbin, Jr. 1977. The accumulation and elimination of radiocesium by naturally contaminated wood ducks. Health Physics. 32:415–422.

Fretwell, S. C. 1972. Populations in a seasonal environment. Princeton Univ. Press, Princeton, N.J. 217pp.

Gilmer, D. S. 1971. Home range and habitat use of breeding mallards (*Anas platyrhynchos*) and wood ducks (*Aix sponsa*) in north-central Minnesota as determined by radiotracking. Ph.D. Thesis. Univ. of Minnesota, St. Paul. 142pp.

Grice, D. and J. P. Rogers. 1965. The wood duck in Massachusetts. Final Rep. Fed. Aid Proj. W-19-R. Mass. Div. Fish and Game. 96pp.

Hardester, J. P., E. Hester, and T. L. Quay. 1963. Movements of juvenile wood ducks as measured by web tagging. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm. 16:70–75.

Hein, D. and A. O. Haugen. 1966. Autumn roosting flight counts as an index to wood duck abundance. J. Wildl. Manage. 30:651–668.

Hepp, G. R. 1977. Ecology of wood duck (*Aix sponsa*) broods in the Piedmont region of South Carolina. M.S. Thesis. Clemson Univ., Clemson, S.C. 113pp.

Lack, D. 1968. Bird migration and natural selection. Oikos 19:1–9.

Landers, J. L., T. T. Fendley, and A. S. Johnson. 1977. Feeding ecology of wood ducks in South Carolina. J. Wildl. Manage. 41:118–127.

Langley, T. M. and W. L. Marter. 1973. The Savannah River Plant Site. USAEC Report DP-1323, TID-4500, UC-2. Savannah River Lab., Savannah River Plant, Aiken, S.C. 175pp.

Leopold, F. 1951. A study of nesting wood ducks in Iowa. Condor 53:209–220.

Marter, W. L. 1974. Radioactivity from SRP operations in a downstream Savannah River Swamp. USAEC Rep. DP-1370-UC-11, Savannah River Lab., Savannah River Plant, Aiken, S.C. 32pp.

McGilvrey, F. B. 1966*a*. Fall food habits of wood ducks from Lake Marion, South Carolina. J. Wildl. Manage. 30:193–195.

———. 1966*b*. Fall food habits of ducks near Santee Refuge, South Carolina. J. Wildl. Manage. 30:577–580.

Mohr, C. O. 1947. Table of equivalent populations of North American small mammals. Am. Midl. Nat. 37:223–249.

Odum, E. P. and E. J. Kuenzler. 1955. Measurements of territory and home range size in birds. Auk 72:128–137.

Odum, R. R. 1970. Nest box production and brood survival of wood ducks on the Piedmont National Wildlife Refuge, 1969. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm. 24:108–117.

Parr, D. E., M. D. Scott, and D. D. Kennedy. 1979. Autumn movements and habitat use by wood ducks in southern Illinois. J. Wildl. Manage. 43:102–108.

Sharitz, R. R., J. R. Irwin, and E. J. Christy. 1974. Vegetation of swamps receiving reactor effluents. Oikos 25:7–13.

Silvy, N. J., J. L. Roseberry, and R. A. Lancia. 1979. A computer algorithm for determining home range size using Mohr's minimum home range method. Proc. Int. Conf. Wildl. Biotelemetry. Univ. Wyoming, Laramie. 2:170–177.

Strange, T. H., E. R. Cunningham, and J. W. Goertz. 1971. Use of nest boxes by wood ducks in Mississippi. J. Wildl. Manage. 35:786–793.

Tamister, A. 1974. Ethoecological studies of teal wintering in the Camargue (Rhone Delta, France). Wildfowl 25:121–131.

Thornburg, D. D. 1973. Diving duck management on Keokuk Pool, Mississippi River. J. Wildl. Manage. 37:382–389.