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Barn Owl Habitat and Prey use in Agricultural Eastern Virginia

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BARN OWL HABITAT AND PREY USE IN AGRICULTURAL EASTERN VIRGINIA

A thesis

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by

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APPROVAL SHEET

This thesis is submitted in partial fulfillment of
the requirement for the degree of

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DEDICATION

This thesis is dedicated to my parents, who initially directed me towards the study of natural history and who have wholeheartedly supported and encouraged me throughout the duration of my academic pursuits.

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ABSTRACT

Barn owl (*Tyto alba*) habitat use and food habits were investigated in an intensively farmed area near Richmond, Virginia to evaluate the effects of agricultural land use on barn owl populations. The results of 784 radiotelemetry samples from six barn owls, 1061 prey item identifications, 6480 small mammal trap nights, and 260 vegetation density samples were used to evaluate where barn owls hunted, what they ate, and what influenced their foraging. Mean home range size was 851 hectares (95 percent confidence ellipse method) and 414 hectares (minimum home range method). Each owl used idle grassland more than expected, based on habitat availability, and fed mostly on *Microtus pennsylvanicus*. One owl used small grain more than expected and consumed large numbers of *Mus musculus*. Another owl used woods more than expected and preyed heavily on blackbirds. Another frequented a barnyard and fed substantially on *Mus musculus*. Heavily grazed pasture and tame hay were used in proportion to their availability. Corn, soybean, woods (except for the blackbird roost), and residential habitats were used less than expected. Prey density, species composition, and prey accessibility in different habitats apparently influenced barn owl foraging. Scarcity of dense grassland limits barn owl populations in heavily cultivated areas.

BARN OWL HABITAT AND PREY USE IN AGRICULTURAL EASTERN VIRGINIA

INTRODUCTION

Common Barn owl (Tyto alba) populations have declined markedly in both Europe (Honer 1963, Ogilvie 1976, Fuchs and Gussinklo 1977, Herren 1977, Prestt 1977, Segnestam and Helander 1977, Ziesemer 1980, Bunn et al. 1982, Hawk Trust 1983) and in North America (Petersen 1980; Colvin 1980; Lerg 1980; Tate 1981, 1986; Daniels 1984). The North American subspecies (T. a. pratincola) has been included on the National Audubon Society's Blue List of declining species every year since the list was initiated in 1972 (Tate 1981, 1986) and it is classified as endangered by seven, threatened by two, and declining by six state wildlife agencies (LeFranc and Millsap 1984, Daniels 1985, National Wildlife Federation [NWF] 1984b). All of the states in which it is endangered are midwestern, and those in which it is threatened or declining are eastern. A thorough evaluation of the status of the barn owl in Virginia from 1984 - 1986 resulted in a recommendation for threatened species classification in the Commonwealth (Appendix A). Factors which are suspected to have contributed most to the barn owl decline include 1) pesticide contamination, 2) a reduced availability of nesting sites, and 3) habitat loss.

Pesticide Contamination

The degree to which pesticide contamination has contributed to the widespread decline of the barn owl is not clear. Mendenhall et al. (1983) found that the barn owl is very sensitive to eggshell thinning by DDE and that dieldrin caused adult barn owl mortality. These organochlorine insecticides were found in concentrations that may have been detrimental to barn owl reproduction in 15 percent of the barn owls in the lower Potomac River, Maryland in the early 1970s (Klaas et al. 1978). Extensive feeding on passerine birds by this small proportion of the population is believed to have caused the elevated organochlorine levels; the majority of the population preyed chiefly on mammals and remained relatively uncontaminated. Few organochlorine insecticides are in use today, and many raptor populations have recovered substantially (Newton 1979).

Organophosphorous insecticides have been shown to be hazardous to predatory birds, including barn owls. Laboratory experiments conducted by Hill and Mendenhall (1980) demonstrated that barn owls which consumed famphur-poisoned prey exhibited secondary poisoning in the form of significant cholinesterase inhibition. Mass mortality of wild raptors, including 22 barn owls, occurred after azodrin was improperly used to kill voles in Israel (Mendelssohn and Pas 1977). Organophosphorous insecticides are still widely used for agriculture, but documentation of their effects on barn owls is lacking.

Secondary poisoning by rodenticides is a potential hazard to barn owls because they consume large number of rodents and frequent agricultural structures, a site where rodent poisons are often applied. Laboratory studies with barn owls have demonstrated that consumption of rats killed with bromadiolone, brodifacoum, or diphacinone causes lethal hemorrhaging and that difenacoum causes sublethal hemorrhaging (Mendenhall and Pank 1980). However, field studies have demonstrated that secondary hazards to barn owls from rodenticide use on farmsteads appear to be low because barn owls typically forage away from farmsteads and feed little upon rodenticide target species, the house mouse (*Mus musculus*) and the Norway rat (*Rattus norvegicus*) (Hegdal and Blaskiewicz 1984, Colvin 1984).

Loss of Nest Sites

A scarcity of secure nesting sites has reduced the breeding potential of barn owls. Tree cavities, which historically have been important as nest sites for barn owls (Bunn et al 1982, Laughlin et al. 1982, Colvin 1984,), are probably less abundant today. It is difficult to evaluate changes in the availability of this resource, but trends towards increased firewood cutting, short rotation forest management, and fencerow removal suggest that they are less abundant.

The gradual deterioration and disappearance of old-style barns and silos has eliminated many previously used nest sites. These old buildings are typically replaced by sheet metal sheds and glass-lined silos which have no openings for owl access and lack platforms for owl nesting sites. Old-style barns and silos are still abundant in some areas, but most of them are no longer suitable for nesting. Many are impervious because they have been closed or screened against pigeon access. Most old silos remain empty year round and therefore owls can not nest on top of silage as they once did. Also, few old barns and silos offer nest sites which are secure from mammalian predation. Raccoon population increases may be preventing breeding in sites where barn owls successfully nested at one time (Colvin 1980). Hay bales, barn platforms, cupolas, silo platforms, and tree cavities are frequented by raccoons; barn owl nests in these sites are vulnerable to predation.

The chief management technique for increasing barn owl populations has concentrated on alleviating the problem of a scarcity of secure nesting sites. Nest box programs can be effective for maintaining or increasing barn owl populations (Marti et al. 1979, Soucy 1980, Ziesemer 1980, Juillard and Beuret 1983, Colvin 1984, Schulz and Yasuda 1985). Nest box programs have been conducted in California (Schulz and Yasuda 1985), Indiana (Parker 1986), Michigan (Maley 1980, pers. commun.), Missouri, Nebraska, Wisconsin (LeFranc and Millsap 1984), New Jersey (Soucy 1980, Colvin 1984), Ohio (NWF 1984c), Utah (Marti et al. 1979, LeFranc and Millsap 1984), and Virginia (Appendix I), Another management technique, captive-release projects, has been used in Illinois (Daniels 1984), Iowa (Ehresman 1984, NWF 1985b), Missouri (NWF 1985b), Nebraska (Hancock et al. 1981, NWF 1984a), and Wisconsin (NWF 1985a).

Habitat Loss

Habitat loss appears to be an important contributor to the barn owl decline throughout the barn owl's range. Habitat changes in agricultural areas have been evident, but the consequences of these changes for barn owls have been less obvious. Habitat has been lost primarily from the development of farmland into residential areas and the intensification of agricultural practices on remaining farmland. The US Department of Commerce (1980) summarizes changes in land use made in Virginia between 1945 and 1978. Virginia had over 9.5 million acres of open farmland in 1945; today less than 6.5 million acres are farmed. Whereas 61 percent of the open farmland in 1945 was in cropland, 74 percent was in cropland in 1978. Most of the land lost to development was ultimately removed from pasture, wild hayfields, and idle areas. The total acreage of these predominantly grass habitats in Virginia has been reduced 55 percent since 1945. These habitats are frequently hunted by raptors (Craighead and Craighead 1956, Honer 1963, Clark 1975, Shrubb 1980, Baker and Brooks 1981, Bechard 1982, Mikkoloa and Willis 1983, Pettifor 1984, Schmutz 1984). Also, pasture is more heavily grazed today;

the number of cattle per acre of pasture in Virginia has risen 364 percent since 1945. Heavily grazed pasture has little protective cover and therefore supports few small mammals (Blair 1940, Lewis 1940, Eadie 1953, Getz 1960). It should be noted that these habitat changes have been most dramatic in Virginia's coastal plain counties. Similar descriptions of habitat loss are given for Britain (Shrubb 1970) and Ohio (Colvin 1980, 1984, 1985).

The US Department of Commerce does not monitor the availability of hedgerows and fencerows, habitats that are important for many raptor species (Dunstan 1970, Shrubb 1980, Bunn et al. 1982, Byrd 1982, Mikkola and Willis 1983, Pettifor 1984). Other authors, though, have shown that these habitat features are much less plentiful today than earlier this century (Shrubb 1970, Leite 1971, Vance 1976, Taylor et al. 1978, Best 1983).

Little study has been directed towards learning how modern agricultural land use affects barn owl populations. The barn owl relies heavily upon dense grassland (Pearson and Pearson 1947; Karalus and Eckert 1974; Fast and Ambrose 1976; Colvin 1980, 1984; Bunn et al. 1982; Hegdal and Blaskiewicz 1984) and is therefore expected to survive poorly in heavily farmed areas where grassland has been nearly eliminated. It is difficult to make irrefutable conclusions, however, because barn owl habitat use has not been studied thoroughly enough and over a wide enough range of habitat availability to affirm that cultivated habitats, some of which support high rodent populations, are not utilized.

An investigation of barn owl habitat use in an area with an abundance of cultivated land and little dense grassland may resolve uncertainties regarding the area of grassland needed by barn owls and the ability of this predator to forage successfully in habitats other than grassland. In light of this possibility, this study was undertaken. Radiotelemetry was used to monitor barn owl movements in an intensively farmed area near Richmond, Virginia. Home range size, flight characteristics, habitat use, and food habits were identified to describe how barn owls foraged amongst agricultural habitats. In addition, habitat characteristics were measured to investigate the factors which influenced barn owl foraging patterns. Comparisons are made between this study and other raptor foraging studies, including four barn owl radiotelemetry studies (Ault 1971, Byrd 1982, Hegdal and Blaskiewicz 1984, Colvin 1984). The results broaden our understanding of barn owl-agriculture interactions and provide information which may be useful for barn owl management programs.

METHODS

Study Area

Eastern Virginia comprises a diversity of open habitats ranging from marshland to intensively farmed cropland. Attempts to locate barn owls in this area were made by publishing ads in farmer's magazines and county newspapers, distributing "wanted posters" to farm supply stores and Virginia Farm Bureau offices, contacting Virginia Society of Ornithology chapters and Virginia Game Commission personel, searching likely barns and silos, and speaking to farmers. Four farmsteads near Richmond, Virginia were chosen as the specific study sites for this research (Fig. 1). These farms were chosen on the basis of the presence of a breeding pair of barn owls, the surrounding habitat, and landowner cooperativeness. Three of the sites are surrounded by rowcrops while the fourth is a dairy farm surrounded by rowcrops and heavily grazed pasture.

Westover Plantation is in Charles City county, Curles Neck Farm and Riverview Farm are in Henrico county, and Townsend Farm is in King William county. The total size of this three county study area is approximately 2000 km^2. Mean annual precipitation for the region is 108 cm, and mean temperatures range from -2 C in January to 31 C in July (National Oceanic and Atmospheric Administration [NOAA] 1980).

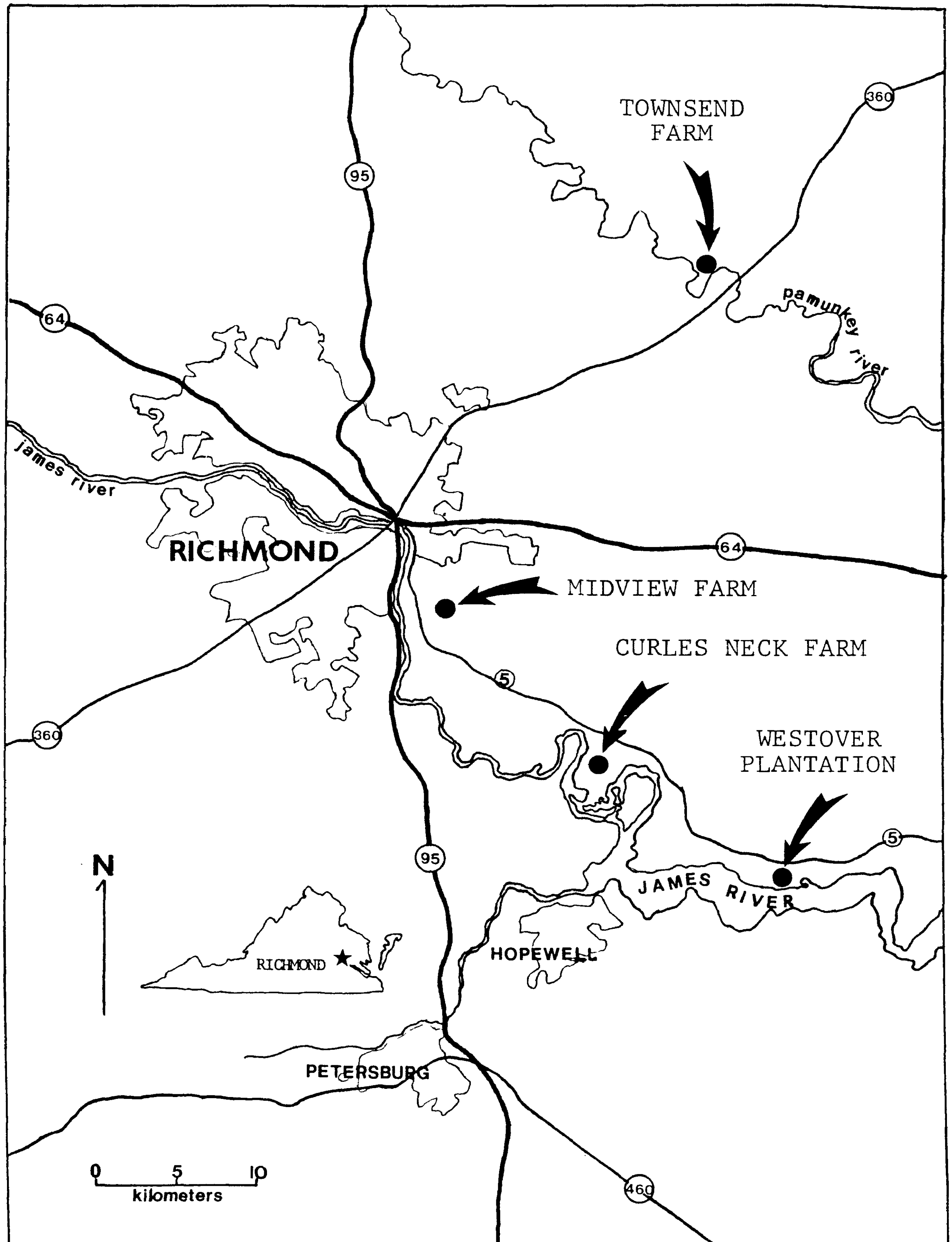


Figure 1. Distribution of the four study farmsteads within the eastern Virginia barn owl study area.

Vegetation types within the study area were grouped into several major habitat categories on the basis of the composition and structure of the vegetation and the way in which the vegetation was managed. The consolidation of specific habitat types (e.g. barnyard, hayfield, marsh) into general habitat categores (e.g. idle grassland) results in a loss of information. However, consolidation was necessary to meet goodness of fit test assumptions; expected frequencies are recommended to be greater than or equal to five (Neu et al. 1974, Sokal and Rohlf 1981). Since the expected number of observations in each habitat category is based on the fraction of the area occupied by that habitat, habitats such as barnyards, which cover only a small fraction of each study site, could not be tested alone.

Eight habitat categories were established:

1. Small Grain - cultivated with wheat (*Triticum aestivum*) or barley (*Hordeum vulgare*). Planted in October and harvested in early June.
2. Corn - cultivated with corn (*Zea mays*). Planted in late April and harvested in early September.
3. Soybean - cultivated with soybean (*Glycine soja*). One hybrid planted in early May, another planted into small grain stubble in mid June. Harvest in early November.
4. Tame Hay - cultivated with alfalfa (*Medicago sativa*) or sudan grass (*Sorghum sudanense*). Alfalfa planted in April and cut several times before final harvest in

October. Sudan grass planted in June and either grazed or harvested for silage by November.

5. Pasture - uncultivated mixture of Canada bluegrass (*Poa compressa*), orchard grass (*Dactylis glomerata*), and redtop (*Agrostis alba*). The pasture studied was cropped close to the ground from heavy grazing.

6. Idle Grassland - uncultivated areas dominated by ungrazed grasses. This category included grassy fields (infrequently mowed), barnyards (infrequently mowed), and wild hayfields (harvested once or twice a year) composed chiefly of bluegrass (*Poa* sp.), purpletop (*Tridens flavus*), timothy (*Phleum pratense*), sweet vernalgrass (*Anthoxanthum odoratum*), yellow bristlegrass (*Setaria lutescens*), and red clover (*Trifolium pratense*); a five year old clearcut with ryegrass (*Lolium temulentum*), bulrush (*Scirpus* sp.), sedges (*Carex* sp.), Japanese honeysuckle (*Lonicera japonica*), blackberry (*Rubus* sp.), loblolly pine (*Pinus taeda*), and red maple (*Acer rubrum*); marsh vegetated with sedges (*Carex* sp.), arrow arum (*Peltandra virginica*), and pickerelweed (*Pontederia cordata*); and residential areas, gravel mine land, or pasture which were too small to occupy separate categories.

7. Woods - forests of loblolly pine, baldcypress (*Taxodium distichum*), tulip-popular (*Lireodendron tulipifera*), white oak (*Quercus alba*), southern red oak (*Quercus falcata*), sweetgum (*Liquidambar styraciflua*), flowering

dogwood (Cornus florida), and American holly (Ilex opaca); brushy areas composed of blackberry, Hercules' Club (Aralia spinosa), winged sumac (Rhus capallina), and red-osier dogwood (Cornus stolonifera).

8. Residential - parking lots, houses, schools, and other buildings surrounded by manicured lots.

Capturing Barn Owls

Barn owls were captured for radio transmitter attachment. Three trapping techniques used by previous researchers were attempted: 1) bal-chatri traps baited with a white laboratory mouse, wild house mouse, or wild meadow vole (Microtus pennsylvanicus) (Berger and Mueller 1959; Brian Millsap, pers. commun.; Peter Bloom, pers. commun.); 2) a stuffed great horned owl (Bubo virginianus), great horned owl tape, and mist net combination (Bechard 1982; Brian Millsap, pers. commun.); and 3) mist netting which covered barn and silo exits to capture owls flushed from these structures during daylight hours or during their routine nocturnal flights (Byrd 1982; Colvin and Hegdal 1983, 1986). Exits were covered either with a long-handled landing net fitted with mist netting or with a mist net which was raised into place via strings from outside the building.

All captured owls were aged and sexed, banded with a U.S. Fish and Wildlife Service (USFWS) aluminum leg band, and fitted with a radiotransmitter. Handling time before release was less than 30 minutes. Age determination was based on molt sequence (Bloom 1978). Sex determination was based on the presence or absence of a brood patch, the color of the breast feathers, and the size and number of spots on the breast (Bloom 1978). Radiotelemetry observations helped to verify sex determinations.

Two types of radiotransmitters and two basic attachment designs were used. In 1984, ten gram (approximately two percent of barn owl body weight), high drain, activity-monitoring, four month life radio transmitters (Wildlife Materials; Carbondale, Illinois) were used. Transmitters were initially tail-mounted by attaching one side of the transmitter firmly to the upper surface of a central retrice using Devcon five-minute epoxy and monofilament line sewed through the feather vein, and loosely attaching the other side to the second central retrice using monofilament line only (Kenward 1978). All owls with tail-mounted transmitters soon lost the central retrices, so transmitters were then attached using a backpack harnass. Backpack harnasses followed the design recommended by Dunstan (1972) and were made of rubber-coated multistrand wire or 45 pound test steel fishing leader enclosed in foam rubber (to prevent chafing).

In 1985 and 1986, eighteen gram (approximately four percent of barn owl weight), low drain, activity-monitoring, twelve month life transmitters (Telemetry Systems, Inc.; Mequon, Wisconsin) were used. All transmitters were attached using a criss-cross backpack harnass (Smith and Gilbert 1981) made of quarter inch tubular teflon (Bally Ribbon Mills; Bally, Pennsylvania). The teflon ribbon was sewn together on the owl's ventral side. All knots and trimmed ends of teflon ribbon were sealed with Devcon five minute epoxy.

Radiotracking

Radiotelemetry is a valuable tool for monitoring movements of nocturnal or otherwise difficult to observe animals (Craighead and Craighead 1965, Kolensky and Johnston 1967, Nicholls and Warner 1971, Dunstan 1972, Fleming 1978). Barn owl movements were monitored with assistance from a research technician. Each observer drove a separate vehicle, parked it at a predetermined observation point, and located the owl using an LA12 receiver and three-element hand-held antenna (AVM Instrument Company; Livermore, California). One exception to this radiotracking system occurred in 1984 when one observer operated a stationary null-peak antenna system consisting of two four-element antennas (AVM Instrument Company). This null-peak system was abandoned early in the 1985 field season because it was producing erratic results. Communication by two-way radio and the use of synchronized watches permitted the taking of simultaneous location bearings from the two observation points. A compass azimuth was determined for each border of the transmitter's signal arch, and a location bearing was calculated by finding the midpoint between these two borders. To prevent excessive inaccuracy, most compass bearings were made within 0.8 kilometer of the transmitter, and observers were positioned such that location bearings intersected at approximately right angles (Heezen and Tester 1967). Only bearings which intersected at angles between 45 and 135 degrees were used for determining locations.

Pairs of location bearings were used to determine owl locations on 1:7920 aerial photographs (obtained from Agricultural Stabilization and Conservation Service, Salt Lake City, Utah; Virginia Department of Highways and Transportation, Richmond, Virginia). All habitat types and observation points were marked on the photographs and each photograph was covered with a transparent vinyl sheet on which a .635 cm (quarter inch) grid system had been drawn. Location bearings were transferred onto the vinyl sheet using a 360 degree protractor and a water-soluble transparency pen. Owl locations were determined from these two location bearings by triangulation. The location was recorded as the grid number in which it fell. The habitat associated with this location and the owl's activity state (perched if slow pulse rate, flying if fast rate) at the time of the bearing were also recorded.

Barn owl movements were monitored during four two month time periods (1 July-31 August 1984, 1 July-31 August 1985, 1 September-31 October 1985, and 1 May-30 June 1986). These time periods correspond in general to seasonal changes in barn owl breeding and agricultural land use. Each farmstead was visited for an entire night approximately once a week. An exception to this occurred during the September-October time period when owls were monitored for half nights (dusk to 0100, 0100 to dawn). The location, associated habitat, and activity state of each owl was sampled once every half hour throughout the night. Sampling began at the first quarter hour following an owl's initial flight. If two owls were monitored at a given farmstead, sampling for the second owl began at the next quarter hour. Subsequent samples were taken until the owl(s) went to roost for the day (determined by the cessation of flight).

Roost sites were identified prior to hunting flights and after completion of hunting in order to determine barn owl roost site selection. Also, owls were periodically located during daylight hours to determine whether daylight hunting or roost relocation occurred.

Home Range Evaluation

Barn owl location data were used to estimate a home range for each owl during each two month time period. Home range is defined here as the smallest region which has a 95 percent probability of enclosing the owl's location at any time during a two month time period (Jennrich and Turner 1969). Location data were analysed following the proceedure described by Dunn and Gipson (1977) which utilizes the multivariate Ornstein-Uhlenbeck diffusion process to account for lack of independence between location samples; their computer program produced a 95 percent confidence ellipse to describe the home range of each owl during each time period. Home ranges were also identified using the minimum home range method (Mohr and Stumpf 1966) for comparison to home ranges identified by other radiotelemetry studies of the barn owl.

The habitat composition of each home range was determined by transferring each ellipse to the appropriate 1:7920 aerial photograph and calculating the percentage of each habitat type within the ellipse. This was accomplished by enlarging the ellipses to 1:7920 scale on acetate sheets, positioning each sheet over the photgraph, and tracing habitat boundaries. The area within each boundary was computed using a Lasico polar planimeter. Areas of extensive open water, such as the James River, were excluded from habitat composition calculations.

Habitat Use Evaluation

In order to evaluate barn owl habitat use, comparisons were made between the availability of each habitat and the percentage of time spent in that habitat. The habitats deemed available were all that were present within an owl's home range except extensive water surfaces. G-tests (Sokal and Rohlf 1981) were used to test the null hypothesis that owls used each habitat type in exact proportion to its availability. The expected number of locations for each habitat was calculated by multiplying the total number of observations times the percentage of the owl's home range occupied by that habitat. During G test calculations, habitats with zero observed locations were assigned a value of one since a zero results in an erroneous G value.

Whenever the null hypothesis of habitat use in exact proportion to its availability was rejected, utilization-availability analyses (Neu et al. 1974) were conducted to determine which habitats were used significantly ($P<0.05$) more or less than expected. These analyses construct ninety-five percent confidence intervals around the observed proportion of locations in each habitat category. Experimentwise error rate is included in each confidence interval calculation since multiple comparisons are being made (Neu et al. 1974, Sokal and Rohlf 1981). The following formula was used to calculate the confidence intervals:

$$p_i \pm t_{.05'} \sqrt{p_i(1-p_i)/n}$$

where p_i is the proportion of locations in the i^{th} habitat category, $t_{.05'}$ is the experimentwise error rate critical value for t at the .05 significance level (from Table 13, Rohlf and Sokal 1981), and n is the total number of locations for the owl during that time period (Neu et al. 1974).

Habitat preferences and avoidances were determined by comparing the confidence limits for the observed proportion of locations to the expected proportion of locations. Habitat preference occurred when the lower confidence limit for observed locations was greater than the expected proportion of locations. Preference is therefore defined here as significantly greater use of a habitat than expected. Habitat avoidance occurred when the upper confidence limit for observed locations was less than the expected proportion of locations. Avoidance is therefore defined here as significantly less use of a habitat than expected.

Prey Consumption Analysis

Barn owl pellets were collected and analyzed to determine animals preyed upon. The main objective of identifying barn owl prey was to compare prey consumed to habitat use and prey availability. Pellets were collected from known roosts once every few weeks, frozen, dried, and grouped by study site and time period. Pellets were carefully dissected to locate all skulls and skull fragments. Prey composition was determined by the number of mammalian skulls, or unduplicated skull fragments, and the number of bird synsacra; synsacra were used for birds because they were typically present in pellets containing feathers whereas avian skulls were often lacking. Identification of mammalian skulls was made using a skull key (Brown and Russell 1976). Synsacra were not identifiable to species, but all bird skulls present were identified by comparing them to skulls in the William and Mary collection.

Assessment of Small Mammal Abundance

Small mammal populations were sampled during 1985 and 1986 to identify the relative abundance of prey in agricultural habitats at each farmstead. Trapping was conducted in four or five habitats simultaneously for three nights between the fourth and sixth week of each time period. Traps were also set in wheat, corn, and soybean fields immediately following harvest to evaluate small mammal abundance at these times of cover removal. Trap lines were set as close to the center of each habitat as possible, usually 50 meters or more from the habitat edge. Trap lines consisted of two parallel rows, spaced 20 meters apart, of ten trap stations. Spacing between trap stations was ten meters, and two museum special snap traps baited with peanut butter and rolled oats were used per trap station. An exception to this, due to the limited number of traps, occurred when trapping Townsend Farm. Traps were used in tame hay instead of corn, and two parallel rows of five stations were each set in alfalfa and sudan grass. The results were compiled to yield the number of animals trapped for tame hay. Traps were set in early evening and checked early the next morning for each of the three trap nights. All animals trapped were identified and frozen. Weights were measured for each mammal at the completion of the study.

Assessment of Habitat Canopy Coverage

Assessments of the canopy coverage within agricultural habitats were made to quantify the degree of prey concealment provided by different habitats at different times of the farm year. These assessments were made by placing a meter square at ten meter intervals in wheat, corn, soybean, alfalfa, and sudan grass habitats and estimating, to the nearest ten percent, the proportion of ground area obscured by vegetation. Ten samples were taken in each habitat at each farmstead. While this proceedure seemed adequate for making comparisons between cultivated habitats, it did not seem appropriate for uncultivated habitats where ground is mostly obscured whether plant cover is dense or sparse. Therefore, no assessments were made in uncultivated habitats.

Statistical Analyses

Statistical Package for the Social Sciences (SPSSx) (SPSSx Inc 1983) was used to calculate Pearson Product Moment Correlation Coefficients, chi-square contingency tests, one way and two way Analysis of Variation (ANOVA), and Tukey's Honestly Significant Difference Method. Minitab (Minitab Inc 1985) was used to compute means, standard deviations, and G Tests. Confidence intervals for utilization-availability analyses were determined using a hand calculator. Statistical significance of all tests was $P<0.05$. Descriptive statistics are reported here as mean $\pm$ standard deviation.

RESULTS

Barn Owl Captures

Twelve barn owls (six adult females, five adult males, and one juvenile) were trapped for transmitter attachment during the course of the study (Table 1). The only successful trapping technique was the use of mist nets inside barns and silos. Owls are identified here using the trapping location and the last three digits of the USFWS band. Six barn owls (four female and two male) were monitored long enough to gather a sufficient sample size for home range and habitat use analyses. One owl (Midview #206) was monitored during three two-month time periods, four (Midview #208, Westover #215, Townsend #217, Curles Neck #224) for two periods, and one (Curles Neck #226) for one period.

Sufficient sample size was not obtained from the other six barn owls because of transmitter removal, dispersal from the study area, or death of the owl. In 1984, Curles Neck #203, #204, and #205 quickly removed transmitters that were tail-mounted or attached using a wire backpack, and further attempts to trap these individuals in 1984 were fruitless. Townsend #225 presumably left the study area for fall migration shortly after transmitter attachment; contact was lost from this bird and his mate in early October 1985. Curles Neck #203, Westover #211, and Westover #233 died

Table 1. Barn owls trapped for transmitter attachment near Richmond, Virginia, 1984-1986.

LOCATION	OWL #	SEX	AGE[1]	TRANSMITTER[2] ATTACHMENT	TRACKING PERIOD	N	NOTES
Curles Neck	202	M	ATY	tail mount	15 June-26 June 84	17	owl removed trans.
	203	F	TY	tail mount	15 June-24 June 84	12	owl removed trans.
	204	?	HY	BP (wire)	10 July-13 July 84	8	owl removed trans.
	202	M	ATY	BP (wire)	11 July-13 July 84	7	owl removed trans.
Midview	206	F	TY	BP (cable)	30 July-25 Aug. 84	57	field season ended
	208	F	TY	BP (cable)	3 Aug.-18 Aug. 84	46	owl damaged trans.
Midview	206	F	ATY	BP (teflon)	10 May -12 Nov. 85	189	field season ended
	208	F	ATY	BP (teflon)	20 June- 3 Sep. 85	52	lost contact[3]
Curles Neck	203	F	ATY	BP (teflon)	13 May - 3 June 85	16	owl found dead[4]
	224	F	SY	BP (teflon)	23 June-13 Nov. 85	154	field season ended
Westover	211	F	ATY	BP (teflon)	1 June-30 July 85	45	owl found dead[5]
	215	M	SY	BP (teflon)	6 June- 4 Oct. 85	134	lost contact[3]
Townsend	217	F	ATY	BP (teflon)	12 June- 6 Oct. 85	117	lost contact[3]
	225	M	TY	BP (teflon)	5 Oct.- 6 Oct. 85	8	lost contact[3]
Curles Neck	226	M	SY	BP (teflon)	2 May - 15 Jun 86	83	field season ended
Westover	233	M	SY	BP (teflon)	17 May - 23 May 86	23	owl found dead[5]

1 HY=hatch year, SY=second year, TY=third year, ATY=after third year
2 BP = backpack harnass
3 presumably left the study area for fall migration
4 great horned owl predation appeared to be immediate cause of death
5 immediate cause of death uncertain; poisoning suspected

before sufficient sample size was obtained. Incumberance from the backpack harnass did not appear to cause the death of these owls; two of the three carcasses were intact and the harnass did not appear to have obstructed breathing, pellet formation, or flight. However, transmitter attachment is suspected to have contributed indirectly to the death of Curles Neck #203 and Westover #233 because of the short duration (21 days, 6 days) between attachment and death. The immediate cause of death for Curles Neck #203 appeared to be great horned owl predation; its remains were found below a dead snag in a grassy field. Poisoning is suspected for Westover #211 and Westover #233; these two owls died within 400 meters of each other, and neither carcass showed signs of predation.

Radiotelemetry Samples

A total of 784 samples of location, habitat use, and activity state were made during the four time periods. The accuracy of this sampling proceedure was assessed by placing transmitters at known locations, determining their location by radiotelemetry, and comparing estimated to true bearings. Mean deviation from true bearings was calculated to be 6.5 $\pm$ 5.1 degrees (N=42). This accuracy would result in a mean deviation from true owl location of 91 $\pm$ 72 meters when bearings were taken .80 kilometers from the owl.

The sampling interval for this study was set at 30 minutes in an attempt to maximize sample size while maintaining independence between samples. Sampling independence was not a requirement for the analysis of location data since the multivariate Ornstein-Uhlenbeck diffussion process incoporated into the home range computer program accounts for lack of independence (Dunn and Gipson 1977). However, habitat use and activity state analyses assume independence between successive samples (Neu et al. 1974, Sokal and Rohlf 1981). There is no statistical test to evaluate sampling independence of habitat use data because it is in the form of nondichotomous nominal variables (Sokal and Rohlf 1981). However, independence seems plausible since 84 $\pm$ 6.7 percent of the intervals between samples contained one minute or more of flight; the frequency of foraging bouts indicates that habitat use was probably independent of habitat use 30 minutes previously. Independence of activity state was examined for each night of sampling data using a Runs Test for Dichotomized Data (Sokal and Rohlf 1981). Significant dependence was found for only one of 74 tests.

Home Range Size and Composition

Home range drawings (Figs. 2-8) were made for at least one time period for each owl to show the habitat composition and the distribution of telemetry locations. Figure 9 shows the degree of overlap between the home ranges of Midview #206 and Midview #208. Home range size varied between 224 and 2306 hectares (Table 2). Mean home range size was 851

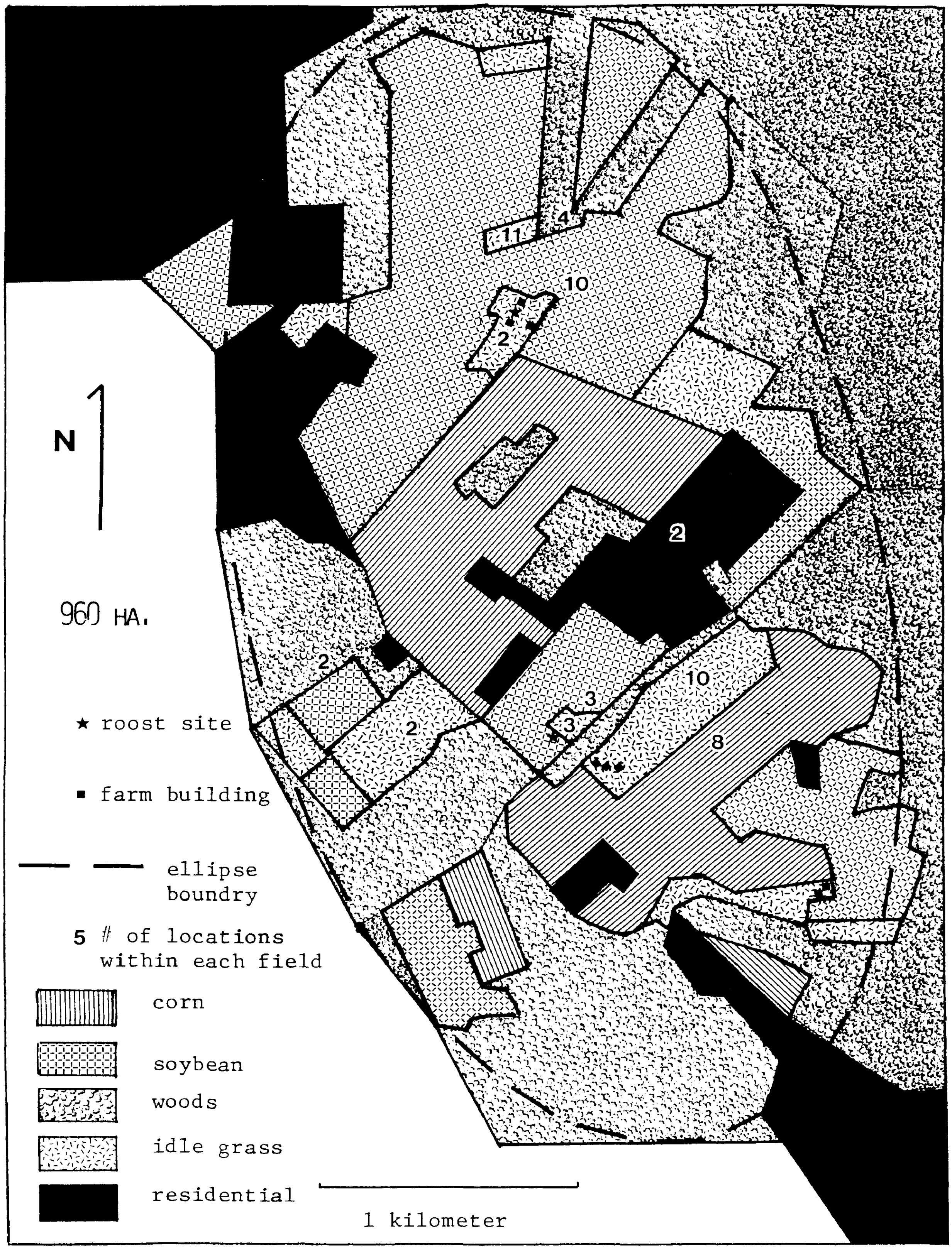


Figure 2. Ninety-five percent confidence ellipse and the distribution of telemetry locations for Midview #206, July - August 1984.

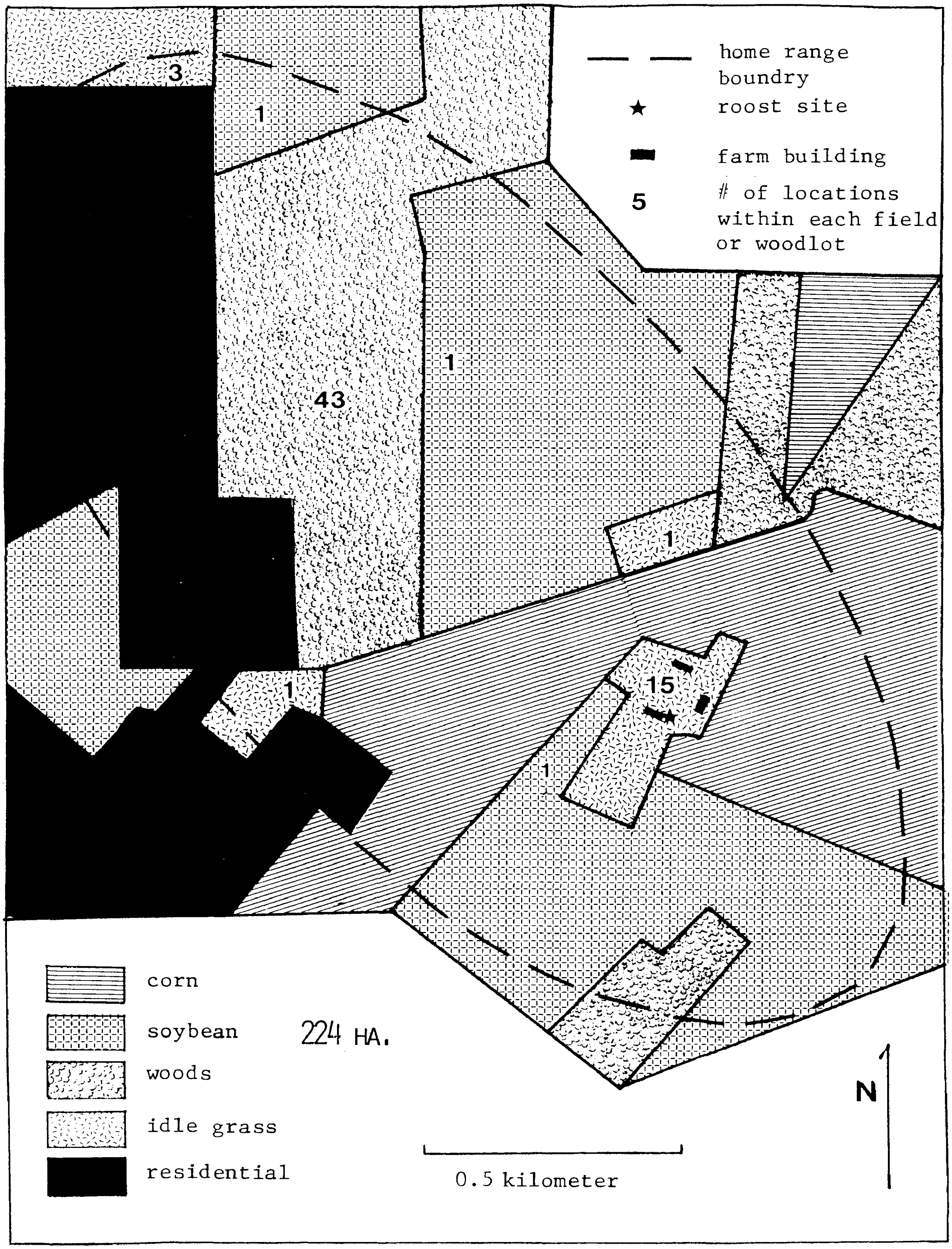


Figure 3. Ninety-five percent confidence ellipse and the distribution of telemetry locations for Midview #206, July - August 1985.

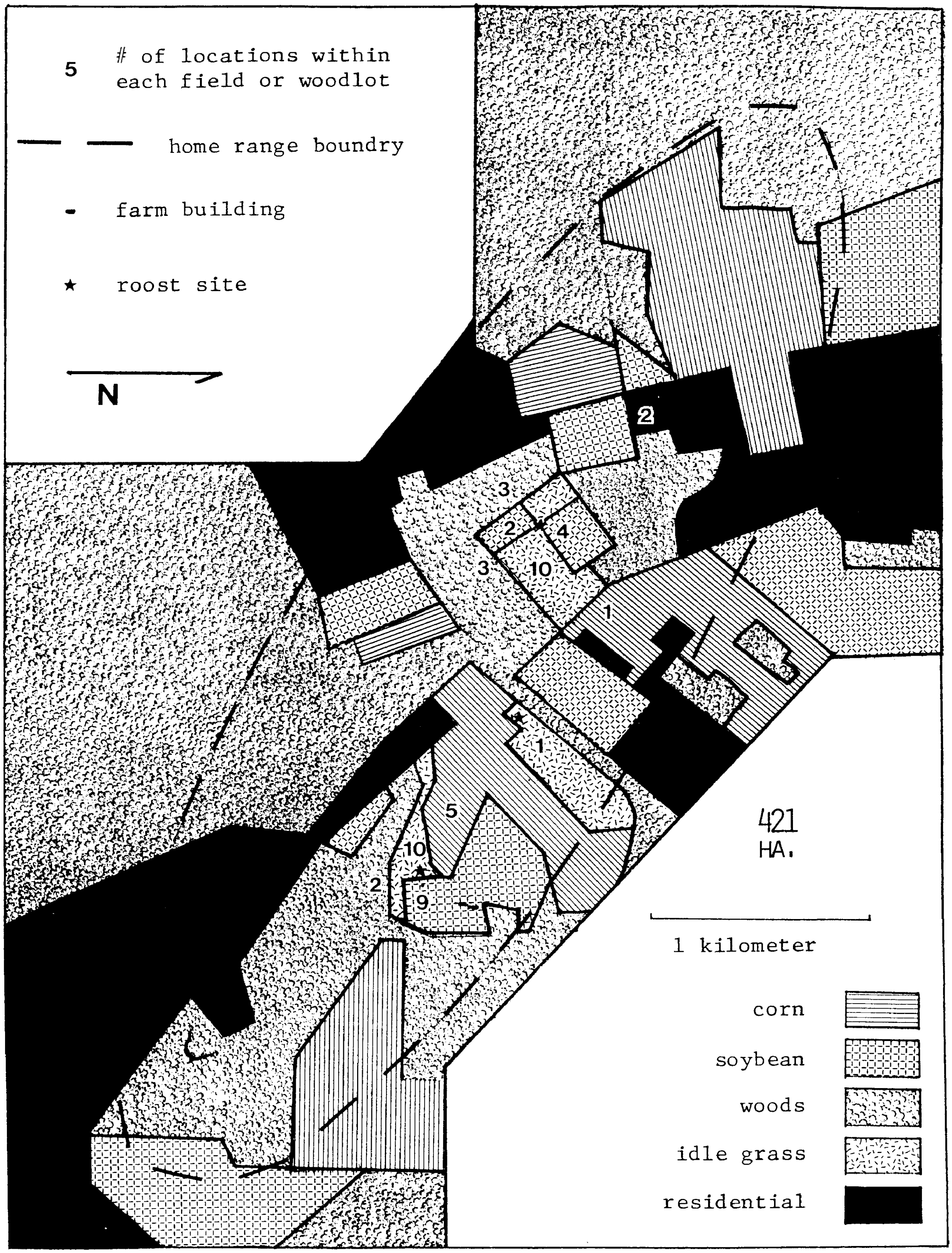


Figure 4. Ninety-five percent confidence ellipse and the distribution of telemetry locations for Midview #208, July - August 1984.

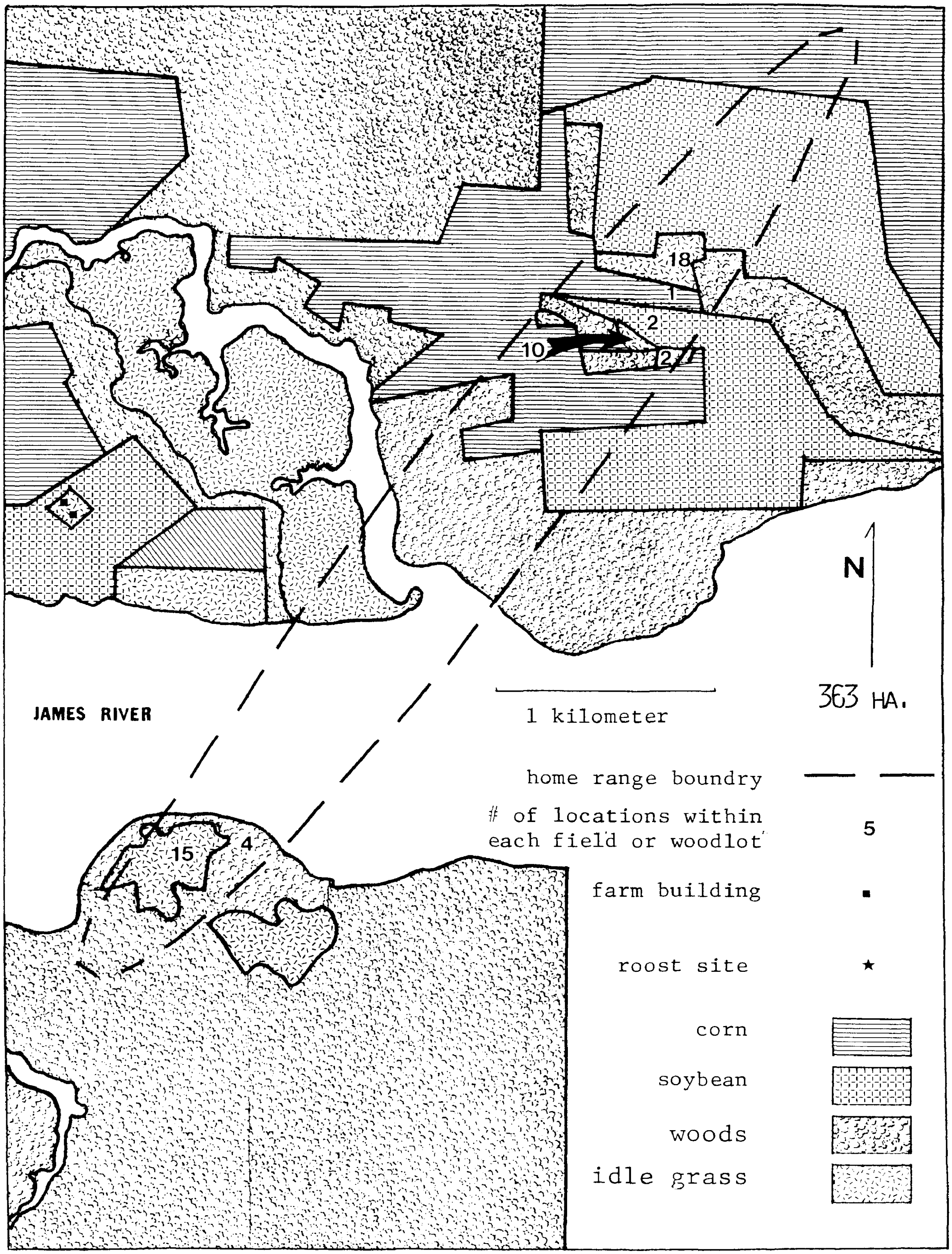


Figure 5. Ninety-five percent confidence ellipse and the distribution of telemetry locations for Westover #215, September - October 1985.

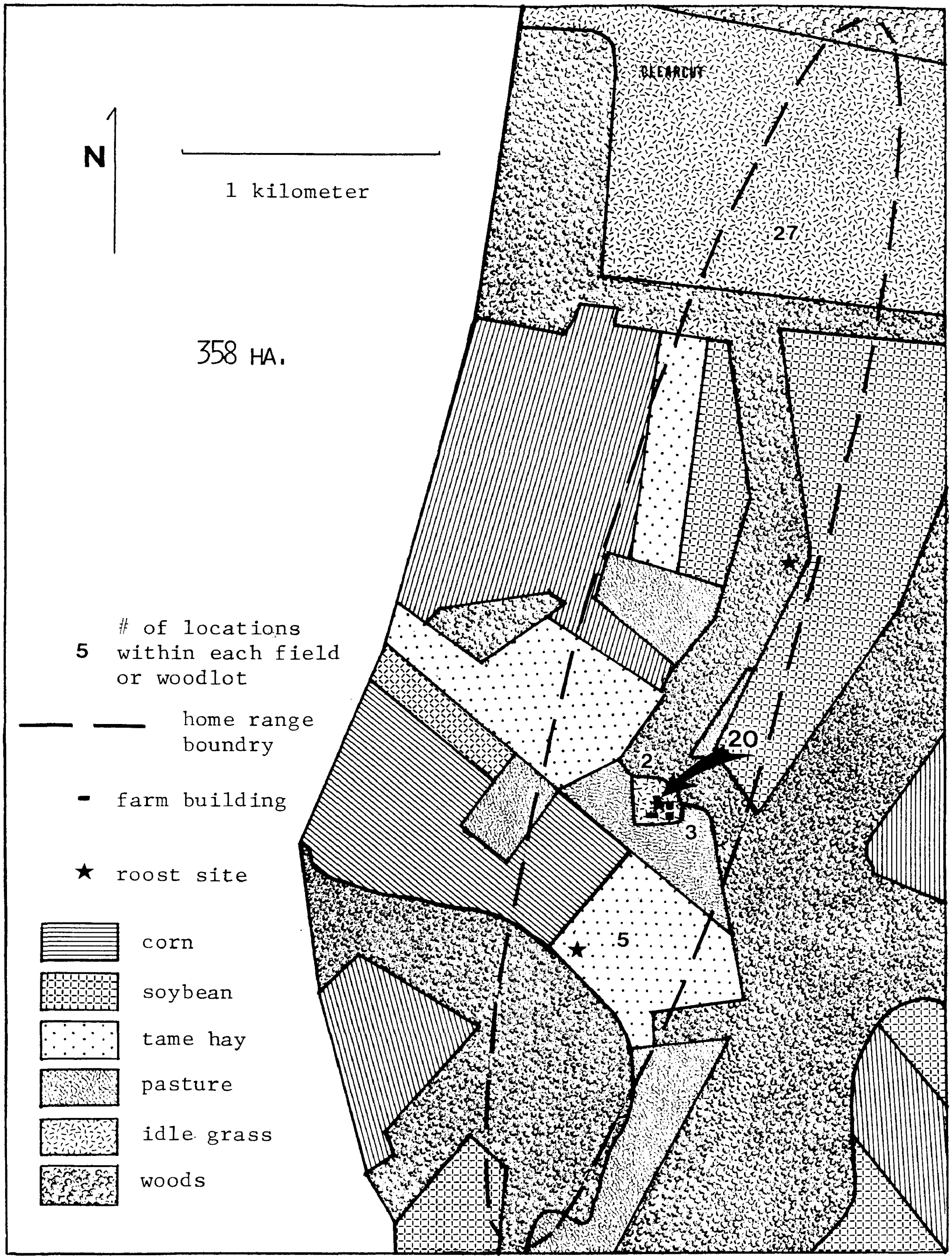


Figure 6. Ninety-five percent confidence ellipse and the distribution of telemetry locations for Townsend #217, July - August 1985.

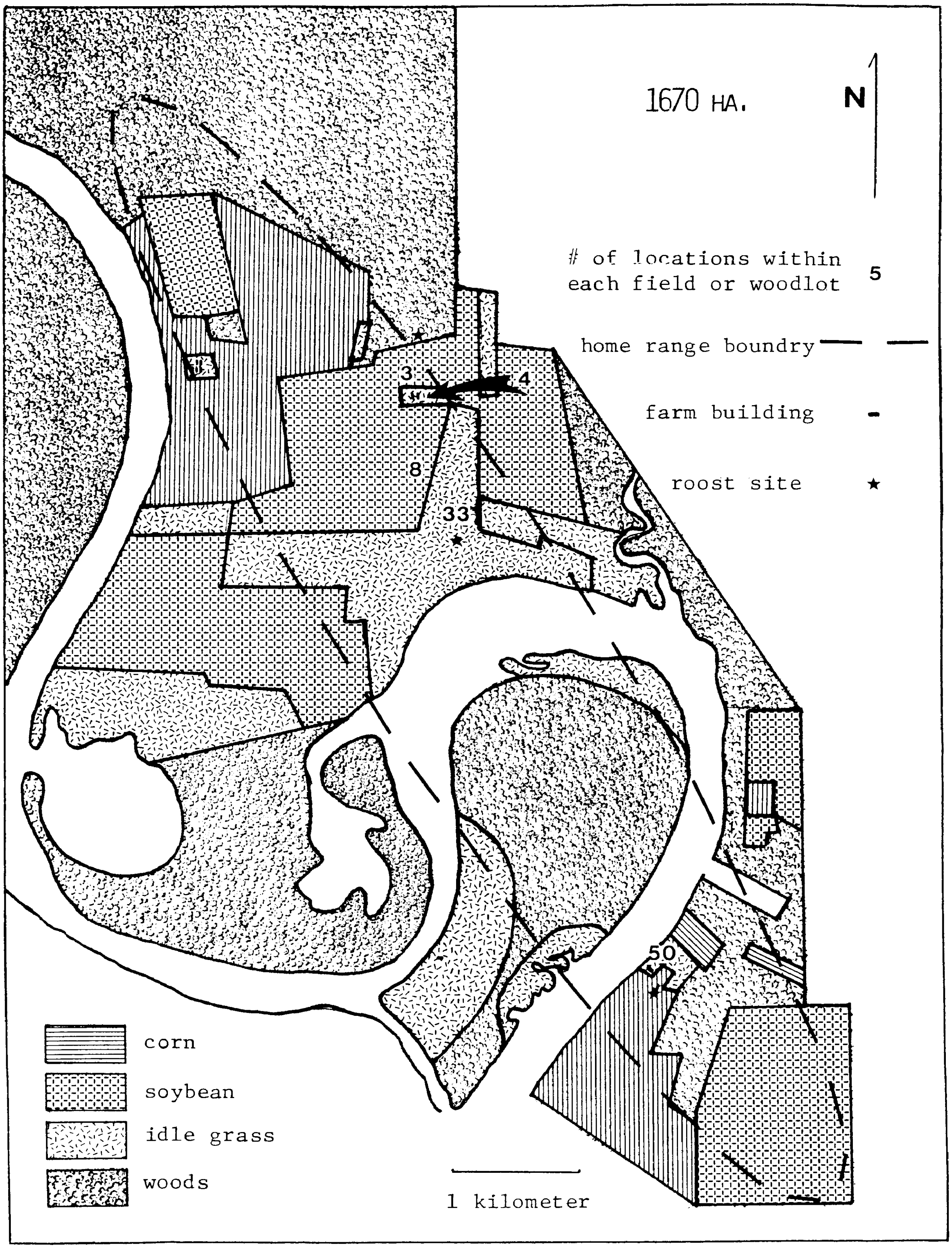


Figure 7. Ninety-five percent confidence ellipse and the distribution of telemetry locations for Curles Neck #224, July - August 1985.

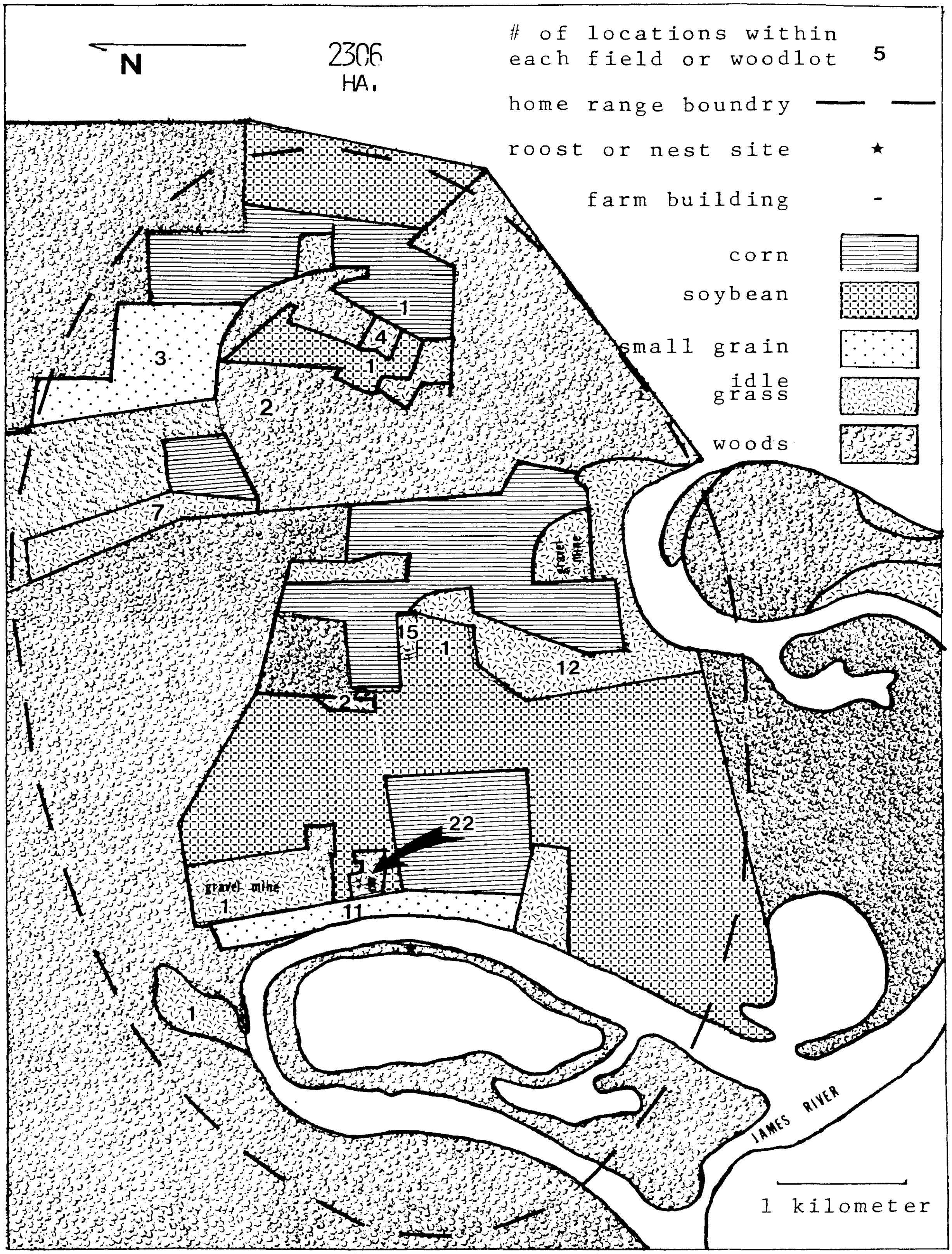


Figure 8. Ninety-five percent confidence ellipse and the distribution of telemetry locations for Curles Neck #226, May - June 1986.

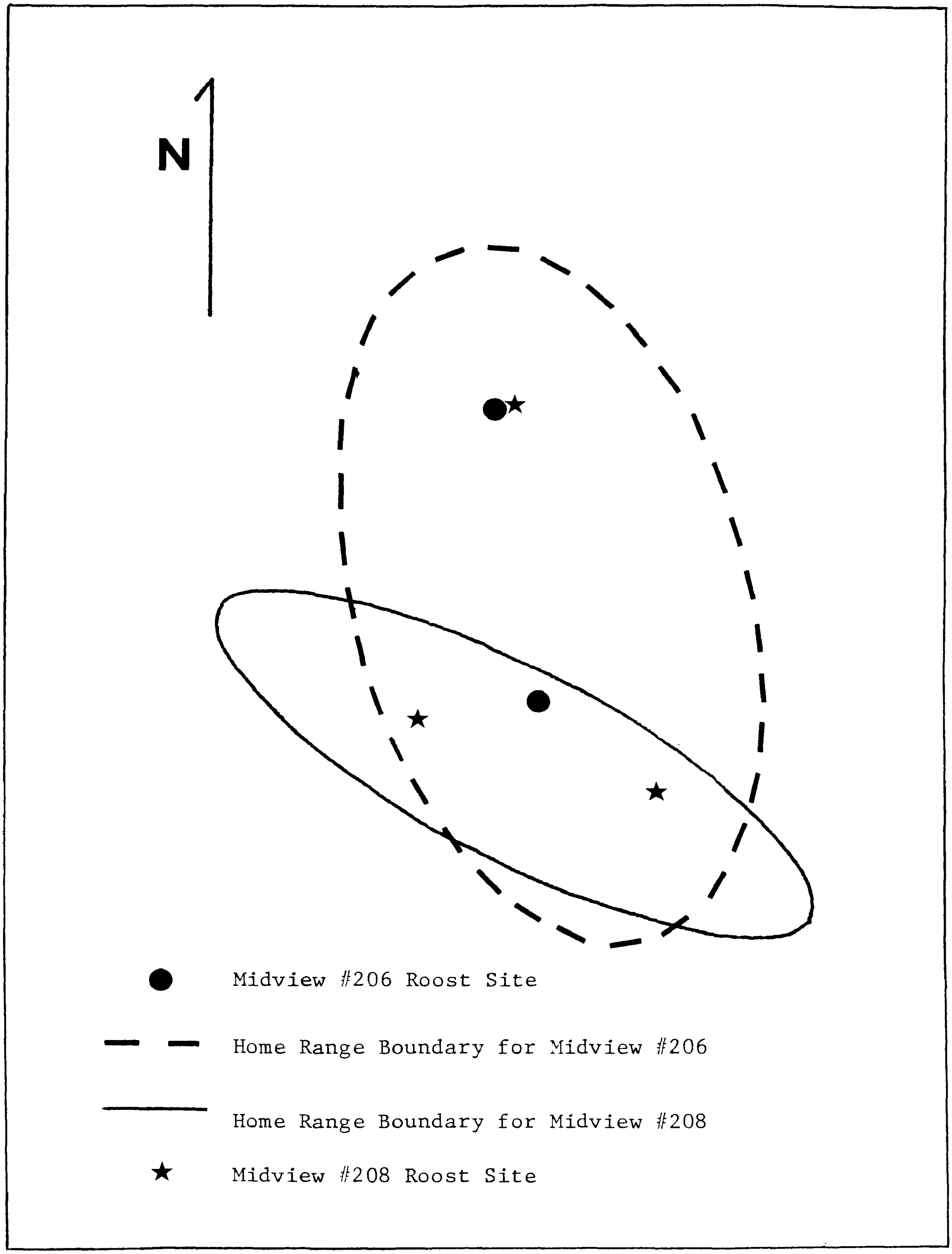


Figure 9. Home range overlap by Midview #206 and #208.

Table 2. Barn owl home range composition and size near Richmond, Virginia, 1984 - 1986.

OWL #	TIME PERIOD	Small grain	Corn	Soy-bean	Wood	Pas-ture	Tame hay	Idle	grass[2]	Resi-dent.	HOME RANGE SIZE (hectares)
		HABITAT COMPOSITION (% OF HOME RANGE)[1]									
206	1 Jul-31 Aug 1984	---	14.7	34.6	29.1	0.0	0.0	7.2	(4.4)	14.4	960
	1 Jul-31 Aug 1985	---	19.2	37.6	20.6	0.0	0.0	5.2	(3.2)	17.4	224
	1 Sep-31 Oct 1985	---	22.1	36.0	25.9	0.0	0.0	6.1	(3.0)	9.9	257
208	1 Jul-31 Aug 1984	---	21.1	21.2	32.9	0.0	0.0	12.3	(10.8)	12.5	421
	1 Jul-31 Aug 1985	---	14.2	14.5	39.8	0.0	0.0	9.8	(7.6)	21.7	367
215	1 Jul-31 Aug 1985	---	24.9	11.1	54.8	0.0	0.0	9.2	(4.9)	0.0	644[3]
	1 Sep-31 Oct 1985	---	36.8	11.6	34.5	0.0	0.0	17.1	(8.3)	0.0	363[4]
217	1 Jul-31 Aug 1985	---	5.1	19.4	31.2	10.9	12.8	20.6	(20.0)	0.0	358
	1 Sep-31 Oct 1985	---	9.0	29.8	27.8	10.1	5.4	17.9	(17.7)	0.0	1043
224	1 Jul-31 Aug 1985	---	21.6	24.4	36.7	0.0	0.0	17.3	(8.3)	0.0	1670[5]
	1 Sep-31 Oct 1985	---	24.2	17.9	40.1	0.0	0.0	17.8	(8.9)	0.0	1597[6]
226	1 May-30 Jun 1986	4.6	16.9	18.1	39.5	0.0	0.0	20.9	(11.2)	0.0	2306[7]
	$\bar{Y}$	4.6	19.0	23.0	34.4	1.8	1.5	13.5	(9.3)	6.3	851
	s	---	8.6	9.4	8.8	4.1	3.9	5.8	(5.5)	8.3	680
	v[8]	---	46	42	26	233	265	44	(56)	132	82

1 habitat composition calculations did not include water surfaces
2 number in parentheses is percentage of home range composed of dense grassland
3 home range size excluding water surfaces = 523 hectares
4 " " " " " " = 252 hectares
5 " " " " " " = 1438 hectares
6 " " " " " " = 1468 hectares
7 " " " " " " = 1979 hectares
8 v= coefficiant of variation in percent

hectares. A relatively small percentage (13.5 ± 5.8 percent) of each home range was composed of idle grassland, and only 9.0 ± 5.4 percent was dense grassland (Table 2). The remainder was a mixture of heavily grazed pasture, cultivated fields, woods, and residential areas. Home range size varied considerably more between owls and time periods than did the habitat composition of each home range, excluding those habitats which were present at only one study site (pasture, tame hay, and residential); the coefficient of variation for home range size was 82 percent whereas the coefficient of variation for each habitat type ranged between 26 and 46 percent. A Pearson product-moment correlation coefficient was computed to test for an association between home range size and the percentage of each home range occupied by dense grassland (from Table 2). No significant correlation was found ($r=.20$, $P=.53$).

Flight Characteristics

Barn owls spent an average of 20 percent of the night in flight (Table 3). This factor was quite variable between owls (range=4-33 percent, $s=9.9$ percent). Two types of flight were noted: 1) relocation flights to and from hunting areas or nest/roost sites, and 2) foraging flights. Relocation flights were relatively high above the ground (produced a strong transmitter signal) and direct (produced a fast, regular pulse rate). Foraging flights were near the ground (produced a weak signal) and consisted of erratic

Table 3. Percentage of time barn owls spent in flight at different hours of the night near Richmond, Virginia. Numbers represent the percentage of telemetry samples from each two hour period during which the owl was flying.

		HOUR						
OWL#	TIME PERIOD	1900-2059	2100-2259	2300-0059	0100-0259	0300-0459	0500-0659	TOTAL
206	1 Jul-31 Aug '84	--	5	4	32	15	10	16
	1 Jul-31 Aug '85	--	35	32	26	29	--	30
	1 Sep-31 Oct '85	50	20	26	35	20	24	27
208	1 Jul-31 Aug '84	--	9	0	11	0	10	6
	1 Jul-31 Aug '85	--	22	17	15	0	--	14
215	1 Jul-31 Aug '85	--	23	20	29	25	--	24
	1 Sep-31 Oct '85	100	10	25	25	0	50	26
217	1 Jul-31 Aug '85	--	0	17	0	0	0	4
	1 Sep-31 Oct '85	0	0	18	27	0	0	10
224	1 Jul-31 Aug '85	0	17	25	44	14	0	27
	1 Sep-31 Oct '85	36	14	30	50	13	18	27
226	1 May-30 Jun '86	0	30	30	29	50	100	33
	$\bar{Y}$ (n)	37 (27)	16 (181)	20 (232)	30 (225)	15 (145)	16 (61)	20 (871)

flight (produced a fast, irregular pulse rate). The bulk of the time spent in flight consisted of foraging flight. Foraging flights ranged in length from under a half minute to over a half hour; most lasted between two and five minutes. Long flights were observed only when an owl was hunting a large field. Most owls (Midview #206, Westover #215, Curles Neck #224, and Curles Neck #226) typically alternated short foraging flights with periods of perching for 10-20 minutes. Townsend #217 had approximately the same frequency of foraging flights, but these flights were very short in duration. Midview #208 set out on few foraging flights.

It was impossible to quantify accurately the percentage of perch time spent hunting (as opposed to loafing) without an image intensifier. This is a weakness of radiotelemetry and forces the researcher to assume that there is no bias caused by sampling at times when the animal was not hunting. One indication of potential validity of this assumption is the strong correlation between the distribution of searching time and prey capture attempts observed for other raptors (Wakely 1978, Pettifor 1984). Barn owls were observed, via radiotelemetry, to make occasional prey capture attempts from perches. These attempts were characterized by a change from a slow pulse rate (owl perched), to a fast pulse rate (owl flying), then quickly returning to a slow pulse rate which was very weak or inaudible (owl landed on ground). This sequence was soon followed by a fast pulse rate which increased in strength as the owl left the ground.

Barn owls left their roost an average of 34 $\pm$ 12 minutes after sunset and returned to roost 40 $\pm$ 19 minutes before sunrise. None of the owls were observed hunting during daylight hours. However, this is based on relatively few observations (approximately one half hour a week for each owl). The male at Midview Farm (no transmitter) was observed hunting a wheat field one afternoon in June 1985. Mobbing by crows (Corvus brachyrhynchos) severely limited his hunting abilities.

Habitat Use

The null hypothesis of habitat use in exact proportion to its availability within an owl's home range was rejected for each owl during each time period; G tests were significant ($P<0.001$) in all cases (Table 4). Eastern Virginia barn owls did not hunt in a random manner throughout their home range. Therefore, utilization-availability analyses (Appendix B) were conducted for all owls during each time period to identify habitat preferences and avoidences. The results are summarized in Table 5. Figures 10-15 depict the degree of deviation from expected use of each habitat. Chi-square contingency tests revealed that only one owl made significant seasonal changes in habitat use (Midview #206, $X^2=62.8$, $P<0.001$).

Idle grassland was preferred by each owl during each time period. Grassy fields were the specific type of idle

Table 4. Results for G-tests comparing the observed versus the expected[1] number of barn owl locations in agricultural habitats near Richmond, Virginia, 1984 - 1986.

OWL #	TIME PERIOD		Small grain	Corn	Soy-bean	Wood	Pas-ture	Tame Hay	Idle grass	Resi-dent.	N	G	P
206	1 Jul-31 Aug 1984	OBS	--	8	13	6	--	--	28	2	57	79.7	<.001
		EXP	--	8	20	17	--	--	4	8			
	1 Jul-31 Aug 1985	OBS	--	0	3	43	--	--	20	0	66	148.2	<.001
		EXP	--	12	25	14	--	--	4	11			
	1 Sep-31 Oct 1985	OBS	--	5	1	65	--	--	31	0	102	198.5	<.001
		EXP	--	23	37	26	--	--	6	10			
208	1 Jul-31 Aug 1984	OBS	--	6	15	8	--	--	15	2	46	25.5	<.001
		EXP	--	10	10	15	--	--	5	6			
	1 Jul-31 Aug 1985	OBS	--	1	7	13	--	--	29	2	52	76.9	<.001
		EXP	--	7	8	21	--	--	5	11			
215	1 Jul-31 Aug 1985	OBS	--	3	3	15	--	--	34	--	55	96.2	<.001
		EXP	--	14	6	30	--	--	5	--			
	1 Sep-31 Oct 1985	OBS	--	1	2	6	--	--	43	--	52	111.0	<.001
		EXP	--	19	6	18	--	--	9	--			
217	1 Jul-31 Aug 1985	OBS	--	0	0	2	6	5	44	--	57	95.9	<.001
		EXP	--	5	11	17	6	6	12	--			
	1 Sep-31 Oct 1985	OBS	--	6	2	2	11	8	31	--	60	70.4	<.001
		EXP	--	5	16	17	6	5	11	--			
224	1 Jul-31 Aug 1985	OBS	--	1	7	2	--	--	46	--	56	126.0	<.001
		EXP	--	12	14	21	--	--	9	--			
	1 Sep-31 Oct 1985	OBS	--	0	11	0	--	--	87	--	98	273.3	<.001
		EXP	--	24	18	39	--	--	17	--			
226	1 May-30 Jun 1986	OBS	14	1	2	2	--	--	64	--	83	180.2	<.001
		EXP	4	14	15	33	--	--	17	--			
	TOTAL	OBS	14	32	66	164	17	13	472	6	784	1061.5	<.001
		EXP	4	152	185	265	12	11	104	46			

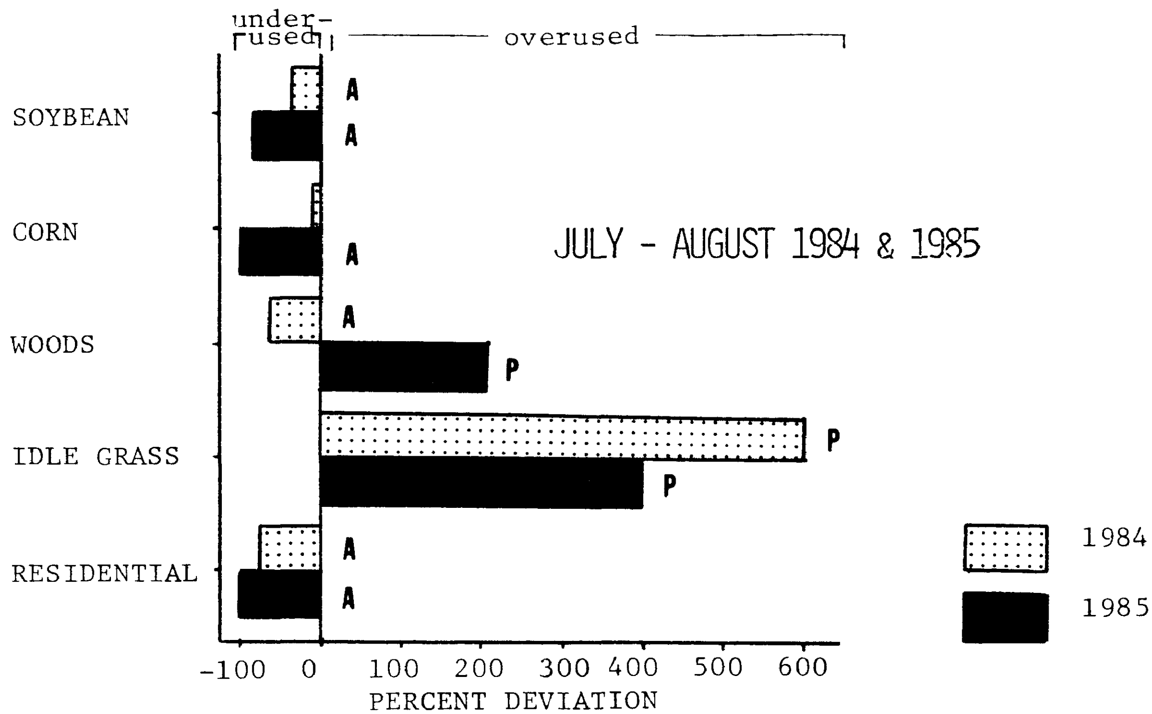
[1] Calculated by multiplying N x the proportion of the owl's home range occupied by each habitat (from Table 2).

Table 5. Barn owl habitat use near Richmond, Virginia, 1984 - 1986.

OWL #	TIME PERIOD	sm grain	corn	soybean	woods	pasture	tame hay	grass	resident
206	July-Aug.'84	-------	NS[1]	avoided[2]	avoided	-------	-------	preferred[3]	avoided
	July-Aug.'85	-------	avoided	avoided	preferred	-------	-------	preferred	avoided
	Sept-Oct.'85	-------	avoided	avoided	preferred	-------	-------	preferred	avoided
208	July-Aug.'84	-------	NS	NS	avoided	-------	-------	preferred	avoided
	July-Aug.'85	-------	avoided	NS	NS	-------	-------	preferred	avoided
215	July-Aug.'85	-------	avoided	NS	avoided	-------	-------	preferred	-------
	Sept-Oct.'85	-------	avoided	avoided	avoided	-------	-------	preferred	-------
217	July-Aug.'85	-------	avoided	avoided	avoided	NS	NS	preferred	-------
	Sept-Oct.'85	-------	NS	avoided	avoided	NS	NS	preferred	-------
224	July-Aug.'85	-------	avoided	avoided	avoided	-------	-------	preferred	-------
	Sept-Oct.'85	-------	avoided	NS	avoided	-------	-------	preferred	-------
226	May-June'86	preferred	avoided	avoided	avoided	-------	-------	preferred	-------

[1] NS habitats are those which were not significantly ($P>0.05$) preferred or avoided.
[2] avoided habitats are those in which the owl spent significantly less time than expected.
[3] preferred habitats are those in which the owl spent significantly more time than expected.

MIDVIEW #206



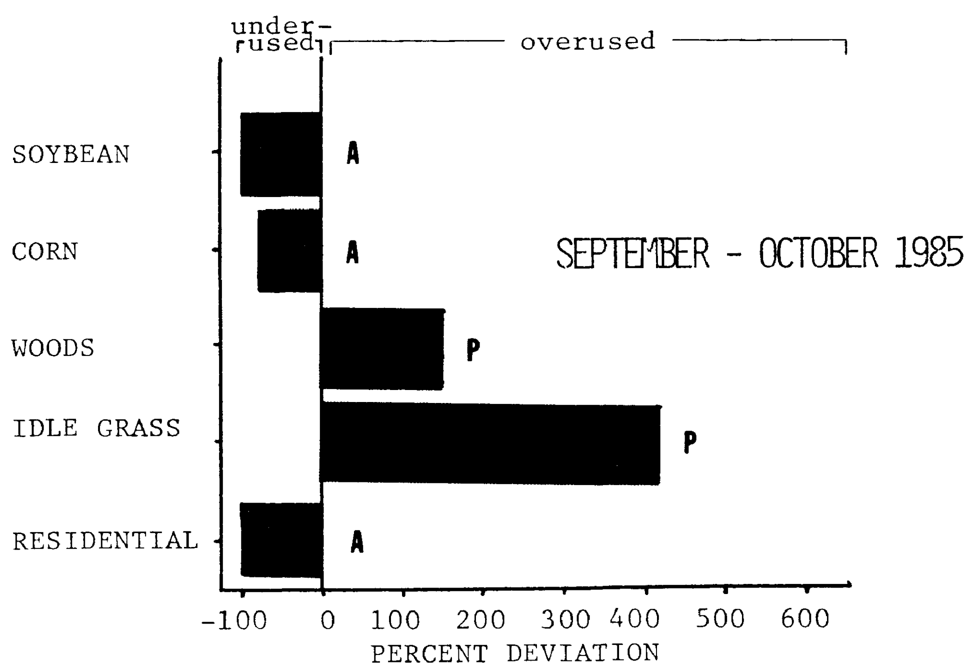


Figure 10. Percent deviation from expected use of habitats by Midview #206. Deviations were calculated by (observed-expected)/expected. P denotes preferred habitats and A denotes avoided habitats.

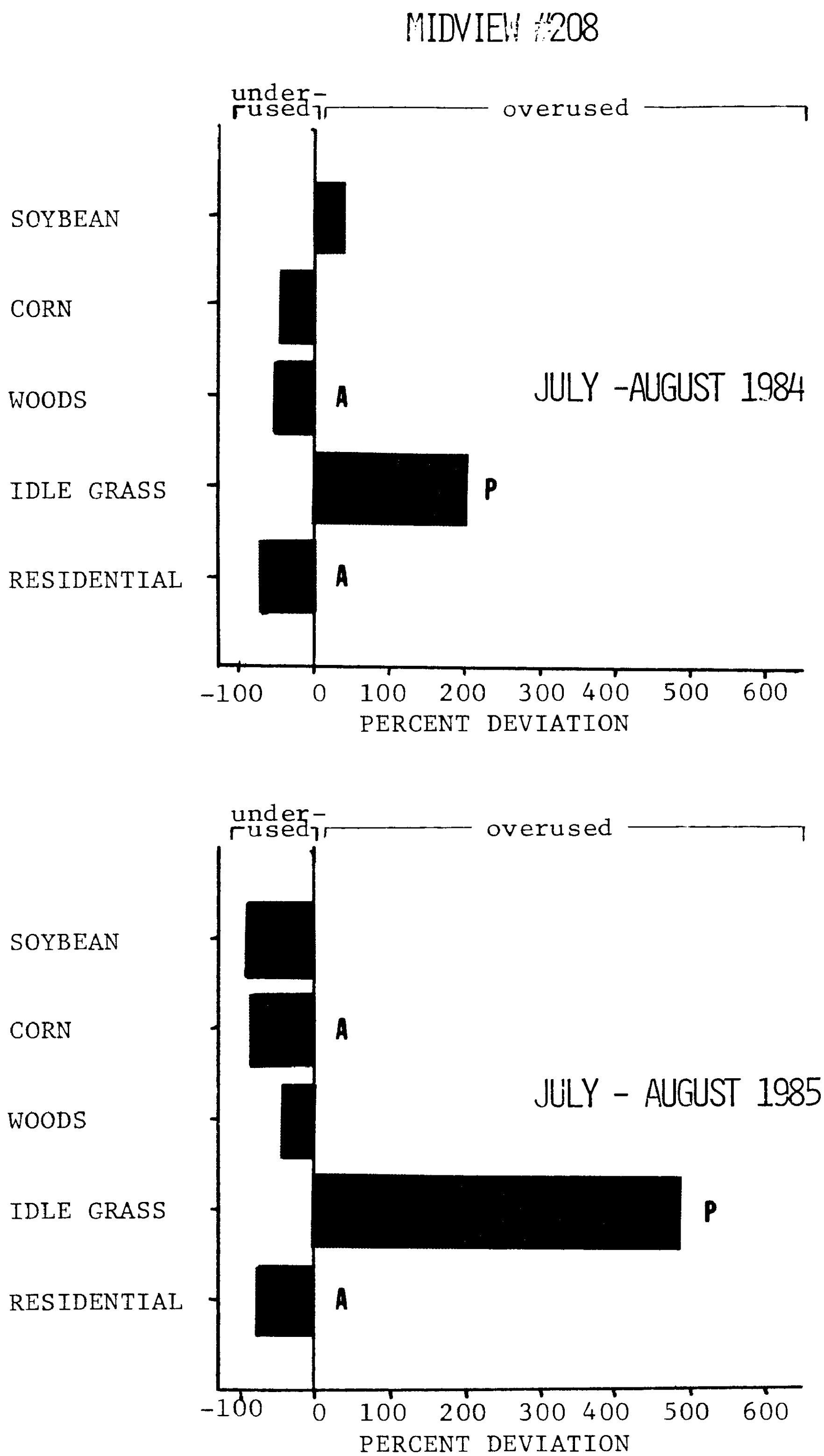


Figure 11. Percent deviation from expected use of habitats by Midview #208. Deviations were calculated by (observed-expected)/expected. P denotes preferred habitats and A denotes avoided habitats.

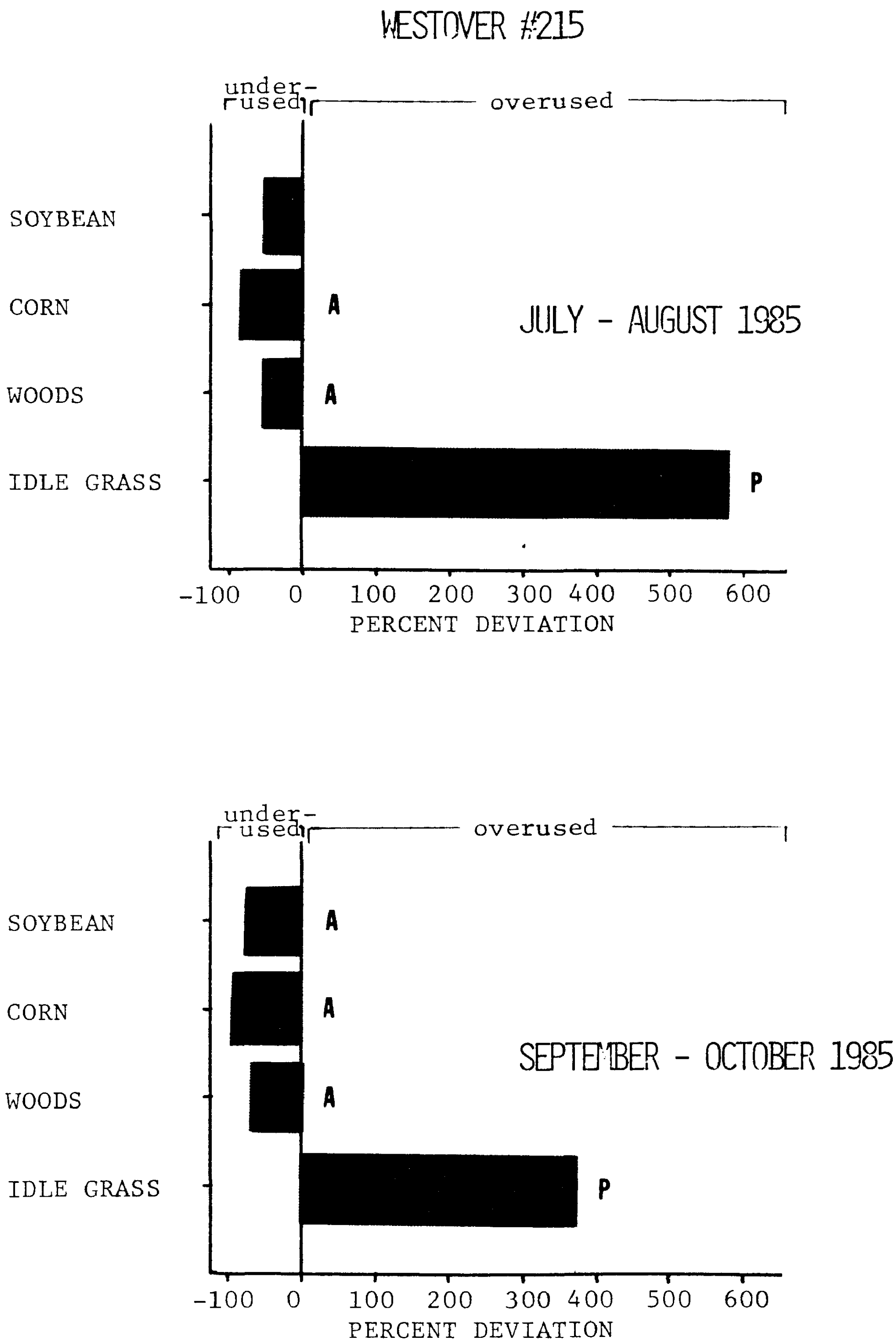


Figure 12. Percent deviation from expected use of habitats by Westover #215. Deviations were calculated by (observed-expected)/expected. P denotes preferred habitats and A denotes avoided habitats.

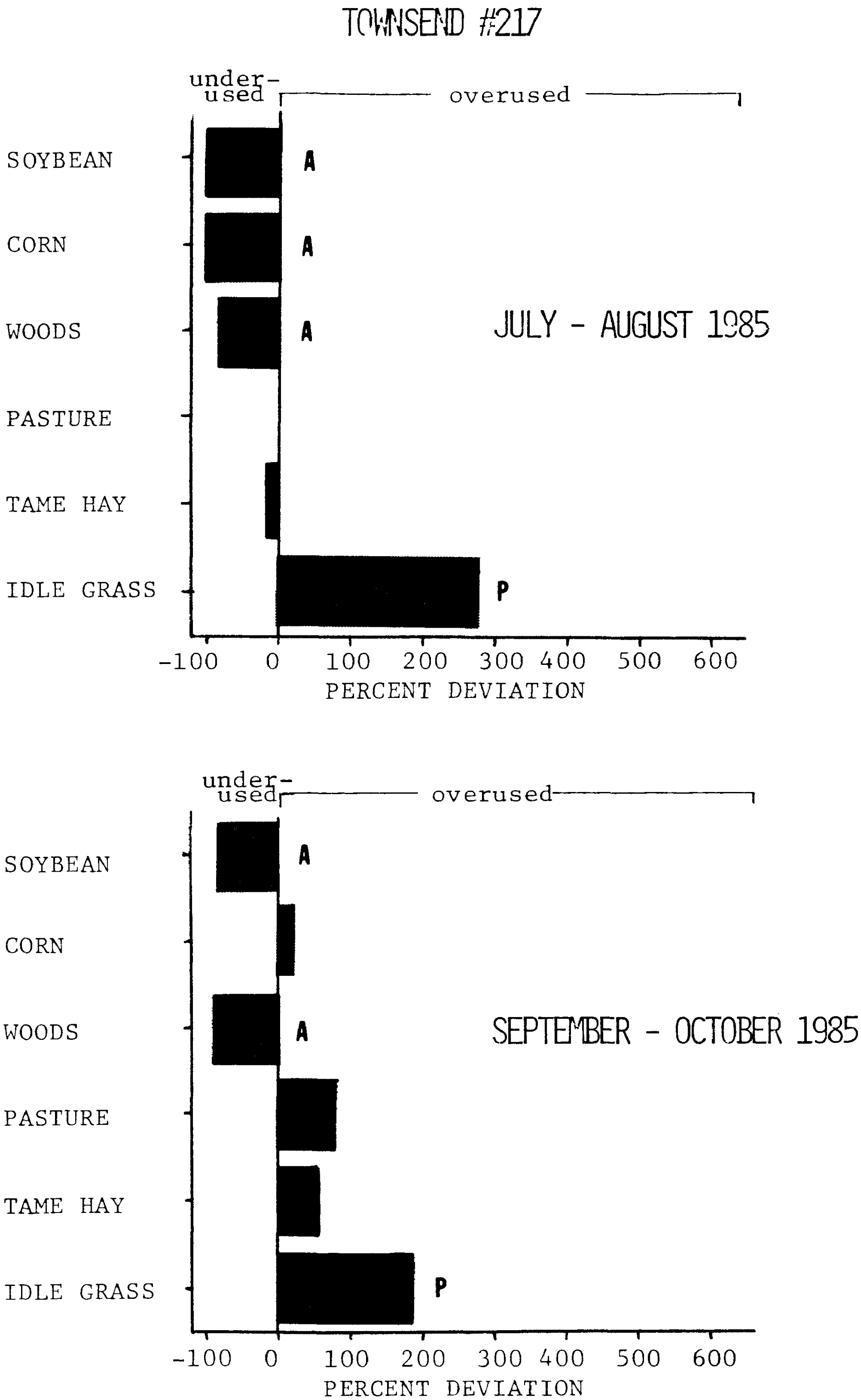
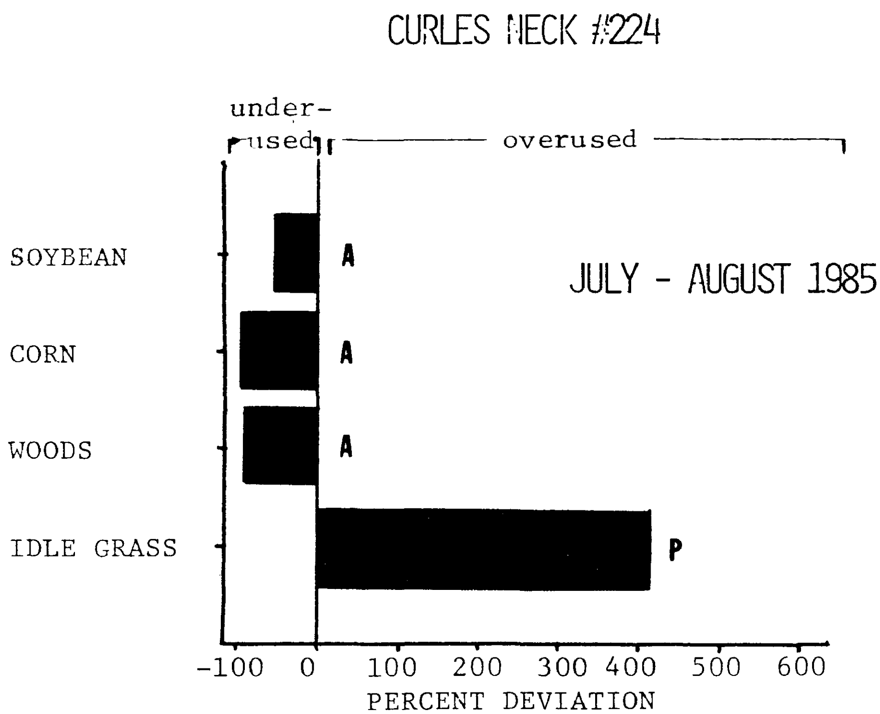


Figure 13. Percent deviation from expected use of habitats by Townsend #217. Deviations were calculated by (observed-expected)/ expected. P denotes preferred habitats and A denotes avoided habitats.



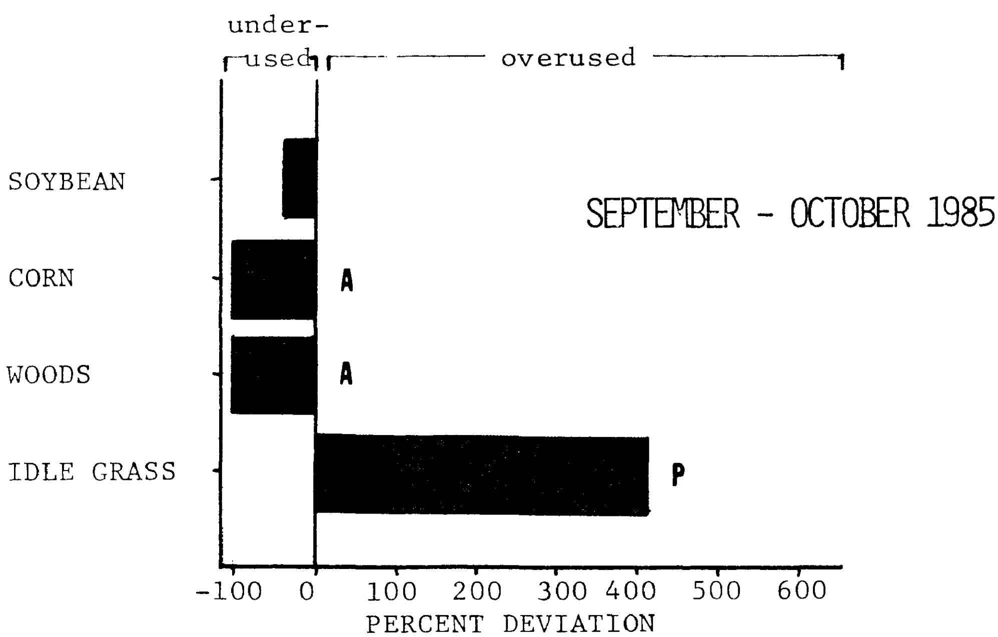


Figure 14. Percent deviation from expected use of habitats by Curles Neck #224. Deviations were calculated by (observed-expected)/ expected. P denotes preferred habitats and A denotes avoided habitats.

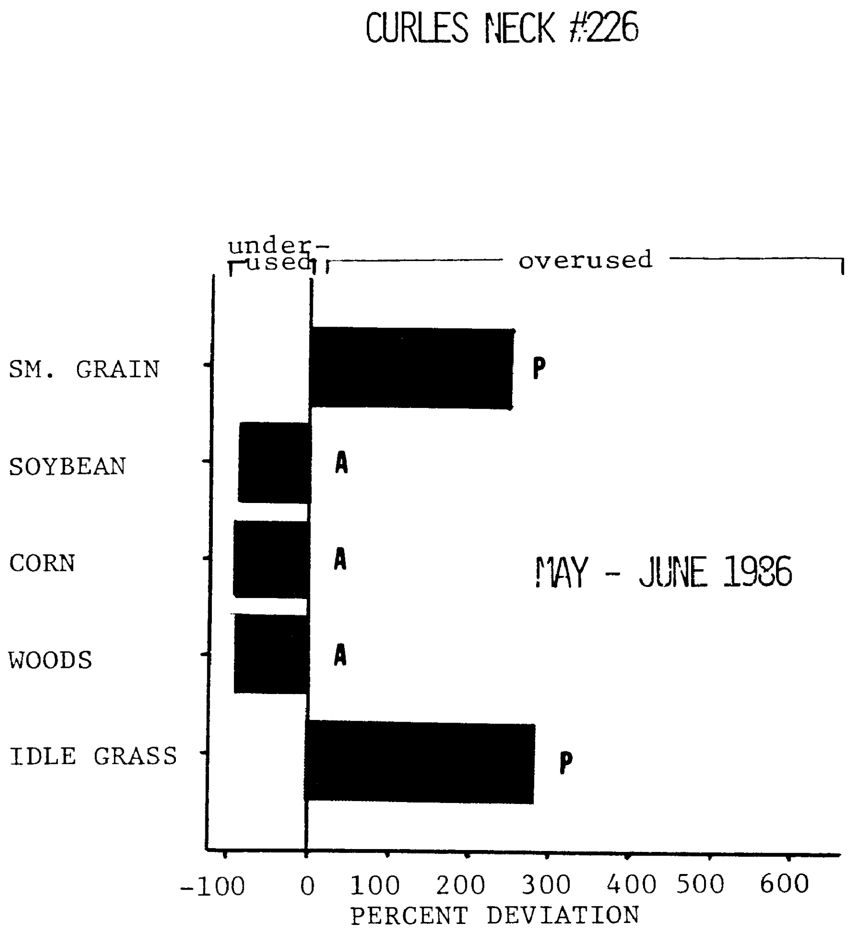


Figure 15. Percent deviation from expected use of habitats by Curles Neck #226. Deviations were calculated by (observed-expected)/ expected. P denotes preferred habitats and A denotes avoided habitats.

grassland most frequently used, but there are a few exceptions. Preference for idle grassland by Midview #206 during July-August 1985 (Fig. 3) and September-October 1985 was due mainly to her frequent use of barnyard. She spent 17 and 28 percent of her time respectively in barnyard habitat, and much of that time was spent in foraging flight. Townsend #217 had no grassy fields nor wild hayfields within her home range; her preference for idle grassland resulted from 30 locations (52 percent) in barnyard and 17 (30 percent) in clearcut during July-August 1985 (Fig. 7), 26 locations (44 percent) in barnyard and seven (12 percent) in clearcut during September-October 1985. Townsend #217 also spent much of her time near the barns in foraging flight. These flights were observed several times and many appeared to be made in search of prey near the barns; she was seen flying continuously around the barns approximately four meters above the ground. Curles Neck #226 distributed his time in idle grassland nearly evenly between barnyard (43 percent) and grassy fields (33 percent) during May-June 1986 (Fig. 9). However, he appeared to hunt little in barnyard. Several apparent foraging flights were noted there, but most of the time was spent perched after apparently delivering food to an incubating female.

Other preferred habitats were small grain and woods. Small grain was available to only one owl during one time period (Curles Neck #226, May-June 1986, Fig. 9). Seventeen percent of his locations were in small grain. The woods habitat, on the other hand, was available to all owls during all time periods but was preferred only by Midview #206 during July-August 1985 (65 percent of locations, Fig. 3) and September-October 1985 (64 percent of locations). At this time, several thousand blackbirds (Sturnidae and Icteridae), which were predominately European starlings (Sturnus vulgaris), red-winged blackbirds (Agelaius phoeniceus), and common grackles (Quiscalus quiscula), roosted in a small loblolly pine plantation near Midview Farm. Residents of this area noted that blackbirds had never reached such densities in previous years. Midview #206 spent long periods of time coursing back and forth at treetop level. Small flocks of blackbirds flushed and vocalized near the estimated source of her tramsmitted signal, apparently in response to capture attempts. Midview #208 was observed hunting this woodlot 13 times (25 percent of July-August 1985 locations, Fig. 5), but this did not result in a significant preference for woods.

Pasture and tame hay, which were present within the home range of Townsend #217 only, were neither preferred nor avoided. During July-August 1985, both habitats were used approximately in proportion to their availability (Fig. 7). During September-October, both were used more than expected, but neither were preferred. Only one of thirteen tame hay locations was in alfalfa; all others were in sudan grass. Corn, soybean, woods (except for the Midview blackbird roost), and residential habitats were typically avoided, although these habitats were used in proportion to their availability eight of 39 times. Use of fencerows, hedgerows, and wood's edges was not documented due to the narrowness of these habitats and the limitations of radiotelemetry accuracy. Use of an image intensifier in collaboration with radiotelemetry is needed to study use of habitat borders.

Roost sites used by barn owls included barns, silos, and trees. Tree species used were scrub pine (*Pinus virginiana*), loblolly pine, eastern redcedar (*Juniperus virginiana*), white oak, and a small pin oak (*Quercus palustris*) entangled with grape vine (*Vitis* sp). These owls were very habitual with their use of roost sites. If more than one site was frequented, the owl predictably retired to the site closest to its last foraging bout. Roost sites are labeled on each of the home range drawings (Figs. 2-9).

Prey Consumption

Raptor diet studies describe prey species in terms of either the relative frequency or the relative biomass of the diet. Frequency comparisons are useful for identifying selectivity for particular prey (Lovari et al. 1976, Glue 1974). Biomass comparisons give a better indication of the energetic importance of each prey species to the predator since prey vary considerably in weight and therefore caloric value to the predator (Giles 1971, Otteni et al. 1972, Lovari et al. 1976). Eastern Virginia barn owl food habits are compared chiefly by relative biomass (Table 6, Figs. 16-19). Prey numbers were converted to prey biomass using average weights determined from eastern Virginia trapping or other trapping data (Appendix C). Relative frequency results are also given, mainly for comparison to studies which make all of their descriptions using relative frequency.

The meadow vole was the most important prey item, by biomass, for each owl during each time period (average frequency=55 percent, average biomass=66 percent) except for Midview #206 during September-October 1985. At this time, Midview #206 consumed blackbirds more than any other prey item (70 percent frequency, 84 percent biomass). The few avian skulls that were present in the pellets were all starling. Blackbirds were also an important prey item for Midview #206 during May-June 1985 (12 percent frequency, 26 percent biomass) and July-August 1985 (23 percent frequency, 39 percent biomass). The short-tailed shrew (Blarina brevicauda) was an important food item for Midview #206 during May-June 1985 (30 percent frequency, 11 percent biomass), and Midview #208 during July-August 1984 (31 percent frequency, 13 percent biomass) and July-August 1985 (50 percent frequency, 21 percent biomass). The house mouse was eaten frequently by Curles Neck #226 during May-June 1986 (26 percent frequency, 10 percent biomass), and by Townsend #217 during July-August 1985 (31 percent frequency, 16 percent biomass) and September-October 1985 (29 percent

Table 6. Relative frequency (rf) and relative biomass (rb) of prey identified in barn owl pellets collected from Midview #206, Midview #208, Westover #215, Townsend #217, Curles Neck #224, Curles Neck #226, Westover #233, and the total from all pellets collected during this study.

PREY SPECIES	#206								#208				#215			
	J-A '84		M-J[1] '85		J-A '85		S-O '85		J-A '84		J-A '85		J-A '85		S-O '85	
	rf	rb	rf	rb	rf	rb	rf	rb	rf	rb	rf	rb	rf	rb	rf	rb
Microtus pennsylvanicus	72	68	40	56	46	47	19	14	51	71	40	63	82	96	84	97
Blarina brevicauda	7	2	30	11	11	3	11	2	31	13	50	21	9	3	4	1
Mus musculus	7	2	12	5	8	3	0	0	5	3	0	0	0	0	0	0
bird[2]	2	4	12	26	23	39	70	84	1	3	6	15	0	0	0	0
Cryptotis parva	1	<1	2	<1	2	<1	0	0	2	<1	4	1	9	1	8	1
Microtus pinetorum	2	1	2	1	6	2	0	0	2	1	0	0	0	0	0	0
Reithrodontomys humulis	1	<1	0	0	1	<1	0	0	1	<1	0	0	0	0	0	0
Rattus norvegicus	6	23	0	0	1	4	0	0	1	4	0	0	0	0	0	0
Peromyscus leucopus	1	<1	2	1	1	<1	0	0	4	3	0	0	0	0	4	1
Oryzomys palustris	1	<1	0	0	0	0	0	0	2	2	0	0	0	0	0	0
Sylvilagus floridanus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
unidentified cricetid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sigmodon hispidus	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
N	219		52		107		37		116		52		34		25	

Table 6 (Continued)

PREY SPECIES	#217 J-A '85 rf	rb	#217 S-O '85 rf	rb	#224 J-A '85 rf	rb	#224 S-O '85 rf	rb	#226 M-J '86 rf	rb	#233 M-J '86 rf	rb	TOTAL rf	rb
Microtus pennsylvanicus	31	56	44	64	67	90	73	93	54	74	49	69	55	66
Blarina brevicauda	7	3	5	2	9	3	3	1	6	2	2	1	13	4
Mus musculus	31	16	29	12	11	4	13	5	26	10	17	7	12	4
bird[3]	0	0	1	3	0	0	0	0	1	2	0	0	6	13
Cryptotis parva	17	3	5	1	11	2	9	1	11	1	16	2	6	1
Microtus pinetorum	6	4	6	3	0	0	0	0	0	0	2	1	2	1
Reithrodontomys humulis	1	<1	5	1	0	0	2	<1	0	0	10	2	2	<1
Rattus norvegicus	1	10	0	0	0	0	0	0	0	0	0	0	2	7
Peromyscus leucopus	3	2	1	1	0	0	0	0	1	1	0	0	1	1
Oryzomys palustris	3	5	1	1	0	0	0	0	0	0	2	2	1	1
Sylvilagus floridanus	0	0	1	11	0	0	0	0	1	10	2	16	<1	2
unidentified mouse	0	0	2	1	2	1	0	0	0	0	0	0	<1	<1
Sigmodon hispidus	0	0	0	0	0	0	0	0	0	0	0	0	<1	<1
N	71		86		54		55		95		58		1061	

1 prey captured by Midview male since #206 was incubating eggs and brooding young.
2 all birds captured by #206 and #208 in 1984 were meadowlarks; all captured in 1985 were blackbirds, most of which were starlings.
3 the bird captured by #217 was a meadowlark; the bird captured by #224 was a starling

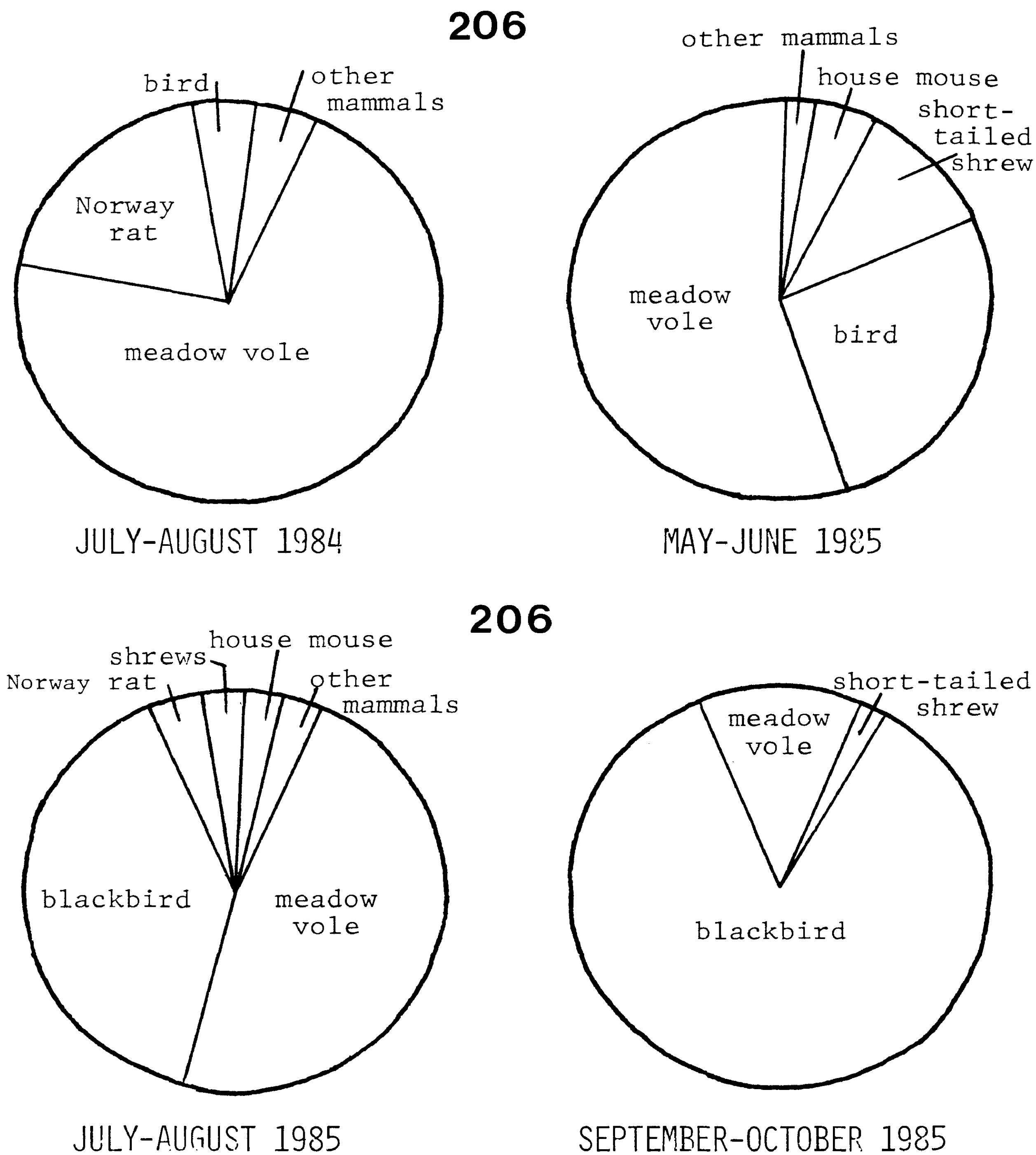


Figure 16. Relative biomass of prey in the diet of Midview #206.

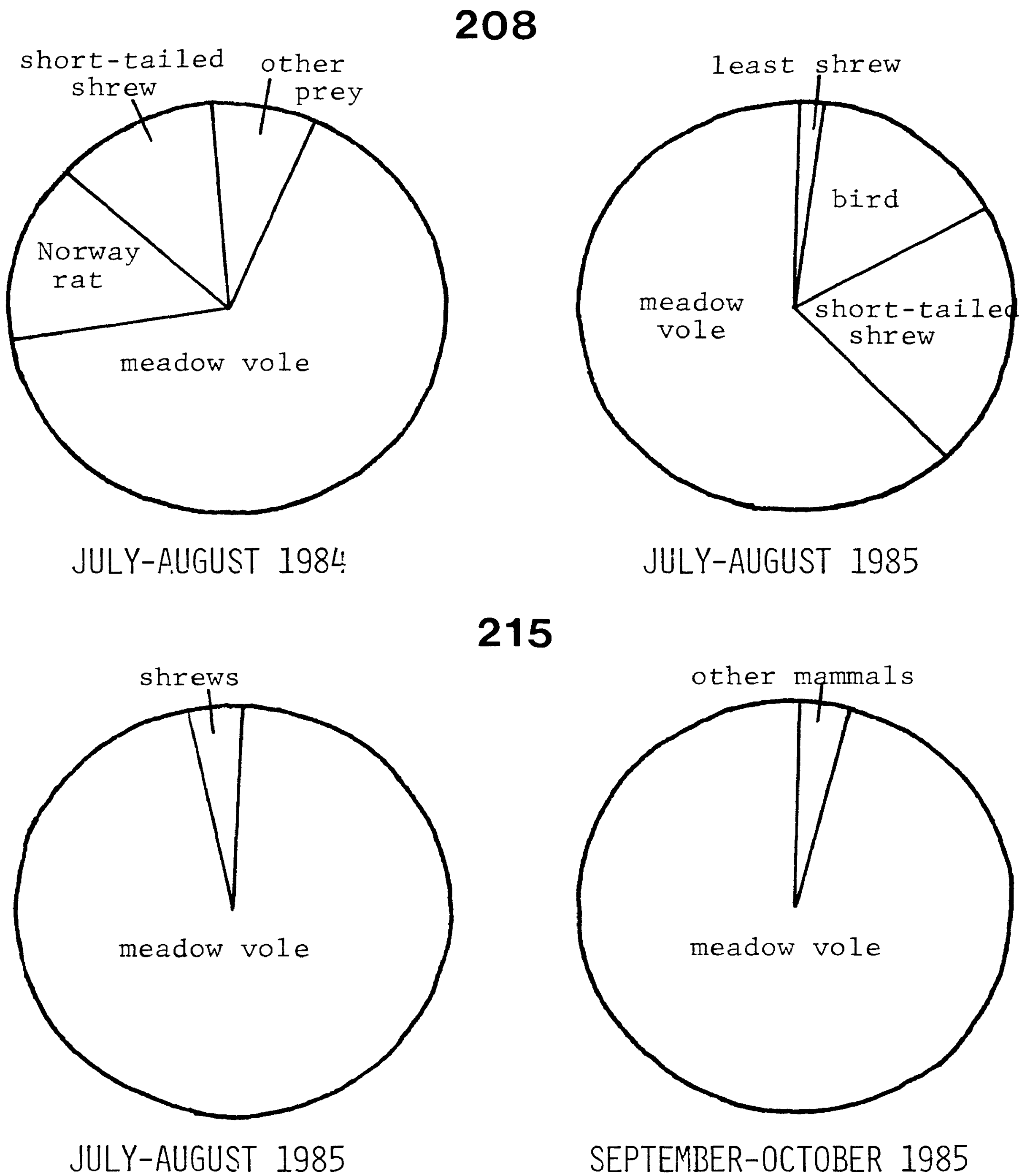


Figure 17. Relative biomass of prey in the diet of Midview #208 and Westover #215.

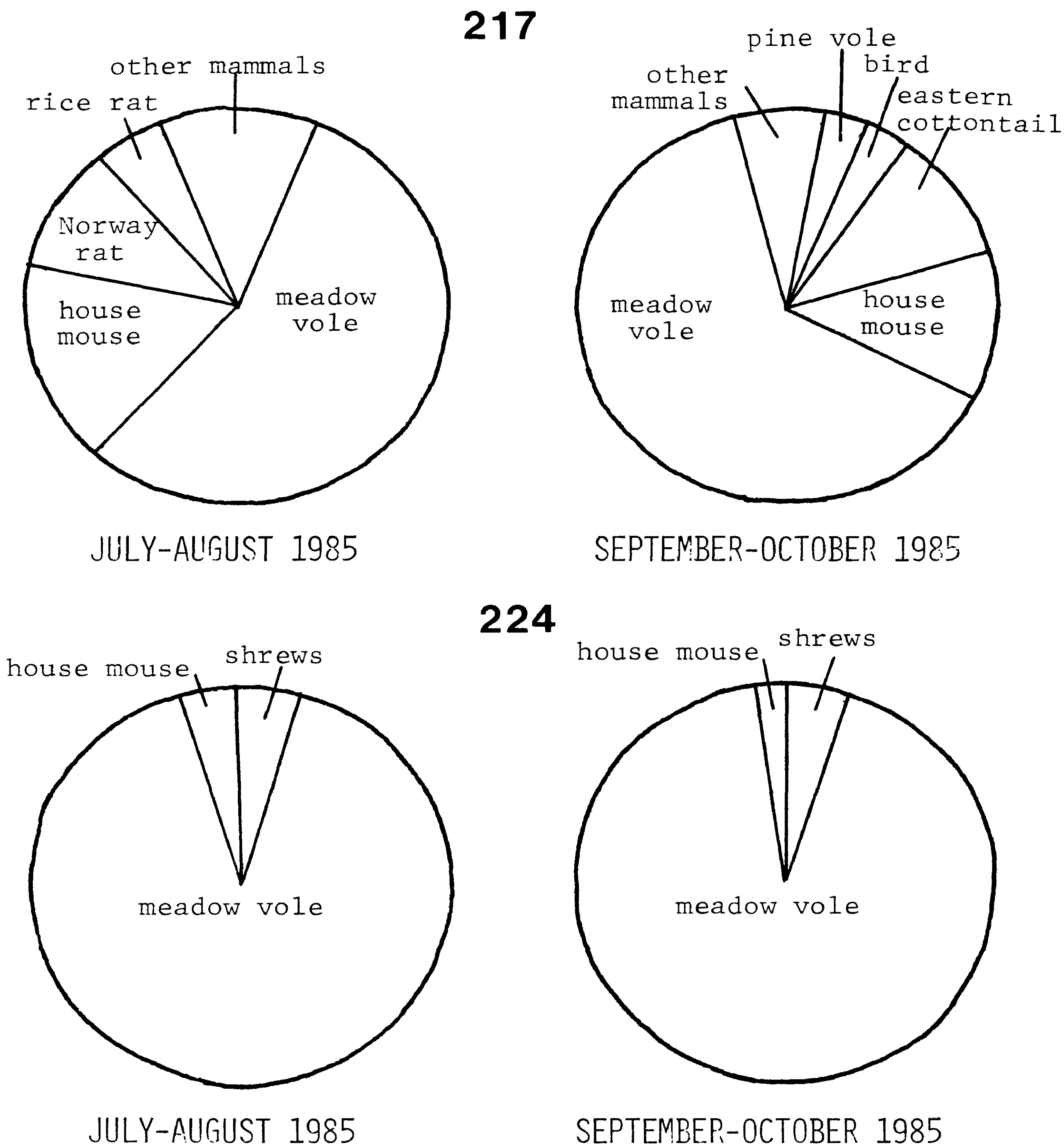


Figure 18. Relative biomass of prey in the diet of Townsend #217 and Curles Neck #224.

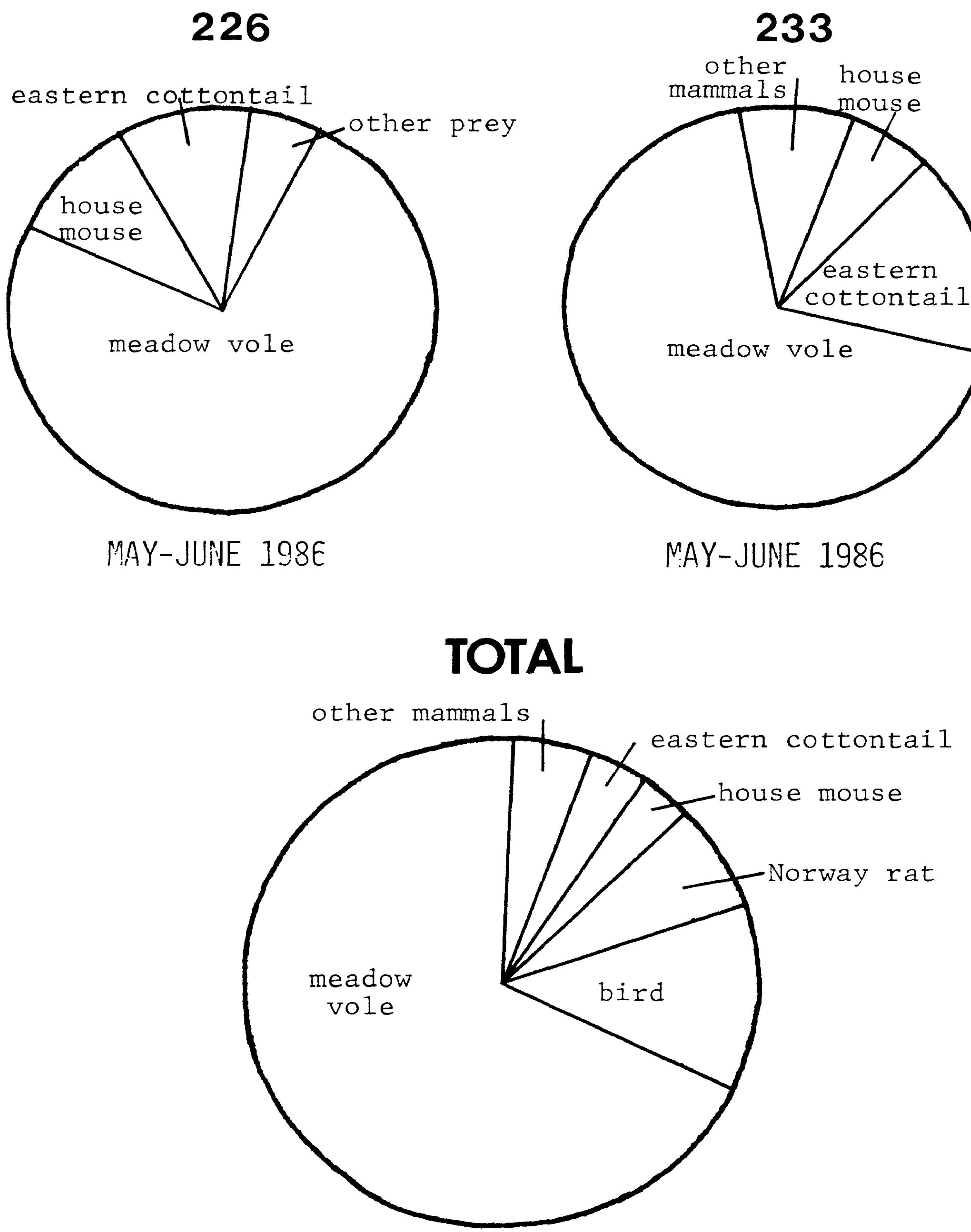


Figure 19. Relative biomass of prey in the diet of Curles Neck #226, Westiver #233, and all eastern Virginia owls combined.

frequency, 12 percent biomass). Finally, the Norway rat was an important prey item for Midview #206 during July-August 1984 (6 percent frequency, 23 percent biomass).

Other noteworthy prey items include the least shrew (Cryptotis parva) in the diet of Townsend #217 during July-August 1985 (17 percent frequency, 3 percent biomass) and Westover #233 during May-June 1986 (16 percent frequency, 2 percent biomass). Young eastern cottontail rabbits (Sylvilagus floridanus) contributed to the biomass consumed by Townsend #217 during September-October 1985 (1 percent frequency, 11 percent biomass), Curles Neck #226 during May-June 1986 (1 percent frequency, 10 percent biomass), and Westover #233 during May-June 1986 (2 percent frequency, 16 percent biomass). A single hispid cotton rat (Sigmodon hispidus) was preyed upon (Midview #206, July-August 1985). Midview Farm is near sites identified by Pagels (1977) as the northern limit of the hispid cotton rat's range on the coastal plain.

Relative Abundance of Small Mammals

A total of 6480 trap nights captured 321 small mammals for comparisons of small mammal abundance in seven agricultural habitats. Frequency results (Appendices D-F) indicate that the house mouse was the most abundant mammal in all agricultural habitats except grass. Small grain supported dense populations of the house mouse during May-June. Soybean also supported dense house mouse populations, especially during July-August. Moderate numbers of the house mouse were consistently trapped in barnyards, also. Few were trapped in corn, pasture, or tame hay. Trapping success in grassy fields was moderate during May-June and July-August, but very high September-October. The meadow vole was the most frequently trapped animal, and intermediate numbers of the house mouse, white-footed mouse (Peromyscus leucopus), eastern harvest mouse (Reithrodontomys humulis), and least shrew were trapped.

A total of 160 trap nights per habitat, set at two farmsteads for two nights immediately after the harvest of wheat, corn, and soybean, revealed that few mammals are present after the removal of cover. None was trapped in wheat stubble, one house mouse was trapped in corn stubble, and one house mouse was caught in soybean stubble.

The average weight for each species (Appendix C) was used to calculate the biomass trapped in each habitat during each season (Table 7). A Model I two-way ANOVA, using habitat biomass from each farmstead as a replicate, tested the null hypothesis that small mammal biomass was similar in all habitats and during all three time periods. Small grain, tame hay, and pasture were omitted from the ANOVA because these habitats either were not present during each time period or at each farmstead. Heteroskedasticity of the biomass figures was eliminated using a square root transformation (Sokal and Rohlf 1981). Table 8 shows the results of this two-way ANOVA. Significant differences were found between habitats and between time periods. Also, significant interaction was present between habitats and seasons. Therefore, each season was analyzed individually, using a one-way ANOVA followed by Tukey's Honestly Significant Difference Method, to identify significant differences in small mammal biomass between habitats. The results are given in Table 9 and Figure 20.

Overall, wheat, soybean, and idle grassland supported the highest small mammal biomass. Seasonal differences in rank and the degree of significance of differences between habitats make season-by-season descriptions necessary. During May-June, there was no significant differences among small grain, grass, soybean, or barnyards, but all four habitats were significantly greater in biomass than corn. During July-August, soybean and grass had equivalently high biomass, and soybean supported a significantly higher biomass than barnyard and corn. During September-October, grass supported a significantly higher biomass than all other habitats, and soybean and barnyard were not significantly different in biomass but supported a significantly higher biomass than corn. Although tame hay and pasture are not statistically comparable in small mammal biomass to the other habitats, the results from Townsend Farm indicate that tame hay supports approximately the same biomass as barnyard, and pasture approximately the same biomass as corn.

A Pearson product-moment correlation coefficient was

Table 7. Biomass of small mammals trapped in agricultural habitats, using 120 trap nights per habitat at each farmstead, near Richmond, Virginia, 1985 and 1986.

		BIOMASS[1] (GRAMS) PER HABITAT						
TIME PERIOD	FARMSTEAD	Small Grain	Corn	Soybean	Pasture	Tame Hay	Idle Grass	Barn-yard
MAY-JUNE	Curles Neck '85	147.0	36.2	145.9	---	---	72.8	73.5
	Midview '85	152.7	0.0	29.4	---	---	72.8	92.0
	Curles Neck '86	117.6	14.7	80.3	---	---	153.9	88.2
	Westover '86	276.3	0.0	58.8	---	---	145.6	44.1
JULY-AUGUST 1985	Curles Neck	---	73.5	147.0	---	---	177.4	88.2
	Midview	---	44.1	249.9	---	---	74.8	94.0
	Westover	---	44.1	88.2	---	---	117.3	58.8
	Thompson	---	---	227.3	29.4	87.1	115.8	88.2
SEPTEMBER-OCTOBER 1985	Curles Neck	---	29.4	88.2	---	---	261.9	102.9
	Midview	---	0.0	220.5	---	---	262.6	133.2
	Westover	---	0.0	102.9	---	---	491.7	58.8
	Thompson	---	---	58.8	44.1	58.8	188.6	58.8

[1]biomass determined by multiplying the number of each species trapped (see Appendices G - I) by the average weight of each species (from Appendix D).

Table 8. Results of two-way ANOVA, using data from each farmstead as a replicate, testing for significant differences in small mammal biomass (square root transformation) between habitats and seasons.

TWO-WAY ANOVA WITH REPLICATION[1]			
SOURCE OF VARIATION	df	F_s	P
Habitat	3	25.951	.001
Season	2	5.005	.012
Habitat x Season	6	4.091	.003

[1]small grain trapping results not included in two-way ANOVA with replication.

Table 9. Results of one-way ANOVA testing for significant differences in small mammal biomass (square root transformation) between habitats during each season.

ONE-WAY ANOVA			
SEASON	df	F_s	P
May - June	4	10.26	<.001
July - August[1]	3	6.24	.009
September - October[1]	3	19.63	<.001

[1]corn was not trapped at Townsend Farm (shortage of traps)

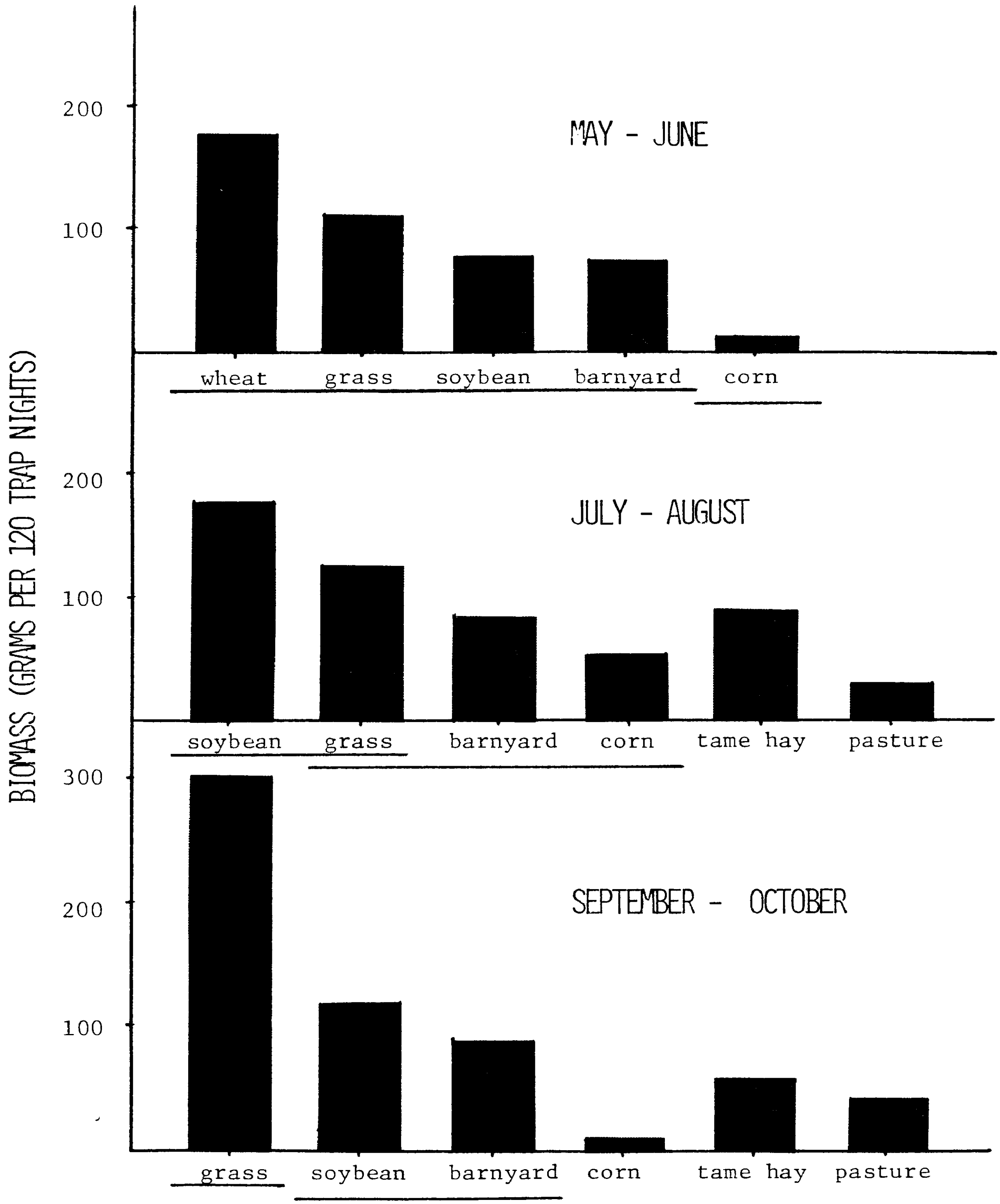


Figure 20. Biomass of small mammals trapped in agricultural habitats near Richmond, VA. The biomass given for each habitat represents the mean of all study sites trapped (from Table 5). Habitats connected by lines are not significantly different (P 0.05) in small mammal biomass. Pasture and tame hay are not comparable because only one study site was trapped.

computed to test for an association between the number of locations in agricultural habitats (normalized with a $\log_{10}$ transformation) and the small mammal biomass trapped in those habitats (normalized with a square root transformation). A significant correlation (r=.32, P=.03) with a low coefficient of determination (r^2=.10) was identified.

Habitat Canopy Coverage

Habitat canopy coverage estimates are given in Appendix G. These results show that agricultural habitats are very dynamic environments in terms of vegetative coverage. During the course of a farming year, corn and soybean fields progress from bare ground to extremely dense canopy coverage. Wheat, alfalfa, and sudan grass progress from bare ground to moderately dense canopy coverage. Although the sampling proceedure used was inadequate to show exact time scale changes, it should be noted that extreme loss of canopy coverage occurs in a matter of hours at the time of harvest.

DISCUSSION

Home Range Size

Eastern Virginia barn owls, in general, ranged over large areas (mean home range size=851 hectares). Large home ranges can be expected for a highly mobile predator (Schoener 1968, 1971) such as the barn owl. Barn owl home range sizes, based on visual observation only, have been reported as 60 hectares (Ticehurst 1935) and 67 hectares (Evans and Emlen 1947). Home range measurements based on visual observations probably underestimate home range size because of the difficulty of monitoring all movements. Radiotelemetry estimates of barn owl home range size have also been made. Differences in assessment methods make comparisons difficult, so home range sizes for eastern Virginia barn owls and southern Texas barn owls (Byrd 1982) were recalculated using the minimum home range method (Mohr and Stumpf 1966) to make them comparable to home range sizes determined for southwestern New Jersey barn owls (Hegdal and Blaskiewicz 1984, Colvin 1984). Home range sizes determined in this manner using data from this study, Byrd (1982), and Colvin (1984) are given in Appendix H. Differences in the length of radiotracking time, the sampling interval, and the season during which owls were monitored hinder comparisons between studies, but a few similarities and differences deserve discussion.

A comparison between male and female home range size, using a one-way ANOVA for data from all study sites, showed no significant difference between the sexes (F_s=2.56, P=.126). The greater similarity between Virginia home range size (mean=414 hectares) and Texas home range size (mean=355 hectares) versus New Jersey home range size (mean=921 hectares [Colvin 1984] and 668 hectares [Hegdal and Blaskiewicz 1984]) is noteworthy. The southern Texas study area, a dry region dominated by grazed prairie, brushland, cotton, and maize, is much less similar to eastern Virginia than southwestern New Jersey with its moist climate, corn, soybean, pasture, and saltmarsh. Explanations for differences in home range are difficult to make because many factors affect home range size (Schoener 1968, Hixon 1980). Differences in breeding status may have contributed to home range size differences. New Jersey barn owls were monitored during the breeding season, when energy demands are greater, whereas the bulk of the Virginia and Texas owls were not breeding. The higher energy demands may have resulted in larger home ranges.

The extreme variability in home range size for eastern Virginia barn owls (cv=91 percent) is difficult to explain. The variability was not nearly as great for Texas (cv=51 percent) and New Jersey barn owls (cv=40 percent). The observed differences could not be explained by differences in prey availability between sites. Optimal foraging rules predict a negative correlation between home range size and prey availability (Schoener 1968, 1971; Ford 1983). Evidence for such a correlation exists from studies which determined prey availability directly (Craighead and Craighead 1956, Stenger 1958, Honer 1963, Cade 1967, Village 1982, Hixon et al. 1983) and indirectly by assessing the availability of productive habitat (Kenward 1982, Marquis and Newton 1982). It appears that Midview #206 responded to an increased availability of prey (blackbirds) during 1985 with a reduction in home range size, compared to July-August 1984. This could not be tested statistically because blackbird availability was not quantified. The availability of productive habitat did not appear to affect home range size; a negative correlation between availabilty of dense grassland and the size of each owl's home range was not present. Two technical inadequacies may have limited the explanation of home range size variability using the availability of productive habitat. The availability of dense grassland does not seem to be a good index of prey availability since prey abundance, based on snap trapping results, differed between grassy fields (see Table 7). Also, two owls frequently hunted habitats other than grassland; Midview #206 preferred woods and Curles Neck #226 preferred small grain. Removal of these data does not result in a significant negative correlation ($r=-.18$, $P=.64$), however.

The very patchy distribution of dense grassland at each farmstead probably contributed to home range size variability. Differences in distances from patch to patch and distances from patch to nest/roost sites may contribute substantially to the home range size variability. Craighead and Craighead (1956) note that the distribution of vegetation affects home range size, and Schoener (1971) states that the possibility of patchiness underscores the primary weakness of the home range concept: an animal may have a large home range yet use intensively only a small part. The greater variablility in eastern Virginia home range size, compared to southern Texas and southwestern New Jersey, may be a result of the greater patchiness of productive habitat (see Figs. 2-9; Byrd 1982, p.59-78; Colvin 1984, p.179-183).

Foraging Techniques

Eastern Virginia barn owls hunted most frequently using low foraging flights. Some prey capture attempts from perches were also noted. This agrees well with most descriptions of barn owl foraging behavior (Honer 1963, Haverschmidt 1970, Burton 1973, Karalus and Eckert 1974, Marti 1974, Rudolph 1978, Bunn et al. 1982, Mikkola and Willis 1983). Byrd (1982) reported that southern Texas barn owls occasionally hunted via long flights, but most of their time was spent perch hunting along habitat edges. He concluded that perch hunting is probably the best strategy for hunting areas where prey are concentrated, while flight hunting is best for searching extensive areas of scattered prey.

Habitat Use and Prey Consumption

Radiotelemetry observations and pellet analyses indicate that eastern Virginia barn owls most frequently hunted dense grassland and fed primarily on the meadow vole. These findings are consistent with most other barn owl foraging and food habits studies. Grassland has been reported to be the most important habitat by most investigations (Pearson and Pearson 1947; Hegdal and Blaskiewicz 1984; Colvin 1980, 1984). Most barn owl pellet analyses have identified microtines as the primary prey (Ticehurst 1935; Wilson 1938; Wallace 1948; Boyd and Shriner 1954; Carpenter and Fall 1967; Glue 1967, 1974; Smith et al. 1972; Marti 1973; Webster 1973; Lovari et al. 1976; Pagels and Trumbo 1976; Smith and Marti 1976; Dexter 1978; Rudolph 1978; Bethge and Hayo 1979; Colvin 1980, 1984; Castrale et al. 1983; Colvin 1984, p. 314). Grassland microtines are absent throughout much of the southern United States, and the cotton rat is reported to be the primary prey in this area (Baumgartner and Baumgartner 1944, Parmalee 1954, Otteni et al. 1972, Hamilton and Neill 1981, Byrd 1982, Baker 1986).

Midview #206 (in 1985) and Townsend #217 spent substantial amounts of time hunting in barnyards. Pellet analysis revealed that the primary mammalian prey for Midview #206 in 1985 was the meadow vole. Meadow voles were never trapped in the Midview barnyard, but runways and cuttings were present in the surrounding hectare of grassland. In 1984, Midview #206 fed occasionally on rats (6 percent frequency, 23 percent biomass). The exact location where the rats were taken is uncertain. Townsend #217 fed substantially upon the house mouse (30 percent frequency and 14 percent biomass of total prey). Since she spent an average of 43 percent of her time in barnyard, she frequently made what appeared to be foraging flights there, and she spent little time in other habitats which supported many house mice, it is suspected that most of the Mus in her diet were taken in barnyard. Radiotelemetry locations, made from within 400 meters, showed that she also hunted a 0.4 hectare meadow adjacent to the barnyard. Some of the meadow voles in her pellets may have originated from this meadow.

Barnyard has not been reported as an important foraging habitat by any other intensive studies of the barn owl. Several North American pellet studies (Cahn and Kemp 1930, Evans and Emlen 1947, Davis 1948, Cunningham 1960, Blem and Pagels 1973, Pagels and Trumbo 1976) and European pellet studies (Ticehurst 1935; Fairley 1966; Glue 1967, 1974; Herrera 1974) have noted a high incidence of the house mouse and Norway rat in the diet of the barn owl. It is impossible to infer whether the Mus and Rattus were captured in barnyard, though, since no foraging observations were made and both species are found in a variety of habitats. Hegdal and Blaskiewicz (1984) and Colvin (1984), during their radiotelemetry studies of secondary hazards of rodenticides to barn owls, studied critically the use of barnyards by barn owls. Hegdal and Blaskiewicz (1984) reported that little time was spent foraging in barnyards; Colvin (1984) reported that 36 percent of all locations were in barnyard but that little of this time was spent foraging. Rattus comprised four and two percent, and Mus two and seven percent of the diet determined by Hegdal and Blaskiewicz (1984) and Colvin (1984), respectively. New Jersey barn owls concentrated their hunting efforts in the abundant grasslands and fed mainly upon Microtus.

Curles Neck #226 hunted small grain frequently, where he apparently preyed upon the house mouse; Mus populations were relatively dense in small grain, and 26 percent of the animals identified in this owl's pellets were Mus. No voles were trapped in small grain, and no vole runways or cuttings were found. Southwestern Oklahoma barn owls spent 54 percent of radiotelemetry time in wheat fields (Ault 1971). The frequent use of Oklahoma wheat was probably due to moderate rodent populations amongst sparse cover. Southwestern New Jersey barn owls were rarely located in wheat (Colvin 1984), which had low prey populations.

The degree to which barn owls use small grain habitats deserves further study. The potentially high abundance of Mus in this habitat (Appendix D, Mumford and Whitaker 1982) and the availability of this habitat throughout much of the barn owl's range during its breeding season indicate that it could be important seasonally.

The intensive hunting efforts of Midview #206 and, to a lesser degree, Midview #208 for blackbirds in the pine plantation blackbird roost are noteworthy. Midview #206 apparently harried blackbirds that she located roosting near the tops of pine trees. The capture of large numbers of birds from woods has never been reported for barn owls. Birds made up 25 percent (by frequency) of the diet of southeastern South Carolina barn owls in 1925 (Townsend 1926), 37 percentage of the diet of northwestern Ohio barn owls in September 1964 (Carpenter and Fall 1967), 20 percent of the diet of southern Texas barn owls between 1967 and 1971 (Otteni et al. 1972), 20 percent of the diet of central Utah barn owls in autumn 1970 (Smith et al. 1972), and 93 percent of the diet of Missouri barn owls in winter 1980-1981 (Fritzell and Thorne 1984). Most of these were blackbirds which were apparently captured in marshland and cropland. It is evident that barn owls can adapt their hunting strategies to utilize avian prey, especially large aggregations of birds (Glue 1968, 1974; Lovari et al. 1976).

Heavily grazed pasture and sudan grass were of limited importance to barn owls. Few small mammals were trapped in these habitats. No voles were caught nor were any runways or cuttings found. Southern Texas barn owls were frequently located in pasture, but this was apparently due to their heavy use of fencerows along the pasture edge (Byrd 1982).

New Jersey barn owls spent 11 percent of their time in pasture (Colvin 1984). Colvin's trapping results indicated that small mammals, including Microtus, were relatively abundant in dense pasture but were absent in heavily grazed pasture. He did not specify whether dense grass pasture, which was much more abundant than heavily grazed pasture, received more use.

Woods (other than the Midview blackbird roost), corn, soybean, and alfalfa were hunted very infrequently. Many of the locations for these habitats are suspected to have been idle grass or edge locations which were misidentified by radiotelemetry; most were very close to borders with idle grass. Other radiotelemetry studies found dense cultivated habitats, in general, to be avoided (Ault 1971, Byrd 1982, Hegdal and Blaskiewicz 1984, Colvin 1984). However, Colvin (1984) recorded many locations in alfalfa. This alfalfa had grass intermixed and was populated by low numbers of meadow voles. Alfalfa fields at Townsend Farm had no grass intermixed, no voles were trapped there, and no vole runways or cuttings were found.

Little information was learned about the importance to barn owls of fencerow, hedgerow, and wood's edge habitats. The frequent take of the short-tailed shrew, especially by Midview #206 and #208, suggests that edge habitats were hunted; Blarina occurs in most habitats, but is especially abundant along edges (Preble 1942, Lindsay 1960, Mumford and Whitaker 1982; Zegers and Ha 1981; Pagels, pers.

commun.). Also, since the owls spent 80 percent of their time perched, and most perching sites are located along fencerows or woods edges, perch hunting efforts may have been concentrated along the edges. Observations using an image intensifier are needed to verify this hypothesis. Transient small mammals, which appear to be more vulnerable to predation than residents (Errington 1946, Metzgar 1967, Ambrose 1972, Golley et al. 1975), are often concentrated along edges (Taylor 1978). Therefore, edges should be a productive raptor foraging habitat. Ault (1971) found that cotton rats in Oklahoma were more abundant along edges, and he found a significant correlation between the availability of edges within 1.6 kilometers of barn owl nests and the productivity of those nests. Byrd (1982) also found that edges were productive sites for prey, and he observed a significant preference for edges by barn owls.

Factors Affecting Barn Owl Habitat and Prey Use

This section of the discussion is devoted to reviewing factors which affected barn owl foraging patterns. It is basicly an attempt to explain why grassland was used most frequently, although other habitats were also used on occasion, and why the meadow vole was taken most frequently, although other prey were occasionally important. Explanations are difficult to make because of the very complex nature of predator-prey interactions; many factors and interactions between these factors are involved.

Craighead and Craighead (1956) describe several factors that influence raptor foraging. These, amongst others proposed by various authors, are grouped here into three major categories. These categories include factors which are characteristics of 1) the predator, 2) the prey, and 3) the habitat. It is impossible to identify objectively the precise role of each factor, but the following discussion reviews some of the available knowledge.

Predator Characteristics

The barn owl is well adapted for preying upon small mammals after dark. The combination of its adaptations appears to favor hunting open habitats, especially grasslands. It can detect prey at light levels as low as 0.000,002 foot candles (light levels during an overcast, moonless night are often below 0.000,012 foot candles) (Dice 1945), and it can capture prey using hearing alone (Payne 1971, Konishi 1973). The capture of prey by sound is especially advantageous for hunting animals, such as voles, which are often concealed from view as they travel in runways beneath grass cover. The barn owl has low wing-loading, which is adaptive for hunting via long flights (Poole 1938, Marti 1974, Bunn et al. 1982). Its flight is nearly silent, thus enabling it to hunt on-the-wing without interfering with its hearing or alerting its prey (Thorpe and Griffin 1962). Finally, its feet are adapted to pin prey to the ground, an advantage for hunting in dim light or when prey is concealed under grass (Goslow 1967, from Marti 1974).

Predators, as a result of evolutionary selection pressures, tend to harvest their food efficiently (Krebs 1978). Based on this premise, optimal foraging models (Emlen 1966, MacArthur and Pianka 1966, Schoener 1969, Werner and Hall 1974, Charnov 1976) predict ways in which a predator should forage to maximize efficiency. One major prediction is that a predator will choose prey types which are most profitable. The most profitable prey type energeticly is that with the highest energy yield per unit handling time. Field and laboratory tests of prey choice have found that shore crabs (Carcinus maenas) (Elner and Hughes 1978), bluegill sunfish (Lepomis macrochirus) (Werner and Hall 1974), pied wagtails (Motacilla alba) (Davies 1977), redshanks (Tringa totanus) (Goss-Custard 1970), wood storks (Ogden et al. 1976), loggerhead shrikes (Lanius ludovicianus) (Slack 1975), and screech owls (Otus asio) (Marti and Hogue 1979) select prey which appear to be most profitable in energy yield per unit handling time. However, the conditions under which these studies were made were relatively simple. Pyke et al. (1977) note that optimal foraging models are able to predict optimal prey choice only when different sized items of one kind of food are available; prey choice within more complex systems invloving more than one prey species is difficult to predict. Prey selection depends on many factors (Emlen

1966); Royama (1970) intensively studied great tit foraging under complex field conditions and found that several factors, in addition to prey size, affect prey selection.

Barn owl selectivity has been studied by four researchers. Fast and Ambrose (1976) found that barn owls captured significantly more meadow voles than white-footed mice in simulated field habitat. Wallick and Barrett (1976) studied prey selection using meadow voles and deer mice (*Peromyscus maniculatus*) in an outdoor aviary consisting of dense grass and mowed grass habitat. This time, barn owls captured deer mice significantly more than meadow voles. Derting (1981) found that *Microtus* were selected more than *Peromyscus* in a simulated environment, but found no selection in an outdoor enclosure with natural vegetation. She concluded, for the outdoor trial, that the overall caloric value of prey per minute spent obtaining them was similar for all prey types. Colvin (1980, 1984) studied barn owl prey selection by comparing the numbers of each prey species available, estimated by snap and live trapping, versus the numbers consumed. He concluded that the meadow vole was selectively preyed upon, apparently because it is of optimal size energeticly. Since many factors, in addition to prey size, affect prey capture by predators, explanations must be made cautiously (Emlen 1966).

Prey Characteristics

Prey characteristics, such as habitat associations, activity periods, conspicuousness, and ease of capture, influence interactions between predator and prey. These characteristics will be discussed for prey species that were either relatively abundant in eastern Virginia or which were frequently preyed upon by barn owls.

Prey habitat associations can affect how often prey interact with a predator. Since the barn owl is adapted to hunt open areas, especially grassland, it rarely encounters woodland species such as the eastern chipmunk (Tamias striatus) and southern flying squirrel (Glaucomys volans). The starnosed mole (Condylura cristata) and eastern mole (Scalopus aquaticus) are rarely encountered because of their chiefly subterranean existence; barn owls seem to prey on moles only during times of above-ground dispersal of young (Glue 1974; Colvin 1980, 1984). Any prey species that frequent open areas are exposed to barn owl predation, especially species highly associated with grassland since the barn owl appears to be adapted to hunt this habitat most efficiently. Such species include the least shrew (Hamilton 1944, Davis and Joeris 1945, Golley et al. 1965), eastern harvest mouse (Lewis 1940, Golley et al. 1965), and meadow vole (Lewis 1940, Getz 1961a, Golley et al. 1965, Zimmerman 1965, M'Closkey 1975, Chapman and Feldhamer 1982, Mumford and Whitaker 1982). The short-tailed shrew occupies most habitats, but is often abundant in grass (Blair 1940, Lewis 1940, Lindsay 1960, Golley et al. 1965, Zegers and Ha 1981, Mumford and Whitaker 1982). The white-footed mouse is most abundant in woodland but may be found in low numbers in open areas, including cultivated fields and weedy-brushy fields (Lewis 1940, Getz 1961b, M'Closkey 1975, Zegers and Ha 1981, Mumford and Whitaker 1982). The house mouse occupies all open habitats, and may be moderately abundant in grassland (Golley et al. 1965, Mumford and Whitaker 1982). The Norway rat can be found in low numbers in cultivated fields and ditch banks (Mumford and Whitaker 1982).

An animal's activity periods may make it more or less vulnerable to predation, depending upon the degree of overlap with the predator's activity periods. The barn owl has been shown by this and other studies (Marti 1974, Rudolph 1978, Colvin 1984) to be mostly nocturnal. All of the major small mammal prey species have been described as mostly nocturnal (Johnson 1926, Davis and Joeris 1945, Osterberg 1962, Mumford and Whitaker 1982), with the possible exception of the meadow vole. Ambrose (1973) reviews the dispute concerning diel activity rhythms of the meadow vole. He states that there is both nocturnal and diurnal activity, and 50 percent of the population is active at any hour. There seems to be little difference in vulnerability between prey species based on their activity periods, except that the meadow vole may be slightly less vulnerable due to its more even distribution of activity between day and night.

The conspicuousness of a prey animal depends partly upon its size and color, as well as its movement patterns.

Large prey are typically more visible than small prey. Individuals which contrast with ground color are captured by barn owls more than cryptic individuals (Kaufman 1974). Prey which move within runways beneath vegetative cover are less visible than those that do not, but differences may be neutralized by the barn owl's ability to capture prey by hearing alone; movement and chewing sounds may make concealed prey just as conspicuous to a barn owl (Payne 1971, Konishi 1973). The least shrew is tiny, gray (cryptic), and frequently travels in runways (Hamilton 1944, Davis and Joeris 1945). The short-tailed shrew is medium-sized, black (conspicuous), and frequently travels in runways (Hamilton 1931, Preble 1942, Mumford and Whitaker 1982). The white-footed mouse is medium-sized, brown (cyptic), and usually travels outside of runways. The meadow vole is relatively large, dark brown (conspicuous), and confines its movements to runways (Lewis 1940, Zimmerman 1965, Chapman and Feldhamer 1982, Mumford and Whitaker 1982). The house mouse is medium-sized, gray (cryptic), and usually travels outside of runways. The Norway rat is large, grayish brown (cryptic), and frequently travels in runways (Mumford and Whitaker 1982).

Even though some prey may be more easily perceived by barn owls, differences in ease of capture will affect their vulnerability to predation. Large prey items have a greater probability of escaping and pose a greater risk of injury to the predator. All of the animals discussed thus far, except the Norway rat, are small and weak enough that they are apparently handled easily by barn owls. An adult Norway rat weighs approximately 400 grams, and is probably a formidable prey item for a barn owl. Morris (1979) and Colvin (1980, 1984) found that barn owls selected small rats (mean weight between 59 and 86 grams) which are more easily handled. Small rats are also young and therefore inexperienced, which may also have made them more vulnerable to predation.

Wary and agile animals are obviously more difficult to capture than those that are not as well adapted for detection of and escape from danger. The ability of desert rodents to detect and avoid avian predators has been studied by Kotler (1985). He found that kangaroo rats (Dipodomys spp.) and kangaroo mice (Microdipodops spp.), which have hyperinflated auditory bullae and bipedal locomotion, are preyed upon by long-eared owls (Asio otus) less than rodents lacking such adaptations. Similar studies have not been conducted in the east, but a few relevant observations have been made. The meadow vole probably has difficulty detecting avian predators while traveling in runways (Ambrose 1972). Other mammals that travel in runways, such as the least and short-tailed shrew, may experience similar sight limitations. Derting (1981), during barn owl prey selectivity studies, noted that meadow voles required fewer capture attempts than white-footed and deer mice. Observations of captive short-tailed shrews revealed that they appear quite oblivious to the presence of a predator

(Mumford and Whitaker 1982).

Based on prey habitat associations, conspicuousness, and ease of capture, the least shrew, short-tailed shrew, and meadow vole are probably most vulnerable to predation by the barn owl. This may explain why these animals have comprised such a large percentage of the barn owl diet in eastern Virginia and throughout much of eastern North America. The high energetic value per capture of the meadow vole may explain why it is preyed upon more than the least shrew and short-tailed shrew.

Habitat Characteristics

The chief habitat characteristics affecting barn owl predator-prey relationships appear to be prey abundance and the density of protective cover. The significant positive correlation found between barn owl use of a habitat and the biomass of prey in that habitat suggests that barn owls responded to prey abundance. This has been recorded for several avian species (Goss-Custard 1970, Simons and Alcock 1971, Smith and Dawkins 1971), including raptors (Baker and Brooks 1981). The low coefficient of determination (r^2=.10) indicates that much of the variation in use of habitats by eastern Virginia barn owls is not explained by differences in prey abundance (Zar 1974:238). Other factors, such as the density of protective cover in each habitat, must also be important.

Differences in protective cover density between habitats appeared to affect barn owl foraging. The large Mus populations within soybean were probably unexploitable because of the dense cover provided by this crop. Movements of house mice on the bare ground beneath the dense canopy were probably imperceptible by barn owls. Even if prey were detectable, such as by their vocalizations, capture through the dense vegetation would probably be very difficult. Small grain had comparable populations of Mus, provided much less protective cover (Appendix G), and received significantly more use than expected. Ault (1971) made a similar conclusion for barn owl use of Oklahoma wheat fields. Dense grassland had moderate to high prey populations within dense protective cover. This dense cover probably limited prey visibility, especially for animals like the least shrew, short-tailed shrew, and meadow vole which usually travel within runways, but barn owl hearing appeared to sufficiently compensate for the lack of prey visibility.

Dense protective cover has been found to alter use of habitats with comparable prey populations by other raptors. Red-tailed hawks (Buteo jamaicensis) and rough-legged hawks (B. lagopus) infrequently hunted densely-vegetated straw and old field habitats near Toronto, Ontario even though meadow voles were most abundant there (Baker and Brooks 1981). Swainson's hawks (B. swainsoni) in southeastern Washington hunted sparsely-vegetated areas instead of wheat and pea fields with abundant deer mouse populations (Bechard

1982). Juniper, grass-shrub, and alfalfa habitats in Idaho had the highest rodent biomass, but these areas were significantly underused by ferruginous hawks (*B. regalis*), apparently because of the vegetation density (Wakely 1978). Ferruginous hawks in southeastern Alberta avoided alfalfa, clover, and irrigated hay habitats, probably because of the cover density (Schmutz 1984). West Sussex kestrels (*Falco tinnunculus*) did not hunt dense cereal and hay fields even though microtines were common there (Shrubb 1980). Dense protective cover appears to limit raptor foraging use of various habitats, many of which are cultivated.

The harvesting of crops provides an opportunity for studying raptor responses to changes in cover. Great horned owls (Dunstan 1970), kestrels (Shrubb 1980, Pettifor 1984), and barn owls (Colvin 1984) are reported to have increased their foraging activities in areas of recent crop harvest. Virginia farmers report that kestrels and red-tailed hawks frequently follow their combines to capitalize on the sudden removal of cover. Interestingly, eastern Virginia barn owls responded in no way to the harvesting of agricultural fields. This is probably due to the quick dispersal of prey from harvested fields. Poor snap-trapping results following harvest indicated that few small mammals remained by nightfall of the day of harvest.

Interaction Between Factors

Adding to the complexity of predator-prey relationships is interaction between variables (Royama 1970, Gutzke 1977, Marti and Hogue 1979). An important interaction exists between a predator's selectivity for prey and prey availability. Optimal foraging models predict that the degree of specialization of diet decreases as prey abundance decreases (Emlen 1966, MacArthur and Pianka 1966, Pulliam 1974, Werner and Hall 1974, Charnov 1976). This relationship has been documented for the bluegill sunfish (Werner and Hall 1974), great tit (Parus major) (Krebs et al. 1977), redshank (Goss-Custard 1970), kestrel (Shrubb 1980, Pettifor 1984), screech owl (Marti and Hogue 1979), great horned owl (Rusch et al. 1972, Marti 1974), long-eared owl (Kotler 1985), and short-eared owl (Asio flammeus) (Colvin and Spaulding 1983). In addition to preying upon less profitable prey, predators may also forage in less profitable patches when prey abundance is low (MacArthur and Pianka 1966, Royama 1970). Some researchers predict that predators should ignore unprofitable prey regardless of how common they are (Schoener 1971, Pulliam 1974). Krebs et al. (1977) showed experimentally that great tits essentially ignored small but abundant prey and remained selective for large, less abundant prey. Other researchers predict that an abundant but less profitable prey item may be consumed in large numbers, even when more profitable prey are still available (Emlen 1966). Field evidence for this is cited for the great tit by Royama (1970).

Barn owl pellet analyses have reported greater prey opportunism in times of poor vole or cotton rat availability (Fitch 1947; Pearson and Pearson 1947; Wallace 1948; Glue 1967; Otteni et al. 1972; Webster 1973; Marti 1974; Pagels and Blem 1972; Bethge and Hayo 1979; Hamilton and Neill 1981; Colvin 1984, p. 314) and in areas of poor vole or cotton rat availability (Ticehurst 1935; Hawbecker 1945; Ault 1971; Glue 1967, 1974; Marti 1974; Smith and Marti 1976; Bauer 1983; Colvin 1984). Some pellet studies have also shown that barn owls consume large numbers of less profitable prey when such prey are abundant (Carpenter and Fall 1967, Blem and Pagels 1973, Smith et al. 1972, Fritzell and Thorne 1984). Eastern Virginia barn owls showed greater opportunism for both prey and foraging patch at sites, such as Midview and Townsend Farms, that had little dense grassland. Midview #206 fed substantially upon an abundant blackbird population roosting in woods, and also consumed relatively large numbers of short-tailed shrews and Norway rats. Midview #208 captured many short-tailed shrews, possibly due to frequent use of edge habitats. Townsend #217 captured many house mice, apparently from barnyard.

Management Considerations

Barn owl habitat preferences and avoidances identified by this and other studies suggest that intensively farmed areas provide little productive habitat for barn owls.

Cultivated habitats, with the exception of small grain, have low prey populations and/or dense protective cover. Heavily grazed pasture supports few small mammals. Dense grassland may be present in small fields which are very patchily distributed, and therefore less efficiently utilized. In areas with little dense grassland available, or in years of low vole populations, barn owls may be absent or may have low fecundity.

Barn owls may respond to a low availability of grassland, Microtus population declines, or seasonally abundant barnyard rodent populations by increasing their foraging efforts in barnyards. One notable hazard associated with foraging in barnyards is secondary poisoning by rodenticides. As mentioned in the introduction, various anticoagulant rodenticides have the potential to kill barn owls if they consume poisoned prey. Colvin (1984) tested the potential for barn owls to consume rodenticide-poisoned prey by replacing brodifacoum poison within poison bait boxes with demethylchlorotetracycline (DMCT), a nontoxic bone marker. During a three month period, three Mus at one site; three Mus and one Rattus at another; one Mus, one Peromyscus, and two Rattus at another; and one Peromyscus each at three other sites had consumed DMCT before being preyed upon by barn owls. Hegdal and Blaskiewicz (1984) found trace levels of brodifacoum in one electrocuted barn owl. In New Jersey, it appears that barn owls interact with hazardous prey, but at minor levels. Rodenticide use in areas with less available grassland or during times of low Microtus populations may pose greater hazards to barn owls. Further study involving DMCT bone marking of commensal rodents in areas with little dense grassland and during seasons of low Microtus populations may resolve this uncertainty.

The most productive management practice for barn owls is the preservation of dense grassland. The bulk of dense grassland is found on private land, thus making preservation measures difficult. State wildlife agencies with tax incentive programs, such as Indiana's Classified Wildlife Habitat Program, could encourage maintenance of dense grassland and edge habitats. Educating landowners about the barn owl's uniqueness, rodent-catching abilities, and reliance upon grassland may help to decrease loss of grassland. Education may also help reduce incidences of barn owl shooting and intentional nest destruction, and educated landowners may use rodenticides more cautiously and accept nest boxes on their property more readily.

Nest box provision has been the chief means of managing for barn owls. It is essential that nest boxes are placed in close proximity to prouctive habitat, which is best described as dense grassland supporting high Microtus populations. The mean area of dense grassland within eastern Virginia barn owl home ranges was 97 hectares indicating that, in general, nest boxes should be erected only in areas with a similar availability of grassland.

Ninety-seven hectares is an approximate figure, of course, since all of the owls studied were nonbreeding, small grain asnd woods were preferred in some cases, and grassland varies in its capacity to support Microtus.

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Appendix A. Barn owl status evaluation for Virginia, 1986 (excerpted from Byrd and Rosenburg [1986]).

STATUS EVALUATION:

The status of the barn owl in Virginia was evaluated by compiling information about their past and present abundance in the state. Roost and nest sites from around the state were identified, using techniques discussed in the following paragraph, and nearly every site was visited during the 1986 breeding season. A comparison was then made between the number of sites where barn owls were known to have bred in the recent past and the number of sites used in 1986.

Roost and nest sites were located by 1) searching over 900 barns, silos, tree cavities, church steeples, duck blinds, and other structures which barn owls have been known to use; 2) requesting reports from the public using over 60 ads in farmer's magazines, county newspapers, and agricultural or naturalist newsletters; 3) contacting all of the Virginia Society of Ornithology chapters by mail and using a display at the 1986 annual meeting to request barn owl reports; 4) contacting all of the Virginia Commission of Game and Inland Fisheries wildlife biologists and game wardens; 5) talking to farmers, Cooperative Extension Service and ASCS employees; 6) posting over 100 "wanted posters" in feed stores, ASCS and Virginia Farm Bureau offices; and 7) searching Raven and American Birds for mention of barn owls.

A total of 214 sites which have definitely, or very probably, been used as barn owl nest sites or roost sites were identified. Sixty-two (29 percent) of these were found by searching likely structures and 185 (71 percent) were reported by farmers, naturalists, and Game Commission employees. Advertising was a very efficient means of locating barn owls around the state, and the bulk of the reports (78 percent) resulted in the identification of definite or very probable barn owl sites. The ads also served as a means of educating the public about the decline of the barn owl and of getting an indication of the public's interest in barn owls. Over 350 requests for barn owl nest box pamphlets were received indicating that there is considerable public interest in barn owls.

Of the 111 sites which are known to have been used for nesting by barn owls in the recent past (within the last ten years), only 43 (39 percent) were still active in 1986. Loss of habitat, destruction of nest site, and loss of accessibility to nest site (many buildings have been sealed to prevent pigeon access) seem to explain why barn owls have disappeared from some areas; increased raccoon predation and competition with pigeons for nest sites appear to be limiting barn owl breeding in other areas.

Since the barn owl in Virginia has "exhibited a considerable decrease in numbers beyond the limits of normal fluctuation or documented range contraction" (Linzey 1979), we recommend that the barn owl be classified as a threatened species in Virginia.

Appendix B. Habitat utilization-availability analyses for barn owl telemetry data collected during July - August 1984 (A), July-August 1985 (B), September-October 1985 (C), and May-June 1986 (D).

OWL#						HABITAT TYPE			
& TIME		sm. grain	corn	soybean	woods	pasture	tame hay	idle grass	residential
206	OBS	---------	.017<P2<.263	.000<P3<.289	.000<P4<.213	---------	---------	.314<P7<.668	.000<P8
A	EXP		.147	.346	.291			.072	.144
B	OBS	---------	.000<P2<.000	.000<P3<.113	.496<P4<.808	---------	---------	.153<P7<.453	.000<P8<.000
	EXP		.192	.376	.206			.052	.174
C	OBS	---------	.000<P2<.105	.000<P3<.036	.512<P4<.762	---------	---------	.184<P7<.424	.000<P8<.000
	EXP		.221	.360	.259			.061	.099
208	OBS	---------	.000<P2<.264	.140<P3<.512	.023<P4<.174	---------	---------	.140<P7<.512	.000<P8<.124
A	EXP		.211	.212	.329			.123	.125
B	OBS	---------	.000<P2<.070	.008<P3<.262	.089<P4<.411	---------	---------	.374<P7<.742	.000<P8<.109
	EXP		.142	.145	.398			.098	.217
215	OBS	---------	.000<P2<.135	.000<P3<.135	.118<P4<.428	---------	---------	.451<P7<.785	---------
B	EXP		.249	.111	.548			.092	
C	OBS	---------	.000<P2<.068	.031<P3<.107	.001<P4<.229	---------	---------	.691<P7<.963	---------
	EXP		.368	.116	.345			.171	
217	OBS	---------	.000<P2<.000	.000<P3<000	.000<P4<.102	.000<P5<.216	.000<P6.191	.619<P7<.925	---------
B	EXP		.051	.194	.312	.109	.128	.206	
C	OBS	---------	.000<P2<.205	.000<P3<.096	.000<P4<.096	.048<P5<.320	.014<P6<.252	.341<P7<.693	---------
	EXP		.090	.298	.278	.101	.054	.179	
224	OBS	---------	.000<P2<.064	.011<P3<.239	.000<P4<.100	---------	---------	.688<P7<.954	---------
B	EXP		.216	.244	.367			.173	
C	OBS	---------	.000<P1<.000	.031<P3<.193	.000<P4<.000	---------	---------	.807<P7<.969	---------
	EXP		.242	.179	.401			.178	
226	OBS	.061<P1<.277	.000<P2<.043	.000<P3<.068	.000<P4<.043	---------	---------	.650<P7<.892	---------
D	EXP	.046	.169	.181	.395			.209	

[1] OBS = 95 percent confidence interval for the proportion of observed locations
[2] EXP = proportion of expected locations

Appendix C. Average weights of animals snap trapped and/or fed upon by barn owls near Richmond, Virginia.

SPECIES	AVERAGE WEIGHT (grams)	s	SOURCE
<u>Cryptotis parva</u> (least shrew)	5.1	---	Hamilton 1944 N=30
<u>Blarina brevicauda</u> (short-tailed shrew)	13.7	2.0	Williamsburg, VA data[1] N=59
<u>Reithrodontomys humilis</u> (eastern harvest mouse)	8.8	---	Webster et al. 1985 N not stated
<u>Peromyscus leucopus</u> (white-footed mouse)	21.5	3.4	Richmond trapping data N=11
<u>Oryzomys palustris</u> (rice rat)	50.5	---	Webster et al. 1985 N not stated
<u>Sigmodon hispidus</u> (cotton rat)	65.5	---	Pagels and Blem 1984 N=140
<u>Microtus pennsylvanicus</u> (meadow vole)	51.3	18.8	Richmond trapping data N=15
<u>Microtus pinetorum</u> (pine vole)	21.1	---	Miller and Getz 1969 N=32
<u>Rattus norvegicus</u> (Norway rat)	201.0	---	Davis 1949 N=1002
<u>Mus musculus</u> (house mouse)	14.7	5.5	Richmond trapping data N=56
<u>Sylvilagus floridanus</u> (eastern cottontail)	340.0	---	Gutzke 1977 N not stated
<u>Sturnis vulgaris</u> (European starling)	82.7	---	Baldwin & Kendeigh 1938 N=29
<u>Sturnella magna</u> (eastern meadowlark)	105.0	---	Gutzke 1977 N not stated

[1]courtesy of Dr. C.R. Terman, College of William and Mary

Appendix D. Numbers of small mammals trapped in agricultural habitats, using 120 trap nights per habitat at each study site, during the 1 May - 30 June 1985 and 1986 time periods.

		TRAPPING LOCATION					
HABITAT	MAMMAL SPECIES	CURLES NECK 85	MIDVIEW 1985	CURLES NECK 86	WESTOVER 1986	TOTAL OF EACH SPECIES	TOTAL FOR EACH HABITAT
Wheat	_Reithrodontomys humulis_	0	0	0	3	3	47
	Peromuscus leucopus	0	3	0	0	3	
	Mus musculus	10	6	8	17	41	
Corn	_Peromyscus leucopus_	1	0	0	0	1	3
	Mus musculus	1	0	1	0	2	
Soybean	_Peromyscus leucopus_	2	0	1	0	3	20
	Mus musculus	7	2	4	4	17	
Grass	_Peromyscus leucopus_	1	1	0	2	4	11
	Microtus pennsylvanicus	1	1	3	2	7	
Barnyard	Blarina brevicauda	0	2	0	0	2	22
	Reithrodontomys humulis	0	4	0	0	4	
	Mus musculus	5	2	6	3	16	

Appendix E. Numbers of small mammals trapped in agricultural habitats, using 120 trap nights per habitat at each study site, during the 1 July - 31 August 1985 time period.

HABITAT	MAMMAL SPECIES	TRAPPING LOCATION				TOTAL OF EACH SPECIES	TOTAL FOR EACH HABITAT
		CURLES NECK	MIDVIEW	WESTOVER	TOWNSEND		
Corn	*Mus musculus*	5	3	3	--	11	11
Soybean	*Peromyscus leucopus*	0	0	0	1	1	48
	Mus musculus	10	17	6	14	47	
Pasture	*Mus musculus*	--	--	--	2	2	2
Tame Hay	*Peromyscus leucopus*	--	--	--	2	2	5
	Mus musculus	--	--	--	3	3	
Grass	*Reithrodontomys humulis*	1	1	0	0	2	15
	Peromyscus leucopus	0	0	0	3	3	
	Microtus pennsylvanicus	3	1	2	1	7	
	Mus musculus	1	1	1	0	3	
Barnyard	*Reithrodontomys humulis*	0	4	0	0	4	24
	Mus musculus	6	4	4	6	20	

Appendix F. Numbers of small mammals trapped in agricultural habitats, using 120 trap nights per habitat at each study site, during the 1 September - 31 October 1985 time period.

HABITAT	MAMMAL SPECIES	TRAPPING LOCATION: CURLES NECK	MIDVIEW	WESTOVER	TOWNSEND	TOTAL OF EACH SPECIES	TOTAL FOR EACH HABITAT
Corn stubble	*Mus musculus*	2	0	0	--	2	2
Soybean	*Mus musculus*	6	15	7	4	32	32
Pasture	*Mus musculus*	--	--	--	3	3	3
Tame Hay	*Mus musculus*	--	--	--	4	4	4
Grass	*Cryptotis parva*	1	0	5	0	6	47
	Reithrodontomys humulis	0	4	3	0	7	
	Peromyscus leucopus	0	0	0	4	4	
	Microtus pennsylvanicus	3	3	8	2	16	
	Mus musculus	7	5	2	0	14	
Barnyard	*Blarina brevicauda*	0	2	0	0	2	25
	Reithrodontomys humulis	0	2	0	0	2	
	Mus musculus	7	6	4	4	21	

Appendix G. Estimates of canopy coverage, based on the percentage of ground within a meter square obscured by vegetation, in agricultural habitats near Richmond, Virginia. Each entry represents the mean ± one standard deviation for ten random samples.

		TIME PERIOD		
HABITAT	LOCATION	1 May-30 June '86	1 July-31 Aug. '85	1 Sep.-31 Oct. '85
Wheat	Curles Neck	61 ± 5.7	--	--
	Westover	66 ± 14.3	--	--
Corn	Curles Neck	9 ± 4.8	100 ± 0.0	13 ± 4.8
	Midview	--	100 ± 0.0	14 ± 5.2
	Westover	12 ± 4.2	100 ± 0.0	11 ± 3.2
	Townsend	--	100 ± 0.0	14 ± 7.0
Soybean	Curles Neck	33 ± 4.8	100 ± 0.0	77 ± 4.8
	Midview	--	100 ± 0.0	82 ± 6.3
	Westover	35 ± 5.3	100 ± 0.0	78 ± 4.2
	Townsend	--	100 ± 0.0	71 ± 7.4
Alfalfa	Townsend	--	81 ± 7.4	77 ± 6.8
Sudan grass	Townsend	--	94 ± 5.2	92 ± 4.2

Appendix H. Standardized home range sizes, calculated using the minimum home range method, for barn owls in eastern Virginia, southern Texas, and south-western New Jersey.

STUDY AREA	OWL NUMBER	SEX	TRACKING TIME (days)	N	HOME RANGE SIZE (hectares)
	206 J-A '84	F	60	57	306.8
	J-A '85		60	66	139.6
	S-O '85		60	102	61.4
Eastern	208 J-A '84	F	60	46	238.6
Virginia	J-A '85		60	52	104.9
	215 J-A '85	M	60	55	437.3
	S-O '85		60	52	183.1
$\bar{Y}$ = 414	217 J-A '85	F	60	57	158.3
s = 378	S-O '85		60	60	394.8
v = .91					
	224 J-A '85	F	60	56	837.9
	S-O '85		60	98	812.8
	226 M-J '86	M	60	83	1297.1
	127	M	235	274	583.2
Southern[1] Texas	124	F	160	189	515.7
	128	F	219	200	222.6
$\bar{Y}$ = 355					
s = 180	125	?	48	50	201.0
v = .51					
	121	M	58	134	252.0
	83	M	30	24	662
Southwestern[2] New Jersey	83	F	7	13	436
$\bar{Y}$ = 921	90	F	60	67	977
s = 364					
v = .40	108	F	72	61	632
	108	M	34	111	1414

[1] Byrd 1982
[2] Colvin 1984

VITA

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