HOME RANGE AND HABITAT USE OF BREEDING MALLARDS (<u>ANAS PLATYRHYNCHOS</u>) AND WOOD DUCKS (<u>AIX SPONSA</u>) IN NORTH-CENTRAL MINNESOTA AS DETERMINED BY RADIO TRACKING

A THESIS
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HOME RANGE AND HABITAT USE OF BREEDING MALLARDS (*ANAS PLATYRHYNCHOS*) AND WOOD DUCKS (*AIX SPONSA*) IN NORTH-CENTRAL MINNESOTA AS DETERMINED BY RADIO TRACKING

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ABSTRACT

Thirty mallards and 47 wood ducks were studied during the breeding seasons of 1968, 69 and 70 in a 17-square-mile study area in the Chippewa National Forest with the use of a radio-tracking system.

The mean size and maximum length of mallard home ranges were approximately 550 acres and 1.5 miles, respectively. Mean wood duck home range size and maximum length were approximately 500 acres and 1.5 miles, respectively. Wood duck males that were unpaired and those observed with several females used home ranges with a mean size of 1300 acres and a maximum length of about 2.5 miles. Within each species individual home range size varied considerably. Mean home ranges were similar between sexes. Mallard and wood duck hens used a larger home range during the pre-incubation period than during incubation. In many cases mallards and wood ducks enlarged their home range throughout the breeding season.

The overlap zone of adjacent mallard pairs included one or several lakes while the overlap zone of wood ducks appeared to be associated with small wetlands. Mallard pairs with overlapping ranges generally used different shorelines but when habitats were shared temporal spacing may have reduced conflicts.

Within the study area fine sedge wetlands and sand shorelines were used mostly by mallards while wood ducks made the greatest use of coarse sedge and shrub swamp wetlands. Over 40 percent of mallard

locations were in shoreline habitat and more than 50 percent of wood duck locations were in wetlands smaller than two acres.

Based on availability within the home range, coarse sedge wetlands and sand shorelines were used more than expected by both mallards and wood ducks. Flooded pasture wetlands were used more than expected by mallards whereas wood ducks used hardwood swamp wetlands more than expected.

Greater amounts of shoreline occurred in mallard home ranges than in wood duck home ranges but the latter had greater densities of small wetlands. Wood ducks appeared to be more flexible than mallards in their habitat requirements and use of habitat appeared to be influenced by location of the cavity tree. Lake shoreline habitat may be desirable in mallard home ranges because of the open area afforded even though the species has shown amazing adaptability in using forest wetlands.

Nearly 60 percent of the total mallard nests found were in sedge areas with the remainder in a wide variety of other habitat types. Over 60 percent of wood duck nests were located in quaking aspen (*Populus tremuloides*).

Mallards and wood ducks nested within 0.1 and 0.3 mile, respectively, of the nearest water. Mallard nests were always within 0.5 mile of large permanent water but about 30 percent of wood ducks nested more than 0.5 mile from these waters.

Mallard pairs appear to select the home range for its desirable resting and feeding locations without being restricted by nesting requirements which are probably always available. In contrast, the discovery of a nesting cavity may be the primary factor in the selection of a home range by breeding wood ducks.

Apparent increase in wood duck production in the region since the 1950's may be due to the increased availability of cavities in aspen established during the logging era of the 1890's.

Protection of wetlands and shorelines from destruction or alteration by human activity and a timber management plan permitting potential cavity trees to be saved are considered the best approach to waterfowl management in the study area.

Approved ______________________
Major Advisor

INTRODUCTION

The forested regions of the Lake States and eastern Canada have long been recognized as an important breeding ground for several species of waterfowl. Although species composition is different and population densities are much lower than those found on the prairies during wet years (Wellein and Lumsden 1964) the northern forests, because of their vast area and environmental stability, have contributed to continental waterfowl populations and particularly to those in the Mississippi and Atlantic Flyways.

Traditionally the prairies, because of their high waterfowl densities, have received much attention. Recently, however, resource management agencies have assigned increased importance to woodland areas as potential waterfowl breeding habitat. The unique characteristics of the northern forest regions which have resulted in significant and relatively stabilized waterfowl production are permanency of water and abundance of wetlands with little immediate threat of large scale drainage or development. In contrast, continual drainage of prairie potholes for agricultural purposes (U.S. Fish and Wildlife Service 1961 and 1969) threatens to eliminate all but a small portion of the original prairie breeding areas. Furthermore prairie regions experience periodic droughts which result in drastic reductions in annual waterfowl productions. Considering these factors the difference between production from the prairies and forest regions may be less than originally thought.

Responding to the need for ecological knowledge requisite to effective waterfowl management in forested areas the U.S. Forest Service and the U.S. Fish and Wildlife Service cooperated in conducting an inventory and developing a management plan for wetlands of the Chippewa National Forest of Minnesota (U.S. Dept. of Agriculture 1965). However, a more thorough understanding of forest waterfowl ecology was necessary before specific management recommendations could be made. The Chippewa was selected as a suitable area for continuing research directed towards obtaining basic ecological data on resident waterfowl.

Preliminary investigations conducted in 1966 using the conventional technique of color-marking and direct observation provided poor results due to restricted visibility and accessibility. Because of these problems, a pilot project was conducted in the late summer 1967 to evaluate the feasibility of using radio tracking techniques in waterfowl studies. This trial demonstrated that the technique was practical and a biotelemetry study was initiated in the spring of 1968.

This study concerns aspects of the breeding ecology of mallards (Anas platyrhynchos)[1] and wood ducks (Aix sponsa) in a portion of the Chippewa National Forest and is part of a large scale waterfowl ecology study still being conducted. Objectives of my study were to determine the home range of

[1] Scientific and common names of North American birds are from the A.O.U. Check-List (1957).

breeding individuals and pairs, and the habitat used by these birds through the nesting season. Mallards and wood ducks were studied because of their relative abundance in the study area. The study began in the spring of 1968 and was continued through the early summer of 1970. Field work was carried out as a joint effort by Dr. Lewis Cowardin, Joseph Ball, various summer assistants and myself.

Effective use of the results of this study in future wide-scale management of forested areas will depend on whether the area studied is representative of the northern forest region. Further research in other forest areas will be necessary to determine if major differences exist.

DESCRIPTION OF THE STUDY AREA

PHYSICAL DESCRIPTION

The study area is located on the western edge of the Chippewa National Forest in Beltrami County, in north-central Minnesota. It is situated approximately 12 miles east of Bemidji and 6 miles north of the town of Cass Lake. Thirty-six square miles (T.146N.R.31W. Ten Lakes Township) were recognized as the limits of the study area; however, boundaries were not formally recognized in order to permit flexibility in following radio-marked birds. For this study the 17 sections bounded roughly by Andrusia, Cass, Buck, and Big lakes contained most of the ducks tracked on a regular basis and was considered the study area. Ball (1971:3) described these lakes as "peripheral" and the smaller more centrally located lakes as "interior" lakes. This description will also be used in this study. Figure 1 indicates the distribution of lakes (permanent bodies of water larger than 10 acres) and wetlands in the study area and surrounding region. Selection of this area was primarily because of its proximity to suitable living facilities, good road network, prior familiarity, and a reasonably good distribution and variety of wetlands.

The climate of north-central Minnesota is humid-continental with short warm summers and long cold winters. According to Trewartha (1954) the region lies within Koppen's Dfb climate (subhumid, microthermal, no dry season). Climatic data (Table 1)

Figure 1. Map of the study area and surrounding region showing the distribution of lakes and wetlands.

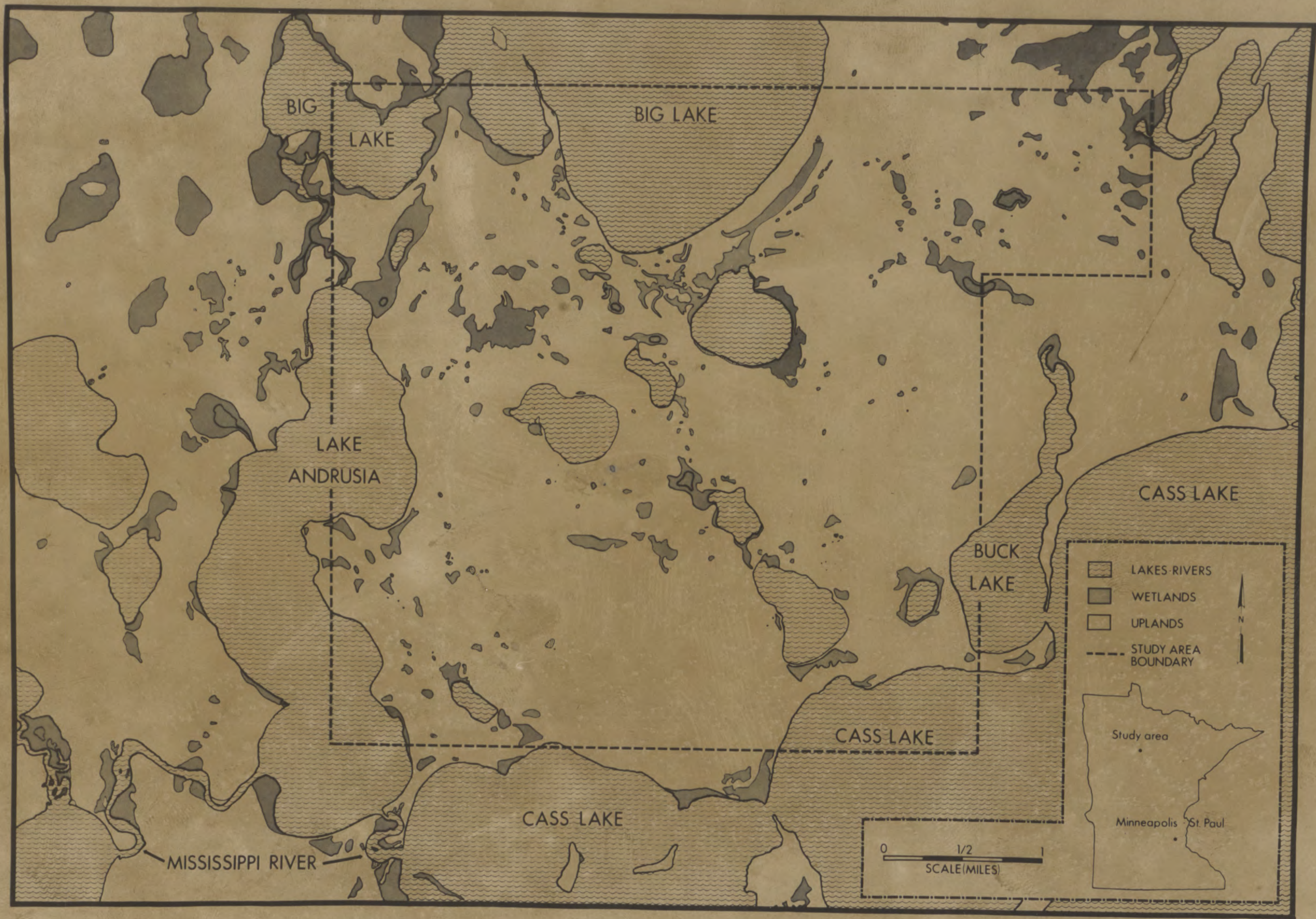

BIG
LAKE
BIG LAKE
LAKE
ANDRUSIA
BUCK
LAKE
CASS LAKE
CASS LAKE
CASS LAKE
MISSISSIPPI RIVER
LAKES RIVERS
WETLANDS
UPLANDS
STUDY AREA
BOUNDARY
N
Study area
Minneapolis
St. Paul
0
1/2
1
SCALE(MILES)

Table 1. Summary of pertinent climatological data during 1968-1970 field seasons. (Environmental Data Service 1968, 1969, 1970)[a].

Period	Average temp.(°F)	Departure[b] from normal (°F)	Lowest temp.(°F)	Total precip. (in)	Departure[b] from normal (in)	Snow on ground until
1968						
March	29.6	+9.0	-15.0	1.75	+0.74	March 25
April	39.8	+1.5	- 2.0	3.96	+2.03	-
May	49.6	-4.0	16.0	1.89	-1.32	-
June	60.4	-2.1	34.0	5.21	+1.29	-
1969						
March	18.9	-1.7	-14.0	0.14	-0.87	Entire month
April	42.3	+4.0	7.0	1.23	-0.70	April 13
May	52.5	-0.1	24.0	4.25	+1.04	-
June	55.4	-7.1	28.0	3.83	-0.09	-
1970						
March	16.1	-4.5	-16.0	0.78	-0.23	Entire month
April	36.8	-1.5	- 5.0	3.23	+1.30	April 24
May	49.6	-3.9	24.0	2.16	-1.05	-
June	65.5	+3.1	36.0	2.36	-1.56	-

[a] Location of weather station: U.S. Forest Service, Cass Lake, Minnesota.
[b] Normal based on station climatological standard from the period 1931 to 1960.

do not indicate any great variations from the normal during the period of study. However, the 1969 and 1970 field seasons were slightly drier and cooler than average. During the study period all water areas were usually free of ice by the third week in April with small wetlands and the Mississippi River clear one to two weeks earlier. According to Visher (1954), May 25th is the mean date of the last freezing temperature in the spring. Mean annual precipitation for the region is 24.58 inches with nearly 50 percent occurring during the summer (Environmental Data Service 1968). Baker (1958:55) calculated annual evapotranspiration at approximately 21.5 inches. Water levels in wetlands are at a maximum in April and May due to surface runoff and low seepage rates. Throughout spring and summer, levels drop at varying rates depending on the characteristics of the individual wetland (Manson et al. 1968). Temporary rises are usually observed in wetlands after heavy summer rains.

Wright and Ruhe (1965) describe glaciation in the region as a complex history of ice advance and retreat. A variety of deposits from the most recent Wisconsin stage glaciation mantle the undiagnostic granitic and metamorphic bedrock of north-central Minnesota. Goltz's (1969) soil map of the Chippewa National Forest indicates that the northeastern quarter of the study area is underlain by soils of the Nebish Association formed from glacial till. This association has good inherent fertility and supports the finest hardwood stands on the study area. The remaining portion of the study area is underlain by the Menahga Association derived from glacial outwash. These soils are droughty, low in fertility and typically support certain conifers or scrub oak. Both associations grade locally to finer textured organic soils.

The elevation of the area is between 1200 to 1400 feet above sea level (Baker and Strube 1963). Topography is generally undulating or rolling with locally steep hills. Mean land elevation above the local lake level is about 25 feet.

Fourteen lakes are within or adjacent to the study area and comprise approximately 21.2 percent of the area. According to Zumberge (1952) peripheral lakes Andrusia, Cass, and Big are ice block basins as are most of the smaller interior lakes. Buck Lake and the small lake immediately to its west were formed by the isolation of a small bay of Cass Lake. Hard water lakes are typical in this region of Minnesota, and the average alkalinity of Andrusia and Cass Lakes is about 150 mg/l (Minnesota Pollution Control Agency 1968). According to Eddy's (1938:11) classification most of the lakes within the study area resemble the "Pike Lake No. 2" type. However, several lakes are too shallow to support game fish populations. In contrast to the southern portion of the study area the northeastern two-thirds contains numerous interior lakes and wetlands. Blocked-drainage patterns and scattered small kettle basins are evident. The entire study area is located within the Mississippi headwaters watershed unit as defined by Frellsen (1959). The Mississippi River flowing from west to east is immediately south of the study area. A dam constructed at the outflow of the Mississippi from Cass Lake in 1918 resulted in a major rise in water levels of Andrusia, Cass and Buck Lakes (U.S. Forest Service, Cass Lake Range District Office Records).

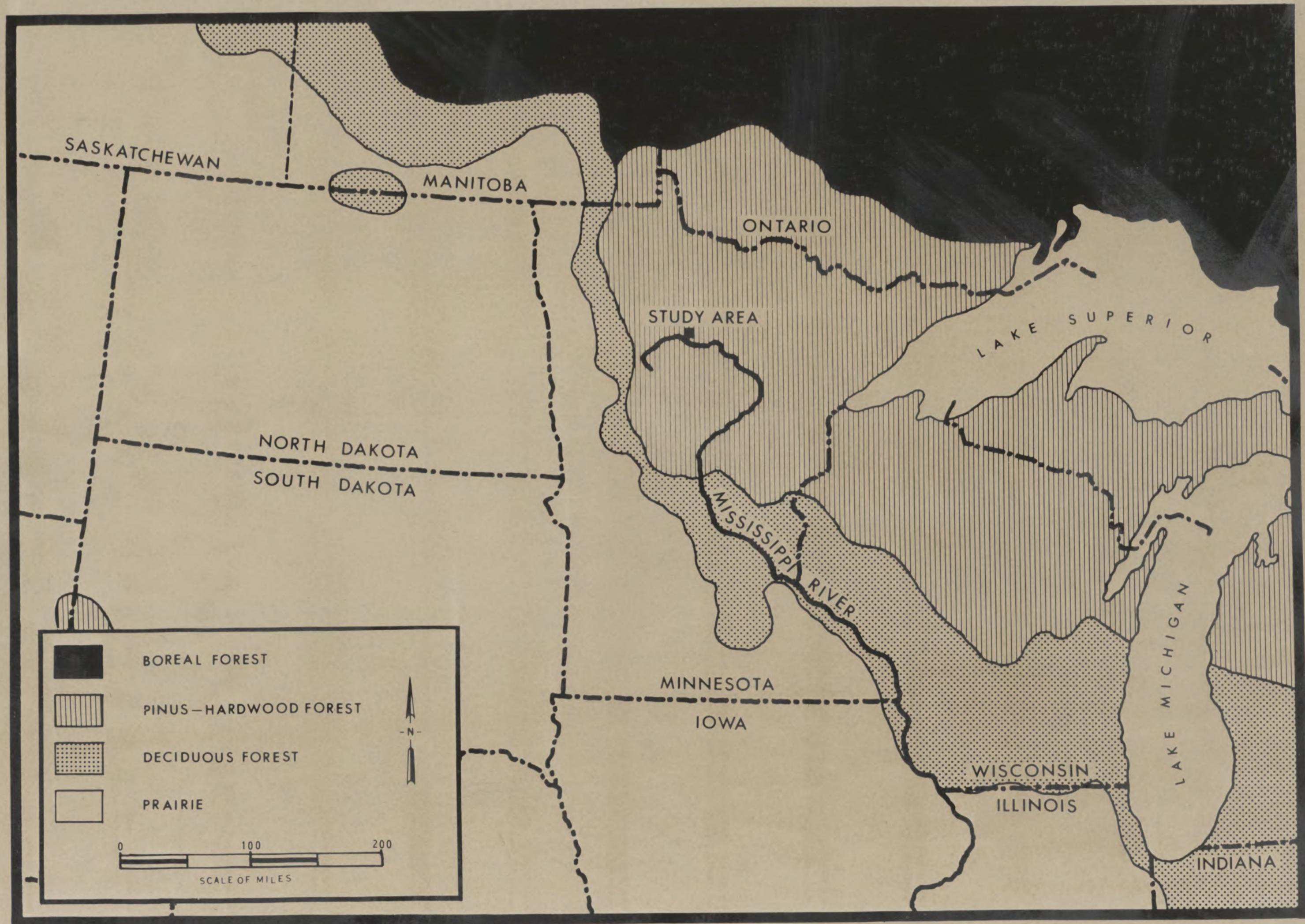
VEGETATION

McAndrews (1963:1), using pollen analysis to reconstruct the postglacial vegetation and climatic history of northwestern Minnesota, described three major plant formations: Prairie, Deciduous Forest, and *Pinus*-Hardwood Forest. The study area lies within the *Pinus*-Hardwood Forest and is about 75 miles to the east of the Prairie formation (Fig. 2). Braun (1950) considered this area as the Minnesota Section of the Hemlock-White Pine-Northern Hardwood Region.

The *Pinus*-Hardwood Forest described by McAndrews (1963:25) is characterized by white pine (*Pinus strobus*)[1] and red pine (*P. resinosa*) mixed with aspen (*Populus* spp.), paper birch (*Betula papyrifera*), and oaks (*Quercus* spp.). Pure stands of jack pine (*Pinus banksiana*) usually grow on the direst sites. Dominant species of the Boreal Forest, such as Balsam fir (*Abies balsamea*) and white spruce (*Picea glauca*) and characteristic species of the Deciduous Forest are found in certain locations.

[1] Plant names are from Fernald (1950).

Figure 2. Location of the study area in relation to major vegetation formations of the region.



SASKATCHEWAN
MANITOBA
ONTARIO
STUDY AREA
LAKE SUPERIOR
NORTH DAKOTA
SOUTH DAKOTA
MISSISSIPPI RIVER
MINNESOTA
IOWA
WISCONSIN
ILLINOIS
LAKE MICHIGAN
INDIANA
BOREAL FOREST
PINUS—HARDWOOD FOREST
DECIDUOUS FOREST
PRAIRIE
N
0
100
200
SCALE OF MILES

Soils and land use have resulted in various vegetation patterns within the study area. The heavier and more fertile soils in the northeastern part support several large mature stands of mixed sugar maple (*Acer saccharum*), basswood (*Tilia americana*) and red oak (*Quercus rubra*). Fine stands of aspen, mostly quaking aspen (*Populus tremuloides*), are found on the same soils. A mixture of scrub oak (*Quercus* spp.) paper birch, large-tooth aspen (*Populus grandidentata*), and quaking aspen form a major portion of the study area forest cover. Pure stands of aspen are common in many locations throughout the area and pure jack pine is typical on sandy, well drained sites. Several red pine plantations are present but only a few scattered mature red and white pines remain of the stands that dominated the area prior to logging. According to Shirley (1936:25) the logging of pine during the late 1800's and early 1900's resulted in a ten-fold increase in quaking aspen and scrub oak in Minnesota. Original township survey maps indicate that prior to 1890 pine types occupied more than 87 percent of the forest area in Ten Lakes Township and hardwoods were extremely scarce compared to the present day cover types (John Mathisen, pers. comm.). Black spruce (*Picea mariana*), associated with some bog communities, and lowland hardwoods such as American elm (*Ulmus americana*) and ash (*Fraxinus* spp.) are found in limited areas. Openings associated with abandoned homesteads are scattered throughout the area and several are dominated by big bluestem (*Andropogon gerardi*) and other plants associated with the prairie community. A few hayfields and pastures support a limited agricultural industry. Commercial cutting of pulpwood and resort operations on the larger lakes are the most important economic uses of the area.

Many of the wetlands in the study area can be described as a continuum between pure emergent vegetation to nearly pure shrub. Sedges (Carex spp.) are the most common emergent plants; speckled alder (Alnus rugosa), and willow (Salix spp.) represent the most common wetland shrubs. Although wetlands vary considerably in the amount and duration of surface water most hold water until early summer. Wetlands scattered through the study area are generally small (less than five acres); exceptions to this are the large wetlands usually associated with adjacent lakes. Small pools occurring beneath hardwood stands are fairly common in the spring but their temporary nature and the forest overstory make them difficult to locate. Hardwood swamps are present in small numbers in the study area as are several extensive acid bogs. Stands of hardstem bulrush (Scirpus acutus) and occasionally reed (Phragmites communis) are usually found along shorelines of the larger lakes. Wild rice (Zizania aquatica) is common on certain lakes although it does not emerge until after midsummer. Lakes in the area generally support the Hard-Water Flora described by Moyle (1945).

WILDLIFE

Bird and mammal species which have been observed and are known or suspected to interact with breeding mallards and wood ducks in the study area, will be discussed in this section.

During the spring migration the large numbers and numerous species of waterfowl that pass through the area restrict their brief stops to the ice-free portions of large lakes and the Mississippi River. The study area is in the vicinity of the most northernly reaches of the Mississippi River and may be a "jumping off" point for migrating waterfowl which follow the river valley to that point and continue north. Hochbaum (1955:120) described these major migration routes as "trunk lines" from which waterfowl depart at various points depending on their ultimate destinations. It appears that only locally breeding ducks tend to disperse into the smaller lakes and wetlands during the spring.

Although mallards and wood ducks constitute a large proportion of ducks breeding on the study area, blue-winged teal (Anas discors), American goldeneyes (Bucephala clangula), and ring-necked ducks (Aythya collaris) are fairly common in certain habitats. American widgeon (Mareca americana) and hooded mergansers (Lophodytes cucullatus) are observed infrequently but are suspected to breed on or near the study area. The common loon (Gavia immer) is frequently observed on local lakes. Mathisen (1965) used breeding pair and brood counts to describe the breeding population of waterfowl on the Chippewa National Forest and estimated that the mallard, blue-winged teal, goldeneye, ring-necked duck, widgeon and wood duck comprise over 90 percent of the breeding population in 1965. The relative importance of widgeon and wood duck had increased and blue-winged teal had decreased since 1937.

Other avian fauna common to the area include: bald eagle (Haliaeetus leucocephalus), osprey (Pandion haliaetus), great horned owl (Bubo virginianus) and cooper's hawk (Accipiter cooperii). The goshawk (Accipiter gentilis) has been observed occasionally. Common crows (Corvus brachyrhynchos) are abundant throughout the area. Yellow shafted flickers (Colaptes auratus), reported by Cunningham (1968) as potential wood duck nest predators, are frequently seen. Pileated woodpeckers (Dryocopus pileatus) and flickers may excavate tree cavities eventually used by wood ducks.

Raccoon (Procyon lotor)[1], mink (Mustela vison), striped skunk (Mephitis mephitis), and red fox (Vulpes vulpes) are frequently observed. Muskrat (Ondatra zibethicus) and beaver (Castor canadensis) are common in parts of the study area.

[1] Common and scientific names of mammals are from Hall and Kelson (1959), and Churcher (1959).

METHODS

TRAPPING AND MARKING

Various waterfowl trapping techniques were used depending on the situation. Small cannon nets (Dill and Thornsberry 1950, Miller 1957) were effective in capturing pairs but frequently required large amounts of time and their use was restricted to solid, open shorelines. The behavior patterns of birds captured in this manner were not noticeably affected. Evans and Black (1956:57) noted little disturbance caused by spring cannon netting of breeding pairs in Waubay, South Dakota.

Welded wire funnel bait traps (Addy 1956) and a floating treadle type trap (Thornsberry and Cowardin 1971) accounted for most captures and could be used in nearly all situations.

Nest trapping of mallards was used as a last resort and frequently resulted in nest abandonment. Nesting wood ducks were captured by blocking the cavity entrance with a cloth plug at the end of a pole, climbing the tree, and removing the duck from the cavity (Grice and Rogers 1965:7).

All electronic equipment was built by the University of Minnesota's Bioelectronics Laboratory located at the Cedar Creek Natural History Area, Bethel, Minnesota. Transmitters were crystal controlled pulse-type, using a circuit design similar to that described by Cochran and Lord (1963). A pulsing signal permitted better discrimination between the true signal and spurious "noise". Calculated transmitter life was 75 days using a Mallory RM1-CC battery and an average transmitter current drain of 0.56 milliamperes. VHF band frequencies between 51.500 and 53.500 MHz were used, and each bird was assigned a different frequency. A minimum spread of 0.015 MHz between individual transmitters was usually necessary to avoid confusion.

Transmitter potting techniques and basic harness design were described by Ball (1971:6). Harness body loop diameters were designed to fit the "average size" bird. A three inch diameter body loop was used for wood ducks and a 3-5/8 inch diameter for mallards. Very few instances occurred when a bird could not be marked because of an unsatisfactory transmitter fit.

Improvements in both potting materials and techniques allowed a reduction in total transmitter package weight from approximately 27 grams in 1968 to about 23 grams in 1969 and 1970. The lighter package weight was about 2 percent of the body weight of a large mallard and 4 percent of the weight of a small wood duck. Weights were essentially the same for both mallard and wood duck transmitters.

In 1968 and 1969 transmitter equipped birds were also marked with consecutively numbered orange patagial tags described by Ball (1971:7). Birds that were not radio-marked were color-marked with yellow or white patagial tags to provide supplementary data. No color marking was done in 1970. All birds were banded with U. S. Fish and Wildlife Service leg bands.

TRACKING

Tracking receivers were superheterodyne type with a pre-amplifier converter and attached small bidirectional loop antenna. Each receiver was also provided with an external antenna connection for use with mast-mounted Yagi antennae (Hy-Gain Electronics Corp., Lincoln, Nebraska).

Ten to 13 antenna sites were established throughout the study area. These consisted of a Yagi antenna mounted on a 30 to 50 foot telescoping mast that was easily moved to a new location as tracking requirements necessitated (Fig. 3a). A permanent 70 foot mast was located in approximately the center of the study area (Fig. 3b). Each antenna was equipped with a bearing circle and pointer (Fig. 4a). The bearing circle was oriented to true north and the pointer indicated the antenna direction. Bearing accuracy was approximately ±3 degrees and was considered sufficient for the tracking requirements of this study. Searches for birds that could not be located from the antenna sites were accomplished mostly by using an antenna on a telescoping, crank-up mast mounted on a jeep (Fig. 4b). A boat mounted antenna mast and a loop antenna mounted on the wing strut of a light aircraft were occasionally used for search purposes. Most locations of radio-marked birds were determined by bearings from two or more Yagi masts, by use of one mast bearing in addition to a close-range cross bearing obtained with the loop antenna, or entirely by use of the loop antennae.

Figure 3a. Portable, telescoping field mast with Yagi antenna.

Figure 3b. Permanent 70 foot mast. Mast could be lowered to permit periodic maintenance.

Figure 4a. Bearing circle and pointer mounted near the base of the 70 foot mast. Similar devices were attached to all field masts.

Figure 4b. Yagi antenna and a telescoping, crank-up mast mounted on a jeep (shown in the lowered position).

Grid maps (1:7920) made from aerial photographs (1:15840) were used to plot locations in the field. The animal's location was read from the field map in terms of an eight digit X-Y coordinate providing a plotting resolution of .064 acres. All bearings and the resultant map coordinates were recorded on a field data form along with bird identification number, date, time, weather information and any additional data obtained if a visual observation was made. The configuration of the transmitting antenna resulted in signal fluctuations whenever the animal moved. The presence or absence of these fluctuations was recorded on the field form as "bird activity". A bird in flight produced a characteristic signal and usually a rapid bearing change. The time interval between two bearings was usually less than 10 minutes and any significant movement of the animal during this period was usually apparent when plotting the second bearings. Radio communications between field workers using "walkie-talkies" frequently permitted coordination of tracking efforts.

Ranges up to 0.25 mile were attained with the loop antenna and up to 1.5 mile with a Yagi array. Ranges of approximately 5 miles were common from an aircraft flying 1000 feet above the ground. Average ground to ground ranges were slightly reduced in the summer because of tree and understory vegetation which caused increased signal attenuation. Other range determining factors were height of antenna, topography, aspect and size of the transmitter antenna loop, atmospheric conditions, and operator experience. Occasionally topographic features caused signal bounce and channeling.

Locations for each bird were obtained as frequently as possible. Nearly continuous day-to-day contact was maintained for most birds during the study period with an average of about two locations per day per bird. Although most tracking was done between sunrise and sunset considerable effort was made to locate birds throughout the night.

DATA PROCESSING AND ANALYSIS

All data were assigned numerical codes in the field. Numerical data were transcribed to coding forms and then to machine punch cards. Each batch of machine punch cards was sorted chronologically and machine listed. A program called "Error Check" was used to locate omission errors and inconsistencies. Control Data Corporation (CDC) 6600 and 1700 computers were used to process and analyze data.

Handling of large quantities of data was facilitated by recording card data on magnetic tape using MODIFY, a file editing system (Control Data 1970a) which permitted the insertion, deletion and correction of card images. Listings of card or tape data were simplified by using SORT/MERGE, a machine sorting system (Control Data 1970b).

Locations of selected birds or groups of birds and symbols representing points such as trap locations and nests were plotted using a CDC 160/CALCOMP system. Plots permitted direct determination of home range area by using a compensating polar plainimeter and also were used as overlays for habitat analysis. A computer program calculated incremental increases and cumulative home range using the method described by Mohr (1947) for any desired time span. Other programs calculated the geometric center of the home range (Hayne 1949) and a frequency distribution of fixes falling within 0.10 mile intervals from the geometric center or nest location.

An arbitrary minimum of 20 locations over a period of at least two weeks was required before home range size was calculated. I use the term home range to refer to the apparent home range during the period of tracking. Defining home range by the use of Mohr's (1947) minimum area method provided results which could best be compared with other home range data in the literature. Maximum length of the home range was defined as the distance between the two most distant locations. Maximum width was the width of a rectangle enclosing the home range measured perpendicular to the maximum length axis. The ratio of the maximum length to the maximum width was defined as the "index of linearity" (Ables 1969) and provided a quantitative value for the shape of the home range.

The approximate size of the more intensively used portion of the home range was called the "primary range" and was determined by the removal of all "peripheral" points before calculating the home range by the minimum area method. A point was peripheral if it was an outer point and was not within a 200 yard radius of an adjacent point recorded on a different day.

For the purposes of habitat analysis each wetland was assigned a code according to its size and dominant vegetation. Linear shoreline was described as an area by including a zone approximately 66 feet (1 chain) out from the shoreline. This area was considered a shoreline zone and coded according to the type of shoreline. The map outline of each wetland and shoreline zone in the study area was converted to a polygon by changing each curved line segment into several straight line segments. Using a "digitizer"[1] the coordinates and code of each polygon were recorded on magnetic tape (Fig. 5). A program designed for use with digitizer data and tracking data provided a rapid and accurate means of analyzing habitat use.

HABITAT CLASSIFICATIONS

Waterfowl habitat in the study area was inventoried by ground survey and aerial photographs. Classification was based on the recognition of two broad "categories": Wetlands and Shorelines. A wetland was considered to be a shallow (maximum depth approximately six feet) body of water of temporary or permanent nature. Most wetlands, during the period

[1] Auto-trol Corporation Model 3400 with a Kennedy incremental 1500 magnetic tape unit.

Figure 5. Auto-trol Corporation "digitizer" used to convert habitat maps into a digitized form for numerical analysis.

of study, contained surface water throughout the spring; however, the number of wetlands varied somewhat from one year to the next depending on moisture conditions. Shorelines were the edges of permanent, deep water bodies larger than 10 acres.

A number of distinct habitat types were characteristic of each category. Within the wetlands the following habitat types were recognized: a) Coarse Sedges, b) Fine Sedges/Sedge Bog, c) Shrub Swamp, d) Deep Water Ponds, e) Sedge-Shrub, f) Acid Bog, g) Leaf Litter/Hardwood Swamp, h) Flooded Pasture, and i) Other Emergents. The following types were recognized for shorelines: j) Sand, k) Floating Mat, l) Flooded Sedge/Shrub, and m) Other Emergents. Each habitat type is briefly described below and for wetland types the approximate corresponding USFWS wetland classifications according to Shaw and Fredine (1956) are given in parentheses.

Wetlands:

(a) Coarse sedge - Coarse-leaved sedges such as _Carex lacustris_, _C. rostrata_, and _C. atheroides_ were the dominant species. These stands, typically smaller than two acres, comprised over 30 percent of the total number of wetlands in the study area. Water depths of up to several feet were common in the spring and about 50 percent of these wetlands retained water throughout the summer in most years. (Type 3 and Type 4-Inland deep fresh marshes).

(b) Fine Sedge/Sedge Bog - Fine-leaved sedges and grasses such as Carex lasiocarpa, and C. aquatilis and blue-joint Calamagrostis canadensis were the dominant species. Flooded sedge meadows were common in the study area and approximately 60 percent of these wetlands were larger than two acres. If the sedge stand contained 20-50 percent areal cover by acid bog plants it was designated as a sedge-bog. These wetlands contained up to several feet of water in the spring and many retained water throughout the summer in most years. (Type 2-Inland fresh meadows and Type 3-Inland shallow fresh marshes).

(c) Shrub Swamp - These stands consisted of 50 percent or more areal cover by shrubs such as willow, speckled alder, or red osier dogwood (Cornus stolonifera). Shrub swamp wetlands contained as much as several feet of water in the spring. Stands varied in size from less than two acres to nearly 100 acres. (Type 6-Shrub swamps).

(d) Deep Water Ponds - Wetlands that contained no dominant emergent vegetation. These ranged in size from less than one acre to nearly 10 acres, usually steep sided, with depths up to approximately six feet and usually permanent in nature. (Type 4 and Type 5-Inland open fresh water).

(e) Sedge-Shrub - Stands that consisted of either coarse or fine sedges in which shrubs comprise 20-50 percent of the vegetation cover. (Types 2, 3, 4 and 6).

(f) Acid bog - Vegetation stands consisting of 50 percent or more areal cover acid bog plants such as leather-leaf

(*Chamaedaphne calyculata*) and labrador-tea (*Ledum groenlandicum*). In many instances portions of these stands were flooded to a depth of several feet and the stand was usually surrounded by a water filled "moat" supporting a shrub swamp vegetation stand. (Type 8-Bogs).

(g) Leaf Litter/Hardwood Swamp - Leaf litter wetlands were generally shallow and temporary in nature with no characteristic vegetation but usually having a complete forest canopy. Hardwood swamps were more permanent and of greater depth and the forest canopy frequently consisted of typical lowland hardwoods such as black ash (*Fraxinus nigra*) and American elm. All wetlands in this group were less than two acres in size. (Type 1-Seasonally flooded basins or flats and Type 7-Wooded swamps).

(h) Flooded Pastures - This type resulted when standing water occurred in pastures. These were shallow, temporary and localized in distribution and could materialize during prolonged rains. These wetlands were less than two acres in size. (Types 1 and 2).

(i) Other Emergents - This group actually consisted of several distinct stands combined because of low frequency of occurrence. Cattail (*Typha* spp.) wetlands and wetlands dominated by horsetail (*Equisetum* spp.) were included in this group. All wetlands in this group were less than two acres in size. (Types 3 and 4).

Shorelines:

(j) Sand - Characterized by a firm beach consisting of sand, gravel, or rocks. Shoreline vegetation was sparse and frequently a distinct bulrush or Phragmites band ran parallel to the waters edge beginning at least several yards out from the shoreline. Shoreline slope was usually gradual providing a shallow water zone up to several yards wide.

(k) Floating mat - Floating vegetation mat consisting mostly of fine sedge species and frequently scattered shrubs at the waters edge. The mat was typically "spongy" and the drop-off was usually abrupt at the mat's edge.

(l) Flooded Sedge/Shrub - Identified by sedges or shrubs rooted to a generally firm bottom. Sedges consisted of either fine or coarse-leaved species and were frequently mixed with shrubs such as alder and willow overhanging the waters edge. Shoreline drop-off was usually gradual providing a shallow water zone up to several yards wide.

(m) Other Emergents - This group included several distinct vegetation stands, mostly cattail, and infrequently spike-rush (Eleocharis palustris). Vegetation was rooted to a firm or soft bottom with a gradual or moderate slope.

SUMMARY OF DATA COLLECTED

A total of 77 radio-marked mallards and wood ducks provided data for this study. Sixty-eight percent of all ducks radio-marked were females and wood ducks comprised nearly 63 percent of the total (Table 2). In addition to radio tracking data numerous observations of color-marked individuals and unmarked birds were made. A total of 5717 radio locations or visual observations were recorded and used in data analysis (Table 3). Radio-marked birds provided 4502 locations on over 2000 duck-days (the number of days each duck was located). Serious transmitter difficulties were encountered during the 1968 season resulting in an average tracking period of approximately 14 days per bird. An improved transmitter provided an average tracking duration of over 30 days in 1969 and 1970.

Occasionally radio-marked birds would disappear and could not be located in or adjacent to the study area. It was assumed in these cases that: 1) the transmitter had failed, 2) the bird had strayed a considerable distance beyond the study area boundaries, or 3) the individual was killed by a predator and disposed of in a manner that the signal was not easily detected or the predator rendered the transmitter inoperative. In 1968 transmitter failure probably accounted for many of the unexplained disappearances. After 1968, transmitters were considered highly reliable and very few failures were documented or suspected. During the three field seasons several instances were noted where individuals

Table 2. Radio-marked mallards and wood ducks providing data on habitat use and/or home range, April through June 1968-1970.

	1968		1969		1970		
	Male	Female	Male	Female	Male	Female	Total
Mallards	3	6	3	4	5	9	30
Wood ducks	4	9	3	14	6	11	47
Total	7	15	6	18	11	20	77

Table 3. Location and observation data obtained for mallards and wood ducks between April and June, 1968-1970[a].

Location and/or observation data	1968		1969		1970		Totals
	Mallards	Wood ducks	Mallards	Wood ducks	Mallards	Wood ducks	
Radio-marked birds (non-visual)	326	418	537	1108	842	888	4119
Radio-marked birds (visual)	29	56	50	109	96	43	383
Color-marked birds[b] (visual)	11	107	12	19	5	5	159
Unmarked birds (visual)	324	190	103	58	298	83	1056
Totals	690	771	702	1294	1241	1019	5717

a Habitat and behavioral data were recorded for all visual observations. In most cases only location was recorded for a radio-marked bird triangulated but not observed.

b Includes radio-marked birds marked in 1968 and 1969 if transmitter inoperative.

or pairs strayed out of the area after radio-marking. This phenomenon occurred most frequently in the early spring when birds were probably still unsettled; however, it was occasionally noted throughout the field season. In one case a pair of wood ducks, captured and marked on the Mississippi River in early April, disappeared and was subsequently relocated several days later approximately 8 miles up river. A similar situation occurred with a mallard pair. These birds were evidently still transient when captured and marked. During each of the three years wood ducks radio marked as pairs slowly drifted along a chain of lakes or wetlands, eventually settling down in one area. In other cases wood duck pairs remained in one area for several weeks and then suddenly shifted their range by a mile or more. Occasionally post breeding mallards en route to a distant molting area may have been inadvertently marked. Birds that appeared to be transient were not considered in the home range or habitat use analysis.

Although few cases of predator kills were actually documented during the spring and early summer, the known cases represent a minimum, and the actual rate was certainly higher. Known predation of radio-marked birds is summarized in Table 4. A total of four birds were known to be taken by predators, three wood duck hens and one mallard hen. All three wood ducks were killed by avian predators. Two of these were evidently killed during an off-nest period by great-horned owls. A goshawk was the suspected predator of the third wood duck hen.

Table 4. Known predator loss of radio-marked females during April-June 1968-1970.

Year	Mallards		Wood ducks		Totals	
	No. killed	Percent of species marked	No. killed	Percent of species marked	No. killed	Percent of birds marked
1968	0	0	2	15.4	2	9.1
1969	1	14.3	1	5.9	2	8.3
1970	0	0	0	0	0	0
Totals	1	3.3	3	6.4	4	5.2

The only mallard killed was taken on its nest by a mink. No observations were made of predator killed males. Although sample sizes were small in this study, it is my opinion that observed predation rates were not much different from the estimates reported by Keith (1961:44) for ducks breeding in southern Alberta.

A total of 41 nests or nest sites was observed during the study. Some hens were probably marked between nesting attempts or during a renesting. Nests of several marked birds were initiated much later than would be expected and were probably renests. In several other cases where a nest was found but then destroyed by predators, the hen was subsequently located in cover that was most likely used for nesting although no renest was discovered. Our efforts to keep the disturbance of radio-marked ducks at an absolute minimum prevented the documentation of short term nests.

RESULTS

HOME RANGE DATA

Data describing waterfowl mobility provide insight into many ecological relationships when analyzed in conjunction with various environmental factors such as habitat features and population densities. Mobility data also provide a basis for comparison within and among species.

This section is concerned mainly with the analysis of mallard and wood duck mobility data in order to delineate and compare various mobility patterns under different conditions without emphasis on habitat features. A subsequent section will integrate more thoroughly the analysis of mobility and habitat data.

Home range was determined for individuals of both sexes and for pairs when both members were radio-marked. Movements were considered from the time of initial marking until incubation was terminated in the case of hens or until the drake departed the area in the case of males. If a nest site was never located for a hen her movements were used for home range determination until a significant change was observed in the area used or until June 30th, whichever occurred first. Species and sexes were treated as separate groups for most analyses. Wood duck males were separated into two groups; Group I (4 birds) consisted of drakes that were known to be pairs (two with radio-marked hens) and periodic visual observations indicated an apparent "normal" situation.

Group II (5 birds) consisted of one individual that was believed to be unpaired, and three other males that apparently were paired but were observed at least on one occasion with a different female. Another male in this group was marked at the same time as his mate but the hen was killed within several days after marking and the drake was never known to obtain a new mate. Most Group II males appeared to move about more frequently and travelled greater distances than other male wood ducks.

Estimating Home Range

Waterfowl are capable of high mobility and even during the breeding season their movements, though greatly reduced, are still extensive compared to most birds and mammals. Specific habitat requirements and the tendency of some ducks to increase their home range throughout the nesting season complicates the estimation of home range.

The "observation area" curve of Odum and Kuenzler (1955), normally used to determine whether home ranges of territorial animals during a particular phase of the nesting cycle (i.e. pre-nesting, egg laying, and incubation) have been adequately measured, could not be used here because the tracking period usually included several phases in the nesting cycle.

I felt that an accurate estimate of the mean home range for each category of ducks could be obtained by considering only individuals with the longest tracking period and consequently the greatest number of locations. The advantage of this is shown by arbitrarily dividing 22 wood duck females (the largest sample of home range data for a single category of ducks) into two equal groups (Table 5). Group A consists of ducks with 60 locations or less and a mean tracking period per bird of 32 days. Group B has more than 60 locations per bird and a mean tracking period of 42 days. Comparison of the two groups demonstrates that mean home range tends to increase as the number of locations and tracking period increases although standard deviation increases only slightly. Some of the variability between the two groups can be attributed to inadequate sampling of locations but an actual increase in the cumulative home range during the tracking period probably accounts for most of the difference. Group B (birds with the longest tracking period) were used for determining the mean home range for the wood duck female category discussed in this section. I attempted to improve the accuracy of mean home ranges for the other species and sex categories in a similar manner. In most categories five birds were selected with the most complete tracking coverage which greatly exceeded the minimum standard of 20 locations during a two week tracking period.

Table 5. Comparison of mean home ranges and home range standard deviations of two groups of female wood ducks with differing number of locations and tracking days.

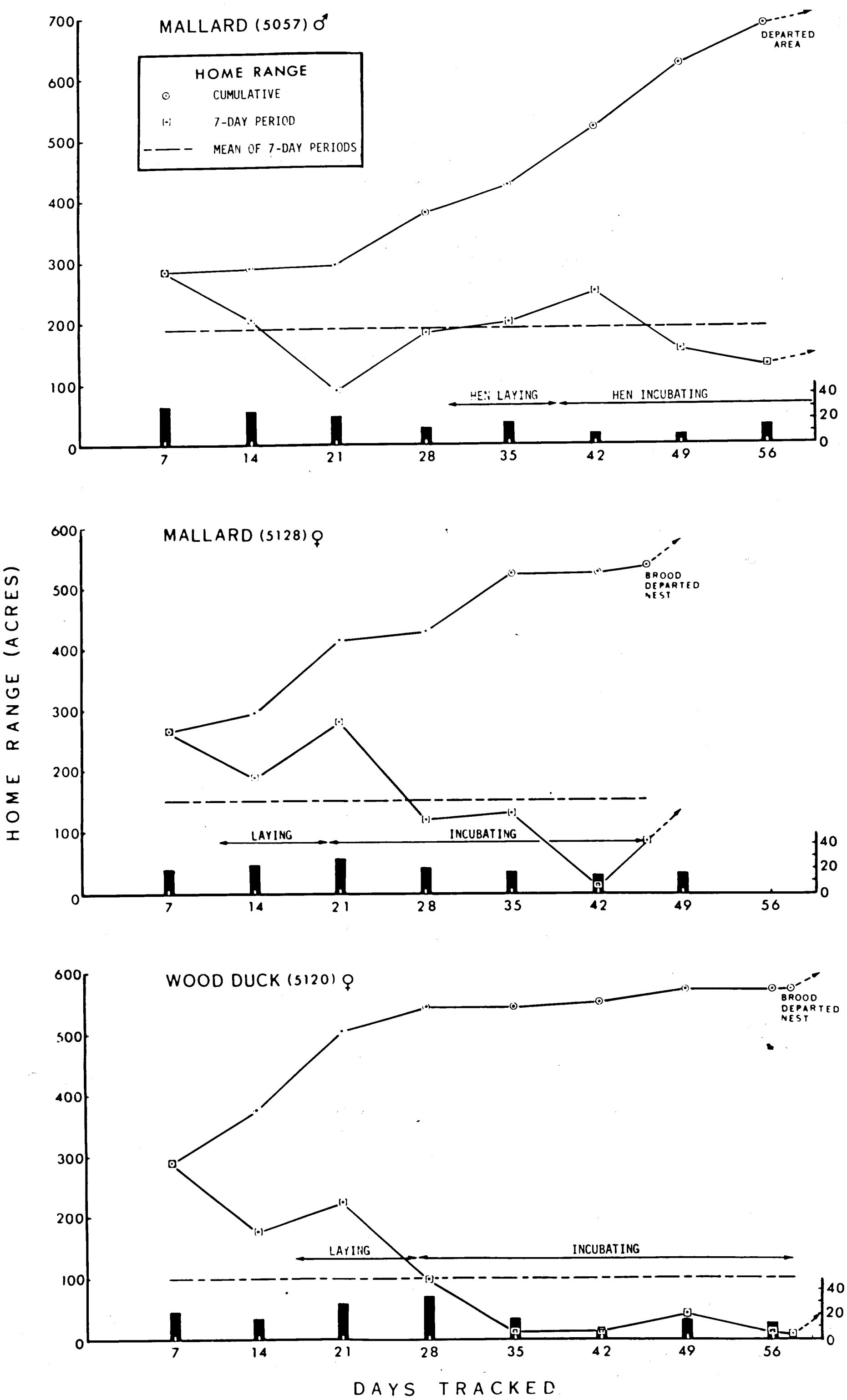
Group (locations/bird)	Sample size	Mean tracking period (days)	Mean home range (acres)	Home range S.D.
A (≤ 60)	11	32	321	170
B (> 60)	11	42	483	189

Home Range and Mobility of the Individual

A modification of Odum and Kuenzler's (1955) "observation area" curve similar to Ables (1969) was used to demonstrate that home ranges in some birds appeared to increase over the tracking period while others tended to stabilize. The minimum area method was used to measure the size of the home range for each seven-day period and to calculate the cumulative increase in the total range size. An evaluation of these results indicates that several situations may exist: 1) a range may reach a stable size and not increase thereafter; 2) it may reach a stable size and maintain this for a period of time but thereafter continue to increase; or, 3) it may continue to increase throughout the tracking period. Figure 6 shows the relationship between the cumulative home range, home range for each seven-day period and the breeding chronology of a male and female mallard and a female wood duck. The figure is illustrative of several ways in which the observed home range may change.

Changes in the size of the home range during the tracking period may indicate changes in the mobility of some birds during the breeding season. It was apparent that only a portion of the total home range finally recorded was used during any given seven-day period. A pair or an individual may continually return to one location over a period of weeks but during the same period may be exploring new areas. Factors which might explain the changes in size of a home range are: 1) disturbances

Figure 6. Relationship between the cumulative home range, home range for each 7-day period and the breeding chronology of a male mallard (5057), female mallard (5128), and a female wood duck (5120). Numbers of locations for each 7-day period are also indicated.

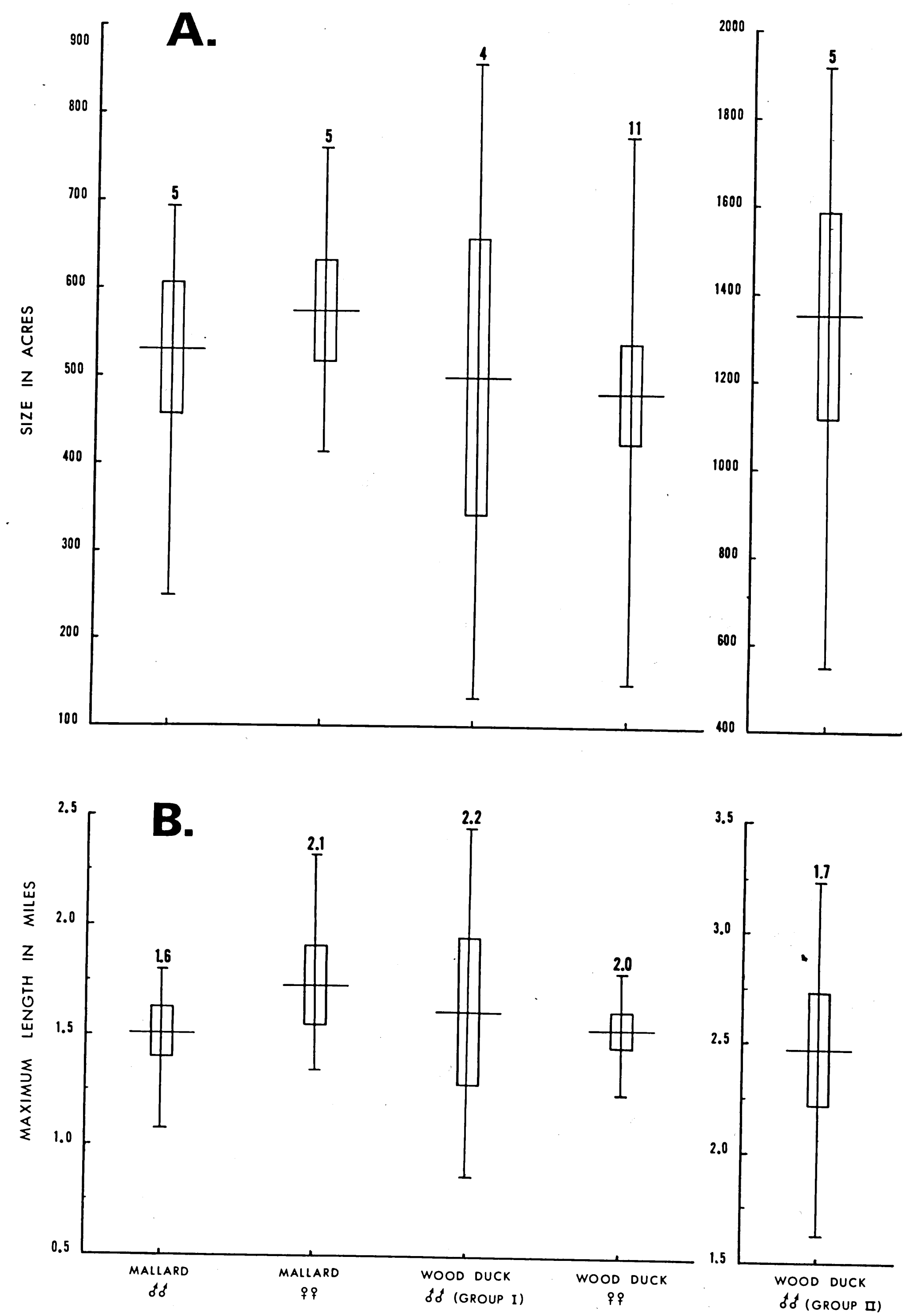

MALLARD (5057) ♂
HOME RANGE
CUMULATIVE
7-DAY PERIOD
MEAN OF 7-DAY PERIODS
DEPARTED AREA
HEN LAYING
HEN INCUBATING
MALLARD (5128) ♀
BROOD DEPARTED NEST
LAYING
INCUBATING
WOOD DUCK (5120) ♀
BROOD DEPARTED NEST
LAYING
INCUBATING
HOME RANGE (ACRES)
LOCATIONS EACH 7-DAY PERIOD
DAYS TRACKED

by predators or a nest loss, 2) changes in the habitat necessitating a shift in feeding or loafing area, 3) reconnaissance by an incubating hen to seek out desirable feeding and brood rearing areas, 4) changes in the behavior patterns of adjacent pairs, 5) wanderings of the drake prior to abandoning the hen.

According to the "observation area" curves less than 50 percent of the birds demonstrated any stability in their home range during the tracking period. I felt that in many cases the ranges of radio-tracked ducks actually increased over the tracking period and that a stabilized range did not exist in these cases.

Means, standard errors, and ranges of home range size and maximum length for 29 radio-marked ducks separated by species and sex are summarized in Figure 7, A. and B. With the exception of wood duck Group II males, mean home ranges were approximately 500 acres. Values for mallard females were slightly larger than for the males primarily due to the longer tracking period for the females. In addition, females may expand the home range just before egg hatch occurs. Mallard males in some cases extended their home range while also becoming more gregarious shortly before abandoning the hen (usually mid-incubation), but their final departure was abrupt. Maximum length within each group also showed considerable variation and the relative magnitude of mean maximum length was approximately proportional to the mean

Figure 7. Means, standard errors, and ranges of size (A.) and maximum length (B.) of home ranges of mallards and wood ducks. Horizontal lines, rectangles, and vertical lines represent means, one standard error on each side of means, and ranges respectively. Numbers above the symbols indicate sample size in A. and mean index of linearity in B.

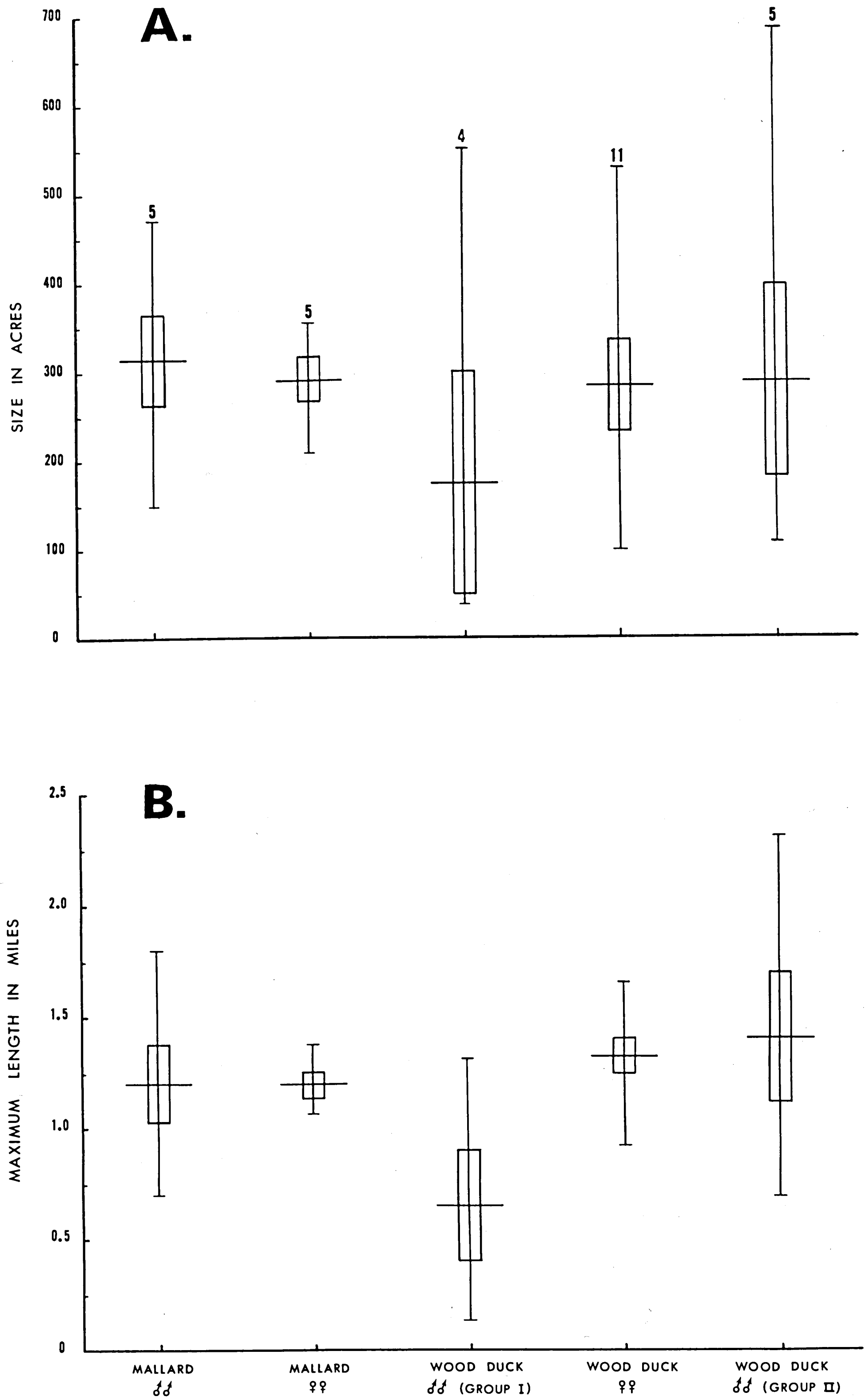

A.
B.
SIZE IN ACRES
MAXIMUM LENGTH IN MILES
900
800
700
600
500
400
300
200
100
2000
1800
1600
1400
1200
1000
800
600
400
5
5
4
11
5
2.5
2.0
1.5
1.0
0.5
3.5
3.0
2.5
2.0
1.5
1.6
2.1
2.2
2.0
1.7
MALLARD ♂♂
MALLARD ♀♀
WOOD DUCK ♂♂ (GROUP I)
WOOD DUCK ♀♀
WOOD DUCK ♂♂ (GROUP II)

home range area for each group. Index of linearity (Ables 1969:114), indicated that most home ranges were decidedly linear. Considerable variation exists within each group, but particularly among wood duck males. This variation may be attributable to individual genetic difference, environmental factors, and to some extent to tracking errors or inadequate sampling. Repeated observations of several relatively sedentary individuals indicated no apparent abnormalities, such as difficulty in flying. Data for individual radio-marked ducks are provided in Appendix I.

Wood duck males that were believed to be unpaired or that demonstrated a weak pair bond tended to wander throughout the tracking period and covered relatively large areas. Four of five individuals utilized areas in excess of 1000 acres and the largest was nearly 2000 acres in size. Some wood ducks appeared to be more closely associated with a female and these seemed to wander less. Wood ducks in many instances did not demonstrate the strong pair bond typical of many species of waterfowl. This aspect of wood duck behavior deserves a more thorough investigation than was possible in this study.

Means, standard errors, and ranges of primary range size and maximum length are presented in Figure 8, A. and B. Primary range (described on page 22) represents the area in which the duck was most likely to be found and was somewhat similar to the "core area" described by Kaufman (1962:170) and the "biological center of activity" of Ables (1969:111).

Figure 8. Means, standard errors, and ranges of size (A.) and maximum length (B.) of primary ranges of mallards and wood ducks. Horizontal lines, rectangles, and vertical lines represent means, one standard error on each side of the means, and ranges respectively. Numbers above the symbols in A. indicate sample size.

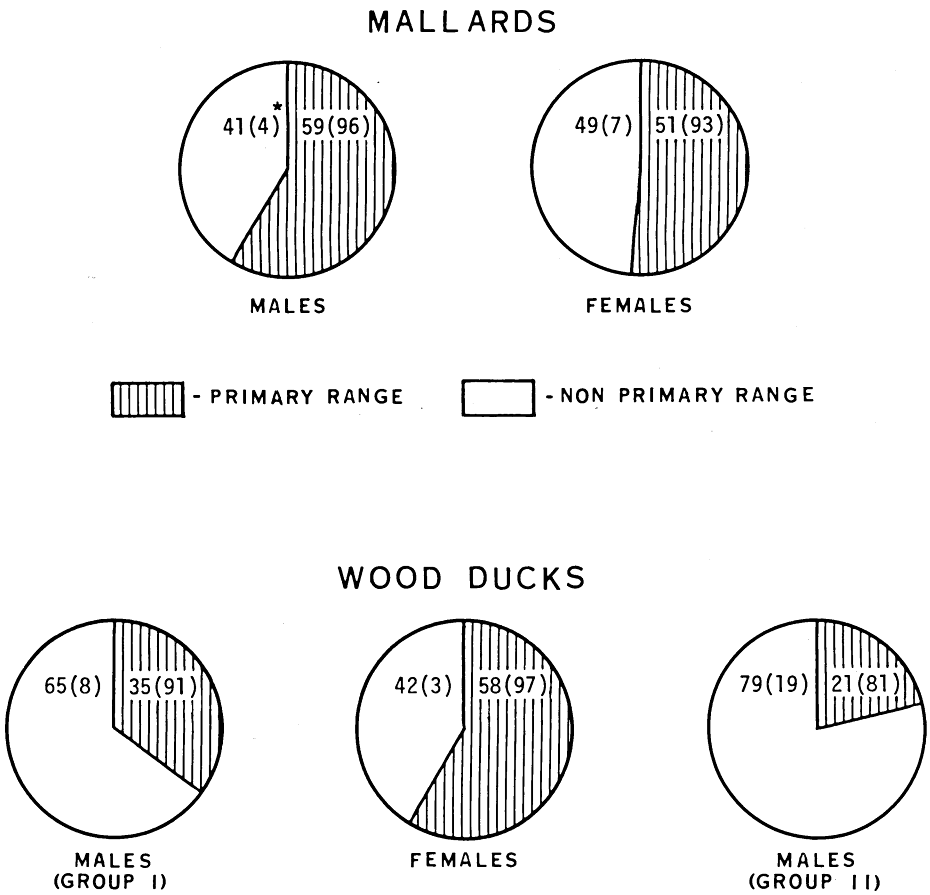

A.
B.
SIZE IN ACRES
MAXIMUM LENGTH IN MILES
700
600
500
400
300
200
100
0
2.5
2.0
1.5
1.0
0.5
0
5
5
4
11
5
MALLARD
♂♂
MALLARD
♀♀
WOOD DUCK
♂♂ (GROUP I)
WOOD DUCK
♀♀
WOOD DUCK
♂♂ (GROUP II)

Primary range tended to be considerably smaller than the home range although the mean maximum length of the primary range did not change proportionately. In many cases the primary range of radio-marked ducks actually consisted of two or more shoreline areas or wetlands which were used consistently from day to day. Primary range represented a mean of about half of the home range for mallards and wood duck females (Fig. 9). Group I and Group II wood duck male primary ranges averaged about one third and one fourth of the home range, respectively. The greatest amount of variation was among wood duck males and the least among mallard females. On the average the primary area includes the greatest proportion of locations for female wood ducks and least for the Group II male wood ducks but the proportion of points inside the primary range varied considerably within groups. Group II male wood ducks, with typically high mobility and large home ranges, tended to use a primary range that was approximately the same size as other groups. Male wood ducks known to be paired showed large variation in the size of the primary range but three of the four spent over 80 percent of their time in an area less than 100 acres. Data for individual birds are provided in Appendix I.

Home Range and Mobility of the Pair

Tracking data were obtained on four mallard and four wood duck pairs where both members of each pair were radio-marked.

Figure 9. Mean percentage of the home range that is considered the primary range is indicated by the circular diagrams. Percentage values are indicated. Numbers in parentheses indicate the average percentage of locations in the primary range and in the nonprimary range.



*Percentage of locations inside and outside the primary range are shown in ( ).

Table 6 indicates the mean size and maximum length of mallard and wood duck pair home ranges. In most cases the data represent movement recorded only during a portion of the nesting period. Pair status was determined by visual observations or if the radio fixes for both members of the pair were in close proximity the members of the pair were assumed to be together.

Female wandering outside the limits of the pair home range in many cases occurred after the departure of the male. Wood ducks paired with Group II males indicated the greatest tendency to stray outside the pair home range. Pair home ranges were smaller than ranges of individual members of a pair. This situation was partly due to signal nulls[1] indicating only one member of a pair was present when actually both were together. Members of a pair were not always together during the hen's off-nest period but were occasionally a considerable distance apart. Members of each of the four mallard pairs were together an average of 74 percent of the time that their locations were sampled. Wood duck pairs involving Group I males (2 pairs) and Group II males (2 pairs) were together an average of 59 percent and 36 percent respectively, of the time members of each pair were located. These percentages

[1] Signal may not be received when the transmitting antenna is oriented in a certain way relative to the receiving antenna.

Table 6. Mean size and maximum length of mallard and wood duck pair home ranges. Mean percentage of female locations within the pair home range, are also indicated.

Species	Sample size	Mean home range[a] (acres)	Mean max. length (miles)	Percent of female locations within pair H.R.
Mallard	4	434	1.50	92.1
Wood duck (Group I)	2	417	1.58	93.1
Wood duck (Group II)	2	242	1.59	73.5

[a] Using only locations where both members of the pair were together.

consider only the off-nest locations of females known to be nesting and represent minimum values. Comparison between groups indicate that mallard pairs appeared to spend the greatest proportion of time together and wood duck pairs involving Group II males were together the least. Home range data for individual pairs are presented in Appendix II.

Home Range and Mobility of Nesting Hens

For purposes of analysis, nesting was divided into two periods; the "pre-incubation" period included both the pre-nesting and egg-laying phases, the "incubation period" included only the incubation phase. Nesting chronology was determined by a combination of: 1) back-dating from the time of egg hatch, 2) examination of the nest during the incubation period or shortly after nest destruction by a predator, and 3) analyzing movement patterns of the bird. Mean home range size and mean maximum distance travelled from the nest for mallard and wood duck hens during the pre-incubation and incubation periods are indicated in Table 7. Data suggest that hens may have a larger home range during the pre-incubation period than during incubation as indicated by the mean difference between the two periods. This difference is influenced to a great extent by the pre-nesting movements of the pair. Large differences between the two periods were not always apparent and in some cases the hen actually showed a greater tendency

Table 7. Means for home range sizes and maximum distances travelled by hens from the nest during the pre-incubation and the incubation periods. Means for the differences between home range size of hens tracked during both periods are indicated.

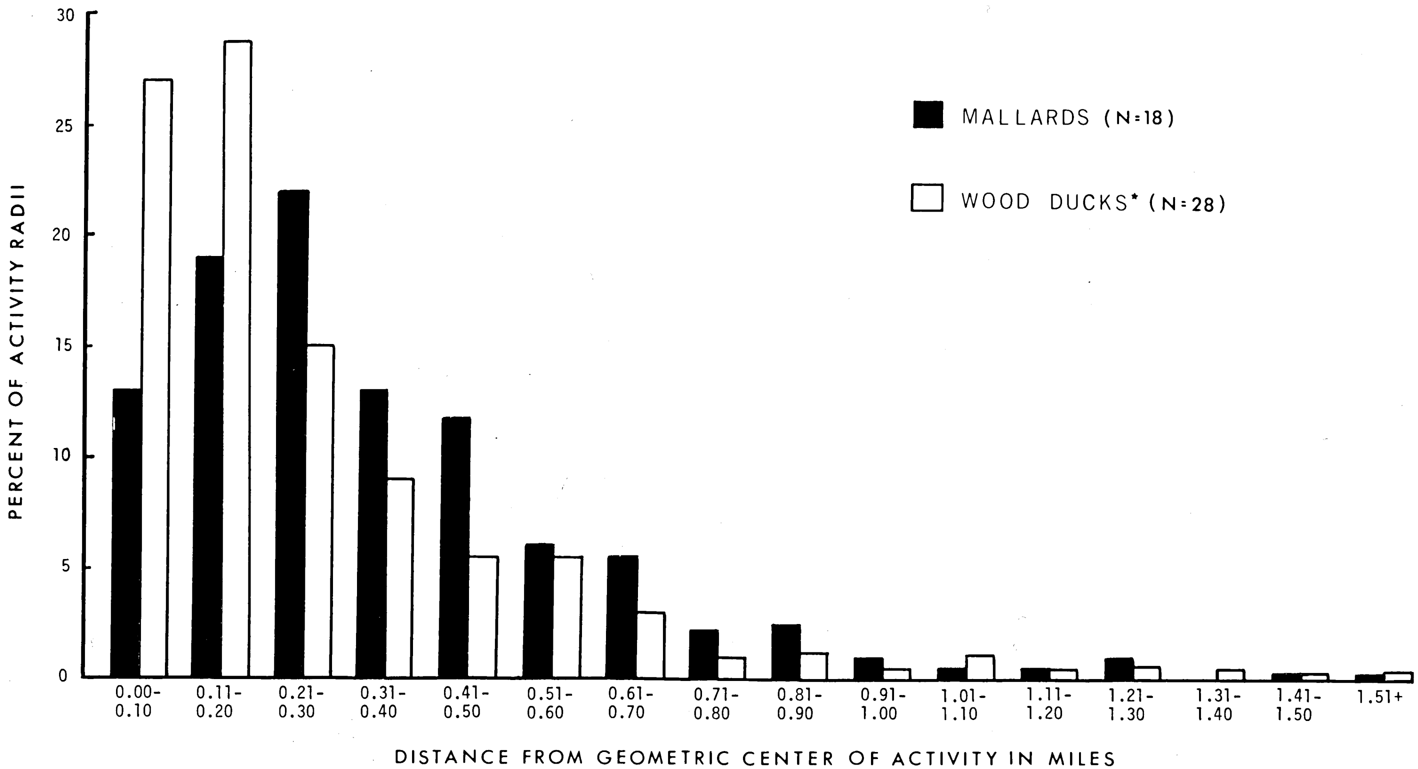
Species	Pre-incubation period: Size (acres)	Pre-incubation period: Max. dist. from nest (miles)	Incubation period: Size (acres)	Incubation period: Max. dist. from nest (miles)	Mean difference (pre-incubation H.R.-incubation H.R.)
Mallard	466(4)	1.38(4)	152(6)	0.95(6)	+281(4)
Wood duck	367(4)	1.07(4)	215(14)	1.09(14)	+235(4)

to range during the incubation period. Home range data for nesting hens are presented in Appendix III.

Other Mobility Estimates

As an alternative to area determination the geometric center of activity (Hayne 1949) and the frequency distribution of lengths of activity radii from this point have been useful in describing home ranges (Odum and Kuenzler 1955, Tester and Siniff 1965). This technique was incorporated to permit additional comparisons between species. Approximately 54 percent of the mallard locations and 70 percent of wood duck locations (except Group II males) were within a 0.3 mile radius of the geometric center of activity (Fig. 10). Mean activity radius was 0.36 miles for mallards and 0.25 miles for wood ducks. Difference between these means was significantly different from zero ($t = 2.42$, $df = 42$; $P < 0.05$). An additional comparison between females of both species was obtained by determining the activity radii from the nest site. Locations within 0.10 mile of the nest included both on-nest and off-nest situations because in most cases it was difficult to determine the exact position of the hen. Inclusion of the on-nest locations resulted in the highly skewed distributions for both species (Fig. 11). Mean activity radius for nesting mallard and wood duck hens were 0.33 and 0.32 mile, respectively. Difference between these means was not significantly different from zero ($t = 0.11$, $df = 36$; $P > 0.05$).

Figure 10. Distributions of lengths of activity radii from the geometric center of activity for mallards and wood ducks. Group II wood ducks are not included.



* GROUP II MALE WOOD DUCKS NOT INCLUDED

Home Range and Spacing

Limited visual observations obtained during this study revealed that woodland breeding mallards demonstrated typical territorial behavior (e.g. hostility, aerial pursuits) described in the literature (McKinney 1965). However, these encounters may be relatively limited in occurrence due to visual partitioning of small lakes and wetlands by shrub and timber. Because of the low frequency of encounters this mechanism may have less effect on the spacing of pairs and the size of the home range than in more open habitat.

Wood ducks appeared to be much more gregarious than mallards. Pairs were generally tolerant of other individuals and the few aggressive encounters noted occurred only when individuals were in close proximity.

Home Range Overlap

Home range overlap was analyzed to some extent and was considered only for females. In most cases, data for females permitted the accurate determination of breeding chronology and more females were tracked than males providing more overlapping situations. If one considers only spatial overlap between two female individuals the mean percent of overlap (overlap area/home range x 100) was 35 percent in fourteen situations involving mallards and about 30 percent for sixteen situations involving overlap in wood duck home ranges. Some individuals of both species shared over 50 percent of their home range with an adjacent female. Spatial overlap between two adjacent home ranges cannot be used as a direct indication of the degree of interaction between two individuals; however, the more overlap the greater the possibility that these individuals do interact. Differences between mean overlap in mallards and wood ducks was not significantly different from zero ($t = 0.76$, $df = 28$; $P > 0.05$). In mallards the overlap area always involved one or several lakes. Wood duck overlap zones appeared to be associated mostly with certain wetlands.

Adjacent females with nesting chronologies that were somewhat similar were analyzed in more detail to determine their interactions and intensity of overlap zone use. In 1969 two mallard hens had overlapping ranges and the expected dates of their egg hatches differed by less than three weeks (Fig. 12). The late pair (hen 5080 and unmarked male) was located in the overlap area 80 percent of the time but only about 8 percent of the other pair's locations (hen 5056 and marked male 5057) were in the overlap area. The two hens used distinctly different parts of the lake shoreline until several days prior to the departure of the marked drake at which time hen 5080 (and presumably her drake) began using specific shoreline areas traditionally used by the other pair. No evidence of interaction between the two pairs was obtained.

In 1970 adjacent mallard hens had overlapping ranges and their expected hatch dates differed by approximately nine days (Fig. 13). The late pair (hen 5134 and unmarked male)

Figure 12. Home ranges of mallard hens 5056 and 5080. Dotted and dashed line indicates the manner in which the shoreline was partitioned between the two hens. Locations of Hen 5056 and marked male (5057) were south of the line while Hen 5080 remained mostly to the north. Nest locations are indicated. Nesting chronologies of the hens differed by approximately 20 days.

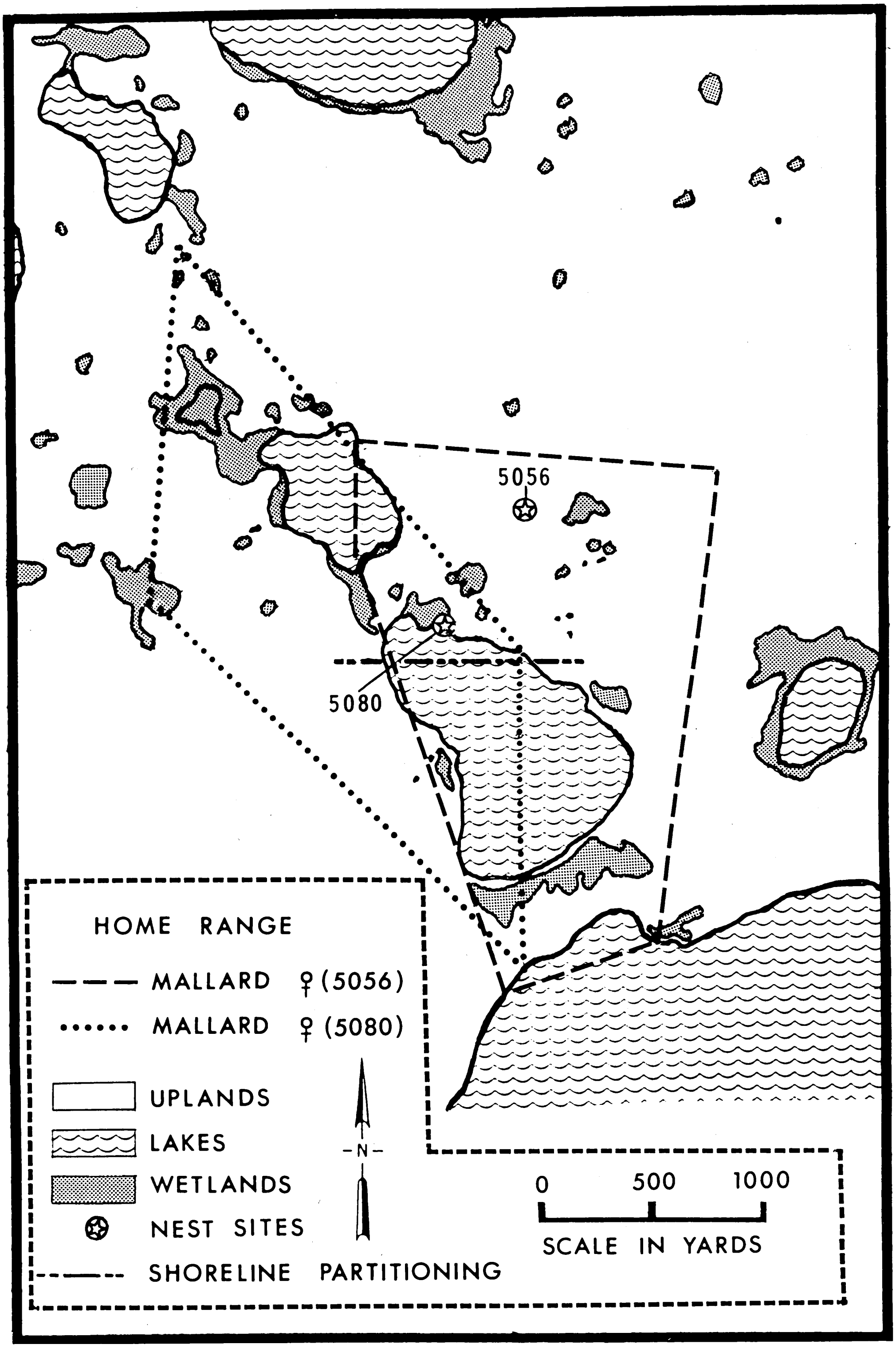
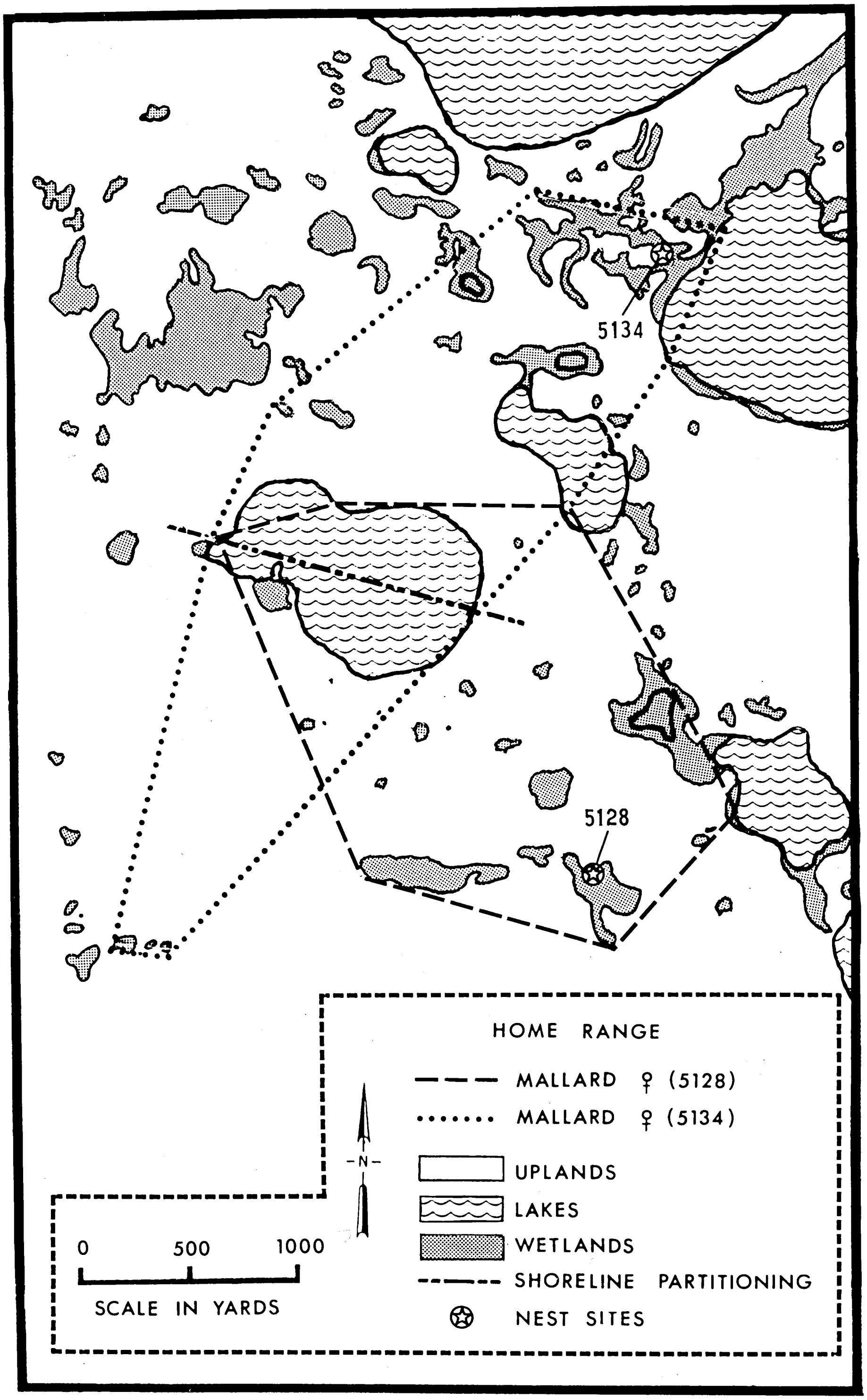

5056
5080
HOME RANGE
MALLARD ♀(5056)
MALLARD ♀(5080)
UPLANDS
LAKES
WETLANDS
NEST SITES
SHORELINE PARTITIONING
N
0 500 1000
SCALE IN YARDS

Figure 13. Home ranges of mallard hens 5128 and 5134. Dotted and dashed line indicates the manner in which the shoreline was partitioned between the two hens. Locations of Hen 5128 and marked male (5129) were mostly south of the line while Hen 5134 remained mostly to the north. Nest locations are indicated. Nesting chronologies of the hens differed by approximately nine days.


5134
5128
HOME RANGE
MALLARD ♀ (5128)
MALLARD ♀ (5134)
N
UPLANDS
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SCALE IN YARDS

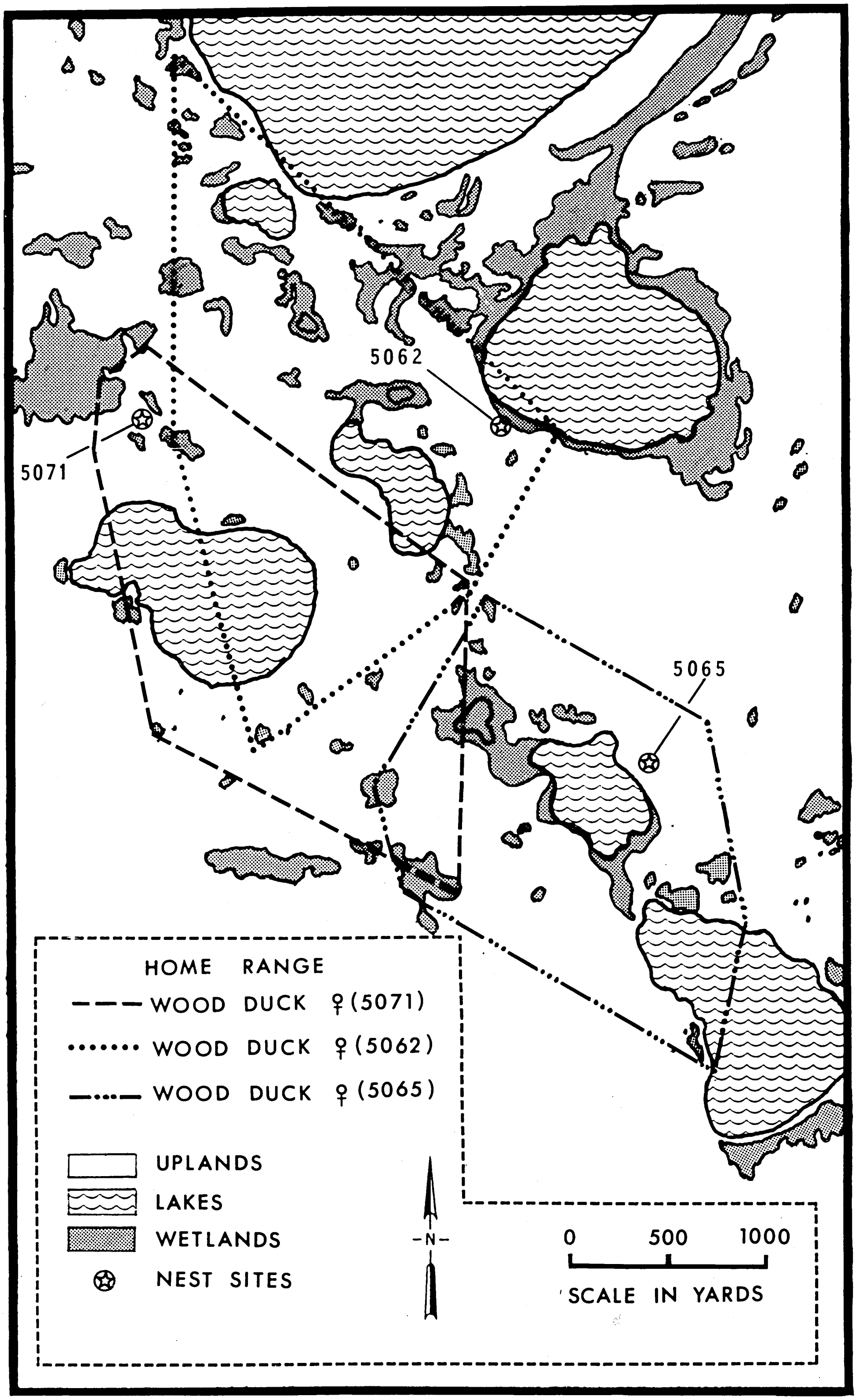
was located in the overlap zone about 36 percent of the time and about 19 percent of the other pair's (hen 5128 and marked male 5129) locations were in the zone. Both females tended to use different parts of the lake shoreline within the zone. Some sharing of specific shoreline area was indicated but in only one case was this known to occur during the same 24 hour period.

The only wood duck hens with overlapping ranges and similar nesting chronologies were three individuals tracked in 1969. Two individuals (5062 and 5065) overlapped the third (5071) (Fig. 14). The expected hatch dates for eggs of overlapping ducks were within ten days of each other. Percentage of fixes located in the overlap zones varied between one and 16 percent. Certain wetlands were shared by adjacent hens; however, the only evidence of interaction (i.e. both ducks used the same wetland during a single 24 hour period) was indicated during the last few days of 5071's incubation period when this bird and 5062 used the same wetland during the same day. In other situations as many as three wood duck hens have been known to use a small wetland at the same time during the incubation phase of at least one of the birds.

Night Activity

Tracking data did not indicate that birds flew about during darkness although birds were known to take flight when disturbed, particularly on clear nights. Ducks were

Figure 14. Home ranges of wood duck hens 5062, 5065 and 5071. Nesting chronologies of the hens differed by less than ten days.



5062
5071
5065
HOME RANGE
WOOD DUCK ♀(5071)
WOOD DUCK ♀(5062)
WOOD DUCK ♀(5065)
UPLANDS
LAKES
WETLANDS
NEST SITES
N
0 500 1000
SCALE IN YARDS

frequently active at night, probably swimming and feeding, as evidenced by the signal quality.

DISCUSSION

HOME RANGE AND MOBILITY

Analysis of tracking data during this study indicated that most home ranges changed noticeably in size and shape throughout the tracking period. Numerous factors, both environmental and physiological, may cause changes in mobility and movement patterns which may result in apparent changes in home range. Observations on canvasback (*Aythya valisineria*) pairs by Dzubin (1955:282) and gadwalls (*Anas strepera*) by Gates (1962:49) suggested that pairs were more mobile during the period before nesting than after egg laying began. Status of some birds prior to radio-marking could not be determined by indirect evidence (i.e., backdating a nest); however, these individuals were probably captured during pre-nesting or prior to or after the loss of the initial nest. In nearly all cases tracking data indicated that both mallards and wood ducks were most mobile early in the breeding season and mobility usually decreased as the nesting season progressed. This activity was indicated by a greater tendency to travel long distances as well as an apparent increase in frequency of movements. Activity of pairs during this period probably related to the establishment of the pair in the area, familiarization with the terrain, nest searching and food gathering. Sowls (1955:109) described exploratory flights of the pair just prior to egg laying. According to McKinney (1965:94) the "nuptial flights" described by Hochbaum (1944:28-29) served primarily as home range reconnaissance flights. Nesting hens generally moved about a larger range prior to commencing incubation than during incubation. Gates (1962:51) reported that early nesting gadwall pairs appeared to deliberately reduce their daily ranges in order to minimize the number of possible encounters with other pairs.

Reluctance to move considerable distances was not necessarily typical of the late stage of the nesting period. Mallard hens appeared to spend much of their off-nest time feeding at nearby wetlands or shorelines as Gates (1962:52) had observed in nesting hen gadwalls in Utah; however, occasional movements to distant lake shorelines were made which may have been reconnaissance flights prior to initial brood movement.

Dzubin (1955:286) observed that ranges of drake mallards in Manitoba appeared to increase in size soon after incubation had begun and that they began to associate with other males during this period. Coulter and Miller (1968:19) noted that after 8-12 days of incubation, mallard and black duck drakes began to spend more time in company with small groups of drakes. Several mallard drakes tracked during the incubation period of the hen tended to wander beyond the area normally used and spent some of their time on lake shorelines, presumably loafing. Occasional visual observations on these birds showed that they were in the company of other males.

Apparently, new habitat was being investigated by some radio-marked birds throughout the tracking period resulting in a continually increasing cumulative home range. The tendency to investigate new habitat was probably strongest during the prenesting period; however, for drake mallards the tendency seemed to increase somewhat during the hen's incubation. Range extension of the males during this time was not extensive but the final departure was very abrupt. When the drake departed it moved rapidly out of the study area and was never located again. All male mallards and most females were known to depart the study area prior to molting. In Alberta, Keith (1961:95) noted that during the interval between hen abandonment and just prior to molt large numbers of drakes wandered about as they chose. Incubating hen mallards also ventured into new areas during off-nest periods but this was not frequently observed.

Information regarding the mobility of wood ducks during the nesting season was not found in the literature. In this study the mobility of wood ducks was similar in many respects to that of mallards. Pre-nesting or early nesting seemed to be the period of highest mobility. On the average wood duck hens used a larger range prior to incubation than during incubation.

During the study one marked wood duck pair and four hens (approximately 20 percent of wood duck hens tracked) were never known to establish a nest. These birds remained in one area for at least several weeks which indicated that a nesting effort could have taken place but confirmation was never made.

After residing in one location for as much as four weeks, an abrupt home range shift occurred. Several of these birds left the study area but the others re-established residence in a shrub swamp bordering a large lake at the north end of the study area. No nesting attempts were known to take place after the move. Both members of the marked pair were together periodically for several weeks after the move. The cause of this behavior was not determined but it seemed unlikely that a nesting attempt beyond the early stages of incubation could have gone undiscovered. Grice and Rogers (1965:35) stated that in Massachusetts yearling wood duck hens in some cases failed to establish a nest because of increasing population and limited numbers of nest boxes. Ages of wood duck hens that failed to nest were not known but the experience of these individuals in selecting a cavity may have been a factor in their apparent non-breeding.

Variations between individuals of the same species and sex in the size and maximum length of the home range, index of linearity, primary range and other measurements were very apparent. Home range characteristics of the individual may be determined by numerous factors such as genetics, nesting chronology, or conspecific interactions, but the effect of the habitat is probably the most important. Layne (1954:256), studying red squirrels (Tamiasciurus hudsonicus), stated that variation is to be expected in the size of the home range in different environmental situations. Dzubin's (unpubl. ms.) data indicated that ranges of mallards in the parklands and grasslands varied considerably and may be due to wetland densities and other habitat characteristics. Armstrong (1965:619), studying nighthawks (Chordeiles minor) in Detroit, Michigan, noted that home ranges varied more than threefold but showed no significant correlation with the density of any measured environmental feature. Odum and Kuenzler (1955:134) noted that the home ranges of different individuals in two passerine species engaged in the same stage of the nesting cycle showed considerable variation. Mendall (1958:63) noted variation in the size of ring-necked duck home ranges and attributed this to the density of essential habitat requirements in the home range. Some authors generally believe that for many birds and mammals the average size of the home range decreases as the population density increases. Dow (1969:112) indicated a definite reduction in the area occupied or utilized by cardinals (Richmondena cardinalis) under increased population density. However, it would seem that innate mobility and the quality of the habitat would limit the minimum home range size and the most efficient means of fulfilling physiological and psychological needs would establish an upper limit. Blair (1953:21) felt that in rodents the ability to learn the terrain was important in limiting the size of the area over which the animal ranged but this may have little influence in ducks.

Home ranges of both mallards and wood ducks were mostly elongate (index of linearity > 1.00) although a few ranges appeared to be approximately circular. Several home ranges were long and narrow with areas of concentrated use at both ends. In most of these cases the individuals used wetlands located on opposite sides of a large lake. Home range shape appeared to be a function of the distribution of required habitat units perhaps modified to some degree by territorial behavior (mallards) and topographic features of the terrain.

Mean home ranges for paired mallards and wood ducks were very similar; however, significant differences might be demonstrated if larger samples could be compared. Certain unpaired or weakly paired wood duck males ranged over large areas but comparable data on mallard males with a similar status were not obtained.

Dzubin (1955) found considerable differences in ranges occupied by canvasback, mallard and blue-winged teal during the pre-nesting and laying phases. Gates (1962:52) observed movements of six species of waterfowl in Utah and concluded that differences in species mobility were obscure but were at least partly innate. A large number of factors both physiological and psychological determine the size of the home range and the importance of these factors is different between mallards and wood ducks. Woodlands of some type were ancestral breeding grounds of the wood duck but probably not for the mallard and consequently the wood duck may be better adapted to the forest environment. In this study it would appear that the factors determining the size of the home range for mallards and wood ducks have interacted in such a way that both species can fulfill their necessary breeding requirements in approximately the same size home range even though these requirements may be much different.

Home ranges based on visual observations of marked birds have been made in numerous waterfowl studies (Table 8). In general the smaller home ranges characteristic of blue-winged teal and shoveler (Anas clypeata) were probably quite accurately determined. Larger home ranges would be more difficult to determine because of the difficulty in maintaining contact with the animal.

Home ranges of waterfowl breeding in forested habitats reported in the literature were very approximate and wood duck ranges have not been reported. No previous studies used radio tracking techniques in determining home ranges.

Dzubin (1955 and unpubl. ms.) and Drewien (1967) provided comparable home range data on mallards. Sample sizes in some cases are small but it appears that considerable variation exists between the different studies. Studies conducted by Sanderson (1966:219) and Dow (1969:112) indicated that increasing population densities resulted in a decreasing mean home range in mammals and some birds but this situation is not clearly demonstrated in mallards. Dzubin's data for mallard drakes at several locations in Manitoba and Saskatchewan revealed a home range of over 700 acres in a grassland situation (Minnedosa, Man.) and a mean of 81 acres in a parkland region (Roseneath, Sask.). Dzubin (unpubl. ms.) showed that density

Table 8. Summary of waterfowl breeding home ranges and other mobility estimates reported in other studies.

Species	Location of study	Approximate area of home range (acres) and/or mobility estimates	Reference
Tribe Anatini (Dabbling ducks)			
Mallard	Minnedosa, Man.	700+ (1 drake), prenest-mid incubation. Max. length-1.47 mi. (1 drake), 1.06 mi. (1 pair)	Dzubin 1955
"	Ogden Bay Refuge, Utah	Large-unable to estimate	Gates 1962
"	Waubay, S.D.	680+ (2 pairs), breeding season	Drewien 1967
"	Maine and Vermont	Up to 5 square miles, breeding season	Coulter and Miller 1968
"	Roseneath, Sask. (Parkland)	158 (6 drakes), prenest. Mean max. length 0.88 mi. 81 (6 pairs), prenest. Mean max. length 0.47 mi.	Dzubin unpubl. ms.
"	Kindersley, Sask. (Grassland)	431 (8 drakes), prenest. Mean max. length 1.80 mi. 240 (8 pairs), prenest. Mean max. length 0.99 mi.	Dzubin unpubl. ms.
"	North-central Minn.	532 (5 drakes), breeding season. Mean max. length 1.52 mi. 434 (4 pairs), breeding season. Mean max. length 1.50 mi.	This study
Black duck	Maine	"Black ducks wander over parts of several adjacent lakes, brooks and wooded swamps".	Mendall 1958
"	Maine and Vermont	Up to 5 square miles, breeding season	Coulter and Miller 1968
"	St. Lawrence Estuary, Quebec	Daily movements between 5.0 miles or less than 1/8 mile depending on nest location	Reed 1970

Table 8. Continued.

Species	Location of study	Approximate area of home range (acres) and/or mobility estimates	Reference
Pintail	Ogden Bay Refuge, Utah	Large-unable to estimate	Gates 1962
"	Waubay, S.D.	1200+ (1 pair), six week period	Drewien 1967
Gadwall	Ogden Bay Refuge, Utah	67 (5 hens), prenest-egg laying	Gates 1962
"	Waubay, S.D.	320+[a] (7 pairs), breeding season	Drewien 1967
Shoveler	Delta, Man.	200 (1 hen), breeding season	Sowls 1955
"	Ogden Bay Refuge, Utah	20 max., breeding season	Gates 1962
"	Waubay, S.D.	320+[a] (1 pair), breeding season	Drewien 1967
"	Strathmore, Alberta	49.7 (6 pairs), breeding season	Poston 1969
Blue-winged teal	Minnedosa, Man.	250+ (1 drake), prenest-mid incubation. Max. length-0.89 mi. (1 drake), 0.63 mi. (1 pair)	Dzubin 1955
"	Waubay, S.D.	200[b] (1 pair) prenest-incubation. Mean radius = 0.18 mi. (11 pairs)	Evans and Black 1956
"	Waubay, S.D.	165 (11 pairs), breeding season	Drewien 1967
"	Ogden Bay Refuge, Utah	20 max., breeding season	Gates 1962
Green-winged teal	Waubay, S.D.	600 (1 pair), breeding season	Drewien 1967
Cinnamon teal	Ogden Bay Refuge, Utah	20 max., breeding season	Gates 1962

Table 8. Continued.

Species	Location of study	Approximate area of home range (acres) and/or mobility estimates	Reference
Tribe Aythyini (Pochards)			
Canvasback	Minnedosa, Man.	1300+ (1 drake), prenest-mid incubation. Max. length 2.22 mi. (1 drake), 1.98 mi. (1 pair)	Dzubin 1955
Ring-necked duck	Maine	Black duck range 5-10 times larger than ring-necked duck	Mendall 1958
Tribe Cairinini (Perching ducks)			
Wood duck	North-central Minn.	501 (4 drakes), breeding season. Mean max. length 1.64 mi. 417 (2 pairs), breeding season Mean max. length 1.58 mi.	This study
Tribe Tadornini (Shelducks)			
Common shelduck (*Tadorna tadorna*)	England, Isle of Sheppey, North Kent	"Nests were found at widely different distances from territories ranging from 200 yards to two miles".	Hori 1964

[a] Estimate based on incomplete data

[b] Area estimated from map

of wetlands may be an important factor in regulating home range size. Density of breeding mallards is lower in the Chippewa than in the breeding areas of the central Canadian provinces; however, the mean home range of drakes observed in the Chippewa study is intermediate to that of mallards breeding in high population areas and not larger as might be expected. Limited data provided by Coulter and Miller (1968:19) for mallards breeding in low population density areas in Maine and Vermont indicated home ranges much larger than observed in the Chippewa. Factors controlling the size and shape of waterfowl home ranges are evidently complex and may depend on a combination of factors including population densities and habitat characteristics.

Portions of the usable habitat in a duck's home range, such as loafing and waiting areas, receive a much greater amount of use than other locations. The concept of primary range was used in this analysis to approximate the size of the most intensively used portion of the home range by removing peripheral points that represent infrequently used habitat. In most cases these data demonstrated that the area containing approximately 80 percent or more of a bird's locations usually represented about 50 percent of the home range. In some home ranges areas of concentrated use were separated by distances of up to one mile. This resulted in a primary range only slightly less than the home range. Dzubin's (letter quoted in Barclay, 1970:17) activity center[1] represented a similar concept and included that portion of the breeding pair's home range within which 75-80 percent of the pair and drake activity was confined during the breeding season. Barclay (1970:18), studying mallard and black ducks at Winous Point marsh in Ohio, stated that nesting, loafing, and feeding as well as the pursuit flights of the males were largely confined to the activity center.

Distribution of lengths of activity radii from the geometric center of activity may have no biological significance but is useful for comparative purposes. Dice and Clark (1953) considered this concept useful in describing the mobility of animals which do not have a fixes limit to their wanderings. Data in this study indicated that some birds tended to wander considerably more than others, but their home range could be approximately determined because of the tendency to periodically return to the same area.

Distribution of lengths of activity radii from the nest site were similar for mallard and wood ducks and both species were frequently known to travel over 1.5 miles from the nest site. In some cases much greater distances were recorded.

[1] Not to be confused with the Geometric Center of Activity used elsewhere in this thesis.

PAIR SPACING AND HOME RANGE OVERLAP

Social behavior of mallards differed noticeably from that of wood ducks. Aerial pursuits involving groups of mallards were occasionally noted and aggressive encounters between pairs were observed in some instances along lakeshores. In one instance a radio-marked mallard pair (5118 and 5119) was observed to be chased from a shoreline area by an unmarked paired male. Within one week of the observed encounter the marked pair began to frequent the shoreline of a large lake 1.7 miles from the nearest previously used habitat (the distant shoreline points were not used in the calculation of the pair or individual home ranges). This site was used periodically for eight days after which the pair did not depart from the original home range. The situation causing this behavior in the marked pair was not determined; however, it may have been related to frequent encounters with a neighboring pair or the loss of a nest during early incubation. The pair was believed to have made at least one unsuccessful nesting attempt.

Encounters between mallard pairs were occasionally observed but the frequency was probably very low compared to that occurring in the open prairies more typical of mallard breeding habitat (Dzubin 1957). Timber and shrub cover around wetlands and lakes may have reduced these encounters considerably and chasing probably occurred mostly over lakes where visibility between adjacent pairs was unrestricted.

Aggressive encounters among wood ducks were rarely observed and then only when birds were in close proximity to each other. Many situations were recorded in which several pairs or pairs and unattached males and females were occupying very small wetlands at the same time. Grice and Rogers (1965:20) noted that the general lack of agonistic behavior in the wood duck in Massachusetts, except in situations where the female was closely approached, contrasted with the highly aggressive behavior of the black duck (*Anas rubripes*). Jones and Leopold (1967:228) attributed inefficiency of nesting of a dense population of wood ducks in California to lack of territorial defense of the nest site. Mendall (1958:67) commented that paired ring-necked ducks in the forested area of Maine were isolationists but were frequently gregarious when feeding. He also observed sharing of waiting areas by males after the late stages of egg laying.

Visual observations during the three years of study indicated that fidelity among some wood ducks was questionable. On numerous occasions birds thought to be paired to a particular individual were observed with other companions of the opposite sex--but subsequently observed with the original mate. Copulation was never observed, but apparent "mate swapping" does pose some questions that require further study.

In a marsh where numerous artificial nesting boxes had been provided, Grice and Rogers (1965:20) observed wood duck nesting densities far in excess of those occurring under natural conditions and concluded that birds with specialized nesting requirements may be less likely to exhibit strong territorial behavior. A suitable nesting cavity is the prime requisite for the breeding wood duck pair and such cavities may be scarce and restricted to a particular habitat which may not be suitable for division into territorial units. In addition, trees containing cavities generally tend to occur in a clumped distribution. The low threshold of aggression of the wood duck may permit the species to fully utilize the nesting habitat encountered in the natural situation. The genetic mechanism involved here is not clear; however, natural selection may tend to favor individual wood ducks that do not expose themselves to predator attacks by the conspicuous defense of a forest wetland.

The small number of mallard nests located each year and the heterogeneous habitat did not permit the statistical determination of nest dispersion in this study. However, in one situation two nests were within several hundred feet of each other. I suspect that with a larger sample of nests some degree of clumping may be evident in the vicinity of certain lakes. In open habitat more typical of mallard breeding areas McKinney (1965:104) believed that chasing in the mallard and other species appeared to cause spacing of pair home ranges and the resulting nest dispersion had survival value as an antipredator device.

Sowls (1955:48 and 53), Dzubin (1955), Gates (1962) and Reed (1970:52) observed overlap in the home ranges of waterfowl pairs. Radio-marked mallard and wood duck pair home ranges in this study were observed to overlap to a considerable degree.

Extreme cases in both species demonstrated that one range may completely overlap another home range. An analysis of overlap situations in mallard hens in about the same breeding phase showed that most of the time pairs may effectively isolate themselves by using distinctly different portions of the overlap zone. In nearly all cases the overlap zone was comprised of portions of one or two lakes. Specific areas shared by mallard pairs were shoreline habitat such as points or mud bars where a shallow water feeding area was present. The few hostile encounters observed between mallard pairs were usually in such locations. Temporal spacing may reduce conflicts when areas are shared. Tracking data indicated that breeding mallard pairs using adjacent home ranges may rapidly move into areas vacated by the drake of a hen in a more advanced breeding condition (i.e. late incubation).

Sharing of small wetlands appeared to be more common in wood ducks and on numerous occasions several pairs were observed using a small wetland at the same time. During the later portion of the nesting season up to three radio-marked wood ducks were located in a small wetland at one time. In many cases tracking data indicated that sharing of wetlands in the overlap zone did not occur. However, I had the impression that sharing of wetlands occurred mostly during periods of peak aquatic invertebrate production and that incubating hens and other ducks quickly responded to these situations.

RESULTS

HABITAT USE

General Considerations

Habitat used by mallards and wood ducks was analyzed in four ways: 1) A comparison was made between mallards and wood ducks. I assumed that habitat availability was the same for both species (i.e. the habitat that was available to mallards was also available to wood ducks). 2) Using data on 11 mallards and 14 wood ducks habitat preference was demonstrated. 3) For the above individuals an analysis of each home range was made to determine the density of wetlands and shorelines and their utilization in each home range and a comparison was made between the two species. 4) Analysis of nesting habitat considering the various vegetation stand types used and the distances of nest sites from water. In the case of wood ducks the characteristics of the cavity tree were also examined.

Habitat Use Comparisons

No attempt was made to adjust for habitat availability in the comparison of mallards and wood ducks as this would affect both species in the same manner. The habitat classification system previously described was used in the comparison presented in Table 9. Wetland types were also subdivided into two size categories (i.e. less than two acres and two acres and greater). Locations for 23 mallards and 47 wood ducks were compared using the Wilcoxon Rank Sum Test (Diem 1962:191) which provided

Table 9. Comparison of the mean percentages of locations in wetlands and shoreline habitat types based on 23 mallards and 47 wood ducks. Mallard and wood duck preference is denoted by + and - respectively. Percentages of area and wetland units in each habitat type are based on all habitat within the study area.

Wetland Habitat Types and Size Categories:

	Coarse Sedges		Fine Sedges/Sedge Bog		Shrub Swamps		Deep Water Ponds	
	< 2 acres	≥ 2 acres	< 2 acres	≥ 2 acres	< 2 acres	≥ 2 acres	< 2 acres	≥ 2 acres
Observed locations (%):								
Mallards	12.7	1.6	1.5	16.2	4.4	0.3	0	9.0
Wood ducks	32.6	1.7	0.3	7.6	7.3	3.2	0.1	1.6
Difference	-19.9**	-0.1	+1.2	+8.6*	-2.9	-2.9*	-0.1	+7.4
Area available (%)	4.6	1.3	1.5	26.8	2.8	19.3	0.6	3.3
Wetland units available (%)	32.6	1.2	4.0	8.7	11.5	10.6	2.2	1.9

	Sedge-Shrub		Acid Bog		Leaf Litter/ Hardwood Swamp[a]	Flooded Pasture[a]	Other Emergents[a]
	< 2 acres	≥ 2 acres	< 2 acres	≥ 2 acres			
Observed locations (%):							
Mallards	1.9	1.5	0	3.0	4.0	2.5	0.4
Wood ducks	0.4	1.9	0.1	0.8	9.3	0	1.6
Difference	+1.5	-0.4	-0.1	+2.2	-5.3	+2.5	-1.2
Area available (%)	1.5	6.7	0.9	10.5	0.4	0.1	0.3
Wetland units available (%)	8.7	1.9	2.5	3.7	7.1	1.6	1.9

Table 9. Continued.

Shoreline Habitat Types:	Sand	Floating Mat	Flooded Sedge/Shrub	Other Emergents
Observed locations (%):				
Mallards	20.1	7.4	10.0	3.5
Wood ducks	9.1	5.8	14.6	2.0
Difference	+11.0*	+1.6	-4.6	+1.5
Area available (%)[b]	7.8	6.3	4.6	0.7

[a] All wetlands less than two acres

[b] Includes area approximately 66 feet out from shoreline

*Significant at the 0.05 probability level

**Significant at the 0.01 probability level more conservative results than other statistical tests. Significance was determined at the 0.05 probability level.

Habitat use comparisons indicated that both species used small Coarse Sedge wetlands but that wood ducks used these wetlands significantly more than mallards. Large Coarse Sedge wetlands were used by individual ducks but only four of these wetlands were located within the study area. A mean of 34.3 percent of individual wood duck locations were in all Coarse Sedge type wetlands as compared to 14.3 percent for mallards. Small Coarse Sedge wetlands in the aggregate comprised a small proportion (4.6 percent) of the usable habitat acreage. However they made up a much larger proportion (32.6 percent) of the total number of available wetlands and were fairly well distributed. In contrast mallards used large Fine Sedge/ Sedge Bog type wetlands significatnly more than wood ducks. This type of wetland made up the greatest proportion (28.3 percent) of any habitat types. Mallards averaged 17.7 percent of their locations in these wetlands as compared to 7.9 percent for wood ducks. Large Shrub Swamps were used significantly more by wood ducks. Most individuals of this species made some use of Shrub Swamps although average use was relatively low. Shrub Swamp types comprised the second largest proportion (22.1 percent) of habitat in the study area. Wetlands with a timber or shrub overstory (i.e. Shrub Swamps and Leaf Litter/ Hardwood Swamp types) in the aggregate were used significantly more ($P < .05$) by wood ducks than by mallards. Percentage of fixes in this habitat group was 8.7 percent and 19.8 percent for mallards and wood ducks, respectively. Small wetlands of all types were used significantly more ($P < 0.01$) by wood ducks than by mallards. Percentage of wood duck locations in small wetlands was 51.7 percent as compared to 27.4 percent for mallards. Wetland types such as Flooded Pasture and Other Emergents were very localized in their distribution and consequently received use by a relatively small number of individuals.

Shoreline vegetation stands generally received more use by mallards than by wood ducks (Table 9). Sand type shorelines received significantly more use by mallards and over 20 percent of mallard fixes were located on Sand type shorelines as compared to 9.1 percent for wood ducks. Mallards used Floating Mat and Other Emergent type shorelines slightly more than wood ducks; however, the latter made greater use of Flooded Sedge/Shrub type shorelines.

The percent of pooled mallard and wood duck locations in habitat groups for both day and night periods is presented in Table 10. In general the shift in habitat use between daylight and darkness is not greatly noticeable in the wood ducks. Mallard use of shoreline habitat increased during darkness but considerable variation existed among individuals. Using the Wilcoxon test for pair differences (Diem 1962:191) day and night shoreline use was not significantly different ($P > 0.05$) for mallards or wood ducks.

Table 10. Percent of pooled mallard and wood duck locations in habitat groups for day and night periods based on 23 mallards and 47 wood ducks.

Habitat	Mallard locations (%)		Wood duck locations (%)	
	sunrise sunset	sunset sunrise	sunrise sunset	sunset sunrise
Wetland Types:				
Coarse Sedges				
< 2 acres	15.1	5.6	27.1	28.6
≙ 2 acres	0.6	0	1.7	1.4
Fine Sedges/Sedge Bog				
< 2 acres	1.3	0.4	0.8	0
≙ 2 acres	23.9	16.7	7.8	6.1
Shrub Swamp				
< 2 acres	3.9	9.4	9.4	7.1
≙ 2 acres	0.2	0	2.7	0.7
Deep Water Ponds				
< 2 acres	0	0	0	0
≙ 2 acres	8.7	4.7	2.4	0
Sedge Shrub				
< 2 acres	1.0	1.3	0.7	1.1
≙ 2 acres	1.4	1.7	2.8	5.7
Acid Bog				
< 2 acres	0	0	0	0
≙ 2 acres	1.9	1.7	1.1	4.3
Leaf Litter/ Hardwood Swamp[a]	1.8	0	12.2	14.6
Flooded Pasture[a]	2.0	3.8	0.1	0
Other Emergents[a]	0.7	1.3	2.0	1.8
Shoreline Types:				
Sand	16.8	26.9	9.1	6.4
Floating Mat	6.6	7.7	4.3	7.5
Flooded Sedge/Shrub	11.6	13.2	12.4	14.7
Other Emergents	2.5	5.6	3.4	0
Totals	100.0	100.0	100.0	100.0

[a] All wetlands less than two acres

Habitat Use in Relation to Availability

If a species tended to use a particular habitat to a greater or lesser degree than the amount of that habitat available, certain assumptions may be made as to the species "preference" or "avoidance" for the habitat. Before this can be done the "available" habitat must be defined. Available habitat was considered to be that contained within the home range. Available wetland and shoreline habitat was described for 11 mallards and 14 wood duck home ranges using the classification system previously mentioned. These home ranges were situated in approximately the middle portion of the study area and tracking coverage was considered better than average for these 25 ducks. The number of locations and the length of the tracking period per bird were similar within each species. Calculations of the difference between the percentage of locations in each habitat and the percentage of each habitat group available were averaged separately for each species. Mean differences were then used to compute a mean and variance. This method was used to determine selection for or against different habitats for each species. Significant "preference" or "avoidance" was determined by using the t-test at the .05 probability level.

Individual habitat preferences of mallard and wood ducks appeared to be highly variable but definite trends were evident. Mallards showed a significant preference for small Coarse Sedge and Flooded Pasture type wetlands even though the latter were highly localized in their distribution (Table 11). Definite avoidance was indicated for most wetlands two acres or larger except for Deep Water Ponds which were used slightly more than expected. Mallards demonstrated a preference for all shoreline types but Sand shorelines experienced significantly greater use than expected.

Wood ducks indicated a strong preference for small Coarse Sedge type wetlands and Leaf Litter/Hardwood Swamp and the Other Emergent type wetlands were also used significantly more than expected (Table 12). Wood ducks generally made little use of large wetlands. Similar to mallards, wood ducks tended to make greater use than expected of all shoreline types and showed significant preference for Sand shorelines. Several wood duck home ranges did not contain shoreline habitat.

Home Range Habitat Characteristics

To analyze further the apparent differences in habitat use between mallards and wood ducks a closer examination of the habitat within each home range was made. The numbers of wetlands in the small (< 2 acre) and large (≥ 2 acre) groups were inventoried and a wetland density was calculated for each home range. For comparative purposes this figure was adjusted to indicate density per square mile even though individual home ranges were larger or smaller than one square mile. It should be noted that the vegetation type of wetland was often associated with the size of the wetland. For instance

Table 11. Selection for (+) or against (-) habitat types based on area and corresponding t values for 11 mallards. Significant (+) and (-) denoted by * and ** respectively.

Wetland Habitat Types and Size Categories:

	Coarse Sedges		Fine Sedges/ Sedge Bog		Shrub Swamp		Deep Water Ponds		Sedge-Shrub	
	< 2 acres	≥ 2 acres	< 2 acres	≥ 2 acres	< 2 acres	≥ 2 acres	< 2 acres	≥ 2 acres	< 2 acres	≥ 2 acres
No. ducks having habitat available	11	a	6	11	10	9	a	6	5	5
Mean percent of observed locations	13.0		1.7	25.7	3.7	0.2		9.7	3.8	6.0
Mean percent of expected locations	4.9		2.5	28.3	2.0	16.0		6.9	2.3	20.0
Mean difference (%)	+8.1		-0.8	-2.6	+1.7	-15.8		+2.8	+1.5	-14.0
t value	4.3*		0.4	1.4	0.9	8.3**		1.5	0.8	7.4**

	Acid Bog		Leaf Litter/ Hardwood Swamp[b]	Flooded Pasture[b]	Other Emergents[b]
	< 2 acres	≥ 2 acres			
No. ducks having habitat available	a	5	8	6	a
Mean percent of observed locations		3.3	1.2	7.1	
Mean percent of expected locations		15.9	0.2	1.1	
Mean difference (%)		-12.6	+1.0	+6.0	
t value		6.6**	0.5	3.2*	

Table 11. Continued.

Shoreline Habitat Types:

	Sand	Floating Mat	Flooded Sedge/Shrub	Other Emergents
No. ducks having habitat available	11	11	11	7
Mean percent of observed locations	21.3	7.0	9.8	3.1
Mean percent of expected locations	13.1	6.5	7.2	2.4
Mean difference (%)	+8.2	+0.5	+2.6	+0.7
t value	4.3*	0.3	1.4	0.4

[a] Habitat available to less than 5 birds

[b] All wetlands less than two acres

t_{table} .05, 14 df = 2.145

Table 12. Selection for (+) or against (-) habitat types based on area and corresponding t values for 14 wood ducks. Significant (+) and (-) denoted by * and ** respectively.

Wetland Habitat Types and Size Categories:

	Coarse Sedges		Fine Sedges/ Sedge Bog		Shrub Swamp		Deep Water Ponds		Sedge-Shrub	
	< 2 acres	≥ 2 acres	< 2 acres	≥ 2 acres	< 2 acres	≥ 2 acres	< 2 acres	≥ 2 acres	< 2 acres	≥ 2 acres
No. ducks having habitat available	13	a	10	13	14	13	a	8	10	a
Mean percent of observed locations	24.9		0.8	10.3	10.4	1.6		4.3	0.6	
Mean percent of expected locations	6.5		2.8	32.7	4.9	16.9		12.5	1.9	
Mean difference (%)	+18.4		-2.0	-22.4	+5.5	-15.3		-8.2	-1.3	
t value	6.8*		0.7	8.3**	2.0	5.7**		3.0**	0.5	

	Acid Bog		Leaf Litter/ Hardwood Swamp[b]	Flooded Pasture[b]	Other Emergents[b]
	< 2 acres	≥ 2 acres			
No. ducks having habitat available	a	8	13	6	6
Mean percent of observed locations		4.2	6.9	0.4	7.6
Mean percent of expected locations		15.5	0.8	0.8	1.4
Mean difference (%)		-11.3	+6.1	-0.4	+6.2
t value		4.2**	2.3*	0.1	2.3*

Table 12. Continued.

Shoreline Habitat Types:	Sand	Floating Mat	Flooded Sedge/Shrub	Other Emergents
No. ducks having habitat available	10	10	11	9
Mean percent of observed locations	16.4	6.8	13.6	5.8
Mean percent of expected locations	8.1	3.9	8.9	2.3
Mean difference (%)	+8.3	+2.9	+4.7	+3.5
t value	3.1*	1.1	1.7	1.3

[a] Habitat available to less than 5 birds

[b] All wetlands less than two acres

t_{table} .05, 14 df = 2.145

96.3 percent of the Coarse Sedge wetlands were less than two acres and comprised 32.6 percent of all wetlands available. All Leaf-Litter/Hardwood Swamp, Flooded Pasture and Other Emergent type wetlands were less than two acres in size. Wetland types such as Fine Sedge and Acid Bog were mostly larger than two acres. Shoreline densities for each home range were given in number of miles of shoreline per square mile. Mean percentages of wetlands within the home range visited one or more times were also calculated. Table 13 indicates that the density of small wetlands was significantly greater in wood duck home ranges than in mallards and also that mallard home ranges contained greater densities of shoreline habitat than wood ducks. This situation is somewhat expected because the more home range area containing small wetlands the less area is available for shoreline. Both species had similar mean densities for large wetlands.

Even though the relative proportions of wetlands and shoreline habitat within the home range are directly related (i.e., more of one type results in fewer of the other type) it is apparent that the habitat components of mallard home ranges differed noticeably from wood ducks for those individuals examined. Variation was greatest among wood ducks for both wetland and shoreline densities. Two wood duck home ranges were not known to contain any lake shoreline and two other wood ducks which had shoreline available in their home ranges were not known to use it. This situation seemed to contrast

Table 13. Mean wetland and shoreline densities and mean percentages of wetlands visited one or more times in mallard and wood duck home ranges.

	Wetlands				Shorelines
	< 2 acres		≥ 2 acres		
	Mean number of wetlands/mi^2	Mean percent units used 1+ times	Mean number of wetlands/mi^2	Mean percent units used 1+ times	Miles shoreline/mi^2
Mallards (N=11)	16.7	37.8	8.2	45.6	2.8
Wood ducks (N=14)	27.9	45.6	8.9	59.0	1.9
Mean Difference	-11.2	- 7.8	-0.7	-13.4	+0.9
t-value	2.56*	1.18	1.07	2.00	2.85**

* Significant at the .05 probability level.

** Significant at the .01 probability level.

t_{table} .05, 23 df = 2.069

markedly with mallards where all 11 individuals were known to use shoreline habitat. Wood ducks tended to use a greater proportion of the wetlands within the home range; however, the percentage of units used at least once was not significantly different between the two species.

Values of correlations between home range size and density of wetlands less than two acres, wetlands two acres and larger, and shoreline area are provided in Table 14. Significant values indicate that both mallard and wood duck home ranges tend to be larger in areas where density of small wetlands is low. An individual wood duck showing noticeable departure from this trend was known to make heavy use of two wetlands that may have provided most habitat requirements but each was situated on opposite sides of a large lake. Mallards also indicated a similar but not significant correlation between the amount of shoreline per square mile and the size of the home range. Characteristics of individual home ranges are presented in Appendix IV.

Nesting Habitat Characteristics

An examination of 19 mallard nests observed during the study indicated that 42 percent of these were located in Fine Sedge stands two acres or larger (Table 15). Shrub Swamp and Sedge-Shrub stands of various sizes were the site of 31 percent of the nests. Acid Bog was used by one individual although several birds nesting in stands classified as other

Table 14. Values of correlations between home range size and density of wetlands less than two acres, wetlands two acres and larger, and shoreline area for mallards and wood ducks.

Species	Wetlands < 2 acres	Wetlands ≥ 2 acres	Shoreline area
Mallards (N = 11)	-.61*	+.31	-.28
Wood ducks (N = 14)	-.63*	-.01	+.28

* Significant at the 0.05 probability level.

Table 15. Stand characteristics for 19 mallard nests observed on or adjacent to the study area.

Stand description	Stand size: less than 2 acres	Stand size: greater than 2 acres	Totals
Wetlands:			
Fine Sedges		8	8
Sedge-Shrub	1	2	3
Shrub Swamp	2	1	3
Acid Bog		1	1
Uplands:			
Oak-aspen-birch		3	3
Brambles	1		1
Totals	4	15	19

than Acid Bog actually nested in the cover provided by leatherleaf, a typical bog shrub. Twenty-one percent of the observed nests were located in upland vegetation stands. Three of these were in oak-aspen-birch mixed forests, and the fourth was in a dense bramble (Rubus strigosus) patch.

Most mallard nests (89.5 percent) were immediately adjacent to some woody vegetation, such as willow, alder, leatherleaf or at the base of a tree. Only two nests were without any woody cover and both were constructed in clumps of mixed sedges and blue-joint located in Fine Sedge stands. Mallards nesting in shrub or forest areas typically located their nests near an edge such as a roadway or natural opening in the overstory. Human disturbance did not seem to affect the selection of a nesting site although tolerance to disturbance may be an individual trait. In several instances nests were located in close proximity to dwellings or roadways where frequent human activity occurred.

Twenty-two wood duck cavity tree sites were examined during the study. Mature stands of northern hardwood were the location of 55 percent of these nests, and four of these nest sites were in areas where large cull aspen overtopped the northern hardwood canopy (Table 16). Aspen stands mixed with lowland hardwood species or with birch and scrub oak were the site of 27 percent of the cavities. Recently logged over areas where large cull aspen were left standing contained the remaining 18 percent of the nest cavities.

Table 16. Stand characteristics for wood duck nest sites observed on or adjacent to the study area.

Stand description	Crown closure (canopy above cavity level)		Totals
	< 50 percent	≥ 50 percent	
Northern hardwoods[a] (> 11.0 inches DBH)	1	7	8
Northern hardwoods (> 11.0 inches DBH) with scattered large cull aspen		4	4
Merchantable aspen cut since 1955(est.), large cull aspen standing. Northern hardwood understory	2	2	4
Aspen or mixed aspen and other hardwoods[b]		6	6
Totals	3	19	22

[a] Major components sugar maple, basswood, with some red oak, american elm, and ash.

[b] American elm-ash or paper birch-scrub oak

DBH = diameter at breast height.

Crown closure of stands of sawlog size, diameter at breast height (DBH) greater than 11.0 inches, was visually estimated and checked against 1969 aerial photographs. In most cases crown closure was 50 percent or greater above the level of the cavity; however, the understory from about ten feet to above cavity height was free from obstruction in nearly all locations. Crown closure did not appear to greatly affect cavity selection in the small sample observed in this study. At two sites aspen with cavities were approximately 100 feet from the nearest tree of similar size, resulting in a crown closure of 20 percent or less. However, in most northern hardwood sites the mean crown closure above the cavity was probably 80 percent or more.

Figure 15 indicates forest stands providing actual or potential wood duck nesting locations. Stands estimated to support the highest density of cavities per acre were northern hardwood or mixed aspen stands with crown closures greater than 50 percent. All of these stands were located on good soils. This situation resulted in a poor distribution of high potential nesting sites within the study area and in some cases produced a noticeable clumping effect of actual nests.

Whenever possible, cavity trees were climbed using climbing spikes or an extension ladder, and a detailed examination was made of the cavity characteristics and the nest. Complete or partial examination of 19 cavity trees indicated that 63.2 percent of these trees were quaking aspen. Aspen with


BIG LAKE
BIG LAKE
LAKE ANDRUSIA
LAKES
WETLANDS
UPLANDS
N
UPLAND STANDS OF NORTHERN HARDWOODS AND/OR ASPEN
DIAMETER AT BREAST HEIGHT > 11.0 INCHES
CROWN CLOSURE ≥ 50 %
CROWN CLOSURE < 50 %
LOCATION OF CAVITY
NUMBER INDICATED IF TWO OR MORE IN CLOSE PROXIMITY.
0
1/2
1
SCALE(MILES)

cavities were large, with a mean DBH of 18.8 inches, and badly infested with canker-producing organisms such as hypoxylon canker (*Hypoxylon pruninatum*), *Fomes igniarius* and other fungi, as well as boring insects. The origins of the cavities were not determined; however, it appeared that in most cases cavity entrances occurred where limbs had been broken off. Animals such as the yellow-shafted flicker and pileated woodpeckers may have excavated the hole which then could have been enlarged by squirrels. Flicker feathers and squirrel hairs were found in several cavities. Increment borings indicated that the mean age of cavity producing aspen was about 69 years of age and ranged from 55 to 75 years. Table 17 indicates the species composition, mean age and dimensions of trees containing wood duck nests.

Sugar maple contained 21 percent of the observed wood duck cavities. Cavities probably originated from broken limbs and were excavated in a manner similar to those in aspen. The mean DBH of sugar maple cavity trees was 19.6 inches and the mean estimated age was 105 years, ranging from 80 to more than 120 years. Three cavities, two in elm and one in a basswood, comprised the remaining 15.7 percent. In all three cases the trees were large, mean DBH 17.1, and badly infected with rot producing disease. An increment boring was obtained from only one tree and indicated an approximate age of 100 years.

Cavity characteristics were generally similar regardless of tree species. Nearly 50 percent of the cavities were

Table 17. Species composition, mean ages and dimensions of trees containing wood duck nests. Sample sizes are indicated in parentheses.

	Percentage of nest cavities	Age (years)	DBH[b] (inches)	Tree height (feet)	Cavity height (feet)	Cavity depth (inches)
Quaking aspen	63.2 (12)	68.6 (9)	18.8 (11)	73.2 (9)	30.7 (10)	20.0 (10)
Sugar maple	21.1 (4)	105.0 (4)	19.6 (4)	74.5 (4)	30.3 (4)	38.0 (2)
Others[a]	15.7 (3)	98.0 (1)	17.1 (3)	73.0 (2)	31.3 (3)	42.3 (3)
Means		81.1 (14)	18.7 (18)	73.5 (15)	30.7 (17)	26.9 (15)

[a] American elm - 10.5 percent (2), American basswood - 5.2 percent (1)

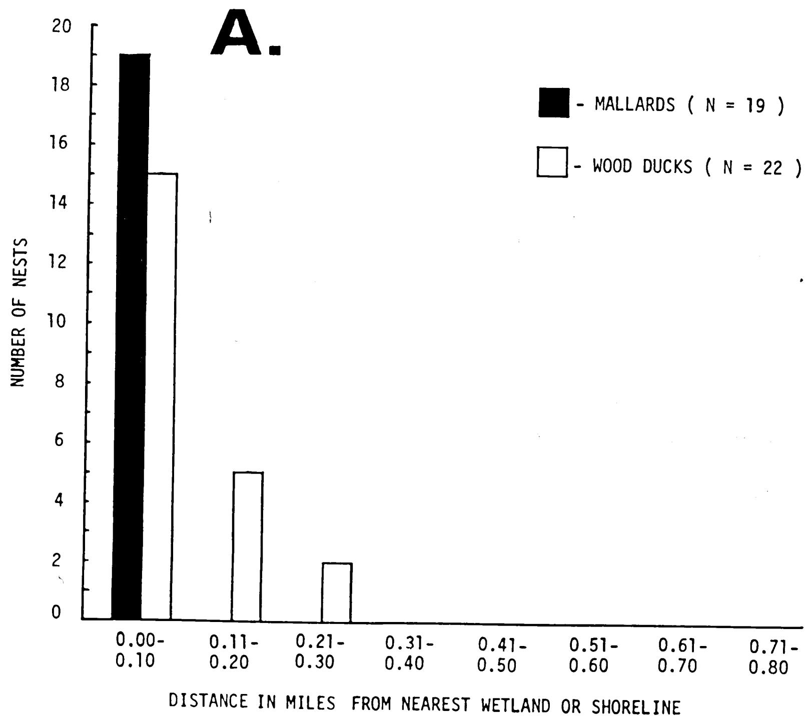
[b] Diameter at breast height

the enclosed type (Dreis and Hendrickson 1952). The bucket type accounted for 33 percent and were typically in aspen. The remaining cavities were best described as a combination of enclosed and bucket types. Only one of the cavity trees examined was dead but numerous others, especially the aspen, may have easily toppled in a moderately strong wind because the trunks were severely weakened by pathogens. Mean cavity height was 30.7 feet and ranged from 12.8 feet to 43.5 feet. Cavity depths were extremely variable, ranging from a shallow 6.0 inches to a depth of 78.0 inches, and averaged 26.9 inches. One additional nest was observed in a wood duck box constructed and erected by a local resident a short distance from several trees containing natural cavities used by other wood ducks. The entrance to the box was 11.5 feet above the ground.

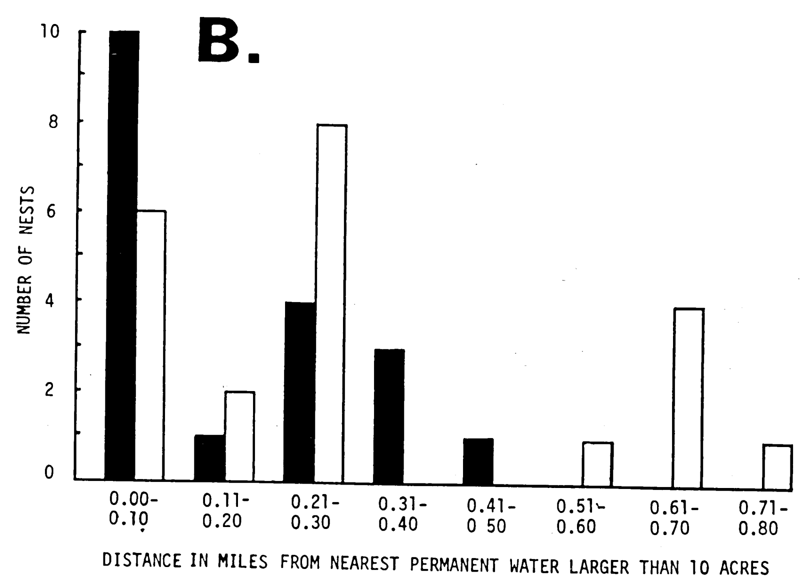
Distribution of distances to the nearest water was determined for 19 mallard and 22 wood duck nest sites (Fig. 16A.). All of the mallard nests were within approximately 500 feet of some kind of wetland or shoreline. For 15.9 percent of the nests the nearest wetland was less than two acres in size. The remaining mallard nests (84.1 percent) were nearest Fine Sedge wetlands two acres or larger in size.

Because of the distribution of available nesting cavities wood ducks rarely found nesting sites adjacent to water. However, it appears that they may attempt to do this by searching outward from wetlands or shorelines. Cavity distances from water indicated that 68.3 percent of the 22 cavities

Figure 16. Distribution of distances of mallard and wood duck nests from water. (A.) Nearest wetland or shoreline. (B.) Nearest permanent water larger than 10 acres.



A.
20
18
16
14
12
10
8
6
4
2
0
NUMBER OF NESTS
- MALLARDS (N = 19)
- WOOD DUCKS (N = 22)
0.00-
0.10
0.11-
0.20
0.21-
0.30
0.31-
0.40
0.41-
0.50
0.51-
0.60
0.61-
0.70
0.71-
0.80
DISTANCE IN MILES FROM NEAREST WETLAND OR SHORELINE



B.
10
8
6
4
2
0
NUMBER OF NESTS
0.00-
0.10
0.11-
0.20
0.21-
0.30
0.31-
0.40
0.41-
0 50
0.51-
0.60
0.61-
0.70
0.71-
0.80
DISTANCE IN MILES FROM NEAREST PERMANENT WATER LARGER THAN 10 ACRES

located were within one tenth of a mile from some water area, 22.7 percent were between one tenth and two tenth mile and only 9.0 percent were located more than two tenths of a mile from any known wetland or shoreline. The nearest type of water area for 59.1 percent of the wood duck cavities was a small wetland less than two acres. Approximately 18 percent were closest to wetlands two acres or larger in size and 22.7 percent were nearest to a lake shoreline.

Distribution of nests from the nearest permanent water greater than 10 acres was determined (Fig. 16B.) even though many wood duck hens did not utilize this water in brood rearing (Ball 1971:43). McGilvrey (1968:9) considered isolated areas less than 10 acres in size as marginal habitat for wood duck broods. No trends were indicated by the distribution of these distances. However, 27.2 percent of the wood duck nests were situated over one half mile from permanent water larger than 10 acres. Mean distances were 0.19 and 0.30 miles for mallards and wood ducks, respectively.

DISCUSSION

HABITAT USE

Small wetlands received heavy use by both mallards and wood ducks during this investigation. Cline's (1965:82) study of forest waterfowl habitat in an area about 35 miles southwest of the Chippewa study area indicated that waterfowl use in general decreased as wetland size decreased. However, of the species observed mallard and wood duck breeding pairs made the greatest use of wetlands two acres or less. Cline (1965:84) attributed this situation to the well known flight maneuverability of wood ducks and mallards which enables them to use small wetlands surrounded by timber and shrub. Observations in the Chippewa indicated that mallards were very agile in flight and were capable of flying into all types of small wetlands with relative ease.

Importance of small wetlands in the breeding ecology was noted in prairie breeding waterfowl. Evans and Black (1956:35) stated that pothole use by mallards and certain other species at Waubay, South Dakota, varied inversely with size, and the smallest areas received the heaviest use per acre even though many were dry during much of the season. They concluded that the best distribution of a given amount of water for pairs only would be many small relatively permanent areas available throughout the breeding season. Drewien and Springer (1969:114), also working at Waubay, showed that the greater use of small shallow marshes appeared to be due to the larger ratio of edge to unit area of water. At Delta, Manitoba, during the spring and early summer Hoffman (1970) observed that small blasted ponds contained more breeding pairs per unit of shoreline than other types of wetlands. He believed these ponds served primarily as isolation and loafing areas for pairs of dabbling ducks. In the Chippewa the desire for isolation may have attracted pairs to small wetlands but other factors such as food probably influenced their use also.

Although small wetlands in general received considerable use by mallards and wood ducks both species tended to make greater use of small wetlands without shrub and timber overstory. Evans and Black (1956:35) believed that prairie waterfowl generally preferred wetlands that contained little or no vegetative cover although this cover was sometimes used for wind protection.

Both species used the large wetlands less than expected but mallards frequently nested in the larger Fine Sedge areas and occasionally in large Shrub Swamps and Acid Bogs. Generally low use of the larger wetlands was probably due to a tendency of mallards and particularly wood ducks to make greater use of the more evenly distributed and accessible but smaller areas. Use of the larger areas was also reduced because only portions of many of these wetlands contained surface water. Mallards and wood ducks frequented the edge of some shrub swamps and acid bogs where surface water was usually available but in most cases the interior of these wetlands probably received little use.

Lake shorelines appeared to be an important habitat component for mallards and received high use by many wood ducks. Compared to wood ducks, mallards made significantly greater use of sandy shorelines. However, on the basis of availability of habitat in the home range, both mallards and wood ducks indicated preference for all shorelines and significant selection for sand shorelines. Sandy shorelines in the study area generally provided a broad shallow zone and were usually devoid of dense vegetation characteristic of other shoreline types. Frequently mallard pairs and occasionally wood duck pairs were known to use sandy shorelines for loafing and feeding. Both species may have been attracted to these shorelines because they provided: 1) easy accessibility from the water, 2) good visibility along the shoreline, 3) usually a wide shallow water feeding area and abundant invertebrates at certain times, and 4) perhaps one of the few easily accessible sources of gravel. Certain sand shorelines receive less use than other areas. This may have been due to frequent human activity or prevailing winds causing heavy wave action.

Partial removal of shoreline vegetation on small impoundments in Alberta was carried out by Keith (1961:50) to observe dabbler duck response to this habitat modification. Keith stated that the partial removal of shoreline cattail resulted in increased use by ducks which was attributed mostly to the greater accessibility of shoreline loafing spots and the desire of waterfowl for an unobstructed view of the shorelines and adjacent terrain. Other factors which may have also been important were the increased accessibility of shoreline food plants and increased abundance of submerged food plants. In western Montana Girard (1941:234) believed that the most attractive shorelines for mallards were those that gradually descended into the water rather than those abruptly shelving. Jahn and Hunt (1964:15) noted that bog lakes attracted few dabbler ducks because the presence of a mat eliminated the shallow waters preferred for resting and feeding by these ducks.

Hochbaum (1944:78) considered shorelines an important habitat requirement of dabbling ducks and demonstrated a close relationship between the length of the shoreline and the number of pairs; however, he also stated that shorelines vary in attractiveness.

Habitat used for night roosting did not show any significant trends for wood ducks or mallards. Wood ducks were likely to be found in the same kinds of wetlands regardless of time of day. Locations of mallards at night showed considerable variability but most of the birds used shorelines, particularly the sand areas with sparse vegetation along the waters edge. Drewien and Springer (1969:114) observed that ducks at Waubay, South Dakota, were found night roosting in all pond types except the more temporary areas. Pairs and waiting males could usually be found in the temporary ponds only after new vegetative growth provided acceptable cover.

Availability of food probably had considerable influence on the habitat used by mallards and wood ducks during the nesting season. Invertebrates probably provide an important source of food for breeding ducks and a qualitative examination of nine study area wetlands during the spring showed large numbers of mayfly (Ephemeroptera) and dragon fly (Odonata) nymphs and caddis fly (Trichoptera) larva, various crustaceans and molluscs as well as numerous other aquatic organisms. On several occasions during the spring caddis fly larvae cases were observed in large quantities attached to vegetation near the surface of small Coarse Sedge type wetlands which were being heavily used by wood ducks. Although no visual observations on feeding were made, ducks were presumably feeding on caddis fly larvae, ingesting the entire case. Cline's (1965:93) observations near Lake Itasca, Minnesota, indicated that mallards fed extensively on mosquito larvae found in proactically all woodland water areas. He believed that this abundant food source of early spring may have attracted mallards to even the smallest ponds and bog meadows with standing water.

Wetlands and shorelines seemed to produce peak invertebrate populations at various intervals throughout the spring and summer. Generally invertebrates were observed in small wetlands shortly after they became ice free. Large wetlands and lakes were the sites of high invertebrate activity later in the season. It was my impression that peak invertebrate production in a specific wetland was often out of phase with neighboring wetlands, a situation probably caused by the variation in the physical and chemical characteristics of individual wetlands. Asynchrony of invertebrate productivity may have accounted for the sudden changes in habitat used by marked birds and the popularity of certain wetlands at various times. Tracking data and visual observations indicated that ducks responded quickly to food availability in small wetlands. In the prairie area of Mahnomen County, Minnesota, Jessen et al. (1962:38) were of the opinion that high use of certain areas by breeding ducks was related to the standing crop of food, although modified by territorial behavior.

Waterfowl movements in the study area demonstrated the great diversity of habitat used by mallards and wood ducks. An individual duck might be located in two or more habitat types during the period of one day and during the breeding season may visit nearly every habitat type and a large proportion of the total wetland units available within the home range. Only a few individual wood ducks were believed to remain for more than a few days in any particular wetland and these areas appeared to contain considerable habitat diversity within a single unit. Home ranges of mallards and wood ducks usually incorporated a complex of habitat consisting of numerous individual units differing in size and vegetation stands. There was considerable variation among the habitat observed in wood duck ranges. Numerous investigators have noted that the requirements of breeding ducks seemed to be fulfilled best in areas containing a diversity of habitat. Mann (1955:9) described a "water area complex" consisting of a few large and many small wetland areas in proximity to each other with each unit supplying one or more habitat requirements for waterfowl production. Jahn's (1961:99) "duck production unit" consisted of a number of temporary water depressions surrounding a more permanent water area required for rearing broods. Jahn and Hunt (1964:142) observed that a variety of types of water areas located in close proximity to each other form a "community of water types" and provide maximum amount of shoreline needed to realize top production of territorial ducks.

I determined that in most cases ducks used a minimum of five habitat units representing not less than about 35 percent of the units available within the home range. Diversity and quality of certain habitat was probably decisive in determining the size of the home range. However, I felt that the amount of time a particular duck spent in one habitat was not necessarily indicative of the importance of that habitat in the overall breeding ecology of the bird. An area visited occasionally could conceivably provide important requirements not frequently needed such as certain foods and gravel.

Home range data indicated that the basic habitat components (i.e. wetlands and shorelines) of mallard home ranges differed noticeably from wood ducks, but perhaps of greater significance is that more variability was present among wood duck home ranges than among mallard home ranges. A possible explanation for this situation is based on the fact that the mallard is extremely flexible in its nesting requirements whereas the wood duck requires a specific type of nesting site--a tree cavity, which is not necessarily abundant, evenly distributed or easy to find. It appears that wood duck pairs find a cavity first and then establish their home ranges around this site. Hilden (1965:57) stated that "to hole-nesters, a suitable nest-hole is indispensable, and in its absence an otherwise suitable habitat remains unoccupied. Lack of nest-holes acts as an ecological minimum factor in modern forest districts." A mallard pair may be permitted to select a suitable breeding area for its desirable resting and feeding locations without being restricted by nesting requirements which are probably always available. However, these situations may be modified in both species by homing and past experience and also perhaps by territorial behavior. Mallards seem to be appropriately described by Hilden's (1965:60) comment: "In many species, a type of terrain that releases the settling reaction always provides suitable nest sites, and hence their stimuli play no role in habitat selection." Hilden (1965:60) further states: "Some species, on the other hand, are so stenotopic in their nest site requirements that suitable sites are hard to come by. Thus, discovery of a nest site in most cases clinches the selection of territory, and the type of terrain that provides a suitable nest site is of relatively slight importance." The latter statement may accurately describe the wood duck.

The differences observed between mallard and wood duck home ranges are: 1) trees containing wood duck cavities or at least the ones many radio-marked birds are finding are not necessarily next to lakes or in the same areas in which mallard pairs tend to settle; and 2) lake shoreline does not seem to be a necessary component of a wood duck pair's home range, although some wood ducks readily use this habitat when available. These basic habitat differences may be indicative of the fact that the wood duck is primarily a duck of small forest wetlands or streams and does not necessarily seek out lake shoreline habitat or even use it when available. However, the mallard probably evolved in an open prairie-like region and requires lake areas in its home range because of an innate requirement for open and unforested habitat, even though it has shown amazing adaptability in utilizing small forest wetlands.

Numerous workers such as Girard (1941:234), Gates (1962:55), Hochbaum (1955:228), Jahn and Hunt (1964:38), Wellein (1942:11) and Cline (1965:100) have stated that mallards are versatile in selecting suitable nesting habitat.

Wellein (1942:11) located 23 mallard nests during a waterfowl nest study in the Chippewa National Forest. Nearly half of these nests were located in down-slash in cut over jack and red pine stands. The remaining 50 percent were approximately equally divided between upland and lowland forest types or brush (assumed to be upland brush) and "meadow" habitat (assumed to be mostly Fine Sedge meadow).

Some of the differences between Wellein's investigations and this study may be attributed to basic changes in habitat, particularly timber types during the nearly 30 year interval between the studies. In addition, the methods used in locating nests were different.

Ericaceous shrubs such as leatherleaf and labrador tea provided primary cover for approximately 25 percent of the mallard nests in this study. Coulter and Miller (1968:30) noted that leatherleaf was preferred for black duck nest sites in Maine. Preference for this shrub was attributed to the excellent cover it provides early in the season before other shrubs have leafed out and a slightly elevated root system which provided a suitable nest platform. In addition Coulter and Miller noted that stands of leatherleaf frequently used by black ducks were not uniform or dense but were usually in combination with other shrubs, sedges and grasses. Leatherleaf serving as nesting cover in the Chippewa was usually associated with willow and sedge. Reed (1970:48) reported that preferred nesting habitat for black ducks in the St. Lawrence Estuary, Quebec, was various associations of _Myrica_-_Chamaedaphne_-_Carex_-_Calamagrostis_. Many black duck nests were located on tufts of blue-joint and frequently sites were chosen where a dead branch or rock added physical support to the brittle stalks of grass. Carex and/or blue-joint provided primary cover for nearly 50 percent of the mallard nests found in the Chippewa study area and all but two of these nests were situated immediately adjacent to some woody vegetation, usually willow.

In this study all mallard nests were within 500 feet of a water area but many of these were probably renests. It is likely that when early-arriving mallards initiate nests the only water permanently free of ice is found on the river. Small shallow wetlands thaw early in the season but may freeze at night or periodically during cold snaps. Cline (1965:88) felt that early arriving mallards may have tended to nest near open water regardless of the size or type of the water area. Sowls (1955:74) observed 123 mallard nests at Delta, Manitoba, of which approximately 90 percent were within 600 feet of water. Wellein (1942:15) determined that the mallard nests he observed were between 40 feet and one mile from open water and the average distance was approximately 1100 feet.

Of the twenty-two wood duck cavity tree locations examined during this study, over 90 percent were considered by professional foresters working in the area to be on good or excellent forest sites. Mature stands of northern hardwoods situated mostly in the northeastern portion of the study area probably had the highest cavity densities per acre. This was based on the number of known cavities and the high percent of crown closure in certain stands. Other "pockets" of potential and actual cavity trees were scattered unevenly throughout the study area. Most cavity trees occurred on moranic soils where small wetland densities were higher than in the more sandy areas. Actual cavity densities were never estimated during this study but Nagel (1969:62-66) calculated cavity densities on the Tamarac National Wildlife Refuge, situated approximately 57 miles southwest of the Chippewa study area. His figures indicated about 1 cavity per 2.5 acres in upland and lowland forests and 1 cavity per 11 acres in aspen types. Table 18 indicates the characteristics of wood duck cavity trees found in the Chippewa study area and the Tamarac National Wildlife Refuge.

Weier (1966:102) found six wood duck nests in Mingo National Wildlife Refuge in southeast Missouri and reported that five of these were located either on roadsides or streambanks. The sixth was in an open stand of upland hardwoods. Wood duck nests in the Chippewa were never more than 0.3 miles from a water area but occasionally a roadway or some other kind of opening was much closer. Prince (1968:499) surveyed nest sites used by wood ducks along the St. John River in central New Brunswick and observed that nest sites usually were near small openings within areas of large timber. The distribution of distances of cavity sites from the nearest water in the Chippewa study area indicates that wood ducks probably move outward from these water areas in search of nesting sites. At Tamarac Nagel (1969:78) believed that potholes served as openings from which hen wood ducks could begin the search for a nest cavity.

Prince (1968:499) believed that competition between wood ducks and goldeneye for cavities on the St. John River flood

Table 18. Characteristics of wood duck cavity trees found in the Chippewa study area and the Tamarac National Wildlife Refuge.

Location	Sample size	Tree Species: Percent Aspen/Birch	Tree Species: Percent others	Mean DBH (inches)	Mean cavity height (feet)	Mean cavity depth (inches)
Chippewa	19	63.2	36.8	18.7	30.7	26.9
Tamarac (Nagel 1969)	9	66.6	33.4	18.0	21.0	11.0

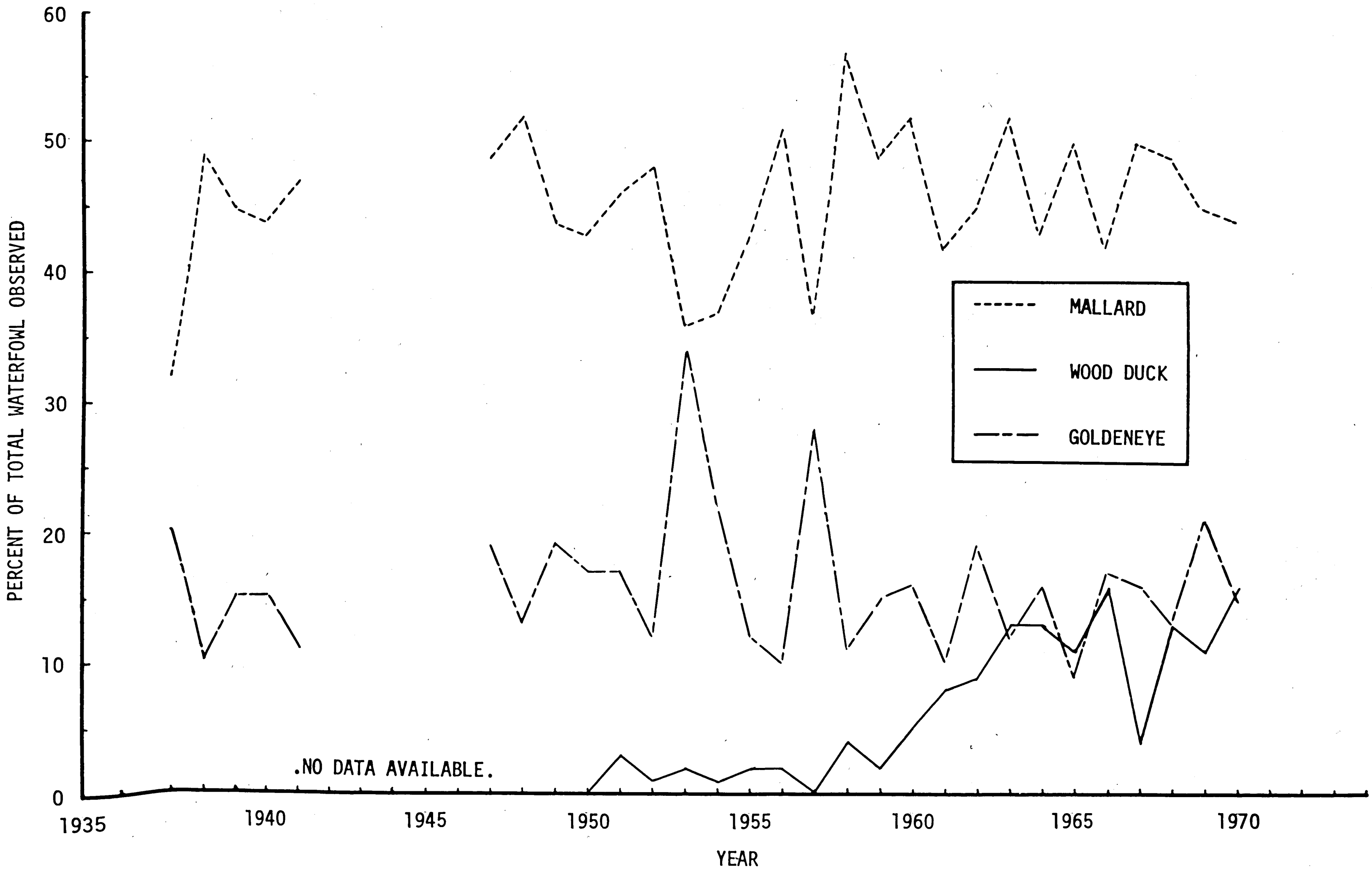
plains was limited because of differences in site and cavity preferences and also differences in feeding and loafing sites. Prince observed wood ducks on small ponds and sloughs within the forest and goldeneye on large bodies of water surrounding the flood plain forests. Consequently wood ducks searched for cavities within the forest and goldeneye searched the forest adjacent to the large water bodies.

CAVITY AVAILABILITY AND WOOD DUCK POPULATIONS

Waterfowl surveys initiated by Stoudt (1940) have been conducted on selected lakes and flowages in the Chippewa National Forest nearly every summer since 1937 (U.S. Fish and Wildlife Service 1955 and U.S. Fish and Wildlife Service unpubl. reports). Figure 17 indicates changes in the total annual production of certain species observed during these surveys through 1970. Except for occasional fluctuations, mallards and goldeneyes have indicated no significant production trends. Prior to 1950 wood ducks were rarely observed during the annual survey but after the mid 1950's production indicated a definite increase.

It is probable that wood ducks have constituted a high proportion of total waterfowl production in the Chippewa during the past 20 years but are given a relatively low standing because of the low visibility rates of broods (Cowardin and Higgins 1967) and their tendency to select habitat difficult to census (Ball 1971:47). Goldeneye, however, are considered

Figure 17. Changes in the total annual production of waterfowl species observed during brood surveys on selected lakes and flowages in the Chippewa National Forest since 1937. Trends for mallards, wood ducks, and goldeneyes are shown.



60
50
40
30
20
10
0
PERCENT OF TOTAL WATERFOWL OBSERVED
1935
1940
1945
1950
1955
1960
1965
1970
YEAR
.NO DATA AVAILABLE.
MALLARD
WOOD DUCK
GOLDENEYE

to be an extremely "visible" duck and production can be estimated reasonably accurately because of the tendency of hens with broods to head for open water when approached.

Apparent increase in the relative importance of wood ducks after 1950 may reflect changes in environmental factors that had previously limited population increase. According to Nagel (1969:3-6) the Tamarac National Wildlife Refuge records indicated a spectacular increase in wood duck breeding pairs between 1939 and 1966. This increase in breeding pairs was not attributed to any management program. Chippewa production surveys and breeding pair counts in Tamarac Refuge indicate that the entire region may have experienced a noticeable wood duck population increase after the early 1950's.

I believe the reason for the increase in wood duck populations in the Chippewa study area and the surrounding region may be that nesting cavities have increased in availability since the time of apparent population increase. Data for Tamarac Refuge (Nagel 1969:75) and this study indicate that 60 percent or more of the wood duck cavities were located in aspen or birch (Table 18). Increment borings obtained from aspen in the Chippewa indicated that most cavity trees were established during or shortly after the logging era of the early 1900's (Fridley 1960:10, and J. Mathisen, pers. comm.). Shirley (1936:25) estimated that aspen type forests increased tenfold in northern Minnesota as a result of the early logging. Increased availability of aspen forests on good sites, which could start producing cavities at about 50 years of age, approximately corresponds to the initial wood duck production increase observed in Figure 17. Although much of this timber is being harvested on a rotational basis numerous pockets, fring areas and occasional cull aspen remain to supply cavities.

Grice and Rogers (1965:87), Sirén (1952:189) and Haartman (1956) demonstrated that the availability of nesting cavities was possibly a limiting factor in populations of wood ducks, goldeneye and pied flycatchers (Muscicapa hypoleuca), respectively.

It is impossible to predict future trends in wood duck populations based on the data available. I do not feel that cavity availability is limiting the wood duck population in the study area under present conditions; however other factors, such as brood survival and hunting pressure must be considered.

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

Radio-tracking techniques permit probing a little more deeply into the breeding ecology of forest breeding ducks than has been possible in the past. However a large amount of knowledge remains to be gathered and evaluated before any large scale waterfowl management program can be effectively implemented. I wish to conclude this thesis with some ideas concerning waterfowl management in the Chippewa National Forest which will always benefit resident waterfowl populations.

Existing wetlands and shorelines should be protected. This study indicated that nearly all types of wetland and shoreline habitat played some role in the ecology of forest breeding waterfowl. Mallards and wood ducks required habitat diversity and many types of aquatic areas were used by individuals over a period of weeks and months. In the spring Coarse Sedge wetlands were used heavily but even Acid Bogs and other habitat considered to be of little use to waterfowl provided habitat requirements for many breeding ducks. Until more is known about the requirements each type of habitat provides under various conditions its relative importance for a species cannot be judged.

Much of the destruction of waterfowl habitat I observed resulted from ignorance and not from a disregard for the requirements of wildlife. Most people seemed genuinely interested and sympathetic towards wildlife. Human needs and waterfowl needs present occasional conflicts but in general I feel the two can be compatible under most situations. Use of small wetlands as garbage dumps may seem logical to most people but these same wetlands in a natural state may be very attractive to breeding waterfowl as well as other wildlife. Use of common dump grounds situated in a carefully chosen location should be encouraged and supervised. This might ensure the preservation of numerous small wetlands on both private and public property.

Construction projects such as road building should not be permitted to indiscriminately destroy wetlands. Improved or hard top roads are frequently unnecessary and more often undesirable because of the tendency of some projects to cut through rather than go around certain wetlands. Federal, state and county road building agencies should be required to justify the necessity for building or widening roads. If a new road is necessary only the route which is least damaging to the environment should be selected.

Even small changes in lake water levels can reduce the attractiveness of shoreline habitat for ducks. For instance, rises in water level can inundate mud bars or destroy shallow weed beds which normally provide loafing and feeding areas for waterfowl. Public land managers and private land owners should be alert to the undesirable effects of water level changes.

Large scale waterfowl management programs involving manipulation of habitat should be undertaken only after experimental evaluation. Man-made improvement of natural habitat seems unlikely especially when based on scanty waterfowl ecological data.

The timing of human recreational activity can be important in many instances. Waterfowl may use wetlands and shorelines in close proximity to cabins and recreational areas but repeated disturbances by well meaning but curious observers will often result in aborted nesting attempts or reluctance of pairs to use otherwise desirable habitat. Tolerance to disturbance may be an individual trait but breeding waterfowl appear to be more sensitive to disturbance in the spring than at other times. A few words of caution to cabin owners, fishermen and early campers may be of value in reducing disturbance to breeding ducks.

Timber management may be used effectively in managing wood duck populations. A continuing source of natural wood duck cavities could be insured on the Chippewa study area by not cutting selected aspen on good sites. Requirements for selected trees would be that the trees be within several hundred feet of a wetland or lake shoreline and within approximately one half mile from suitable brood waters. Morainal areas supporting good timber stands and densities of 20 or more small wetlands per square mile would be excellent areas for this type of management. Aspen clear cutting efficiency would not be greatly reduced because most trees could be situated in clumps around wetlands or at the edges of stands. Marking actual or potential cavity trees on a regular basis in aspen stands that are scheduled for future harvesting would eliminate the need for erecting and maintaining nesting boxes in many areas. An even more desirable aspect of encouraging the development and survival of cavity trees is that local wood ducks would nest in natural cavities without becoming dependent on man for a source of nesting structures.

It is my opinion that the preservation of existing wetland and shoreline habitat and their use based on ecologically sound and carefully tested management plans will provide the greatest benefits for man and wildlife in the future.

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APPENDIX I

Home range and primary range data for individual mallard males 1968-1970.

			Home Range				Primary Range[b]			
Bird no.	No.[a] fix	Inclusive[a] dates	Size (acres)	Maximum length (miles)	Perimeter (miles)	Index of linearity L/W	Size (acres)	Maximum length (miles)	Perimeter (miles)	Percent location within P.R.
5006	39	4/27-5/20	320	1.2	2.9	1.4	232	1.2	2.8	94.9
5013[c]	73	5/8-5/25	593	1.8	4.4	2.1	470	1.8	4.1	97.3
5057[c]	148	4/26-6/19	690	1.6	4.3	1.3	337	1.2	3.1	95.9
5073[c]	59	5/13-6/23	251	1.1	2.8	1.6	154	0.7	2.1	94.9
5077	29	5/15-5/28	490	1.5	4.1	1.5	63	0.8	1.8	93.1
5119[c]	136	5/4-6/9	616	1.6	4.1	1.5	303	1.2	3.0	97.1
5129[c]	79	5/15-6/15	508	1.5	3.6	1.8	304	1.2	2.8	92.3
5131	20	5/15-6/2	674	2.4	5.5	3.0	116	0.8	1.9	84.2
5146	22	6/14-6/28	551	2.2	5.0	3.3	159	2.2	4.4	63.6

[a] Minimum of 20 locations and a tracking period of two weeks.

[b] Minimum area method (Mohr 1947) excluding extra-limital points.

[c] Used in calculating mean home range.

APPENDIX I

Home range and primary range data for individual mallard females 1968-1970.

			Home Range				Primary Range[b]			
Bird no.	No.[a] fix	Inclusive[a] dates	Size (acres)	Maximum length (miles)	Perimeter (miles)	Index of linearity L/W	Size (acres)	Maximum length (miles)	Perimeter (miles)	Percent location within P.R.
5012	74	5/8-5/21	405	1.9	4.0	3.8	348	1.9	4.0	97.3
5056[c]	178	4/26-6/28	514	1.4	3.7	1.5	304	1.1	2.9	96.1
5079	41	5/24-6/25	696	2.1	4.7	2.1	38	0.6	1.3	80.5
5080[c]	113	5/30-7/3	416	1.8	3.9	2.6	213	1.4	2.9	95.6
5118[c]	141	5/4-6/9	765	1.7	4.5	1.4	301	1.2	3.0	92.2
5123	28	5/8-5/20	129	0.9	1.8	2.0	53	0.7	1.5	92.9
5128[c]	128	5/15-6/29	538	1.4	3.7	1.5	352	1.3	3.0	96.1
5134[c]	76	5/25-6/22	631	2.3	5.0	3.5	291	1.2	2.8	86.8
5138	29	5/27-6/10	41	1.2	2.4	10.4	41	1.2	2.4	100.0

[a] Minimum of 20 locations and a tracking period of at least two weeks.

[b] Minimum area method (Mohr 1947) excluding extra-limital points.

[c] Used in calculating mean home range.

APPENDIX I

Home range and primary ranges data for individual wood duck males 1968-1970.

Bird No.	No. fix[a]	Inclusive dates[a]	Home Range: Size (acres)	Home Range: Maximum length (miles)	Home Range: Perimeter (miles)	Home Range: Index of linearity L/W	Primary Range[b]: Size (acres)	Primary Range[b]: Maximum length (miles)	Primary Range[b]: Perimeter (miles)	Primary Range[b]: Percent locations within P.R.
Group I[c]										
5066	35	5/11-6/8	860	2.5	5.6	2.3	40	0.1	0.3	82.8
5115	64	5/1-6/4	133	0.9	2.1	2.0	46	0.6	1.3	96.9
5121	140	5/5-6/23	653	1.9	3.9	1.3	547	1.3	3.6	92.9
5125	58	5/10-6/30	355	1.9	4.6	3.3	62	0.7	1.5	90.0
Group II[c]										
5008	42	4/26-5/7	554	1.6	4.1	1.6	156	1.1	2.3	81.0
5053	100	4/24-6/6	1427	2.4	6.2	1.4	683	2.3	5.1	88.0
5063	27	4/29-5/23	1666	3.2	7.0	2.4	319	1.8	3.9	70.4
5114	32	5/1-5/25	1918	2.8	7.0	1.5	107	0.7	1.7	78.2
5117	42	5/3-5/31	1215	2.4	6.2	1.6	163	1.2	2.6	85.7

[a] Minimum of 20 locations and a tracking period of at least two weeks.

[b] Minimum area method (Mohr 1947) excluding extra-limital points.

[c] All used in calculating mean home range.

APPENDIX I

Home range and primary range data for individual wood duck females 1968-1970.

			Home Range				Primary Range[b]			
Bird no.	No.[a] fix	Inclusive[a] dates	Size (acres)	Maximum length (miles)	Perimeter (miles)	Index of linearity L/W	Size (acres)	Maximum length (miles)	Perimeter (miles)	Percent locations within P.R.
5007	57	4/28-5/9	323	1.6	3.6	3.3	144	0.9	2.2	89.5
5018[c]	106	5/5-6/24	428	1.7	4.1	2.2	428	1.7	4.1	100.0
5019[c]	136	5/18-7/2	150	1.3	2.7	4.2	96	1.3	2.7	96.3
5023[c]	91	5/29-6/22	291	1.8	3.8	3.9	96	0.9	2.0	97.8
5054[c]	107	4/19-6/25	775	1.8	4.6	1.4	515	1.7	3.9	97.2
5055[c]	129	4/25-7/1	360	1.3	3.3	1.5	129	1.3	2.6	98.4
5058[c]	87	4/19-6/20	403	1.3	3.5	1.7	169	1.3	2.8	98.8
5059	44	4/29-5/23	633	2.3	5.1	2.7	147	0.7	1.9	86.4
5060[c]	98	5/4-6/14	774	1.6	4.3	1.3	374	1.3	3.2	94.9
5062[c]	79	5/5-6/6	545	1.9	4.3	2.2	234	1.6	3.4	96.2
5065[c]	72	5/8-6/11	468	1.3	3.3	1.5	390	1.2	3.1	97.2
5067	50	5/11-6/30	237	1.7	3.7	4.4	9	0.2	0.5	94.0
5068	31	5/11-5/31	325	1.3	3.1	1.8	13	0.6	1.2	90.3
5071[c]	108	5/13-6/17	533	1.7	3.8	1.9	135	1.1	2.4	92.6

APPENDIX I

Home range and primary range data for individual wood duck females 1968-1970. Continued.

			Home Range				Primary Range[b]			
Bird no.	No.[a] fix	Inclusive[a] dates	Size (acres)	Maximum length (miles)	Perimeter (miles)	Index of linearity L/W	Size (acres)	Maximum length (miles)	Perimeter (miles)	Percent locations within P.R.
5072	31	5/13-6/2	93	0.9	2.0	3.0	93	0.9	2.0	100.0
5116	37	5/3-5/31	281	1.8	3.8	4.5	93	1.3	2.6	89.2
5120[c]	151	5/5-6/30	576	1.3	3.8	1.1	528	1.3	3.6	99.3
5122	59	5/6-6/15	320	2.1	4.2	5.2	56	0.7	1.6	91.5
5124	61	5/10-6/30	360	1.9	4.1	3.7	216	1.3	2.9	88.5
5126	49	5/14-7/7	603	1.9	4.5	2.3	48	1.8	3.6	93.9
5135	21	5/26-6/9	241	1.7	3.5	5.8	129	1.7	3.4	90.5
5144	56	6/8-7/11	111	0.9	1.9	2.4	95	0.7	1.7	98.2

[a] Minimum of 20 locations and a tracking period of at least two weeks.

[b] Minimum area method (Mohr 1947) excluding extra-limital points.

[c] Used in calculating mean home range.

APPENDIX II

Home range data for individual mallard pairs 1968-1970.

Bird nos. Female/Male	Inclusive dates	Size[a] (acres)	Maximum length (miles)	Maximum distance from nest (miles)	Percent locations female within pair H.R.	Comments
5012/5013	5/8-5/20	342	1.8	1.8	77.0	Female transmitter failed during early incubation.
5056/5057	4/26-6/19	482	1.4	1.2	98.9	Pair nested successfully.
5118/5119	5/4-6/9	616	1.6	-	97.9	Probable nesting attempt.
5128/5129	5/15-6/15	293	1.2	1.0	94.5	Pair nested successfully.

[a] Minimum area method (Mohr 1947) using only locations where both members of pair are together.

APPENDIX II

Home range data for individual wood duck pairs 1968-1970.

Bird nos. Female/Male	Inclusive dates	Size[a] (acres)	Maximum length (miles)	Maximum distance from nest (miles)	Percent locations female within pair H.R.	Comments
5059/5063[b]	4/29-5/23	244	1.4	-	75.0	Pair bond dissolved. Female remated and subsequently nested successfully.
5116/5117[b]	5/3-7/2	238	1.8	-	71.9	Probable nesting attempt. Home range shifted. Pair together periodically.
5120/5121	5/5-6/23	532	1.3	0.98	96.0	Pair nested successfully.
5124/5125	5/10-6/30	301	1.9	-	90.2	No known nesting attempt. Pair remained together.

[a] Minimum area method (Mohr 1947) using only locations where both members of pair are together.

[b] Group II males.

APPENDIX III

Home range data for nesting mallard hens 1968-1970.

Bird no.	Pre-Incubation Period			Incubation Period			Nest status
	Home Range (acres)	Max. distance from nest (miles)	Inclusive dates	Home Range (acres)	Max. distance from nest (miles)	Inclusive dates	
5056	380	1.2	4/26-6/2	325	1.0	6/3-6/28	Hatch
5080	428	1.1	5/30-6/22	10	0.2	6/23-7/3	Hen killed on nest
5123	-	-	-	129	0.9	5/8-5/19	Destroyed
5128	421	1.1	5/15-6/3	329	1.2	6/4-6/29	Hatch
5134	634	2.2	5/25-6/9	78	1.3	6/10-6/22	Destroyed
5138	-	-	-	41	1.1	5/27-6/10	Hatch

APPENDIX III

Home range data for nesting wood duck hens 1968-1970.

Bird no.	Pre-Incubation Period: Home Range (acres)	Pre-Incubation Period: Max. distance from nest (miles)	Pre-Incubation Period: Inclusive dates	Incubation Period: Home Range (acres)	Incubation Period: Max. distance from nest (miles)	Incubation Period: Inclusive dates	Nest Status
5018	360	1.6	5/5-5/19	369	1.7	5/20-6/19	Abandoned eggs rotten
5019	121	1.2	5/18-6/3	88	1.2	6/4-7/2	Abandoned eggs pipping
5023	-	-	-	291	1.1	5/29-6/22	Hatch
5055	363	1.2	4/25-5/31	9	0.4	6/1-7/1	Hatch
5062	26	0.4	5/5-5/7	545	1.3	5/8-6/6	Hatch
5065	436	0.8	5/8-5/14	348	0.8	5/15-6/11	Abandoned eggs pipping
5068	-	-	-	325	1.0	5/11-5/31	Hatch
5071	322	1.0	5/13-5/18	453	1.6	5/19-6/17	Hatch
5072	-	-	-	93	0.9	5/13-6/2	Hatch ?
5120	545	1.0	5/5-5/31	79	0.9	6/1-6/30	Hatch
5126	609	1.8	5/14-6/7	8	1.8	6/8-7/7	Hatch
5135	-	-	-	241	1.6	5/26-6/9	Destroyed?
5143	-	-	-	57	0.4	6/6-6/12	Hatch
5144	32	0.8	6/8-6/12	93	0.7	6/13-7/11	Destroyed

APPENDIX IV

Wetland densities, miles of shoreline and the percentage of wetlands visited one or more times are indicated for mallard home ranges.

	Wetlands								Shorelines		
	< 2 acres				≥ 2 acres						
Bird no.	No. within H.R.	Wetlands/ mi^2	Percent locations	Percent visited 1+times	No. within H.R.	Wetlands/ mi^2	Percent locations	Percent visited 1+times	Miles in H.R.	Miles shoreline/ mi^2	Percent locations
5012	13	20.5	34.4	38.5	5	7.9	23.4	20.0	1.8	2.9	42.2
5013	13	14.0	34.2	30.8	8	8.6	10.9	50.0	2.2	2.4	54.8
5056	14	17.4	48.4	57.2	5	6.2	38.2	60.0	2.3	2.9	13.4
5057	17	15.7	25.5	41.2	6	5.5	44.5	50.0	2.7	2.5	29.9
5079	17	15.6	22.5	17.7	10	9.2	20.0	20.0	3.6	3.3	57.5
5080	15	23.1	4.4	33.3	5	7.7	31.0	60.0	2.4	3.7	64.6
5118	14	11.7	15.6	35.7	11	9.2	35.5	54.6	3.5	2.9	48.9
5119	12	12.4	11.9	33.3	12	12.5	38.1	41.6	2.8	2.9	50.7
5128	13	15.5	12.6	46.2	7	8.3	65.5	42.9	2.1	2.5	21.8
5129	12	15.1	38.5	50.0	3	3.8	39.7	66.6	2.1	2.6	21.8
5134	22	22.3	21.1	31.9	11	11.2	42.1	36.4	2.1	2.2	36.8
Means	14.7	16.7	24.5	37.8	7.5	8.2	35.4	45.6	2.5	2.8	40.2

APPENDIX IV

Wetland densities, miles of shoreline and the percentage of wetlands visited one or more times are indicated for wood duck home ranges.

	Wetlands								Shorelines		
	< 2 acres				≥ 2 acres						
Bird no.	No. within H.R.	Wetlands/ mi^2	Percent locations	Percent visited 1+times	No. within H.R.	Wetlands/ mi^2	Percent locations	Percent visited 1+times	Miles in H.R.	Miles shoreline/ mi^2	Percent locations
5055	15	26.7	83.1	66.7	7	12.4	16.9	57.2	0.6	1.1	0
5058	20	31.7	26.7	20.0	9	14.2	73.3	66.6	0	0	0
5059	18	18.2	16.7	33.3	5	5.0	23.8	60.0	1.3	1.3	59.5
5060	25	20.7	31.8	44.0	11	9.1	27.1	45.4	1.5	1.3	41.1
5062	22	25.8	63.7	18.2	8	9.3	5.6	37.5	2.3	2.7	32.7
5065	15	20.4	41.5	60.0	7	9.5	31.7	71.5	2.1	2.8	26.8
5067	4	10.8	72.0	75.0	3	8.0	2.0	33.3	0.8	2.2	26.0
5071	14	16.8	72.3	57.1	7	8.4	18.5	57.2	1.7	2.0	9.2
5115	13	62.1	57.2	61.5	1	4.7	42.8	100.0	0	0	0
5120	14	15.5	22.8	57.2	7	7.7	5.3	42.9	2.9	3.2	71.9
5121	19	18.6	48.2	63.2	9	8.8	11.1	77.8	2.6	2.5	40.7
5122	20	39.7	22.8	40.0	6	12.0	77.2	66.6	0.6	1.1	0
5124	24	42.3	34.5	20.8	5	8.8	4.9	60.0	1.6	2.9	60.6
5125	23	41.5	30.9	21.7	4	7.1	3.6	50.0	1.6	2.8	65.5
Means	17.6	27.9	44.6	45.6	6.4	8.9	24.6	59.0	1.4	1.9	31.0