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Movements and Habitats of Brood-Rearing Wood Ducks On A Prairie River

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MOVEMENTS AND HABITATS OF BROOD-REARING WOOD DUCKS ON A PRAIRIE RIVER

BY

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MOVEMENTS AND HABITATS OF BROOD-REARING

WOOD DUCKS ON A PRAIRIE RIVER

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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MOVEMENTS AND HABITATS OF BROOD-REARING WOOD DUCKS ON A PRAIRIE RIVER

Abstract

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Radio telemetry and brood surveys were used to evaluate wood duck (Aix sponsa) brood habitat and movements along 40 km of the Big Sioux River in eastern South Dakota during 1979-81. Most of the oxbows and nearby wetlands in the study area contained water in 1979-80, but drought dried all but 2 of the 33 oxbows in 1981. Fourteen brood hens were radio monitored. In 1980, 4 hens utilized oxbows, 1 hen utilized the river, and 2 hens used other habitats for brood rearing. In 1981, 4 hens utilized oxbows, 2 hens utilized the river, and 1 hen utilized the outlet of a nearby lake for brood rearing. The longest brood movements generally occurred during the 2 days following nest exodus. Hens apparently had initial brood-rearing sites selected before nest exodus. In 1979, no wood duck broods were found on 43 upland wetlands located within 0.8 km of the river, 0.46 broods/km were seen on oxbows, and 0.05 broods/km were seen on the river. In 1980 and 1981, respectively, 0.63 broods/km and 1.67 broods/km were seen on oxbows, and 0.15 broods/km and 0.27 broods/km were seen on the river. Oxbows appeared to be preferred brood habitat, while the river served primarily as a travel route between oxbows. The lentic oxbow waters contain abundant emergent and submergent vegetation and support abundant invertebrate populations, thereby meeting brood requirements for food and cover.

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INTRODUCTION

The floodplain forests and wetlands of the Big Sioux River provide excellent habitat for breeding wood ducks (Aix sponsa). The mature floodplain forest provides nesting cavities, and the river, oxbows, and adjacent marshes provide potential pair and brood habitat. Woodland clearance and intensive grazing are decimating many areas of the floodplain forest. Additionally, potential channel modifications for flood control could have harmful effects on the wood duck population by destroying important nesting and brood-rearing habitats.

Understanding habitat requirments is fundamental to wood duck management, and the need for such knowledge increases as intensive management becomes necessary to maintain populations in diminishing habitat. While wood duck habitat requirements have generally been well studied, information on brood movements and habitat use is relatively scarce (Stewart 1958a, Hardister et al. 1962, Webster and McGilvrey 1966, Farmer 1970, Ball 1971, 1973), and is completely unknown for prairie river systems. Riparian habitats, primarily the Big Sioux and James rivers, support most of the breeding wood ducks in South Dakota (L. D. Flake, South Dakota State Univ., unpublished data). Knowledge of wood duck brood habitat in these riparian habitats would enable wildlife managers to protect, manage, or mitigate important habitat which may be jeopardized or lost due to human-influenced changes in the river channel, associated wetlands, and floodplain forest.

The objectives of this study were (1) to evaluate wood duck brood habitat requirements on the Big Sioux River, its oxbows, and floodplain, and (2) to determine brood movements.

STUDY AREA

The study was conducted along approximately 40 km of the Big Sioux River in Brookings and Moody counties, South Dakota (Fig. 1). The Big Sioux is a slow-moving, meandering river that provides the primary drainage for the Coteau des Prairies (Westin and Maio 1978:12). Three small streams, numerous Class I-IV wetlands (Stewart and Kantrud 1971), and approximately 17.5 km of oxbows exist on the floodplain. Several sewage treatment ponds are located on the floodplain at the northern end of the study area.

Oxbows are herein defined as sections of old river channel that have been separated from the present channel either naturally or by human activities. When filled with water, individual oxbows ranged in length from approximately 150 m to 2.5 km. Precipitation during 1979 and 1980 kept most of the oxbows filled, but arid conditions in 1981 dried all but 2 (3.0 km total length) of the 33 oxbows on the study area.

Choate and Spencer (1969:17) classified the woodlands of the Big Sioux floodplain as elm-ash-cottonwood forest. Random point-quarter sampling (Smith 1980:669-670) of the study area indicated the forest, including snags, was primarily composed of boxelder (*Acer negundo* - 28%), green ash (*Fraxinus pennsylvanica* - 25%), sandbar willow (*Salix exigua* - 13%), peach-leaved and diamond willow (*Salix amygdaloides* and *S. rigida* - 11%), and American elm (*Ulmus americana* - 11%). Cottonwood (*Populus deltoides*) comprised less than 0.5% of the forest. Dutch elm disease is decimating the elm population along the river. Sixty-eight percent

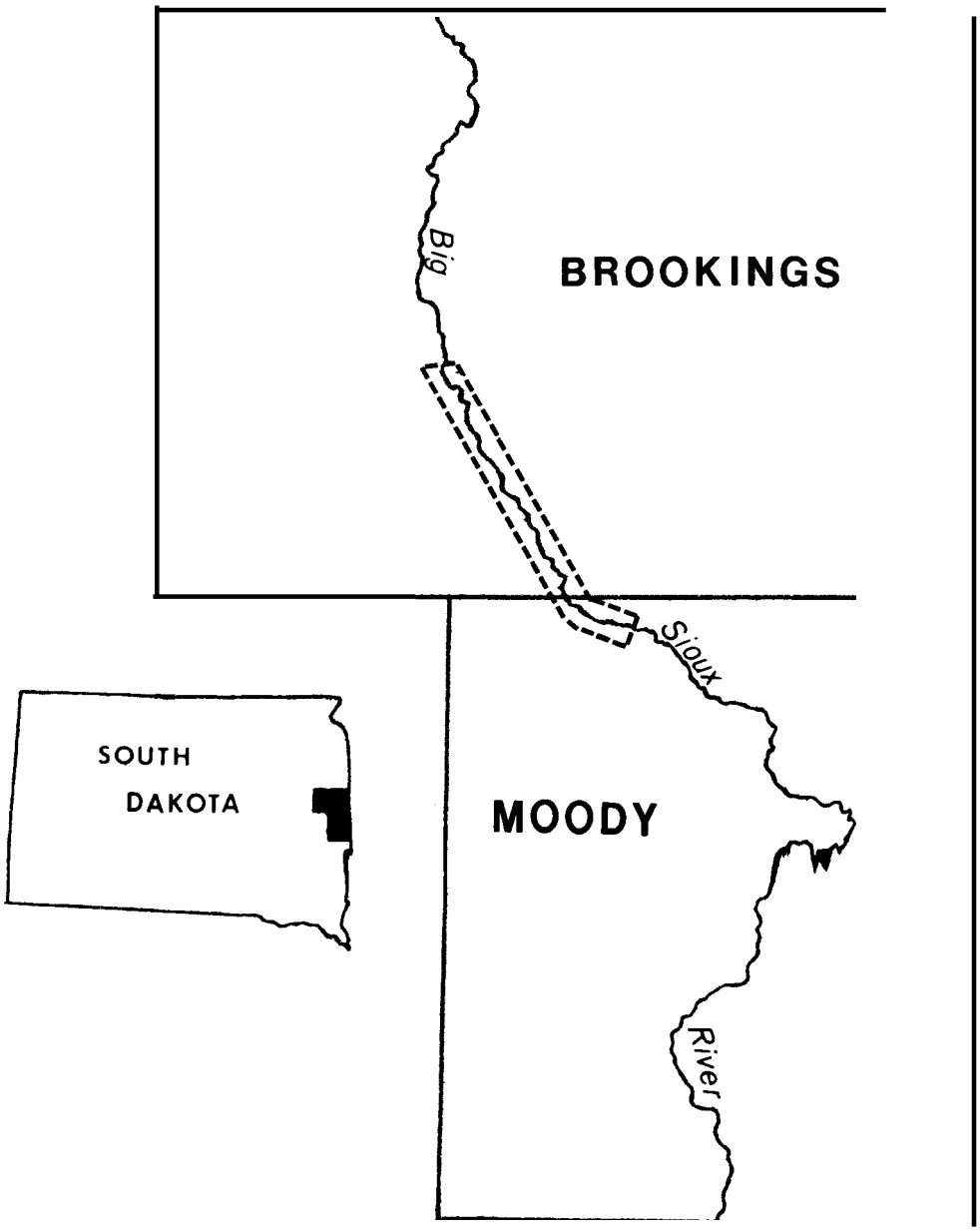


Fig. 1. Big Sioux River wood duck study area in Brookings and Moody counties, South Dakota, 1979-81.

of the elm trees sampled were dead. Approximately 45% of the river bank was forested; the width of the forest varied between 15 and 400 m.

Agriculture is the principal land use along the river. Common crops include corn, soybeans, small grains, sunflowers, and flax. Livestock use the river as a summer water source and as a retreat from heat and insects. Observations made during point-quarter sampling of the forest indicated that livestock grazed about 55% of the floodplain forest in the study area. An additional description of the study area and floodplain forest may be found in Parrish (1981).

METHODS

Brood Habitat and Movements

Wood duck brood habitat was investigated from 1979 to 1981 using radio telemetry and brood surveys. For preliminary telemetry investigations in 1979, 1 hen was captured using a baited funnel trap (Stewart 1958b) and another was captured while incubating in a tree cavity. Back-mounted solar transmitter packages weighing approximately 22 g were attached to the birds with adjustable PVC loop harnesses (Dwyer 1972). Hen locations were determined by triangulation using a mobile Yagi antenna, or by tracking the birds on foot with a small hand-held antenna.

In 1980, 28 cedar wood duck nesting boxes were erected to facilitate capturing hens. The boxes were placed 5-8 m high in isolated trees or snags along the river or oxbows. Roofing tin was wrapped around the trunks of the trees, about 2 m above the ground, to protect the boxes from predators.

In 1980 and 1981, hens were captured on their nests during the last 2 weeks of incubation, equipped with approximately 15.5 g solar transmitters, anesthetized with methoxyflurane (Metofane) (Smith et al. 1980), and returned to their nests. Smith et al. (1980) found that anesthetizing gray partridge (Perdix perdix) after radio tagging reduced nest abandonment. Anesthetic and lighter radio packages were used in 1980 and 1981 to minimize stress on the birds. The solar packages used in 1980 and 1981 weighed approximately 2.3% of the body weight of the birds (Bellrose 1976:77), instead of the packages weighing 3.3% of body weight used in 1979.

Abnormal behavior of radio-tagged waterfowl has been observed by several researchers. Perry (1981) observed that radio-equipped canvasbacks (Aythya valisineria) were more active and fed less often than unmarked birds, and 1 bird commonly used atypical canvasback habitat. Abnormal behavior in canvasbacks was often observed for as long as 2 weeks after radio tagging. Wooley and Owen (1978:741) compared the behavior of radio-equipped black ducks (Anas rubripes) with unmarked birds. Radio-tagged birds spent less time feeding and swimming, and more time preening, resting, and in alert posture than control birds. Marked birds were more secretive than control birds, and noticeably avoided water. Greenwood and Sargeant (1973) found that captive, radio-equipped mallards (Anas platyrhynchos) and blue-winged teal (Anas discors) lost more weight and preened more often than control birds. Test birds also exhibited a partial aversion to water. Farmer (1970:18) attributed nest abandonment by wood duck hens to radio tagging. One clutch and 2 broods still in nest boxes were abandoned. The stress of carrying the transmitters (30-35 g) was suspected of causing the abandonments.

Gilmer et al. (1974) found that mallards and wood ducks wearing radio packages were observed less often on water, but that this was probably because radios facilitated locating birds on land that would not normally be seen due to heavy cover. They concluded that radio instrumentation did not seriously affect the movements and habitat usage of breeding and brood-rearing birds.

Triangulations of radio-tagged hens were taken daily with a null-peak antenna system. Confidence limits were calculated for the

telemetry readings by taking readings on a radio of known location. The limits take into account both system and human errors. Ninety-five percent confidence limits for the readings were + 3°. Discussions of bias and sampling error in radio telemetry may be found in Heezen and Tester (1967) and Springer (1979).

Triangulations on hens were recorded and transferred to aerial photographs. If the error polygon (Heezen and Tester 1967) formed by the intersection of the telemetry readings overlapped more than 1 habitat type, we used a hand-held antenna to locate and observe the birds.

Hens occasionally leave their broods throughout the brood-rearing period. Beard (1964:513) reported that waterfowl hens, including wood ducks, often leave their broods for as long as 1.25 h. Stewart (1974) reported hen wood ducks feeding away from their broods. To minimize the chances of monitoring hens without broods, and at the same time minimize human disturbance that could alter behavior, hens were observed 2-5 days after their broods left their nests, and again whenever major movements (> 0.8 km) from their previous locations occurred. Major hen movements were not used in the analysis unless the presence of a brood was confirmed.

Two Yagi antennas were mounted on an airplane to search for birds that could not be located from the ground. Following aerial locations, hens were tracked and observed from the ground to determine the hen-brood status. Hen/brood movements were calculated from aerial photographs using a map reader. If the error polygons of 2 successive triangulations overlapped, no movement was considered to have occurred

(Springer 1979:926). Movements were measured from the centers of the error polygons and rounded to the nearest 0.1 km. Because the river is a natural travel lane, movements were calculated as the shortest distances the birds could take by water. Movement to 1 oxbow in 1981 required overland travel. In these instances, the shortest distance from the river to the oxbow was used for the calculations.

For movement analysis, the time between the exodus of the brood from the nest until its final radio location was divided into 2-day periods. Movements were calculated only in instances where the birds were located in successive time periods. When birds were located on both days of a period, the later location was used for the analysis. This analysis method minimized the problem of quantifying movements when birds were not located on successive days, yet maximized the number of usable locations.

Brood censuses of the study area were conducted during July 1979, 1980, and 1981. In 1979 and 1980, the river was surveyed by canoe following the guidelines of the Mississippi Flyway Council for wood duck stream surveys (Bednarik and Weeks 1976). Oxbows were surveyed as they were encountered during the downstream float. Because of low water levels in 1981, 4 researchers conducted the census by walking and wading the river and oxbows. In 1979, 43 Class III and IV wetlands (Stewart and Kantrud 1971) located within 0.8 km of the river were also surveyed. The walk/wade and beat-out techniques described by Hammond (1970:10) were used to flush broods from emergent vegetation in oxbows and upland ponds. When possible, the age (Gallop and Marshall 1954) and size of each brood observed were recorded. Unidentified broods and incomplete counts were

recorded as such. Hens exhibiting distractive displays were assumed to have broods hiding nearby. The major species of emergent vegetation were recorded, and the percentage of each wetland or oxbow containing emergent vegetation was estimated. Upland wetlands were not surveyed in 1980 and 1981 because no broods were seen on the wetlands in 1979.

Invertebrate Sampling

Invertebrates were collected in the river and oxbows from 2-8 July 1981 using a dip net 16 cm in diameter, equipped with a no. 10 net. Because wood ducks (Drobney and Fredrickson 1979) and dabbling duck ducklings (Sugden 1973) forage primarily on or near the surface of the water, the net was pulled just under the surface for a distance of 5 m. The river was sampled at 5 locations throughout the study area. At each location, 3 samples were taken from areas of slow-moving water along the banks. The 2 oxbows on the study area in 1981 were sampled at 3 locations each, with 3 randomly located subsamples at each point.

Samples were preserved in the field with 70% ethanol. In the lab, invertebrates were separated from vegetation collected in the sample and identified using a dissecting microscope and keys in Pennak (1978). Vegetation was oven dried at 80 C (Allen et al. 1974:76) and weighed to the nearest 0.01 g.

An analysis of variance was performed on the samples to test the differences in invertebrate abundance between the oxbows and the river, between oxbows, and between subsamples.

RESULTS

Telemetry of Brood Hens

The telemetry equipment used in 1979 proved inadequate for the study. Triangulations with the single Yagi antenna did not provide sufficient accuracy to differentiate whether a bird was on the river or a nearby oxbow. Consequently, hens were frequently disturbed by researchers tracking them with a hand-held antenna.

One hen exhibited apparently abnormal behavior and a lack of brood attentiveness. She was last seen with her brood 25 days after hatching. Before then, 50% of the 22 locations were on oxbows, 45% were in newly planted crop fields, and 5% were on the river. The hen was frequently observed standing in crop fields. She did not appear to be feeding, and her brood was never visible.

Wood ducks nested in 15 (54%) of the 28 nesting boxes in 1980 and 12 (48%) of the 25 boxes in 1981. Thirteen birds were radio tagged in 1980 and 11 birds were radio tagged in 1981. Observations for 10-15 minutes after the birds were tagged, anesthetized, and returned to their nests indicated the birds generally remained calm and on their nests after awakening from the anesthetic. Two of the 13 hens radio tagged in 1980 were found dead on their nests. In both instances there was evidence of the hens struggling with the radios. Perry (1981:787) reported that some instrumented canvasbacks probably fail to adapt to radios and act abnormally until they dislodge the radios or die. The radio antennas on the 2 dead wood ducks were bent and twisted. Possibly the antennas got caught in the doors of the wood duck boxes, thereby

preventing the hens from leaving the boxes. However, neither of the antennas were caught in the doors of the boxes when the hens were discovered. None of the birds exhibited any apparent abnormal behavior after leaving the nests.

Of the 11 successful nests in 1980, 4 of the broods were never seen or were only seen shortly after nest exodus. Movements from the nests to the initial brood rearing areas were generally the longest, averaging 4.8 km during the first 2 days after nest exodus (Fig. 2). In one instance a hen moved her brood 9.2 km upstream in 2 days to reach an area of flooded willows adjacent to the sewage treatment ponds. Another hen moved her brood 10.5 km between days 5 and 8 to reach an area of flooded trees approximately 0.8 km from the river.

Radio locations indicated oxbows were used 5 times more frequently than the river, yet there was at least 2.3 times more kilometers of river than oxbows (Table 1). One hen utilized the river almost exclusively for brood rearing. Four hens utilized oxbows almost exclusively. One hen utilized a wetland surrounding the sewage ponds, as well as the lagoons themselves. Another hen utilized both oxbows and an area of flooded willows approximately 0.5 km from the river.

In 1981, 11 hens were radio tagged. One incubating hen was apparently killed by a predator while she was off her nest. Another hen either abandoned her nest or was killed while off her nest a few days before the anticipated hatch of her eggs. Nine birds successfully hatched broods. Two of these were never located or were located only once. As in 1980, the longest movements occurred during the 2 days following nest exodus (Fig. 3).

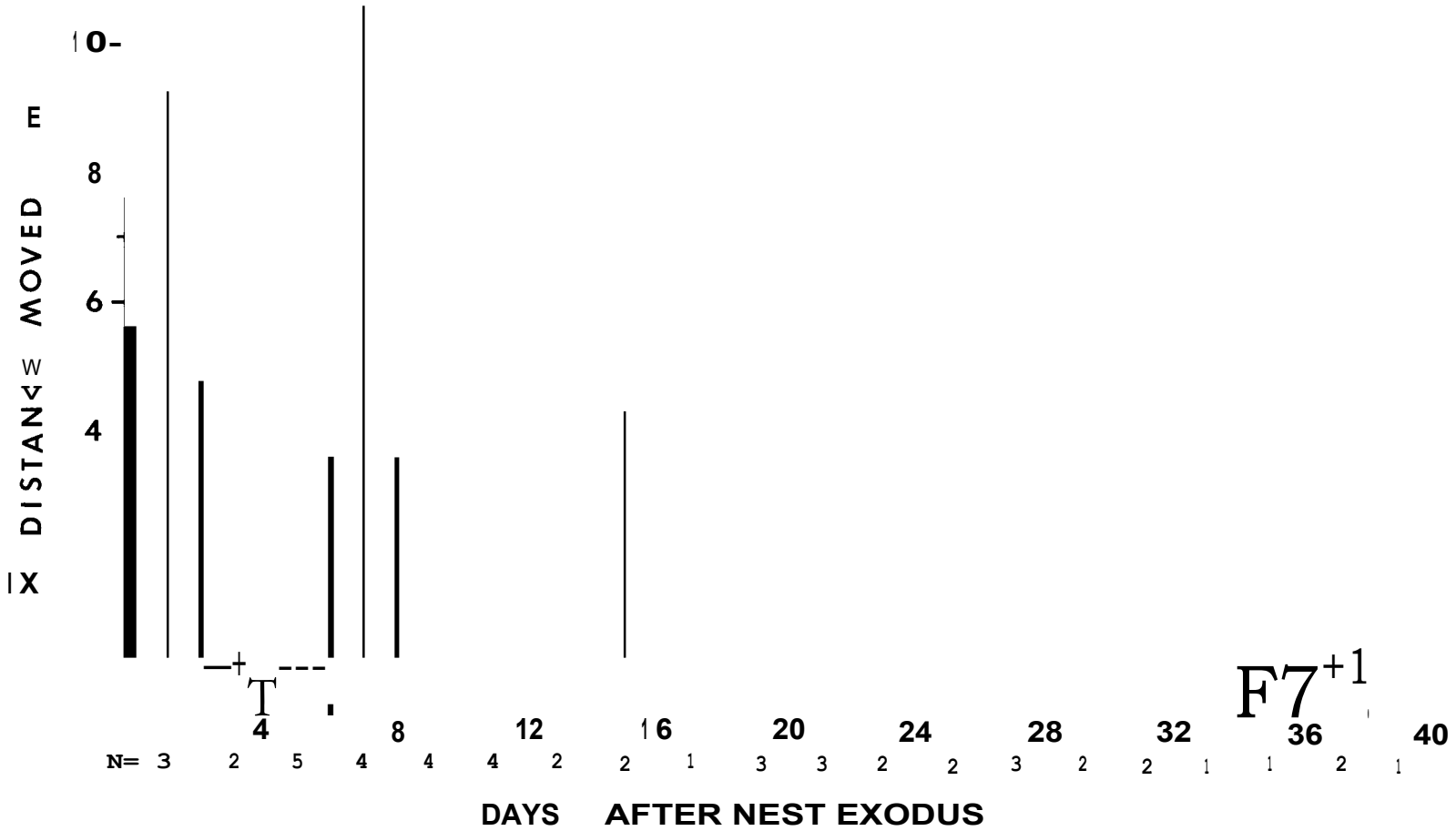
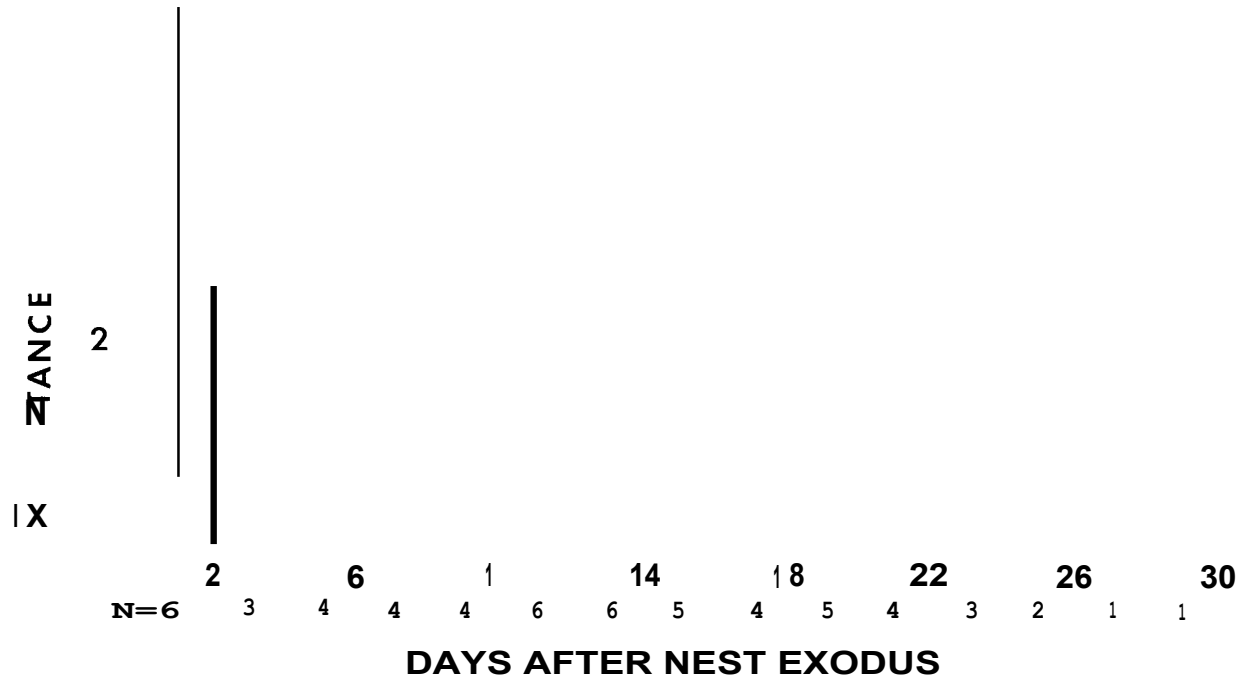


Fig. 2. Average distance (histogram) and range (vertical lines) of movements of brood-rearing wood ducks along the Big Sioux River, 1980. The brood-rearing period was divided into 2-day intervals to maximize usable data from intermittent radio locations. When brood hens were located twice in a 2-day period, the calculated movement was the difference between the last location in successive 2-day periods. Only brood hens located in 2 or more successive 2-day periods were included.

Table 1. Habitats used by brood-rearing wood ducks along the Big Sioux River as determined by radio telemetry.

Habitat	1980			1981		
	Number of bird locations	% of bird locations	Average % bird locations[a]	Number of bird locations	% of bird locations	Average % bird locations[a]
Oxbows	61	65	62	37	36	54
River	12	13	11	45	43	32
Wetland surrounding sewage lagoons	12	13	13	0	0	0
Flooded willows	3	3	7	0	0	0
Creek	3	3	4	22	21	14
Sewage lagoons	2	2	2	0	0	0
Flooded road ditch	1	1	1	0	0	0
TOTALS	94	100	100	104	100	100

[a]Calculated by averaging the % of locations for each hen on each habitat, regardless of the number of locations for each bird.



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Drought left all but 2 of 33 oxbows dry in 1981. One oxbow, 2.5 km long, was located near the northern end of the study area. It contained water 1 m deep in many places. The other oxbow was located at the extreme southern end of the study area. It was 0.5 km long and contained water less than 0.3 m deep. All 4 radio-marked hens in the northern half of the study area moved to the northern oxbow. The longest distance traveled to the oxbow was 5.1 km. To reach the oxbow from the river required an overland movement of at least 0.25 km. Of the 3 remaining radio--tagged birds, 2 utilized the river as brood habitat, and 1 used a marshy area where 2 small streams joined (Table 1). The nests of these birds were approximately 18, 18, and 24 km from the northern oxbow and 13. 13, and 8 km from the southern oxbow.

Brood Census

No wood duck broods were seen on 43 upland wetlands located within 0.8 km of the river in 1979. Even though dense vegetation frequently made censuring difficult, some wood duck broods should have been seen if the wetlands were commonly used as brood habitat. Because of this, upland wetlands were not surveyed in 1980 or 1981.

In 1979, 8 wood duck broods were seen on oxbows (approximately 0.46 broods/km) and 2 broods were seen on the river (approximately 0.05 broods/km). Additionally, 1 unidentified brood, 1 mallard, and 10 blue-winged teal broods were seen on the oxbows, compared with 2 unidentified and 1 blue-winged teal brood on the river.

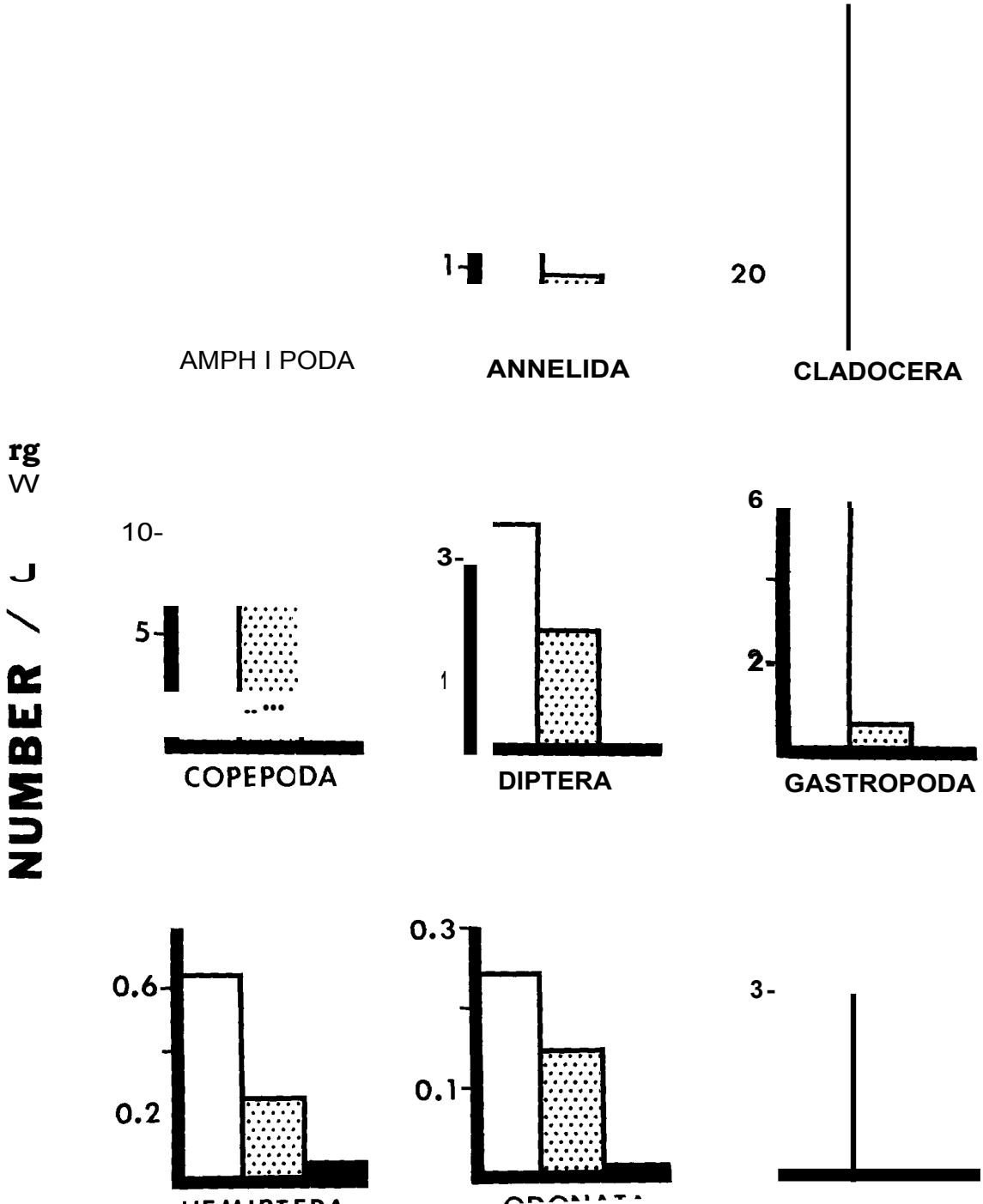
In 1980, 11 wood duck broods were seen on oxbows (approximately 0.63 broods/km), while 6 broods were seen on the river (approximately 0.15 broods/km). Additionally, 5 blue-winged teal broods were seen on oxbows, while broods of 1 blue-winged teal and 1 mallard were seen on the river.

In 1981, 5 wood duck broods were seen on oxbows (approximately 1.67 broods/km), and 11 broods were seen on the river (approximately 0.27 broods/km). Almost half the birds were found on oxbows, which comprised less than 10% of the available aquatic habitat. Broods of 1 blue-winged teal and 1 mallard were also seen on the oxbows. No other broods were seen on the river. No apparent relationship between brood age and habitat usage was observed.

Potential Invertebrate Food Available to Ducklings in River Versus Oxbow Habitat

Highly significant differences ($P < 0.01$) between invertebrate abundance in the oxbows and river were found for Amphipoda, Diptera, Gastropoda, Hemiptera, and Annelida (Fig. 4). Significant differences ($P < 0.05$) were found for Cladocera, Ostracoda, and Copepoda. No significant differences were found for Odonata in river and oxbow samples.

Highly significant differences ($P < 0.01$) between oxbows were found for Amphipoda and Hemiptera. Significant differences ($P < 0.05$) were found for Cladocera, Diptera, Gastropoda, and Annelida. No significant differences were found between subsamples.


10
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6
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GASTROPODA
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0.2
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Submergent and Emergent Vegetation Differences Between River and Oxbow Habitat

Emergent vegetation in the oxbows covered from 5 to 95% of the surface, and averaged 40% coverage. Dominant species included river bulrush (Scirpus fluviatilis), cattails (Typha spp.), bur reed (Sparganium eurycarpum), and smartweed (Polygonum spp.). The river was nearly devoid of emergent vegetation, except in backwater areas.

Submergent vegetation collected in the invertebrate samples (Table 2) and visual observations throughout the study revealed that submergent vegetation was scarce in the river and abundant in the oxbows.

Table 2. Dry weights of aquatic vegetation collected in invertebrate samples of the Big Sioux River and 2 oxbows, 2-8 July 1981.

Species	Dry weight (g)
Oxbow A:	
Lemna trisulca	69.97
Potamogeton foliosus	17.73
Ranunculus longirostris	14.88
Utricularia vulgaris	7.81
Typha sp.	1.65
TOTAL	112.04
Oxbow B :	
Lemna minor	16.83
Ceratophyllum demersum	12.16
Elodea canadensis	0.77
Potamogeton foliosus	0.32
TOTAL	30.08
River:	
Potamogeton sp.	trace

DISCUSSION

Of the 20 radio-tagged hens that successfully hatched broods, 6 were never located or were only located shortly after nest exodus. This could be a result of: (1) transmitter failure, (2) hens losing their broods and moving a considerable distance beyond the study area, (3) predation upon the birds and the subsequent disposal of the radios in a manner which prevented signal transmission, (4) loss of radio transmitters in areas which prevented signal transmission, or (5) movement of hens and broods beyond the surveyed area.

Mink (*Mustela vison*) and great-horned owls (*Bubo virginianus*) were common predators in the study area, and may have been responsible for some of the lost birds. Evidence of predation upon a radio-tagged bird was discovered only once.

Hens that lost their broods may have moved a considerable distance off the study area. Aerial radio locations indicated that many hens moved to 2 large lakes near the study area after the hen/brood bond disintegrated. One bird moved approximately 30 km off the study area to a lake. Birds that moved to lakes even farther from the study area would not have been located. The lakes contained areas of dense emergent vegetation, and the movements were believed to be associated with molting. Gilmer et al. (1977) reported that 59% of the wood duck hens present on a north-central Minnesota study area in the spring remained on the study area through August to molt. Some of the hens apparently moved long distances from the study area to molt, however.

Gilmer et al. (1977) found that birds remained in areas with abundant emergent cover during their flightless period.

Some biases occur in the movement data (Figs. 2 and 3) because only instances when birds were located in successive 2-day periods were used. Birds that were not located for several days because of poor radio transmission or because they moved long distances from their previous locations were not included in the movement data because movements could not be quantified for each 2-day period. Usually when birds were not located for a few days, they were later located near their previous location. Broods probably did not move from the vicinity of their previous locations for those few days, but rather weather conditions, vegetation, the river banks, or some other physical barriers probably inhibited signal transmission. Occasionally birds were not located for several days after leaving their nests, apparently because heavy cloud cover prevented the solar radios from charging and transmitting a sufficient signal. One brood hen traveled 5.1 km from her nest in 4 days, another traveled 3.0 km in 5 days, and a third bird traveled 10.3 km in 16 days before being located. Instances where birds moved long distances (> 1.6 km) without being located occurred only 1 other time. In 1981 a bird traveled 3.0 km between days 2-10 before she was located again. These instances are not believed to represent serious biases in the data.

The large initial movements of hens with broods indicate that hens apparently had definite brood-rearing areas selected before their broods left the nests. In 1980, hens often moved their broods past several oxbows to reach a particular oxbow or area to use as a

brood-rearing site. In 1981, 4 hens moved upstream and overland to reach the only oxbow in the area.

Webster and McGilvrey (1966) analyzed wood duck brood habitat in small impoundments in Maryland. Most of the broods were concentrated on a small number of ponds. Ponds receiving the greatest use had no more than 25% open water and were also characterized by downed timber, herbs, and early-leafing shrubs.

Beard (1953:422-426) listed 6 factors affecting the use of beaver ponds by waterfowl broods, including wood ducks. They were: (1) the amount of cover and water interspersion, (2) the composition and juxtaposition of cover, (3) water depth, (4) the amount and kinds of animal and plant foods present, (5) sufficient isolation from human disturbance, and (6) the availability of suitable nesting cover. All of the above factors varied in oxbows and, except for the availability of nesting cover, undoubtedly affected the differential use of oxbows. Extensive areas of dead elm trees along the river contained abundant nesting cavities. Estimates of potential wood duck nesting cavities along the Big Sioux River taken during point-quarter sampling of the floodplain forest averaged 10.2 cavities/ha, and ranged from 0.0 cavities/ha to 28.2 cavities/ha along different sections of the river.

Vegetative cover was considered to be an essential requirement for wood duck broods by many authors, including Hawkins and Bellrose (1940), Leopold (1951), Klein (1955), Decker (1959), and McGilvrey (1969). Stewart (1958a) determined that the first movements of wood duck ducklings in central Ohio were to areas having abundant vegetation

for cover. Farmer (1970) also noted that movements of wood duck broods from their natal ponds were toward aquatic areas with abundant vegetative cover. The greatest brood use occurred on ponds having the best vegetative cover. Wenner and Marion (1981) found that brood use among different ponds in Florida was positively correlated with the percentage of shrub thicket cover. Vegetation was more abundant in oxbows of the Big Sioux River than in the river itself, which undoubtedly influenced brood use.

Ball (1971) conducted a radio telemetry study of wood duck and mallard broods on lakes, rivers, and small wetlands of a forested region in north-central Minnestoa. Wood ducks preferred river habitats having a good interspersion of open water and heavy cover.

Wood ducks along the Big Sioux River preferred oxbows for brood-rearing areas, using the river primarily as a travel route between oxbows. Hardister et al. (1962) and Farmer (1970) found that rivers in North Carolina were important for wood duck movements, but that broods rarely used the rivers as rearing sites.

In 1981, when most of the Big Sioux oxbows were dry, some wood ducks used areas of the river for brood rearing. These areas were usually associated with log jams or numerous fallen trees. Beard (1964:519) thought the availability of logs and other loafing sites may often be a limiting factor for brood use of an area. Webster and McGilvrey (1966) thought broods needed downed timber for early season cover and loafing sites. Because emergent vegetation was scarce in the Big Sioux River, log jams may have provided escape cover for ducklings. Observations indicated that ducklings reared on the river

also used vegetation on the river banks for escape cover.

Invertebrate abundance probably made oxbows attractive brood-rearing areas. Many researchers have reported that invertebrates dominate the diets of juvenile ducks, and that invertebrates are probably required to satisfy the dietary demands of the birds (Chura 1961, Bartonek and Hickey 1969, Swanson and Nelson 1970, Sugden 1973). Hocutt and Dimmick (1971) found that the diets of wood duck ducklings < 1 week old consisted of approximately 70% animal foods. Adult and immature dipterans comprised 50% of the diet. The percentage of plant foods in the diet increased with duckling age. They further noted that the diets of ducklings > 6 weeks old consisted of 96% plant material. Tubers of sago pondweed (Potamogeton pectinatus) were the most abundant food item. However, ducklings were opportunistic feeders whenever a plant or animal was abundant. Moyle (1961) stated that aquatic plants are low in protein and cannot provide an adequate diet for ducklings. Aquatic invertebrates, however, contain protein levels capable of supplying the nutritional demands of ducklings. Invertebrate abundance may influence brood movements and distribution (Collias and Collias 1963, Ball 1971).

Invertebrate abundance in the Big Sioux River and oxbows appeared to be related to the kinds and amounts of submergent vegetation present. Other researchers (Krecker 1939, Rosine 1955, Moyle 1961, Krull 1970) have shown this relationship in other areas. The variation in submergent vegetation and invertebrates in the oxbows was probably due to many physical and chemical parameters. Variations in grazing intensity, soil runoff from adjacent crop lands, or forest canopy cover

along oxbows could affect water turbidity and light intensity. How these factors ultimately affect invertebrate abundance and brood use of oxbows is uncertain, but invertebrate availability probably has a major influence on brood movements and habitat usage.

Broods reared on the river faced the problem of a less concentrated food supply than broods on oxbows. This may affect the survival of birds reared on the river, but such studies were beyond the scope of this research. The tendency for birds to use oxbows, even when oxbows are scarce, may indicate that selection is favoring birds reared on oxbows. Johnson (1971) studied the effects of dietary protein on wood duck ducklings, and found that survival was directly related to the protein level in the diet. Johnson concluded that a deficiency of foods high in protein could be a significant mortality factor. Protein deficiencies might weaken ducklings and extend the flightless period, rendering the ducklings more susceptible to disease, predation, weather, and other decimating factors. Observations of broods and the esophageal and proventricular contents of 1 Class-IIc duckling captured on the river (Appendix A) indicated that ducklings probably found food in the shallow margins of the river and on the banks and uplands along the river. Specific items eaten by the duckling captured on the river included bent grass (Agrostis sp.) and reed canary grass (Phalaris arundinacea) seeds, aquatic and terrestrial gastropods, aquatic hemipterans, and dipteran larvae.

Brood censuses supported the findings of the telemetry study. Upland wetlands were rarely used as wood duck brood habitat, and oxbows were used more frequently than the river, even though the river contained

more kilometers of aquatic habitat. Oxbows were probably used even more frequently than the censuses indicated because of the difficulty of observing broods in the dense vegetation. Hammond (1970:17) estimated that the percentage of broods not seen during brood surveys is roughly equal to the percentage of vegetative cover. Oxbows averaged 60% open water, so approximately 40% of the broods present during the brood surveys were probably not seen because of vegetative cover. Rumble (1979:16) found that approximately 25% of the broods on South Dakota stock ponds (average 15% cover) were missed using flush counts. Diem and Lu (1960) reported that vegetation, brood age, and species affect brood visibility. Cowardin and Higgins (1967) found that young and adult wood ducks were less visible on a river habitat in Minnesota than blue-winged teal or mallards. Wood duck brood data from censuses along the Big Sioux River probably represent minimum brood numbers.

CONCLUSIONS

Oxbows seem to be preferred wood duck brood habitat. These lentic areas promote the growth of emergent and submergent vegetation, which supports abundant invertebrate populations and provides protective cover for ducklings. Conversely, the lotic waters of the Big Sioux River do not support abundant macrophyte populations, and invertebrates are scarce in the water column. Though food and cover are less concentrated in the river, ducklings are often raised there, particularly during dry years when oxbows are scarce. When oxbows are present, however, the primary function of the river seems to be as a travel route between oxbows. It provides a quick, safe, and efficient means of travel between brood-rearing areas.

Any human activities along the Big Sioux River that eliminate oxbows would probably have a significant impact on the wood duck population of the area. Channelization of the river would have a severe impact on wood ducks by (1) reducing channel length and, therefore, potential river habitat, (2) clearing log jams and fallen trees that may be necessary for river brood habitat, (3) direct and indirect drainage of oxbows and other nearby wetlands, (4) direct and indirect elimination of the floodplain forest, which provides nesting habitat, due to land clearing operations, (5) reduction of emergent cover needed for ducklings by elimination of backwater areas, and (6) direct and indirect reduction of aquatic animal and plant foods by destroying oxbow and backwater areas that permit and promote their growth (Barclay 1978).

LITERATURE CITED

Allen, S. E., M. Grimshaw, J. A. Parkins, and C. Quermby. 1974. Chemical analysis of ecological materials. Blackwell Scientific Publications, Oxford. 565pp.

Ball, I. J. 1971. Movements, habitat use and behavior of wood duck (Aix sponsa) broods in north-central Minnesota as determined by radio-tracking. M.S. Thesis. Univ. Minnesota, St. Paul. 56pp.

. 1973. Ecology of duck broods in a forested region of north-central Minnesota. Ph.D. Thesis. Univ. Minnesota, St. Paul. 67pp.

Barclay, J. S. 1978. The effects of channelization on riparian vegetation and wildlife in south central Oklahoma. Pages 129-138 in R. R. Johnson and J. F. McCormick, tech. coord. Strategies for Protection and Management of Floodplain Wetlands and Other Riparian Ecosystems. Gen. Tech. Rep. WO-12, For. Serv., U.S. Dep. Agric., Washington, D.C.

Bartonek, J. C., and J. J. Hickey. 1969. Food habits of canvasbacks, redheads, and lesser scaup in Manitoba. Condor 71:280-290.

Beard, E. B. 1953. The importance of beaver in waterfowl management at the Seney National Wildlife Refuge. J. Wildl. Manage. 17:398-436.

. 1964. Duck brood behavior at the Seney National Wildlife Refuge. J. Wildl. Manage. 28:492-521.

Bednarik, K. E., and J. L. Weeks. 1976. Wood duck production on Ohio streams. Ohio Dep. Nat. Res. Wildl. In-Serv. Note 330. 5pp.

Bellrose, F. C. 1976. Ducks, geese and swans of North America. Stackpole Books, Harrisburg, Pa. 544pp.

Choate, G. A., and J. S. Spencer, Jr. 1969. Forests in South Dakota. U.S. Dep. Agric. For. Serv., Intermountain For. Exp. Stn. For. Serv. Resour. Bull. INT-8. 40pp.

Chura, N. J. 1961. Food availability and preferences of juvenile mallards. Trans. N. Am. Wildl. Nat. Resour. Conf. 26:121-132.

Collias, N. E., and E. C. Collias. 1963. Selective feeding by wild ducklings of different species. Wilson Bull. 75:6-14.

Cowardin, L. M., and K. F. Higgins. 1967. Visibility, movement, and behavior of waterfowl on a river habitat in Minnesota. Trans. N. Am. Wildl. Nat. Resour. Conf. 32:301-315.

Decker, E. 1959. A 4-year study of wood ducks on a Pennsylvania marsh. J. Wildl. Manage. 23:310-315.

Diem, K. L., and K. H. Lu. 1960. Factors influencing waterfowl censuses in the Parklands, Alberta, Canada. J. Wildl. Manage. 34:113-133.

Drobney, R. D., and L. H. Fredrickson. 1979. Food selection by wood ducks in relation to breeding status. J. Wildl. Manage. 43:109-120.

Dwyer, T. J. 1972. An adjustable radio-package for ducks. Bird Banding 43:282-284.

Farmer, A. H. 1970. Wood duck brood movements as determined by radio-tracking. M.S. Thesis. North Carolina State Univ., Raleigh. 48pp.

Gallop, J. B., and W. H. Marshall. 1954. A guide for aging ducklings in the field. Mississippi Flyway Council Tech. Sec. 14pp. (Mimeo.)

Gilmer, D. S., I. J. Ball, L. M. Cowardin, and J. H. Riechmann. 1974. Effects of radio packages on wild ducks. J. Wildl. Manage. 38:243-252.

breeding activities of mallard and wood ducks in north-central Minnesota. J. Wildl. Manage. 41:345-359.

Greenwood, R. J., and A. B. Sargeant. 1973. Influence of radio packs on captive mallards and blue-winged teal. J. Wildl. Manage. 37:243-252.

Hammond, M. C. 1970. Waterfowl brood survey manual. U.S. Fish and Wildl. Serv. Bur. Sport Fish. and Wildl. 44pp.

Hardister, J. P., Jr., F. E. Hester, and T. L. Quay. 1962. Movements of juvenile wood ducks as measured by web-tagging. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm. 16:70-75.

Hawkins, A. S., and F. C. Bellrose. 1940. Wood duck habitat management in Illinois. Trans. N. Am. Wildl. Conf. 5:392-395.

Heezen, K. L., and J. R. Tester. 1967. Evaluation of radio tracking by triangulation with special reference to deer movements. J. Wildl. Manage. 31:124-141.

Hocutt, G. E., and R. W. Dimmick. 1971. Summer food habits of juvenile wood ducks in east Tennessee. J. Wildl. Manage. 35:286-292.

Johnson, N. F. 1971. Effects of levels of dietary protein on wood duck growth. J. Wildl. Manage. 35:798-802.

Klein, H. G. 1955. Wood duck production and use of nest boxes on some small marshes in New York. N.Y. Fish and Game J. 2:68-83.

Krecker, F. H. 1939. A comparative study of the animal population of certain submerged aquatic plants. Ecology 20:553-562.

Krull, J. N. 1970. Aquatic plant-macroinvertebrate associations and waterfowl. J. Wildl. Manage. 34:707-718.

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

McGilvrey, F. B. 1969. Survival of wood duck broods. J. Wildl. Manage. 33:73-76.

Moyle, J. B. 1961. Aquatic invertebrates as related to larger water plants and waterfowl. Minnesota Dep. Conserv. Rep. 233. 24pp.

Parrish, J. B. 1981. Woodpecker nesting habitat in a prairie river woodland. M.S. Thesis. South Dakota State Univ., Brookings. 31pp.

Pennak, R. W. 1978. Freshwater invertebrates of the United States. 2nd ed. John Wiley and Sons, New York. 803pp.

Perry, M. C. 1981. Abnormal behavior of canvasbacks equipped with radio transmitters. J. Wildl. Manage. 45:786-789.

Rosine, W. N. 1955. The distribution of invertebrates on submerged aquatic plant surfaces in Muskee Lake, Colorado. Ecology 36:308-314.

Rumble, M. A. 1979. Habitat preferences and censusing of waterfowl broods on stock ponds in south central South Dakota. M.S. Thesis. South Dakota State Univ., Brookings. 42pp.

Smith, L. M., J. W. Hupp, and J. T. Ratti. 1980. Reducing abandonment of nest-trapped gray partridge with methoxyflurane. J. Wildl. Manage. 44:690-691.

Smith, R. L. 1980. Ecology and field biology. 3rd ed. Harper and Row, New York. 835pp.

Springer, J. T. 1979. Some sources of bias and sampling error in radio triangulation. J. Wildl. Manage. 43:926-935.

Stewart, P. A. 1958a. Local movements of wood ducks (Aix sponsa). Auk 75: 157-168.

Columbus. Coop. Wildl. Res. Unit Release 209. 13pp.

. 1974. Mother wood ducks feeding away from their broods. Bird Banding 45:58.

Stewart, R. E., and H. A. Kantrud. 1971. Classification of natural ponds and lakes in the glaciated prairie region. U.S. Fish and Wildl. Serv. Resour. Publ. 92. 57pp.

Sugden, L. G. 1973. Feeding ecology of pintail, gadwall, American widgeon, and lesser scaup ducklings in southern Alberta. Can. Wildl. Serv. Rep. Ser. 24. 45pp.

Swanson, G. A., and H. K. Nelson. 1970. Potential influence of fish rearing programs on waterfowl breeding habitat. Pages 65-71 in E. Schneberger, ed. A Symposium on the Management of Midwestern Winterkill Lakes. North Central Division, Am. Fish. Soc.

Webster, C. G., and F. B. McGilvrey. 1966. Providing brood habitat for wood ducks. Pages 70-75 in J. B. Trefethen, ed. Wildl. Manage. Inst., Washington, D.C. 212pp.

Wenner, K. C., and W. R. Marion. 1981. Wood duck production on a northern Florida phosphate mine. J. Wildl. Manage. 45:1037-1042.

Westin, F. C., and D. D. Malo. 1978. Soils of South Dakota. South Dakota State Univ. Agric. Exp. Stn. Bull. 656. 118pp.

Wooley, J. B., Jr., and R. B. Owen, Jr. 1978. Energy costs of activity and daily energy expenditure in the black duck. J. Wildl. Manage. 42:739-745.

APPENDIX

Appendix table A. Esophageal and proventricular contents of 1 Class-IIc duckling collected on the Big Sioux River, 1981.

Item	Number
Agrostis sp. seeds	3,223
Phalaris arundinacea seeds	241
Gastropoda	22
Corixidae	7
Gerridae	6
Diptera	2