Aspects of American Bittern Ecology in Northwest Minnesota

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ASPECTS OF AMERICAN BITTERN ECOLOGY IN NORTHWEST MINNESOTA

by

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This thesis, submitted by David Azure in partial fulfillment of the requirements for the degree of Master of Science from the University of North Dakota, has been read by the Faculty Advisory Committee under whom the work has been done and is hereby approved.

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This thesis meets the standards for appearance, conforms to the style and format requirements of the Graduate School of the University of North Dakota, and is hereby approved.

Harvey Knull
Dean of the Graduate School

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Title	Aspects of American bittern ecology in northwest Minnesota
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ABTRACT

American bittern breeding populations have been declining for at least 3 decades. Lack of information on life history traits precludes the conclusive determination of causal factors. The objectives of this study, conducted in northwest Minnesota, were to 1) estimate summer home-range size of American bitterns, 2) document local movements and habitat use by American bitterns, and 3) refine capture and marking techniques. Results of this study should facilitate further research and may be useful to wildlife managers for implementing management practices to benefit bitterns.

Radio-marked American bitterns were systematically relocated from May through August, 1996-97. Seasonal core-areas and low-use areas were determined from 18 males and 2 females. Male breeding home-ranges averaged 210 ha ($n = 22$) and did not differ ($P > 0.05$) from average post-breeding home-range size (152 ha, $n = 16$). Distances of male post-breeding dispersals ranged from 0.2 - 20.0 km; however, 64% were under 2.0 km (n=22).

Proportion of habitat types within 5 male core-areas did not differ ($P > 0.05$) from that in low-use areas except for cattail, which was less abundant in core-areas ($P < 0.05$). Habitat use was disproportional to abundance ($P < 0.005$). Cattail, deciduous trees, and willow/grassland were avoided while open water was preferred ($P < 0.10$). Small sample size ($n = 5$) likely produced spurious habitat use results.

No refinements were made to marking techniques. It is recommended that the tape recording used with the mirror trap be modified. Improving nest search techniques might aid in the development of effective capture methods for females. Fidelity to breeding and post-breeding home-ranges was 57% and 80%, respectively. Accuracy of predicting sex based on bill and tarsus length was 93%. Upland nests produced more fledglings per nest than wetland nests. The restoration and preservation of shallow wetlands and tall grasslands are recommended as management practices to benefit American bitterns. Additional research at Agassiz NWR, as well as other physiographic regions and wintering grounds, is needed to conclusively identify factors responsible for bittern population declines.

INTRODUCTION

The American bittern (*Botaurus lentiginosus*), a member of the heron family (Ardeidae), is widely distributed throughout most of North America (Bent 1926). Its breeding range includes the southern half of Canada and most of the United States (U.S.) except the extreme southern third (Hands et al. 1989, Svedarsky 1992). Wetlands along the Atlantic, Gulf and southern Pacific coasts and as far inland as temperatures remain above freezing provide winter habitat (Gibbs et al. 1992). "American bitterns also winter throughout Mexico, along the coasts of Central America and in the Greater Antilles" (Hands et al. 1989:1).

American bittern populations have suffered severe declines the last 3 decades. U.S. Fish and Wildlife Service (USFWS) Breeding Bird Survey (BBS) data indicate a 2.2% ($P = 0.02$) annual decline in breeding populations survey-wide from 1966 to 1996. The Minnesota breeding population showed a 10.6% ($P = 0.08$) decline over the same period. Calculations of regional abundance (R.A. = average number of birds/route), also reported by the BBS, indicate that bitterns were more than twice as abundant in Canada (R.A. = 0.66) than the U.S. (R.A. = 0.30) from 1966 to 1996 (Sauer et al. 1997). Gibbs et al. (1992) suggest that bitterns may be adapted primarily to northern climates and that range may have historically shifted northward as bitterns tracked the distribution of palustrine wetlands created by retreating glaciers. More recently, this northward retreat may have been hastened because of habitat destruction in the southern portion of its range. In addition to loss of wetland habitat, other possible causes for population declines include human disturbance, pesticides/contaminants (Gibbs et al. 1992 but see USFWS 1987), and predation. The American bittern is listed as a Migratory Nongame Bird of Management Concern by the USFWS (1995) and was Blue-Listed by the National Audubon Society (Tate 1986).

While egret populations, particularly cattle egrets (*Bubuleus ibis*), have exhibited range expansions in recent years (Telfair 1994), no interspecific competition with American bitterns has been documented. Competition for food is unlikely since microhabitats for foraging differ. Cattle egrets commonly forage in close association with cattle and other livestock, preying mainly on insects (Telfair 1994). Snowy egrets (*Egretta thula*) and great egrets (*Casmerodius albus*) also forage in association with livestock as well as in wetlands; however, these egrets commonly wade in open areas away from emergent vegetation (Palmer 1962) while bitterns prefer to forage near vegetation fringes and shorelines (Gibbs et al. 1992). Bitterns and black-crowned night-herons (*Nycticorax nycticorax*) have similar food and feeding habits, and forage in similar habitats (Davies 1993); however, resource utilization is temporally segregated with black-crowned night-herons foraging primarily at night to avoid competition with other herons (Watmough 1978).

American bitterns consume a variety of prey including fishes, eels, frogs, salamanders, snakes, crayfishes, mollusks, insects, spiders and small rodents (Palmer 1962). Because of their position on the food chain, bitterns could potentially be bioaccumulators of contaminants. However, the lack of information regarding its life history effectively prevents the species from fulfilling its potential as a biological indicator of ecosystem health. A need for in-depth investigations into nearly every aspect of bittern ecology has been cited (Hands et al. 1989, Gibbs et al. 1992, Svedarsky 1992). Yet, prior to Brininger (1996), few studies were completed that offer insight to more than the most rudimentary of life history traits.

The bittern's affinity for wetland habitat is well-documented (Brown and Dinsmore 1986, Gibbs and Melvin 1992). Specifically, shallow water depths and dense vegetation are important (Frederickson and Reid 1986, Hanowski and Niemi 1986, Manci and Rusch 1988). Tall, dense vegetation is also preferred for nesting in both wetland (Gibbs et al. 1992) and upland habitats (Deubbert and Lokemoen 1977, Svedarsky 1992). Nest sites are usually located in emergent vegetation over water 5-20 cm deep (Bent 1926, Mousley 1939, Provost 1947, Middleton 1949) or in upland vegetation >30 cm (Deubbert and Lokemoen 1977). Clutch size is 2-7, typically 3-5 (Hands et al. 1989, Svedarsky 1992) while the incubation period is 24-28 days, beginning with the first egg (Mousley 1939, Vesall 1940).

Brininger (1996) provided results of the first phase of a multi-year study initiated in 1994 by Dr. John Toepfer and the USFWS to investigate the ecology of the American bittern. My study constituted the second phase of that effort. Objectives were to 1) estimate summer home-range size of American bitterns, 2) document local movements and habitat use by American bitterns, and 3) refine capture and marking techniques. Data were also collected on fidelity, adult bittern masses and body measurements, nest site characteristics, nest success, and chick weights and mortality. Results of this study should facilitate further research and may be useful to wildlife managers for implementing management practices to benefit bitterns and other marsh birds.

STUDY AREA

The Agassiz National Wildlife Refuge (NWR), located in Marshall County in northwest Minnesota, served as the primary study area (Fig. 1). The 24,846 ha refuge lies within a remnant depression of Glacial Lake Agassiz and is situated along the transition from prairie to northern coniferous forest (Agassiz NWR, Annual Narrative, Middle River, Minn., 1995). Topographic relief is minimal with a gradient of approximately 0.3 m/km. Elevation ranges from 344 to 352 m above sea level and drainage is slow from northeast to southwest via the Thief and Mud Rivers and drainage ditches, which transect the refuge.

Attempts to convert the marsh to arable land included the excavation of an extensive drainage ditch network in the early 1930's. Tax assessments ultimately forced the state legislature to pass an act authorizing the sale of the land to the U.S. Federal Government and Mud Lake NWR (since renamed Agassiz) was established in 1937. The USFWS now manages the refuge with a main objective of providing habitat for breeding and migrating waterfowl (Agassiz NWR, Annual Narrative, Middle River, Minn., 1995).

Eighteen impoundments equipped with water-control structures provide approximately 16,198 ha of wetland habitat (Agassiz NWR, Annual Narrative, Middle River, Minn., 1995). Impoundments range in size from approximately 75 ha to 4,000

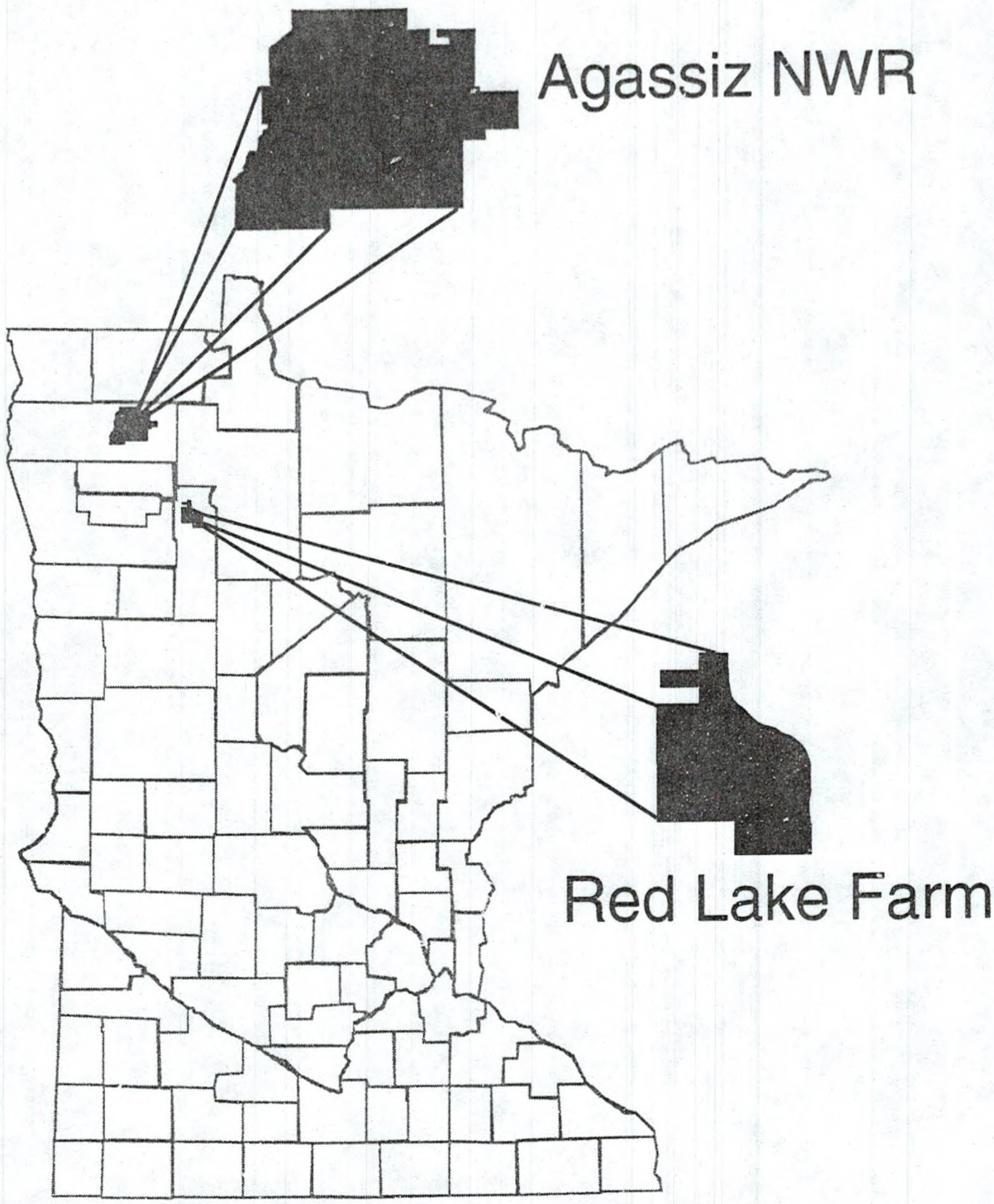

Figure 1. Study areas located in northwest Minnesota (not shown to scale).

ha (Korschgen et al. 1996) and contain areas varying from dense emergent vegetation ("cattail-choked") to "hemi-marsh" (Weller and Spatcher 1965) and open water types. Impoundments are shallow with mean April to August water depths of approximately 1 m (D. Bennet, Agassiz NWR, pers. commun.). However, record spring runoffs in 1996 and 1997 temporarily increased mean water depths substantially and may have forced some American bitterns from their traditional home-ranges. Dominant emergent vegetation is cattail (*Typha* spp.). Other common emergents are bulrush (*Scirpus* spp.), sedge (*Carex* spp.), common reed (*Phragmites communis*), white top (*Scolochloa festucacea*), and reed canary grass (*Phalaris arundinacea*). Uplands consist of willow (*Salix* spp.)-aspen (*Quercus macrocarpa*) woodland/shrublands (6,868 ha), a black spruce (*Picea mariana*)- tamarac (*Latrix laricina*) Wilderness Area (1,616 ha), cropland (61 ha), and tame and native grasslands (1,690 ha) (Agassiz NWR, Annual Narrative, Middle River, Minn., 1995). Willow has invaded several hectares of wetland and grassland habitat.

The regional climate is characterized by wide temperature fluctuations with late spring and early fall frosts. The average frost-free period is 115 days (Agassiz NWR, Annual Narrative, Middle River, Minn., 1995). American bitterns arrive at Agassiz in late April and leave either at the conclusion of the breeding season (late June/early July) or from mid-September to mid-October. Soils are mostly peat or silty loams, typical of lake deposits, underlain with clay. These soils permit little seepage and maintain relatively high water tables, providing readily available ground water of good quality (Agassiz NWR, Master Technical Plan, Middle River, Minn., 1978) .

Nine American bittern nests were monitored on the "Red Lake Farm," a 1,031 ha wildrice farm located in Clearwater County in northwest Minnesota (Fig. 1). The farm was purchased by the Red Lake Band of Chippewa Indians in 1994 and is managed to promote use by wildlife, particularly waterfowl. Climate, soils and hydrology are similar to Agassiz NWR. Habitat types include cultivated wildrice paddies, idle paddies and grassland, pastureland, hayland, lands enrolled in the Conservation Reserve Program (CRP), and brushy and wooded areas (Red Lake Dept. Nat. Res., unpub. manuscript, Red Lake, Minn., 1997).

METHODS

Field Methods

Capture and Marking

Mirror traps (G. Huschle, W. Brininger, J. Toepfer, Agassiz NWR, Middle River, Minn., unpubl. manuscript, 1996), mist nets, long-handled dip nets, and a net gun were used as described by Brininger (1996) to capture 35 American bitterns from May to August 1996-97 (some bitterns were recaptured). Thirty-three chicks were captured at or near the nest by hand. A funnel trap, similar to that used to capture prairie chickens (*Tympanuchus cupido*) (Toepfer et al. 1988), was employed to capture one bittern. Panels of "chicken-wire" were positioned in a "W" configuration with the two apexes directed away from a shallow ditch that was adjacent to heavy cover. Small openings were left at the apexes leading into circular traps constructed of 5x10 cm hardware-cloth and covered with a small piece of mist net. The chicken-wire and traps were staked down with re-bar. The funnel trap was placed near a ditch frequented by bitterns. The ditch was checked periodically and when a bittern was observed in front of the trap, it was approached quietly until it ran into the adjacent cover. The bittern was then pushed into one of the traps. The wire panels prevented it from running laterally. It was removed from the hardware-cloth trap by removing the mist net.

Captured American bitterns were weighed on a balance scale. Measurements taken included: mass, bill lengths from the anterior and posterior margins of the nostril to the tip of the bill, exposed culmen length, bill widths anterior to the nostrils and dorsal to the cere, head width posterior to the eyes, tarsus length, length of middle toe and width of the second phlange, length and width of nail on middle toe, wing chord and tail length, consistent with Brininger (1996). When applicable, molt status was described. All adults captured were banded with a size 6 or 7A USFWS numbered metal return band. When chicks were large enough, they were banded with a size 7A band. Numbered patagial tags made of "Saflag" (Southern 1971) were affixed to 4 individuals. Adult bitterns were fitted with a necklace-style radio package modified after Amstrup (1980) according to (Brininger 1996).

Nest Search and Measurement

A cable-chain drag method (Klett et al. 1986) was used to search for American bittern nests in the uplands. All-terrain vehicles were used to tow the chain. A similar method was developed to search for marsh nests. Airboats were used to tow a 48 m rope supporting 1.5 m lengths of "jack chain" spaced every 1.5 m. In-line swivels were inserted at the ends of the rope and at 1/3 and 2/3 its length. Foam cylinders were added to provide buoyancy.

American bittern nests were also located by observing females make repeated "feeding flights" to the nest (Brininger 1996). The area where a female lit was searched for a nest. The nests of radio-marked females were located by homing-in (Kenward 1987) on the radio signals and visually observing the females on nests.

Nest substrate, width and height, water depth, dominant vegetation within 2.0 m, and height of tallest vegetation within 1.0 m, were recorded at nest sites (S. Maxson, Prog. Rep., Agassiz NWR, Middle River, Minn., 1994). Visual horizontal obstruction was measured either with a Robel Pole (Robel et al. 1970) or a 1.0-m^2 grid divided into 0.01-m^2 blocks (Loft et al. 1987). The grid was viewed from a height of 1.0 m and distance of 5.0 m in the 4 cardinal directions. The total number of blocks and number of blocks in the lower half of the grid not obscured by vegetation were recorded and averaged among the 4 directions. The Robel Pole was also viewed from a height of 1.0 m and distance of 5.0 m and readings were also averaged among the 4 cardinal directions.

Radio Telemetry

Radio-marked American bitterns were systematically relocated using standard triangulation techniques (Kenward 1987). Radio signals were received with an Advanced Telemetry Systems TLR-4000 receiver and a vehicle-mounted, peak-directional antenna or a hand-held yagi antenna. Radio-marked bitterns that could not be located from the ground were located with a Cessna 172 with hand-held yagi antennae mounted to the struts. Accuracy of the vehicle-mounted antenna was determined by obtaining 10 azimuths to a radio-transmitter placed at a known location. Azimuths were plotted and angular error was averaged. The estimated error from plotted to actual transmitter location was then computed (Gould 1991).

In 1996, locations of radio-marked American bitterns were taken during 4 sampling periods: sunrise, midday, sunset and midnight. Each sampling period began 2 hours before sunrise, midday, sunset or midnight and lasted 4 hours, consistent with a tracking schedule used by Gould and Jenkins (1993). Radio-marked bitterns were not monitored in consecutive sampling periods. An average of 43 locations per radio-marked bittern (n = 17) were taken in 1996 and 56 locations per radio-marked bittern (n = 9) in 1997. I strived to obtain an equal distribution of locations among the 4 sampling periods. Because midnight locations did not seem to differ from those taken in other sampling periods, the midnight sampling period was dropped in 1997.

Male Census

The "pumping" survey provided a method of estimating relative abundance and densities of male American bitterns. It was initiated at Agassiz NWR in 1995 and repeated in 1996 and 1997. Methods and results of the 1996 and 1997 surveys provided here were also reported elsewhere (W. Brininger, unpubl. memorandum, Agassiz NWR, Middle River, Minn., 1996, D. Azure, unpubl. memorandum, Agassiz NWR, Middle River, Minn., 1997).

The surveys were conducted during the peak week of breeding activity when weather conditions were conducive (i.e. not raining or windy). Four observers simultaneously traveled 4 separate routes stopping at one-mile intervals. At each stop, the observer exited vehicle, broadcasted the pumping call of the male American bittern every 30 seconds, and recorded the number of bitterns heard for 3 minutes. Individual bitterns were counted only once. Each route was 9 miles long.

Analytical Methods

Adult Body Measurements

Brininger (1996) reported means, standard deviations, and sample size for anatomical measurements of adult American bitterns in northwest Minnesota, 1994-96.

However, he (p. 39) provided no statistical analysis to corroborate his contention that "males are two times larger than females." I used these data plus measurements taken in 1997 to build a model that predicts sex. A Pearson correlation matrix (Wilkinson et al. 1992) was constructed to detect collinear variables ($r > 0.5$). Only measurements of bitterns with no missing values were used to build the matrix (25 males, 17 females). The objective was to eliminate correlated variables to reduce problems associated with collinearity (Naugle et al. 1997). Discriminant function analysis (Wilkinson et al. 1992) was used to produce a linear combination of variables that best predicted sex. When the model was completed, bitterns were classified as males or females according to the largest value of the classification functions (Naugle et al. 1997). Apparent classification rates were used as a method of cross-validating the ability to predict sex. The true classification rate of the discriminant function was also determined with 10 bitterns (6 males, 4 females) that were excluded from the correlation matrix and model building process because of missing values.

Chick and Nest Parameters

Chick weights were plotted and growth rates calculated by dividing gain in mass by number of days between subsequent measurements. Nest success was calculated by dividing the number of nests that hatched at least 1 egg by the total number of nests. Only nests found before hatching were used to determine nest success. Number of chicks fledged per nest was tabulated. A chick was assumed to have fledged if 1) no signs of mortality were evident, and 2) it was known to have been old enough to fledge, approximately 40 days according to Brininger (1996).

Two-tailed t-tests (Sokal and Rohlf 1995) were used to detect differences between marsh and upland nests. Nest parameters were also compared to those in the published literature.

Home-range

Because American bitterns usually make a post-breeding dispersal (post-nesting in females), home-range maps were constructed for 1) the breeding season, and 2) the post-breeding season (ending middle/end of August). When an obvious range shift was not made by a particular radio-marked bittern, the end of the breeding season for that bird was marked by the cessation of calling (males) or when the nest was destroyed or chicks fledged (females).

Universal Transverse Mercator (UTM) coordinates of locations were computed by the program LOCATE II (Nams 1990). Locations of visually observed radio-marked American bitterns were plotted on a 7.5 minute (1:24,000) U.S. Geological Survey topographic map and UTM coordinates were determined. Home-range maps were generated with the program CALHOME (Kie et al. 1994) using the adaptive kernel (Worton 1989) and minimum convex polygon (MCP) (Mohr 1947) methods. Two levels of resolution, 95% and 50% of locations, were used with the kernel estimates while only the 95% level was used for the MCP estimates. The 50% polygon was referred to as the core-area and the balance of the home-range was referred to as the low-use area. The kernel estimator requires a grid-cell size and bandwidth, or smoothing parameter, to be chosen. A grid-cell size of 50 m was used for all estimates.

A "best-fit" estimate of range size and shape was obtained by using bandwidths 70% to 110% of the default bandwidth. However, Lawson and Rodgers (1997) report that Harris et al. (1990) noted relatively minor changes in the smoothing parameter value had a large effect on overall range size, especially for small sample sizes (Worton 1995). Consequently, I reported 2 estimates for the adaptive kernel method. One estimate used the default value for the bandwidth, and the other used the bandwidth value which produced the range estimate that I believed most accurately represented the actual home range. The best-fit estimate provided the smoothest 95% polygon while minimizing the area between the outer-most locations and contour line. The best-fit estimates were used for all analyses.

Occasionally, the kernel estimate produced 2 polygons at the 95% level of resolution. One polygon surrounded the majority of locations and the other encompassed only 2 or 3 outlying locations. In these instances, the area of the outlier polygon was excluded from the range size estimate.

Locations of male 18 were used to test for the minimum number of locations needed to produce a reliable home-range estimate. Locations were randomly subsampled from a pool of 65 locations. Based on 10 trials per estimate, home range estimates were made based on 5, 10, 15, and 20 locations. Acceptability of the sample size was based on a ≤10% increase in the mean range size when compared to subsequent estimates (Jensen 1988). The adaptive kernel and MCP estimators were used at the 95% level of resolution. As Table 1 suggests, an asymptote was reached between 15 and 20 locations for both estimators. Based on this, sample sizes of <15

Table 1. Summary of test to determine minimum number of locations needed to provide a reliable home-range estimate. Estimates are based on 10 trial runs of randomly chosen locations from a pool of 65 locations of male 18.

Number of Locations	5	10	15	20
Adaptive Kernel[a]:				
Mean Area (ha)	42.9	104.9	132.6	122.4
Variance	1,010.9	1,641.6	1,586.7	1,684.6
Convex Polygon:				
Mean Area (ha)	11.4	52.0	81.3	62.5
Variance	91.1	379.3	638.9	919.8

[a]The smoothing parameter providing the best-fit 95% polygon was used.

locations were excluded from analysis. Home-range estimates were averaged by year and by season. A Mann-Whitney U test (Sokal and Rohlf 1995) was used to test for significant differences for all 2-sample comparisons.

Fidelity

Brininger (1996) reported fidelity as the percent of radio-marked American bitterns that migrate from a study-area in one year and return to the same study-area the next year. While this provided valuable information regarding fidelity to a general area, I believe this method may underestimate the faithfulness bitterns exhibit to seasonal home-ranges because some radio-transmitters inevitably fail during the winter and returning radio-marked American bitterns may go unaccounted. Also, no effort was made to describe fidelity to post-breeding home-ranges. Consequently, I considered fidelity to seasonal home-ranges to be exhibited if ranges overlapped in consecutive years. When too few locations were available for a reliable home-range estimate, the mean location of available locations was used to test for fidelity.

Local Movements

Movements from a breeding home-range to a post-breeding home-range were quantified by measuring the distances between the arithmetic centers, or mean locations of the ranges. The program BLOSSOM (Midcontinent Ecological Science Center, Ft. Collins, Colo.) was used to perform a multiple-response permutation procedure (MRPP) (White and Garrott 1990, Meilke and Berry 1982) to test for differences between seasonal ranges for an individual in the same year. MRPP is a non-parametric method that can detect differences in the spatial distribution of two groups of points. MRPP calculates the distances between all pairs, or members, of each group and calculates the average distance for each group. The strategy of MRPP is to compare the observed intragroup average distance with the observed intergroup average distance. The procedure is sensitive to shift in location (central tendency or median), shift in dispersion (spatial variability of locations within a group), and shift in location and dispersion (B. Cade, Midcontinent Ecological Science Center, pers. commun.). These shifts are tested for simultaneously and the procedure cannot assign amount of variability to any one in particular. Therefore, some interpretation of the results was required.

Habitat Use

A complete vegetation map of Agassiz NWR acceptable to evaluate habitat use was not available. Therefore, analyses and results presented here should considered a "work-in-progress" and are included mainly to demonstrate methodology. The term "habitat" is used to refer to the vegetation association. Future analyses may incorporate vegetation density, height, and/or water depth.

To qualitatively assess habitat use, high-altitude infrared photographs of Agassiz NWR were scanned, registered and loaded into ArcView Geographic Information System (GIS) version 3.0a (Environmental Systems Research Institute, Inc. 1996). Most photographs became distorted following registration. Consequently, the area of the refuge accurately depicted by registered photographs was small.

To quantitatively assess habitat composition and use within home-ranges, a vegetation coverage that was developed for use with GIS software was used.

Unfortunately, only approximately 2,400 ha of the refuge have been delineated to date. Five male seasonal home-range maps that fell within this area were used to determine habitat composition of low-use areas and core-areas, as well as use and abundance of 8 habitat types: cattail, open water, mixed emergent (includes sedge meadow and *Phragmites*), road/dike, deciduous tree, willow/sedge, willow/grass, and grassland.

Paired t-tests of habitat types were used to determine if percentages of habitats within core-areas were significantly different from those in low use areas (Gould and Jenkins 1993). Although percentages of habitat types within a defined area are not independent, I believe this test is still valid. If one habitat is more abundant (higher percentage) within a core-area than within a low-use area, intuitively, some other habitat type must be less abundant. This test indicates the abundance of specific habitat types in core-areas and low use areas.

To assess habitat selection, habitat preference was defined as use greater than abundance while habitat avoidance was defined as use less than abundance (White and Garrott 1990, Gould and Jenkins 1993). Telemetry locations excluding outliers were used to determine habitat use. Habitat abundance was the proportion of habitats within seasonal home-ranges. The Chi-square goodness-of-fit test was used to determine whether there was a significant difference between the expected and observed proportion of habitat use (Neu et al. 1974, Byers et al. 1984, Gould and Jenkins 1993). If a difference was detected, 90% Bonferroni confidence intervals were calculated to determine which habitats were preferred or avoided (Neu et al. 1974).

RESULTS

Male Census

The annual male census was conducted on 29 May 1996 and 28 May 1997. Mean number of calling males heard per stop was 2.0 and 1.9 for 1996 and 1997, respectively (Table 2). Impoundments on the west side of Agassiz NWR are larger and deeper than impoundments on the east side. Bitterns are typically found on the east side only in wet years (L. Bennett, Final Report, Agassiz NWR, Middle River, Minn., 1990). Routes 1 and 2 represent the west side of Agassiz NWR while routes 3 and 4 represent the east side. Mean number of calling males heard per stop on the west side was 1.4 and 1.2 for 1996 and 1997, respectively. Mean number of calling males heard per stop on the east side was 2.6 for both years. A two-tailed t-test (Sokal and Rohlf 1995) indicated that calling males were significantly more abundant on the east side ($P = 0.004$) in 1997. Figure 2 compares these results with results from 1995 (W. Brininger, unpubl. memorandum, Agassiz NWR, Middle River, Minn., 1996). Undocumented data prevent the calculation of means for individual routes for 1995 and the calculation of standard errors for 1996.

Adult Body Measurements

Bill length, from the anterior margin of the nostril to the tip of the bill, and tarsus length (Table 3) were used to build the discriminant model. The discriminant

Table 2. Mean number of calling American bitterns heard per stop ($n = 9$) during the annual male census on Agassiz NWR, 1996-97. Standard error is unavailable for 1996.

	1996	1997 (SE)
Route 1	2.4	1.6 (0.18)
Route 2	0.3	0.8 (0.27)
Route 3	2.1	2.3 (0.77)
Route 4	3.0	2.8 (0.93)
Average	2.0	1.9 (0.32)

function had a true classification rate of 83% for males and 100% for females (Table 4). The apparent classification rate was 92% for males and 94% for females.

Chick and Nest Parameters

Approximately 32 ha of CRP (T 157 N, R 42 W, SE1/4 of 34) adjacent to the Agassiz NWR were searched for nests on 11 June 1996. Four blue-winged teal (*Anas discors*), 1 northern shoveler (*Anas clypeata*), and 0 American bittern nests were found. Duck nest success in the CRP was 0%; 4 nests were destroyed by predators and 1 was destroyed by a plow (The CRP contract expired following the initial search).

Approximately 32 ha of cattail habitat in Northwest Pool, 0.8 km east of the CRP mentioned above, were searched for nests with airboats on 25 and 27 June 1996. Approximately 8 ha of cattail habitat were also searched in Headquarters Pool on 27 June. Seven canvasback (*Aythya valisneria*), 3 mallard (*Anas platyrhynchos*), and 0 American bittern nests were found. Duck nest success was 40%; 6 nests were destroyed

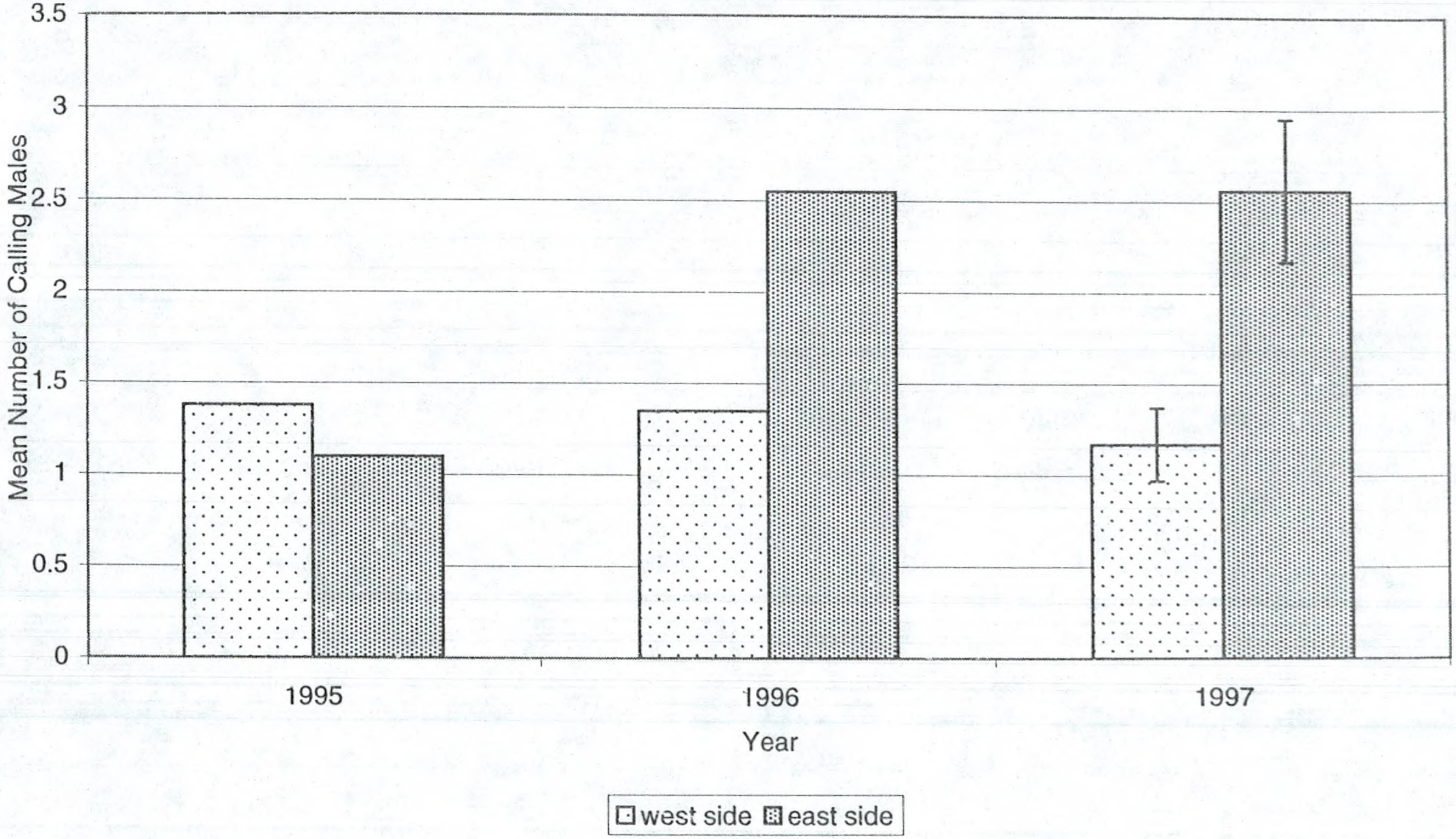

Figure 2. Mean number of calling American bitterns heard during the annual male census conducted on Agassiz NWR, 1996-97. 1995 data were collected during the annual ruffed grouse survey (W. Brininger, Memorandum, Agassiz NWR, Middle River, Minn., 1996). Routes 1 and 2 represent the west side of the refuge and routes 3 and 4 represent the east side. Standard error bars are included with the 1997 means.

Table 3. Means and standard errors of bill and tarsus lengths of adult American bitterns in northwest Minnesota, 1994-97[a].

	Male (SE)	Female (SE)
Bill Length[b] (cm)	5.55 (0.05)	5.14 (0.06)
Tarsus Length (cm)	9.58 (0.14)	7.26 (0.08)

[a]Summary of measurements taken from 1994-96 also reported in Brininger (1996).

[b]Bill length from the anterior margin of the nostril to the tip of the bill.

Table 4. Classification function[a] for discriminating sex of adult American bitterns in northwest Minnesota, 1994-97[b].

	Classification Function Coefficients	
	Male	Female
Constant	-358.67	-299.45
Bill Length[c]	81.95	75.85
Tarsus Length	27.23	24.30
Apparent Classification Rate	92%	94%
True Classification Rate	83%	100%

[a]Wilk's Lambda = 0.42, F = 27.34, df = 2, 39, $P < 0.0001$.

[b]Summary of measurements taken from 1994-96 also reported in Brininger (1996).

[c]Bill length from the anterior margin of the nostril to the tip of the bill.

by predators. Other species flushed during marsh nest searches included male American bitterns – 4 (only 1 was flushed by the rope), least bitterns (*Ixolorychus exilis*) – 8, sora (*Porzana carolina*) – 1, blue-winged teal – 1, mallard – 1, and gadwall (*Anas strepara*) – 1. Several marsh wrens (*Cistothorus palustris*) were also flushed and nests located. No damage to marsh wren nests was observed.

Three American bittern nests were located in 1996 by homing-in (96-01, 96-02, 96-03) and 1 by observing feeding flights by a female (96-04). Two of these nests contained chicks when discovered (96-03, 96-04) and 2 contained eggs (96-01, 96-02). Incidentally, nest 96-01 and 96-02 were both initiated by female 1, representing the first confirmed renesting attempt by an American bittern. Both nests were destroyed by predators, nest success = 0%. Both nests containing chicks were also destroyed by predators before chicks fledged.

Red Lake DNR personnel nest-searched approximately 295 ha of upland (hayland, idle paddies) beginning the third week of May 1997. Though waterfowl nests were targeted, 9 American bittern nests were also discovered. All contained eggs when found, nest success was 67%; 2 nests were flooded and 1 was destroyed by a predator.

Approximately 8 ha of cattail and *Phragmites* habitat in Agassiz Pool were searched with airboats on 25 June 1997. One redhead (*Aythya americana*), 1 canvasback and 2 American bittern nests (97-01, 97-02) were discovered. However, the female bitterns seemed to flush due to the airboat and not the rope. Observation of feeding flights made by female bitterns on 30 June led to the discovery of 2 more nests

(97-03, 97-04) in the vicinity of the first two (see Appendix A for UTM's of nests). All 4 nests contained chicks when discovered.

Approximately 2 ha of cattail habitat were searched with airboats in East Pool on 17 June 1997. No nests were found.

Table 5 contains a summary of American bittern nest parameters from 1996 and 1997. A complete account of individual nest data is provided in Table 11, Appendix A. Clutch sizes of nests at Agassiz NWR were significantly smaller than nests at Red Lake Farm ($P = 0.02$). Neither nest width nor height was significantly different between nests from the two study areas ($P = 0.36$ and 0.07, respectively). Average height of tallest vegetation within 1 m of the nest was significantly higher at Agassiz nests than at Red Lake Farm ($P = 0.03$).

The mass of American bittern chicks at hatch is estimated to be about 24 g, based on a chick measured at nest RL-9. Growth of chicks during the first few days of life seems to be about 8-12 g per day and appeared similar for all nestmates (Table 12, Appendix B). Growth rate by the seventh or eighth day, however, ranged from 20 to 28 g per day, with oldest chicks outgrowing youngest chicks (Fig. 3 and 4). Growth of middle chicks (in nests with >3 chicks) appears to be about equal.

I estimated that 3 of 13 chicks fledged from nests at Agassiz NWR in 1997; mortality of chicks before fledging = 69%. However, I observed no chick mortality on Red Lake Farm. I estimated that all discovered chicks survived to fledge ($n = 26$).

Table 5. Summary of American bittern nest data collected on Agassiz NWR and Red Lake Farm, 1996-97.

Study Area	Agassiz NWR[a]	Red Lake Farm[b]
Apparent Nest Success[c]	0% (0/2)	67% (6/9)
Average Clutch Size	2.6 eggs (n = 8, SD = 1.06)	4.0 eggs (n = 8, SD = 0.93)
Average Nest Width	30.5 cm (n = 6, SD = 5.32)	27.2 cm (n = 6, SD = 5.01)
Average Nest Height	5.5 cm (n = 6, SD = 2.66)	11.7 cm (n = 7, SD = 7.06)
Average Height of Tallest Vegetation Within 1 Meter	2.03 m (n = 7, SD = 0.56)	1.44 m (n = 8, SD = 0.38)
Horizontal Obstruction[d]	lower = 0.0004 m^2 (n = 8) total = 0.0774 m^2 (n = 8)	7.3 (n = 8)
Average Water Depth	31 cm (n = 7)	---

[a]All nests on Agassiz NWR were located in wetlands.

[b]All nests on Red Lake Farm were located in uplands.

[c]Only nests discovered before hatching were used to compute nest success.

[d]A cover-board (Loft et al. 1987) was used to measure horizontal obstruction of wetlands nests, a Robel Pole (Robel et al. 1970) was used for upland nests.

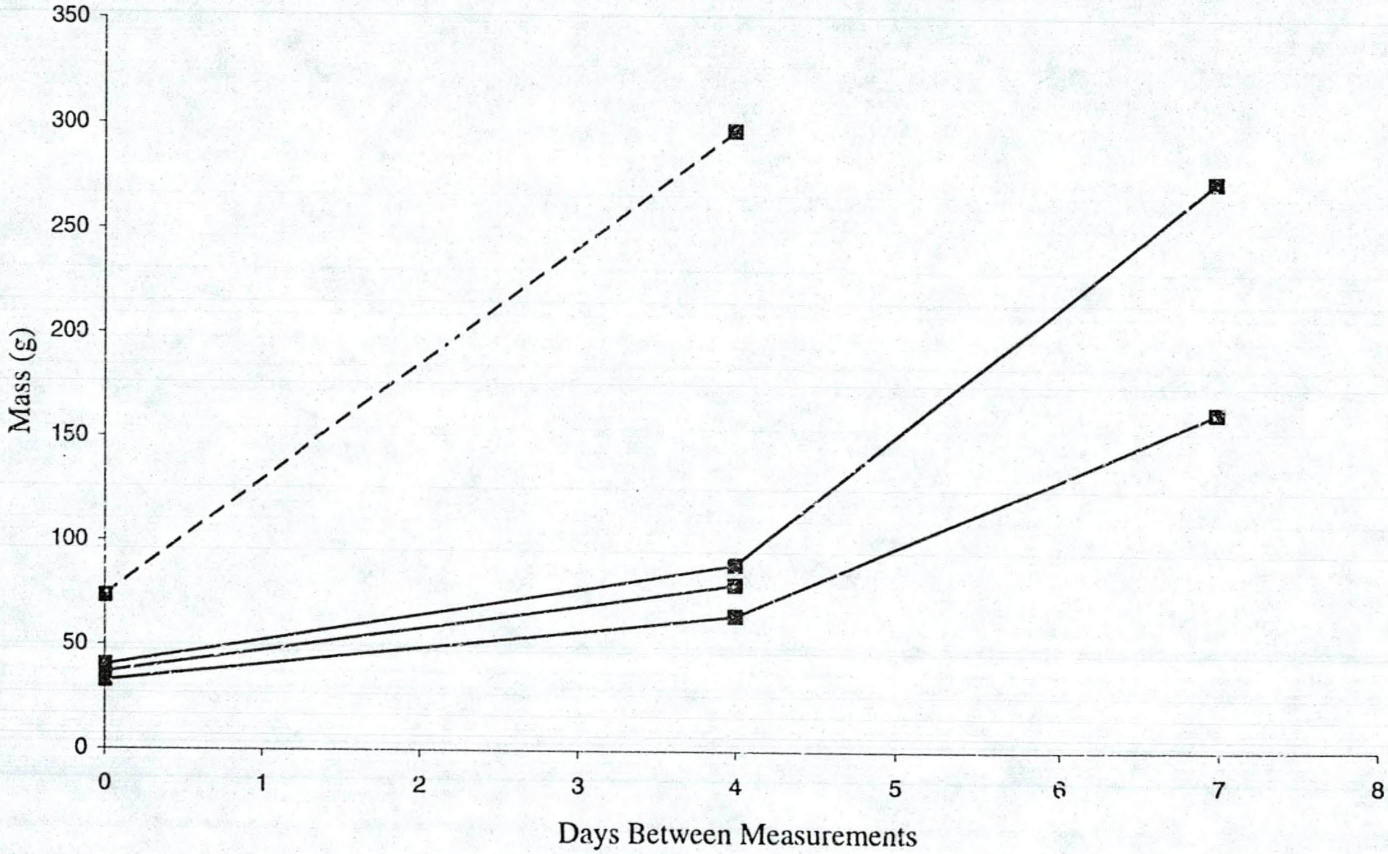

Figure 3. Growth rates of chicks from 2 American bittern nests at Agassiz NWR, 1997. Solid lines represent growth rates of chicks from nest 97-03 while the dashed line represents the growth rate of a chick from nest 97-01.

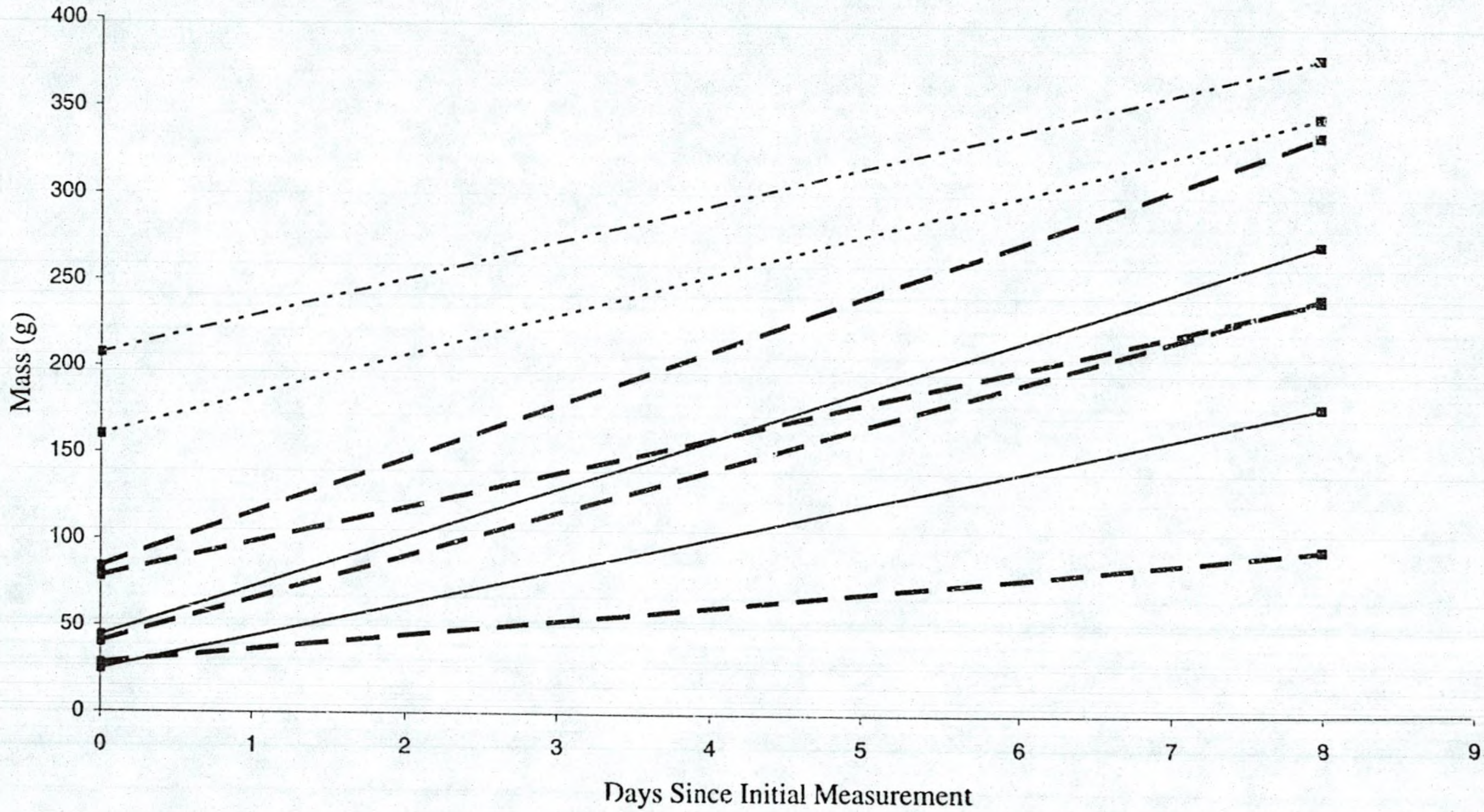

Figure 4. Growth rates of chicks from 3 American bittern nests on Red Lake Farm, 1997. Solid lines represent chicks from nest RL-4, thin dashed lines represent chicks from nest RL-7, and heavy dashed lines represent chicks from nest RL-8.

Home-range

The angular error of 10 azimuths to a known radio-transmitter location was 5.5+/-0.91° (SE). The 95% confidence interval of angular error (95% error arc) was +/-2.1°. The mean antennae-to-bird distance (ABD) derived from randomly selected American bittern locations was 591+/-74 m (SE) (n = 50). The mean antennae-to-transmitter distance during the accuracy test was 484+/-78 m (SE). The estimated distance error, as measured from plotted to actual transmitter location assessed at ABD was 56.6 m.

Reported means and comparisons of seasonal home-range estimates are based on males only unless otherwise noted. Results of female home-range estimates are included in respective individual accounts (Appendix C). Also, means reported here are based on range estimates made by the adaptive kernel method with the bandwidth adjusted to provide the "best-fit" 95% polygon. Estimates of range sizes using the adaptive kernel method with default bandwidths and the minimum convex polygon method are reported in Table 13, Appendix D.

Means of 1996-97 breeding and post-breeding home-ranges were 210 ha (n = 20) and 183 ha (n = 16), respectively (Table 6). Means of respective core-area estimates were 25 ha and 23 ha (Table 7). No significant differences ($P > 0.05$) in home-range or core-area size were detected between seasons or years based on Mann-Whitney U tests. All home-range maps are illustrated in Appendix E.

Table 6. Mean seasonal home-range estimates of radio-marked male American bitterns on Agassiz NWR, 1996-97, using the adaptive kernel method. The smoothing parameter providing the best-fit 95% polygon was used.

	Home-range size (ha)						
	Breeding			Post-breeding			
	mean	SD	*n*	mean	SD	*n*	*P*[a]
1996	208	238.9	14	126	82.2	8	NS[b]
1997	217	174.2	6	179	251.4	8	NS
average	210	216.9	20	152	182.8	16	NS

Additional statistical comparisons

	P
1996 Breeding vs. 1997 Breeding	NS
1996 Post-breeding vs. 1997 Post-breeding	NS

[a]Based on Mann-Whitney U test.
[b]NS = $P > 0.05$.

Table 7. Mean seasonal core-area estimates of radio-marked male American bitterns on Agassiz NWR, 1996-97, using the adaptive kernel method. The smoothing parameter providing the best-fit 95% polygon was used.

	Core-area size (ha)						
	Breeding			Post-breeding			
	mean	SD	*n*	mean	SD	*n*	P^a
1996	28	30.0	14	20	19.8	8	NS[b]
1997	18	18.3	6	26	26.3	8	NS
average	25	26.7	20	23	34.0	16	NS

Additional statistical comparisons	P
1996 Breeding vs. 1997 Breeding	NS
1996 Post-breeding vs. 1997 Post-breeding	NS

[a]Based on Mann-Whitney U test.
[b]NS = $P > 0.05$.

Fidelity

Seven of 15 radio-marked males that migrated from Agassiz NWR in 1996 were located in 1997. Four had breeding home-ranges that overlapped in consecutive years; fidelity to breeding home-ranges = 57%. Distances between mean locations of the 1996 breeding home-ranges and the 1997 breeding home-ranges of the 3 males that did not exhibit fidelity were 1.7, 4.3, and 6.2 km. None of the 6 radio-marked females that migrated from Agassiz NWR in 1996 were located in 1997. Five radio-marked males were monitored during the post-breeding season in both 1996 and 1997, of which 4 had 1997 post-breeding home-ranges that overlapped with their respective 1996 post-breeding home-range; fidelity to post-breeding home-ranges = 80%. Distance between post-breeding home-ranges of the only male not to exhibit fidelity is unknown because this bird moved off the refuge (>20 km) at the conclusion of the breeding season in 1996, but stayed in 1997.

Local Movements

Distances between mean locations of breeding and post-breeding home-ranges varied from 0.2 to >20.0 km (1996 and 1997, combined); however, 64 % were under 2.0 km (n = 22) (Table 8). Five of 8 movements that were greater than 2.0 km were also greater than 20.0 km, as these radio-marked males left the refuge and could not be located.

All breeding home-ranges were statistically significantly different from the following post-breeding home-range in location, dispersion, or location and dispersion based on MRPP ($P < 0.05$). Nine of 23 pairs of breeding and post-breeding home-

Table 8. Distribution of post-breeding dispersal distances of male American bitterns on Agassiz NWR, 1996-97 ($n = 22$).

Kilometers	Number of Males
<1.0	3
1.1 to 2.0	11
2.1 – 3.0	0
3.1 – 4.0	0
4.1 – 5.0	1
>5.0	7

ranges overlapped. Average within group distance (dispersion) was greater in breeding home-ranges than in post-breeding home-ranges in 11 of 18 pairs (5 males dispersed >20 km after the breeding season, no post-breeding range estimate available). All pairs of home-ranges are believed to be different in both location and dispersion.

Habitat Use

Based on examination of the home-range maps superimposed on high-altitude, infra-red aerial photographs, American bitterns appeared to predominantly use emergent vegetation. Core-areas seemed to be associated with habitat edges within marshes.

Based on the 5 male home-range maps that fell within the vegetation coverage, habitat composition within core-areas did not significantly differ from low-use areas for any habitat type except cattail, which was less abundant in core-areas ($P < 0.05$) (Fig. 5). Habitat use was disproportional to abundance ($\chi^2 = 47.15$ (ha), df = 7, $P < 0.005$). The open water habitat type was preferred while the cattail, deciduous tree, and willow/grass habitat types were avoided (Bonferroni confidence intervals, $P < 0.10$). Mixed emergent, road/dike, willow/sedge, and grassland habitat types were used in proportion to abundance ($P > 0.10$) (Table 9).

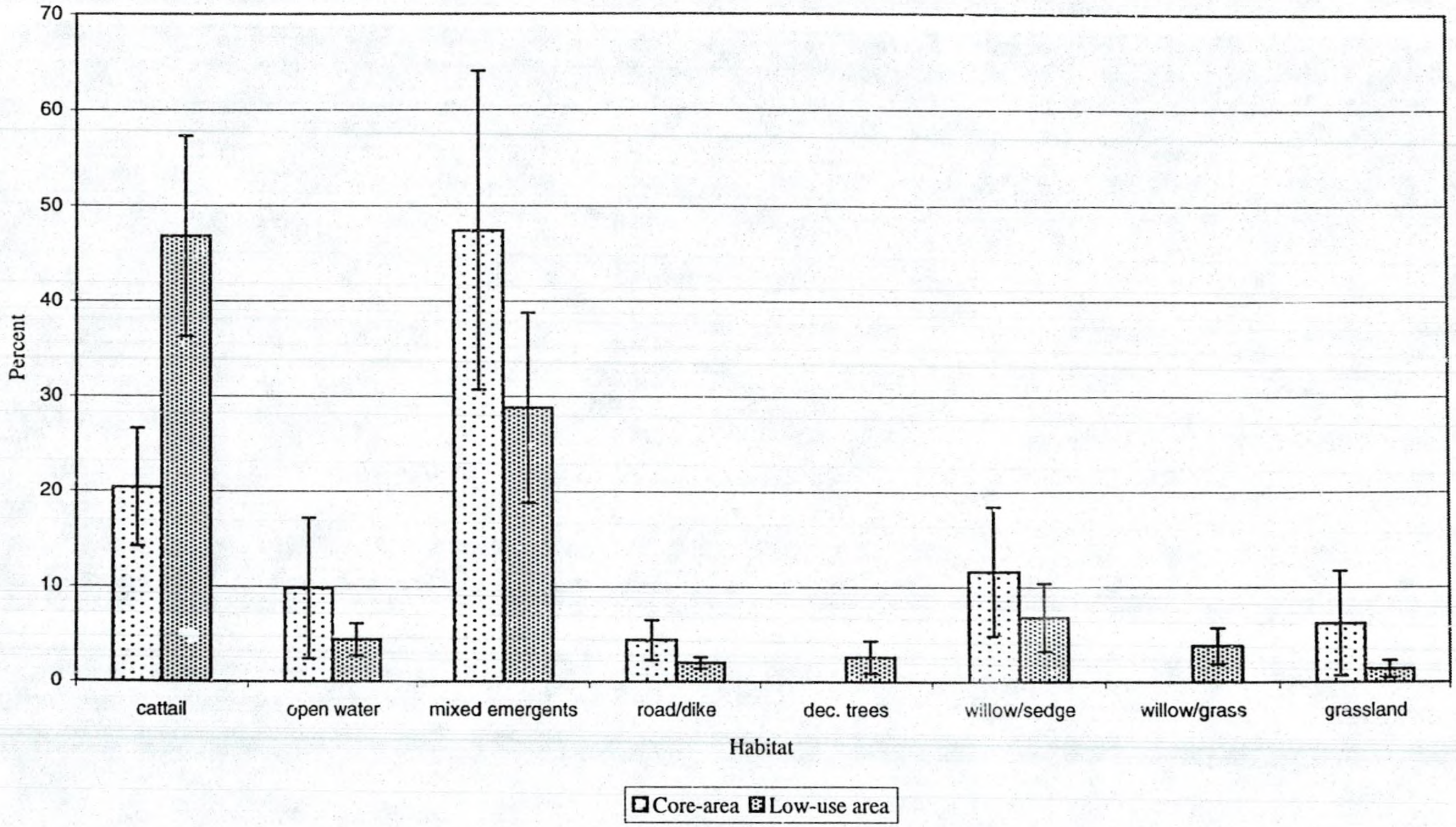

Figure 5. Paired comparisons of percent habitat type within core-areas and low-use areas determined from home-range maps of 5 American bitterns. Standard error bars are shown.

Table 9. Habitat types, abundance[a], use by 5 American bitterns (% Loc), and habitat selection[b] on Agassiz NWR, 1996-97.

Habitat	% Abundance	% Loc	Habitat Selection
Cattail	45	31	-
Open water	5	13	+
Mixed emergents	29	35	
Roads/dikes	2	4	
Deciduous trees	2	0	-
Willow/sedge	9	10	
Willow/grass	6	1	-
Grassland	2	5	

[a]Approximately 1,186 ha.

[b]+ indicates significant habitat preference, - indicates significant habitat avoidance (simultaneous Bonferroni confidence intervals, $P < 0.10$).

DISCUSSION

Home-range

Seventy-five percent of male seasonal home-range estimates were less than 200 ha, while 69% of core-area estimates were less than 20 ha. These data suggest that on average, bitterns spend 50% of their time in only 13% of their home-range. Core areas were often associated with mixed emergents and habitat edges.

Variability of range sizes between birds, as well as between seasons for individual birds, was high. For example, breeding home-range estimates ranged from 41 ha (male 19, 1997) to 1,006 ha (male 6, 1996). Also, the 1996 breeding home-range for male 2 was 165 ha, while its 1996 post-breeding home-range was only 48 ha. Finally, the 1996 breeding home-range for male 12 was 313 ha, but its 1997 breeding home-range was only 90 ha, and highly overlapped its 1996 core-area.

Factors leading to relatively large seasonal home-ranges of some radio-marked American bitterns are unclear. Many heron species defend a feeding territory during the breeding season (Palmer 1962). It is unknown if American bitterns do the same, but if they do, failure to secure a territory may require an individual to move more to find food. Also, most heron species are seasonally monogamous and the defended territory gradually shrinks once pair bonds are formed and nesting progresses (Palmer 1962). Bitterns are believed to be polygamous (Gibbs et al. 1992). If a male is unsuccessful at attracting a female to its territory, it may be inclined to go in search of a mate, perhaps visiting other male's territories. In 1996, male 6 seemed to exhibit this behavior.

Another factor which could potentially lead to a relatively large home-range is limited resource availability. However, in 1996 and 1997, males 11 and 12 occupied the same general area in Madsen Pool. Yet, male 11 was more mobile and had a larger home-range than male 12 in both years. I do not believe that resource availability caused male 11 to be more mobile, nor do I believe food was limiting. Perhaps the propensity for a large home-range is age-related, with younger bitterns unable to successfully defend territories and forced to move. Detailed demographic data might aid in interpreting these results.

Problems associated with the home-range estimation methods might have caused spurious results. Although outlier locations were excluded to estimate home-ranges, I believe the adaptive kernel method still overestimated some utilization distributions. Because distances of daily movements were usually short, often undetectable with our telemetry system, locations often were grouped in clusters. When distances between clusters increased, it seemed the kernel estimate was more likely to overestimate the actual home-range (see the 1997 breeding home-range of male 11, Appendix E). Although the MCP does not indicate core-areas, and home-range size is strongly related to the distribution of the outermost points (Kenward 1987), I think it provides a better estimate of home-range size than the kernel method (Table 10). Brininger (1996) used the MCP; however, he did not exclude outliers, nor did he estimate a breeding and post-breeding home-range separately, even though he described

Table 10. Mean seasonal home-range estimates of radio-marked male American bitterns on Agassiz NWR, 1996-97, using the minimum convex polygon method.

	Home-range size (ha)						
	Breeding			Post-breeding			
	mean	SD	*n*	mean	SD	*n*	P^a
1996	130	118.6	14	82	48.7	8	NS[b]
1997	118	89.3	6	94	111.7	8	NS
average	127	108.4	20	88	83.4	16	NS

Additional statistical comparisons

	P
1996 Breeding vs. 1997 Breeding	NS
1996 Post-breeding vs. 1997 Post-breeding	NS

[a]Based on Mann-Whitney U test.
[b]NS = $P > 0.05$.

the post-breeding dispersal. As a result, he may have overestimated American bittern home-range size.

Because many American bitterns were monitored for more than 1 season, seasonal home-range estimates used in comparisons are not statistically independent. However, Schoen and Kirchhoff (1985) performed a similar analysis. Of greater importance than seasonal comparisons, is the appreciation of the small home-range sizes of most bitterns.

Fidelity

Results indicate American bitterns tend to return to their respective seasonal home-ranges from the previous year. Some bitterns did establish new home-ranges; however, these were relatively close to respective previous ranges. The 1996 breeding home-range of male 2 included its 1995 capture site. In 1997, it was captured approximately 4 km to the northeast. At this time, its 1996 breeding home-range was occupied by another male. This male may have arrived first, driving away male 2. Alternatively, habitat quality may have decreased, causing male 2 to abandon the territory. The new male may have been a young bird, or habitat quality of its previous breeding territory may have degraded. Demographic data would aid in interpreting these range shifts.

On 10 June 1997, male 2 moved to its 1996 post-breeding home-range. It moved 10.5 km to Farmes Pool on 13 June where it remained until 16 June. On 18 June, it was located back at its 1996 post-breeding home-range, where it remained for the rest of the summer. This suggests that bitterns are site-specific in range selection, a trait that may have applicability in population monitoring.

Local Movements

Most radio-marked American bitterns, including females, had a noticeable post-breeding (or post-nesting) range shift. However, results indicate most males moved less than 2.0 km from breeding territories. Data from 2 radio-marked females indicate post-nesting range shifts of 1.6 and 4.8 km. It appeared that if males did not find suitable habitat in the vicinity of their respective breeding home-range, they were likely to disperse from Agassiz NWR. As mentioned, 5 of 8 post-breeding dispersals exceeding 2.0 km also exceeded 20.0 km.

The tendency for American bitterns to make a post-breeding dispersal was known before the commencement of this project. Some authors attribute rare sightings of bitterns in Iceland and Norway, areas outside the bittern's normal range, to this behavior (Gibbs and Melvin 1992). Although Palmer (1962) described varying degrees of post-breeding dispersal in most heron species, causal factors were not suggested.

The term dispersal has generally been used to describe the movement of an organism from its birthplace to breeding locality (Campbell and Lack 1985). Specifically, natal dispersal is the movement from birthplace to first breeding site while breeding dispersal is the movement of an organsim, which has reproduced, between successive breeding sites (Greenwood 1980). There are often age or sex differences in these types of dispersals. Younger members of a population may be prevented from breeding in their natal area and forced to disperse. Female-biased dispersal occurs in polygamous species where males defend resources (Campbell and Lack 1985). Most of the literature on dispersal is related to these types with little mention of post-breeding dispersal (Greenwood 1980, Campbell and Lack 1985, Chepko-Sade and Halpin 1987).

In general, many factors, including changes in the distribution of food sources and population density, may cause dispersal. I believe the post-breeding range shifts exhibited by some bitterns at Agassiz NWR, and possibly other heron species, is resource-related. Because bitterns and other herons typically use shallow wetlands for foraging (Parker 1962, Gibbs et al. 1992), they would be affected by annual wet-dry cycles. While photoperiod, specifically the light:dark ratio, may cue the end of breeding activity (Immelmann 1971), water level, and its effect on prey abundance could possibly determine the timing and extent of bittern dispersal. Campbell and Lack (1985) note that some species of birds, which are subject to fluctuations in their food supply, exhibit high levels of dispersal. Fidelity to post-breeding home-ranges exhibited by 4 of 5 radio-marked male bitterns suggests that direction of dispersal is not random; rather, bitterns are moving to familiar areas.

The average within group distance is not a good measure of an American bittern's movement within its home-range, because the chronological order of locations is ignored. The spatial distribution of locations is an invalid means of measuring bittern movement if locations are not gathered consistently and at a specified time interval. The average within group distance considers all locations simultaneously. Therefore, it measures the same construct as the home-range estimate. In fact, change in home-range size from breeding to post-breeding ranges mirrored change in average within group distance in 12 of 14 pairs. There is no *a priori* reason to believe pairs of breeding and post-breeding home-ranges would be the same. One would, however, expect the utilization distributions to change as a bitterns switch from breeding to molting activities and as habitat conditions change seasonally.

Daily movements seemed greater and more evenly distributed throughout the home-range during the breeding season than the post-breeding season. Daily movements of nesting females were usually within 500 m of the nest. Daily movements during the post-breeding season seemed less; however, small movements to different parts of the home-range seemed to occur more frequently. Brininger (1996) reported mean distance between locations. However, he did not collect locations at regular time intervals, nor did he account for the post-breeding dispersal, which he described. Therefore, his report of mean distance between locations may not have accurately represented bittern movements and possibly overestimated bittern activity.

Brininger (1996) described molting areas and suggested they occur in the middle of impoundments, possibly to avoid mammalian predators. He also described a bittern that was flightless as it molted. As previously mentioned, male 10 was captured on 22 July 1997 and was also flightless at the time. In addition, it had lost 198 g, or about 22% of his body mass, since 5 June 1997. While it is possible that bitterns are seeking areas in the middle of impoundments for molting to avoid predators, they may also be seeking areas with deeper, more stable water levels, in anticipation of the flightless, or nearly flightless period. These areas would likely provide a more stable source of prey. I discovered several molting bitterns in the north end of Pool 8 in August of 1996 and

1997. This area is within 1 km of a dike to the north and east, and within 1 km of agricultural land to the west. Vegetation consisted of an even-aged stand of dense cattail with few pockets of open water or sedge. Pool 8 had water levels of less than 1 m in both years, but did not go dry until the end of the molting period. No bitterns were found molting in the middle of Agassiz Pool in 1997, the area that is described by Brininger (1996).

A second dispersal was noticed in some bitterns towards the end of August 1997, and to a lesser degree in 1996. I believe this was in response to declining water levels. In 1997, refuge personnel enacted a drawdown of some impoundments as called for in the water management plan. As a result, several post-breeding home-ranges of radio-marked bitterns began to go dry. This led to range shifts, usually to the nearest habitat with deeper water.

Based on data collected during the midnight sampling period in 1996, bitterns are not "active" at night. From 2100 hrs, 28 May 1997 to 0400 hrs, 29 May, I monitored radio signals from male 2 and recorded its calling activity, as well as the calling activity of several other males in the vicinity. Calling frequency and intensity (pumps per episode) was greatest around 2100 hrs. Gradually, calling frequency and intensity decreased until each bird would only pump once per episode, once about every hour. Radio signals indicated that male 2 did not move after 2230 hrs. Faint sunlight was visible until about 2345 hrs. During the period of low calling activity, if one male called, it seemed to stimulate the other males in the area to call back. Faint sunlight could be detected at 0300 hrs. At this time, calling frequency and intensity gradually increased. At 0330, male 2 began to move. I do not believe this constitutes nocturnal activity, since no movements were made when it was completely dark. Rather, "activity" coincided with peak periods of calling activity, which occurred during the crepuscular hours.

Habitat Use

Results of habitat analyses conflict with some published literature and corroborate others. I do not think American bitterns are avoiding cattail, as results suggest. One possible explanation of these results is the confounding effect of pooling data from individuals. White and Garrott (1990) warn of pooling data from individuals because any variation between individuals is lost. When a complete vegetation coverage of Agassiz NWR is available for GIS, I will be able to do a more thorough analysis. Secondly, photos used to delineate the habitat types were taken in August. However, 3 of the 5 home-ranges used in the analyses were breeding home-ranges. Locations for these range estimates were gathered in May and June. At this time of the year, new cattail growth is sparse and water levels are high. Though most breeding ranges are established in the vicinity of large cattail areas, I do not think bitterns yet use these areas as extensively as they will later on in the summer. Thirdly, some bitterns tended to use marsh-interior habitat edges. Telemetry error could result in placement of locations in the wrong habitat type. Finally, the minimum mapping unit of the vegetation coverage is 0.5 ha. Small patches of cattail could exist in areas delineated as open water. Bitterns may be using these small patches, or they may be feeding in open water if it is shallow. Both would explain why bitterns seemed to prefer the open water habitat type.

Chick and Nest Parameters

Results of nest measurements agreed with published data. As expected, nests were generally found in tall and/or dense vegetation. Also, wetland nests were located in shallow water, usually less than 35 cm. The juxtaposition of 4 marsh nests at Agassiz NWR in 1997 corroborate implications that bitterns may exhibit a gregariousness characteristic of the nesting habits of other herons (Bent 1926, Vesall 1940, Middleton 1949, Duebbert and Lokemoen 1977, Svedarsky 1992). Three of these nests were located in residual common reed, even though it was clearly less abundant than cattail. Common reed, however, was the tallest vegetative structure available in the area. Nesting was the only activity for which I witnessed bitterns using common reed. Occasionally, a male could be lured into common reed with the broadcasted pumping call associated with the mirror trap.

An important discovery was that an American bittern can renest should its first nest be destroyed. While renesting has been documented in green herons (*Butorides virescens*) and great-blue herons (*Ardea herodias*) (Parker 1962), it was previously unknown that bitterns had this ability. This information provides some insight to the reproductive capacity of females. It negates the possibility that population declines are due to the bittern's physiological inability to initiate a second nest following the destruction of its first. Still unknown is the number of renesting attempts a bittern will make in one season and how clutch size might differ as renesting attempts increase.

American bittern chick survival was lower in marsh nests at Agassiz NWR (23%) than in upland nests at Red Lake Farm (100%). Predation of chicks was documented at 2 nests; however, overall predation of chicks was low. Egg shells, mostly of waterfowl species, were commonly found on dikes and common ravens (*Corvus corax*) were the confirmed predator. Though I never found bittern egg shells, ravens could have depredated bittern nests. More often, I found dead bittern chicks floating near the nest. Like Brininger (1996), I suspect starvation to be the cause of death. Bittern eggs hatch asynchronously (Mousley 1939, Vesall 1940, Svedarsky 1992). Working with parrots, Stoleson and Beissinger (1997:131) suggested that "asynchronous hatching appears to result in the mortality of the smallest young, due in part to the inequitable distribution of food among nestmates, rather than food limitation, and as a direct result of the size disparity among nestmates." Brininger (1996:62) reported that "larger nestlings were more aggressive and consumed more food than smaller nestlings." However, it is unclear whether he observed this activity or was citing other works.

Unlike other asynchronous-hatching species, the proximate factor of starvation in American bittern chicks may not have been nestmate competition. Instead, starvation may have been the result of missed feedings. In a marsh nest at Agassiz NWR, older nestlings were found dead, apparently due to starvation, while a younger nestling survived to fledge. Also, no chick mortality was documented in upland nests. In fact, several nests are believed to have produced 4 or more fledglings.

As chicks grew older, they strayed farther from the nest when the hen was absent. Svedarsky (1992) noted that nests containing older young had a network of trails going out of the nest and suggesed that young were hunting for prey. When I revisited nests, chicks from marsh nests were more easily captured than chicks from upland nests. This is because it was more difficult for chicks to either swim or maneuver through the emergent vegetation. Contrarily, chicks from upland nests became progressively harder to capture because they were adept at running on dry land.

I twice observed a female return to its nest that contained 3 chicks. Each time, it gave a raspy call as it descended upon the nest. I presume this was to alert the chicks of her arrival. American bitterns feed their young by regurgitation (Campbell and Lack 1985). I propose that it becomes progressively more difficult for older chicks from marsh nests to find the female before it regurgitates all its available food. Therefore, younger nestmates who have not yet strayed from the nest gain an advantage. No information is available on the daily nutritional requirements of bitterns or other herons; however, chicks grow rapidly, gaining approximately 25 g per day at 1 week of age. Perhaps missing even 1 or 2 feedings in close succession carries with it fatal consequences for bittern chicks. More mobile chicks in upland nests may be better able to capture prey, may be able to return to the female quicker, and may be less susceptible to starvation.

Research and Management Recommendations

Capture Techniques

With the exception of the funnel trap, no new capture methods were developed and few revisions are recommended. No revisions relative to marking are recommended. The funnel trap is very labor-intensive and its applicability may be limited. Ditches receiving relatively high use by American bitterns would work best. It may be possible to partition a shallow ditch with small-mesh screen and then bait bitterns with minnows. Dense adjacent cover would be required to encourage bitterns to run rather than fly when approached.

We were able to capture females on the nest after hatch in both uplands and wetlands. Though difficult, this method may be more successful on windy days and when the nest is approached from the downwind side.

Discovering a consistent capture method for females continues to be a great challenge. Finding nests appears to be the first step, since it provides the most consistent means of locating females. Consequently, improving nest search techniques may be the best way to increase female catch rate.

Males could often be attracted to mirror traps but were reluctant to enter. Therefore, it is recommended that the tape recording of the pumping call be modified. Currently, a 30-second continuous-loop cassette tape broadcasting a call with 6 "pumps" per episode (Brininger 1996) is used. However, I rarely heard a male pump more than 5 times per episode. In addition, as a male drew nearer to the trap, pumps per episode declined to 1 or 2. More often, when a male was within a few meters of the trap, it would only perform the "pre-pump" (gulping and bill clicking) as described by Bent (1926). It is suggested that 3 or 4 pumps per episode, alternating with the pre-pump, be broadcast instead. A 1-minute continuous cassette could be used.

Population Monitoring

The results of the male census suggest the American bittern population at Agassiz NWR did not fluctuate from 1996 to 1997. Furthermore, the higher number of bitterns heard on the east side compared to the west side (in 1996 and 1997) supports the contention that bitterns on Agassiz NWR have shifted east (G. Huschle, Agassiz NWR, pers. commun., W. Brininger, unpubl. memorandum, Agassiz NWR, Middle River, Minn., 1996). Agassiz NWR experienced record spring water levels in both 1996 and 1997. These levels are thought to have forced bitterns from traditional ranges on the west side, as well as created newly flooded areas on the east side. A large increase in the number of calling bitterns was noted in Dahl and East Pools in 1997 (D. Azure, unpubl. memorandum, Agassiz NWR, Middle River, Minn., 1997). These areas contained few calling bitterns in previous drier years (G. Huschle, Agassiz NWR, pers. commun.)

By continuing the annual male census, trend data could be obtained which would illustrate the bittern's response to future wet-dry cycles. Perhaps expanding the census to other areas in northwest Minnesota would be of value. Red Lake Farm (Fig. 1) and Burham Creek Wildlife Management Area in Polk County would be ideal locations. One could potentially gain insight to whether or not population fluctuations at Agassiz NWR are experienced regionally.

Adult Body Measurements

Determining sex of captured American bitterns should not be problematic for most researchers. This is because only males are captured in mirror traps and only females are captured at nests. However, the sex of bitterns captured during the molt may be difficult to determine for people who do not possess the experience to recognize the size disparity. While males are generally believed to be larger than females (Gibbs et al. 1992, Brininger 1996), too few data are available to conclusively declare that any 1 body measurement can differentiate the sexes. Using body mass is especially risky, as bitterns can lose mass during the molt. For example, male 10 was captured on 5 June 1997 and weighed 911 g. It was recaptured on 22 July 1997 and only weighed 713 g. Campbell and Lack (1985) reported that in some species, the wing muscles atrophy during the flightless period. Male 10 was flightless on 22 July 1997.

The model that I present has an apparent classification rate of 93%. Using additional or different variables might result in greater predictive ability. However, the advantages of using this model are 1) bill and tarsus lengths are relatively easy to obtain and are universally understood, 2) they are not likely to be affected by molts, as are body mass, tail length and wing chord, or soil substrate, as are nail length and width, and 3) they can likely be measured post-mortem after other body parts have partially decomposed.

Researchers should continue to gather several body measurements from each captured American bittern to test for regional differences in size. Also, this model could be strengthened by more data, or a better model may be developed. Ultimately, the goal should be to minimize the amount of time a bittern is handled. This would benefit both the bittern and handler.

Nest Searches

Sufficient data exist to justify restricting searches for upland American bittern nests to areas with vegetation greater than 1 m (Duebbert and Lokemoen 1977, Svedarsky 1992). While no marsh-nesting bitterns were flushed by the rope towed by airboats, this method is in its infancy and should not be yet be abandoned. Slower airboat speeds and earlier search dates may be the key to flushing nesting bitterns. This method, however, is effective at locating marsh nests of waterfowl species.

Conclusions

Loss of wetland habitat (Gibbs et al. 1992) remains the most likely cause of American bittern population declines. Grassland habitat, however, may be more important than previously believed. Dahl (1990) estimated over 50% of wetlands in the conterminous U.S. were lost by the 1980's. Sampson and Knopf (1996) estimate over 99% of the original tallgrass prairie in North America has been destroyed. While results presented here are not conclusive, they suggest bitterns fledge more young per nest in uplands than wetlands. Whether bitterns prefer to nest in wetlands or uplands is unknown. However, preservation and restoration of both habitat types would likely provide the greatest benefit to bitterns.

Habitat use analyses corroborate the findings of others (Frederickson and Reid 1986, Hanowski and Niemi 1986, Manci and Rusch 1988). The maintenance of shallow wetlands with dense vegetation appears to be important. American bitterns exhibit a high degree of fidelity to small home-ranges. Core areas seemed to be associated with emergent vegetation and habitat edges. Providing quality habitat on a consistent basis may be beneficial, since the bittern's ability to "pioneer" is unknown.

Traditionally, managers considered a 50-50 water-cover interspersion to be ideal for many wetland birds (Frederickson and Reid 1986). Several species reach peak abundance when open water covers >50% of the surface area in a marsh (Weller and Frederickson 1974). However, it was my experience that open water was usually correlated with deeper water on Agassiz NWR. Deeper water and areas with high water-cover interspersion seemed to be avoided by American bitterns. Instead, bitterns appeared to prefer large areas of tall, dense cover. Management practices to thin emergent vegetation, such as burning, shearing or herbicide application, could potentially have a negative effect on bitterns. More research is needed, however, to assess these management practices specifically.

Drawdowns, or the de-watering of impoundments, is commonly used to promote the germination of certain plants (Frederickson and Taylor 1982). These plants provide food and cover for a variety of wetland bird species (Frederickson and Reid 1986). However, drawdowns conducted in late July or early August may have detrimental effects on molting American bitterns if wetlands become dry before bitterns can fly. More research is needed to document the extent of the flightless period and determine what precautions, if any, should be taken when enacting drawdowns.

Results of this study will facilitate further investigations of the natural history of American bitterns. However, they do not conclusively determine the cause or causes of population declines. Continued research on the natural history of bitterns is needed at Agassiz NWR, especially on females, as well as in other physiographic regions and on wintering grounds. Until a complete life history is available, explanations of population declines remain speculative.

APPENDICES

APPENDIX A

SUMMARY OF AMERICAN BITTERN NEST DATA

Table 11. Data on American bittern nests monitored on Agassiz NWR and Red Lake Farm, 1996-97. Blank spaces and hyphens indicate missing values.

Nest #	UTMs Zone 15	Nest Substrate	Nest Width/height/ water depth	Dominant vegetation within 1 m	Species and height of tallest vegetation within 1 m	Coverboard[a] Lower	Coverboard[a] Total	Fate[b]	Clutch Size	No. Fledged	Date found
96-01	284450 W 5355250 N	residual c. reed	29/6/35 cm	willow/ c. reed	willow, 2.25 m	0	0.75	3	3	0	6/2/96
96-02	281650 W 5354300 N	sedge	29/4/35 cm	sedge	sedge, 1.16 m	1	48	3	2	0	7/8/96
96-03		residual cattail	26/2/20 cm	cattail	cattail, 2.23 m	0.33	10.7	1	1	0	7/22/96
96-04	278700 W 5354050 N	residual cattail	26/5/24 cm	cattail	cattail, 2.09 m	0	2.5	1	2	0	7/22/96
97-01	283877 W 5357169 N	resid. cattail/ c. reed	40/10/35 cm	cattail	residual c. reed, 2.05 m	0	0	1	4	1	6/25/97
97-02	283813 W 5357210 N	cattail	-/-/35 cm	cattail	cattail, 1.5 m	0	0	1	4	0	6/25/97
97-03	284040 W 5357286 N	residual c. reed	33/6/35 cm	residual c. reed	residual c. reed, 2.90 m	0	0	1	3	1	6/30/97
97-04	283790 W 5357154 N	residual c. reed	-/-/33 cm	residual c. reed	residual c. reed, -- m	0	0	1	2	1	6/30/97
						Robel reading[c]					
RL-1	313568 W 5305611 N	*Agropyron* spp.	33/22/- cm	*Agropyron* spp.	*Agropyron* spp., 1.16 m	5.6		2	3	0	6/30/97

Table 11 (cont.)

RL-2	313282 W 5305611 N	*Agropyron* spp.	25/8/- cm	*Agropyron* spp.	*Agropyron* spp., 1.15 m	6.3	2	3	0	6/26/97
RL-3	312514 W 5305226 N	various grasses	25/6/- cm	various grasses	*Agropyron* spp., 1.15	8.0	1	4	4	6/26/97
RL-4	312283 W 5306502 N	Kentucky bluegrass[d]	23/4/- cm	Reed canary grass	Reed canary grass, 1.52	7.1	1	5	5	7/1/97
RL-5	314520 W 5365028 N	*Agropyron* spp.	-/-/-	*Agropyron* spp.	---	---	3	---	---	6/10/97
RL-6	314651 W 5305581 N	*Agropyron* spp.	-/14/- cm	*Agropyron* spp.	*Agropryon* spp., 1.00 m	6.6	1	3	3	6/10/97
RL-7	313576 W 5303296 N	various grasses	-/-/-	Reed canary grass	Reed canary grass, 1.90m	9.9	1	5	5	6/19/97
RL-8		Reed canary grass	25/20/- cm	Reed canary grass	Reed canary grass, 2.00 m	9.8	1	4	4	6/25/97
RL-9	314289 W 5303488 N	grass/sedge	35/8/- cm	R. canary grass/C. thist.	Canada thistle, 1.65 m	4.9	1	5	5	6/25/97

[a]As described by Loft et al. (1987). "Lower" values are the average number of 0.01-m^2 blocks visible in the lower half of a 1.0-m^2 grid viewed from 5 m in the 4 cardinal directions; "total" values are the average number of 0.01-m^2 blocks visible in a 1.0-m^2 grid viewed from 5 m in the 4 cardinal directions.

[b]1 = successful, 2 = abandoned, 3 = destroyed by predator.

[c]As described by Robel et al. (1970). "Robel reading" is the average of Robel pole values viewed from 5 m in the 4 cardinal directions.

[d]*Poa pratensis.*

APPENDIX B

MASS OF AMERICAN BITTERN CHICKS

Table 12. Mass (g) of American bittern chicks from nests on Agassiz NWR and Red Lake Farm, 1996-97. Numbers in parenthesis represent days since the initial measurement.

Nest	Mass 1	Mass 2	Mass 3
97-01	29.8	---	---
	37.8 (dead)	---	---
	70.0	---	---
	73.2	296.6 (8)	
97-02	40.0	---	---
	59.4	---	---
	75.5	---	---
	87.1	---	---
97-03	32.6	64.6 (4)	162.1 (11)
	36.7	79.4 (4)	---
	40.0	89.1 (4)	278.2 (11)
97-04	169.6 (on 6/30/97)	---	---
	166.4 (on 7/4/97)	---	---
RL-3	28.4	---	---
	63.3	---	---
	84.2	---	---
	130.0	---	---
RL-4	24.6	177.9 (8)	---
	38.4	---	---
	43.8	272.2 (8)	---
	2 eggs – one pipping, one intact	188.6 (8)	---
RL-6	136.5	---	---
	149.1	---	---
	157.0	---	---
RL-7	160.0	346.0 (8)	---
	207.1	380.0 (8)	---
	290.0	---	---
	---	475.9 (new)	---

Table 12 (cont.)

RL-8	27.8	95.5 (8)	---
	40.0	241.5 (8)	---
	77.9	240.0 (8)	---
	83.5	335.2 (8)	---
RL-9	23.6 (hatch day)	---	---
	28.4	---	---
	3 eggs present	---	---

APPENDIX C

ACCOUNTS OF INDIVIDUAL AMERICAN BITTERNS

Accounts of Individual American Bitterns

Male 1

This bittern was captured in a mirror trap approximately 750 m south of the refuge headquarters and 30 m southeast of County Road 7 on the morning of 4 May 1996. It died during handling, possibly due to suffocation. An inexperienced observer tried to assist in controlling the bird and may have squeezed the thoracic cavity too hard. It showed few signs of stress other than some minor wheezing and death was sudden. The carcass was stored in a freezer at refuge headquarters until 1 July 1997. It was sent to the South Dakota Game, Fish and Parks Department in Sioux Falls, SD to be displayed in a diorama at a new interpretive center.

Male 2

This bittern was captured in a mirror trap near the same location as male 1 on the morning of 6 May 1996. It was first captured in 1995 approximately 150 m north of the 1996 capture site. Its band was replaced with band 2397-82001 and it was fitted with a radio transmitter, frequency 150.224 MHz. Its breeding home-range was 165.0 ha (all home-ranges reported in Appendix C were estimated with the adaptive kernel method using the best-fit bandwidth, see text) with a core-area of 10.6 ha; mean location = 278291 E, 5352643 N. Between 18 and 24 June, it moved approximately 5.6 km to the northeast and established a post-breeding home-range which was 48.0 ha with a core-area of 5.1 ha; mean location = 282622 E, 5356203 N. It migrated from Agassiz NWR at the end of the summer.

On the morning of 27 May 1997, male 2 was recaptured in a mirror-trap approximately 6.2 km east-northeast of its 1996 breeding home-range. Its radio-transmitter had failed; therefore, prior to recapture, it was unknown that this bird had returned. Its radio transmitter was replaced; new frequency 149.110 MHz. Too few locations (<15) were gathered to estimate its 1997 breeding home-range, but mean location of available relocations was 283971 E, 5355059 N. On 10 June 1997, male 2 was located at its 1996 post-breeding home-range. From 13 to 16 June, it was located approximately 10.5 km to the southwest in Farmes Pool. On 18 June, it was back at its 1996 post-breeding home-range where it stayed for the remainder of the summer. The 1997 post-breeding home-range overlapped with the 1996 post-breeding home-range and was 60.8 ha with a core-area of 4.5 ha; mean location = 282484 E, 5356383 N. It migrated from Agassiz NWR at the end of the summer.

Male 3

This bittern was captured in a mirror trap approximately 0.5 km north of the refuge headquarters on the southwest side of West Gate Road, next to the ditch on the morning of 7 May 1996. It was marked with band 2397-82002 and a radio-transmitter, frequency 150.446 MHz. Its breeding home-range was 95.4 ha with a core-area of 19.7 ha; mean location = 278416 E, 5354096 N. Between 24 May and 19 June, it moved approximately 1.5 km northeast to its post-breeding home-range which was 103.2 ha with a core-area of 12.0 ha; mean location = 279373 E, 5355246 N. It migrated from Agassiz NWR at the end of the summer.

Male 4

This bittern was captured in a mirror trap in the road ditch on the southwest side of Lansing-Parker Pool on the morning of 7 May 1996. It was marked with band 2397-82003 and a radio transmitter, frequency 150.162 MHz. Its breeding home-range was 93.6 ha with two core-areas totaling 23.9 ha; mean location = 718809 E. 5353058 N. Between 17 and 18 June, it moved from its breeding home-range to an unknown location (>20 km).

Male 5

This bittern was captured in a mirror trap on the west side of Dahl Pool on the morning of 11 May 1996. It was marked with band 2397-82004 and a radio transmitter, frequency 150.655 MHz. Its breeding home-range was 78.6 ha with a core-area of 7.2 ha; mean location = 286483 E, 5355101 N. Between 6 and 17 June, it moved approximately 6.1 km to the west. Too few locations were available for a reliable post-breeding home-range estimate but mean location of available locations was 280758 E, 5357207 N. Male 5 could not be located after 7 August 1996, possibly due to radio failure.

Male 6

This bittern was captured in a mirror trap 300 m west of the East Pool water-control structure on the morning of 12 May 1996. It was marked with band 2397-82005 and a radio-transmitter, frequency 150.895 MHz. Male 6 was more mobile during the breeding season than most radio-marked male American bitterns. Its breeding home-range was 1006.0 ha with two core-areas totaling 115.1 ha; mean location = 284027 E, 5355261 N. Only 18 locations were gathered during the breeding season and, due to their wide distribution, may have caused the breeding home-range to be overestimated. Between 3 and 12 June, male 6 moved approximately 1.9 km northwest to its post-breeding home-range which was 49.9 ha with a core-area of 13.6 ha; mean location = 282950 E, 5356845 N. The radio began to fail towards the end of June and no locations could be gathered after 1 July 1996.

Male 7

This bittern was captured in a mirror trap on the southeast corner of Dahl Pool on the morning of 12 May 1996. It was marked with band 2397-82006 and a radio transmitter, frequency 151.935 MHz. Its breeding home-range was 87.2 ha with a core-area of 12.2 ha; mean location = 286811 E, 5354714 N. It left its breeding home-range after 11 June and moved to an unknown post-breeding home-range (>20 km).

A radio signal was received from the air on 11 June 1997. Two subsequent relocations were gathered (11, 12 June) before male 7 either left the area or the radio transmitter failed. Mean location of the two locations = 290845 E, 5353293 N (4.3 km from the 1996 breeding home-range).

Male 8

This bittern was captured in a mirror trap on the southeast corner of Dahl Pool on the morning of 14 May 1996. It was marked with band 2397-82007 and a radio-transmitter, frequency 151.533 MHz. Its breeding home-range was 112.2 ha with a core-area of 16.0 ha. It left its breeding home-range after 11 June and moved to an unknown post-breeding home-range (>20 km).

Male 9

This bittern was captured in a mirror trap on the north end of East Pool on the morning of 17 May 1996. It was marked with a band 2397-82008 and a radio transmitter, frequency 150.065 MHz. Its breeding home-range was 97.9 ha with a core-area of 5.4 ha; mean location = 284460 E, 5355033 N. Between 12 July and 15 July, male 9 moved 1.4 km west to its breeding home-range which was 85.2 ha with a core-area of 9.2 ha; mean location = 283117 E, 5355433 N. It migrated from Agassiz NWR at the end of the summer.

Male 10

This bittern was captured in a mirror trap on the northwest corner of Dahl Pool on the morning of 19 May 1996. It was marked with band 2397-82009 and a radio transmitter, frequency 150.204 MHz. Its 1996 breeding home-range was 151.1 ha with a core-area of 16.7 ha; mean location = 286143 E, 5356202 N. It left its breeding home-range after 14 June and moved to an unknown post-breeding home-range (>20 km).

A signal was received from the air on 15 May 1997. Male 10's 1997 breeding home-range was 62.3 ha with a core-area of 8.5 ha; mean location = 286958 E, 5354711 N. The 1996 and 1997 breeding home-ranges did not overlap and were approximately 1.7 km apart. Male 10 ceased calling after 1 July 1997. Post-breeding home-range overlapped with breeding home-range and was 21.5 ha with a core-area of 1.9 ha; mean location = 287127 E, 5354573 N.

Male 10 was recaptured in a mist net on its breeding home-range the morning of 5 June 1997. Its radio transmitter was replaced; new frequency 150.751 MHz. The primaries on the left wing were worn. Male 10 was again captured on 22 July 1997 with a dip net. It was molting primaries and secondaries and was flightless at the time. Most notably, it had lost approximately 22% of its body mass since 5 June. Male 10 migrated from Agassiz NWR at the end of the summer.

Male 11

This bittern was captured in a mirror trap on the northwest corner of Madsen Pool on the morning of 20 May 1996. It was marked with band 2397-82010 and a radio transmitter, frequency 150.764 MHz. Its breeding home-range was 175 ha with a core-area of 13.3 ha; mean location = 719134 E, 5357620 N. Male 11 migrated from Agassiz NWR at the end of the summer.

On 15 May 1997, a signal was received from the air placing male 11 at its 1996 breeding home-range. The same areas were used for both breeding and post-breeding home-ranges in 1997, as in 1996. However, more movements between the two areas were made in 1997, consequently, home-ranges were larger. Its 1997 breeding home-range was 428.2 ha with a core-area of 6.1 ha; mean location = 719245 E, 5357058 N. Post-breeding home-range (consisting of two 95% polygons) was 769.9 ha with two core-areas totaling 141.3 ha. Male 11 migrated from Agassiz NWR at the end of the summer.

Male 12

This bittern was captured in a mirror trap in the northwest corner of Madsen Pool the morning of 20 May 1996. It was marked with band 2397-82011 and a radio transmitter, frequency 150.025 MHz. Its breeding home-range was 313.2 ha with 2 core-areas totaling 69.8 ha; mean location = 719945 E, 5357870 N. Between 25 and 26 June, it moved to its post-breeding home-range centered 1.2 km south. Its post- breeding home-range was 147.2 ha with a core-area of 16.1 ha; mean location = 719353 E, 5356833 N. It migrated from Agassiz NWR at the end of the summer, 1996.

On 15 May 1997, a radio signal was received from the air which placed male 12 at its 1996 breeding home-range. It was recaptured in a mist net the morning of 17 June 1997 and its radio transmitter was replaced; new frequency 149.122 MHz. Its 1997 breeding home-range was 89.6 ha and almost completely overlapped the larger core-area of its 1996 breeding home-range. Two core-areas in the 1997 breeding home-range totaled 11.1 ha; mean location = 720204 E, 5358223 N. Between 10 and 12 June 1997, male 12 moved to its post-breeding home-range, which was 1.8 km south and overlapped with its 1996 post-breeding home-range. Its 1997 post-breeding home-range was 270.6 ha with a core-area of 10.7 ha. Male 12 migrated from Agassiz NWR at the end of the summer, 1997.

<u>Male 13</u>

This bittern was captured in a mirror trap on the dike leading to the handicap hunting platform west of North Gate Road on the morning of 28 May 1996. It was marked with band 2397-82012 and a radio transmitter, frequency 150.604 MHz. Its breeding home-range was 116.1 ha with a core-area of 14.0 ha; mean location = 284648 E, 5356983 N. Between 17 June and 1 July, it moved to its post-breeding home-range, centered 8.3 km west, which was 97.6 ha with a core-area of 14.5 ha; mean location = 721339 E, 5357774 N. Male 13 migrated from Agassiz NWR at the end of the summer, 1996.

Male 14

This bittern was captured in a mirror trap near the water-control structure between Agassiz and Madsen Pools the morning of 28 May 1996. It was marked with band 2397-82013 and a radio transmitter, frequency 150.968 MHz. Its breeding home-range was 179 ha with a core-area of 24.1 ha; mean location = 720699 E, 5357941 N. It ceased calling after 25 June and post-breeding home-range was 180.2 ha with 2 core-areas totaling 48.9 ha; mean location = 720337 E, 5357931 N, centered only 362 m from its breeding home-range. Male 14 migrated from Agassiz NWR at the end of the summer, 1996.

On 15 May 1997, a radio signal was received from the air which placed male 14 at its 1996 breeding home-range. While the 1996 and 1997 breeding home-ranges overlapped, male 14 was more mobile in 1997 which resulted in a breeding home-range of 393.0 ha with 2 core-areas totaling 44.4 ha; mean location = 720870 E, 5358055 N. Male 14 moved around Madsen Pool extensively between 16 and 17 June. The morning of 18 June, it was located in Pool 8. An attempt to capture it with mist nets was unsuccessful, as it would not respond to the broadcast pumping call, even though the tape recorder was placed within 100 m. When male 14 was flushed, it was discovered to be with another male American bittern. A third male American bittern, one that had been calling that morning, chased male 14 north into Northwest Pool. Male 14 remained in Northwest Pool until 11 July, it then returned to its previous location in Pool 8 until 23 July, after which it moved to its original breeding home-range in Madsen Pool. Too few relocations were available to reliably estimate a home-range after 11 July, so only relocations in Northwest Pool were used. Post-breeding home-range was 46.5 ha with a core area of 8.9 ha; mean location = 720225 E, 5356300 N, centered 1.9 km north of the breeding home-range.

Male 14 was recaptured during the molt by dip net in Pool 8 on 22 June 1997. Its radio transmitter was replaced; new frequency = 149.100 MHz. It migrated from Agassiz NWR at the end of the summer, 1997.

<u>Male 15</u>

This bittern was first captured and marked in 1995 with band 1026-22926 and a radio transmitter, frequency 152.102 MHz. It was recaptured during the molt with a dip net north of Cormorant Island on 10 July 1996. Its radio transmitter was replaced with frequency 151.510 MHz.

Male 15's 1996 breeding home-range was near its 1995 breeding home-range and was 225 ha with a core-area of 37.7 ha; mean location = 280758 E, 5354948 N. Between 28 June and 1 July, male 15 moved to its post-breeding home-range centered 1.9 km north. Too few relocations were available to reliably estimate its post-breeding home-range; mean location of available relocations = 280577 E, 5356868 N. Male 15 migrated from Agassiz NWR at the end of the summer, 1996.

On 11 June 1997, a radio signal was received from the air which placed male 15 at its 1996 breeding home-range. On 13 June, remains of male 15 (sternum, humerus, ulna, radius, fibia and tibia with band) and the radio transmitter were found in knee-deep water. Because some flesh and feathers were intact, and because no radio signal was detected from the air during the 15 May flight, it was concluded that male 15 returned to Agassiz NWR in 1997 and perished between 15 May and 11 June.

Male 16

This bittern was captured during the molt with a dip net in the northwest corner of Pool 8 on 8 August 1996. It was marked with band 2397-82015, yellow patagial tag "10", and a radio transmitter, frequency 150.704 MHz. No relocations were gathered. Male 16 migrated from Agassiz NWR at the end of the summer, 1996.

Male 17

This bittern was captured during the molt with a dip net in the northwest corner of Pool 8 on 9 August 1996. It was marked with band 2397-82016 and a yellow patagial tag "13".

Male 18

This bittern was captured in a mirror trap near the Pool 8 water-control structure on the morning of 20 May 1997. It was marked with band 2397-82018 and a radio-transmitter, frequency 149.143 MHz. Its breeding home-range was 287.2 ha with a core-area of 35.1 ha; mean location = 720234 W, 5359243 N. It ceased calling after 23 June. Its post-breeding home-range was 115.6 ha with a core-area of 4.2 ha; mean location = 720234 W, 5359426 N. Male 18 migrated from Agassiz at the end of the summer.

Male 19

This bittern was captured in a mirror trap on the southwest side of Dahl Pool on the morning of 20 May 1997. It was marked with band 2397-82017 and a radio-transmitter, frequency 149.089 MHz. Its breeding home-range was 40.8 ha with a core-area of 4.3 ha; mean location = 286655 E, 5354685 N. Between 26 June and 1 July, male 19 moved approximately 4.6 km north to its eventual post-breeding home-range. However, between 2 July and 3 July, it moved back to its breeding home-range, where it stayed until 12 July. On 14 July, it was located back at its post-breeding home-range, which was 39.1 ha with a core-area of 13.6 ha; mean location = 284092 E, 5358522 N. Locations gathered between 3 July and 12 July were included in the breeding home-range estimate. Male 19 migrated from Agassiz NWR at the end of the summer.

Male 20

This bittern was captured in a mirror trap on the west end of the dike running into East Pool from the east side on the morning of 29 May 1997. It was marked with band 2397-82019 and a radio transmitter, frequency 149.132 MHz. Too few locations were available for a reliable breeding home-range estimate; mean location of available locations = 284103 W, 5354609 N. Between 10 June and 14 June, male 20 moved approximately 2.0 km west to its post-breeding home-range, which was 108 ha with a core-area of 25.4 ha; mean location = 282387 E, 5355539 N. Male 20 moved again after 30 July and could not be located for the remainder of the summer. It is believed to have left Agassiz NWR at the end of July.

Female 1

This bittern was first captured in 1995 and was marked with band 1026-22938 and a radio transmitter, frequency 150.747 MHz. A radio signal was received from the air on 10 May 1996 which placed female 1 on the north end of East Pool. It was observed incubating a nest containing 3 eggs on 2 June 1996. It was again observed incubating the nest on 6 and 7 June, but was not flushed. Consequently, total clutch size could not be determined. Radio signals indicated that the nest was incubated until at least 11 June. At 1100 hours, 12 June, it was discovered that the nest had been destroyed by a predator. No eggs or shells were found in or around the nest.

Female 1 was observed incubating a second nest containing 2 eggs on 8 July 1996. Several unsuccessful attempts at capture were made between 10 and 17 July in an effort to replace the weakening radio transmitter. At 1000 hours, 17 July, it was discovered that the second nest had been destroyed by a predator. One egg remained intact in the nest bowl; however, the female never returned and the radio transmitter failed. This is the first documented renesting attempt by an American bittern.

Home-range size from 10 May to 11 June 1996 was 31.9 ha with a core-area of 3.6 ha; mean location = 284282 E, 5355304 N. Too few locations were available to reliably estimate a home-range after 11 June; mean location of available locations = 281747 E, 5354596 N (female 1 moved approximately 3.0 km southwest for the renesting attempt).

Female 2

This bittern was first captured in 1995 and marked with band 1026-22931 and a radio transmitter, frequency 150.441 MHz. A radio signal was received from the air on 7 June 1996 which placed female 2 southeast of the refuge headquarters in South Pool. However, subsequent attempts to locate her from the ground were unsuccessful. A radio signal was again received from the air on 14 June and female 2 was visually observed in the northwest corner of Lost River Pool on the Elm Lake Wildlife Management Area, which borders the south side of Agassiz NWR. I was able to get 4 locations from 14 June to 19 June; however, by this time the radio transmitter was so weak that a signal could be received from the ground only if female 2 was flying. A signal was again received from the air on 5 July placing female 2 in the vicinity of the 7 June location; however, attempts to locate it by airboat were unsuccessful. On the morning of 9 July, two refuge employees and I positioned ourselves on the dikes surrounding the northwest corner of Lost River Pool, in an effort to observe female 2 return to her nest. At approximately 1300 hours, I received a weak radio signal from South Pool. The 2 refuge employees walked in the direction of the signal and observed female 2 fly north into Headquarters Pool. An attempt to capture her in Headquarters Pool was unsuccessful. Between 1945 and 2000 hours on 10 July, I was able to get 2 bearings on female 2 as she flew to and from her nest. On 12 July, another refuge employee and I, both equipped with radio receivers, walked in from these 2 receiving locations following the bearings with compasses. We eventually located female 2 on a nest with 1 chick. It was captured with a dip net and the radio transmitter was replaced, new frequency 151.010 MHz. Female 2 was located near its nest on 13 July, but by 15 July, it was only found in Agassiz Pool north of "hairpin" curve, approximately 2.0 km north of its nest. I believe its chick was destroyed by a predator on or about 14 July. Female 2 stayed in Agassiz Pool until it migrated from Agassiz NWR at the end of the summer. Too few locations were available to reliably estimate a home-range; mean location of available locations = 280455 E, 5356905 N.

Female 3

This bittern was captured with a dip net during the molt near Cormorant Island on 31 July 1996. It was marked with band 1026-22942 and a radio transmitter, frequency 151.380 MHz. No locations were gathered and female 3 migrated from Agassiz NWR at the end of the summer.

Female 4

This bittern was captured with a dip net during the molt in the northwest corner of Pool 8 on 8 August 1996. It was marked with band 1026-22946 and a radio transmitter, frequency 151.635 MHz. No locations were gathered and female 4 migrated from Agassiz NWR at the end of the summer.

Female 5

This bittern was captured with a dip net during the molt in the northwest corner of Pool 8 on 9 August 1996. It was marked with band 1026-22948 and a radio transmitter, frequency 151.095 MHz. No locations were gathered and female 5 migrated from Agassiz NWR at the end of the summer.

Female 6

This bittern was captured in a funnel trap on 23 June 1997 near the East Pool water-control structure. It was marked with band 1026-22949 and a radio transmitter, frequency 149.032 MHz. Too few locations were available to reliably estimate a "nesting" home-range, but based on its movements and behavior, I believe it was feeding a brood between 26 June and 8 July at a nest in the north end of East Pool. I reached this conclusion based on telemetry information and visual observations; suspected nest location = 284250 E, 5355150 N. After 9 July, female 6 was located approximately 1.6 km to the west. Post-breeding home-range was 86.0 ha with a core-area of 13.5 ha; mean location = 282500 E, 5355129 N. Female 6 migrated from Agassiz NWR at the end of the summer.

Female 7

This bittern was captured on a nest with a dip net on 26 June 1997. The nest was discovered on 25 June while nest-dragging with airboats. It was marked with band 2397-82020 and a radio transmitter, frequency 151.522 MHz. It had 4 chicks at this time. No radio signals could be received for the next several weeks. On 30 June, it was discovered that the nest had been abandoned. Two dead chicks were found floating near the nest and a third was found dead in the nest on 14 July, when the nest was revisited. A radio signal was received from the air on 6 August which placed female 7 in the southeast corner of Agassiz Pool, within 2 km of its nest. It was located in this vicinity from an airboat on 7 August; however, the radio signal was only received if the antenna was held so that the elements were horizontal. This explains why a signal could not be received from the tracking truck, where the elements are arranged vertically. Female 7 was flushed by airboat on 11 August to confirm that it was still alive. No further attempts to locate it were made.

Female 8

This bittern was captured with a dip net on Red Lake Farm on 2 July 1997. It was marked with band 1026-22950. When captured, it was incubating 4 eggs. The nest (RL-3) was discovered by Red Lake DNR personnel on 26 June and contained 4 eggs. The nest was revisited on 17 June; female 8 was not present but the nest was successful and 4 chicks were present.

<u>Female 9</u>

This bittern was captured with a dip net on Red Lake Farm on 9 July 1997. It was marked with band 1026-22951. When captured, 4 chicks were present at the nest. The nest (RL-8) was discovered by Red Lake DNR personnel on 25 June and contained 4 eggs. The nest was revisited on 16 July and the chicks were re-weighed. Three chicks were marked with bands 2397-82035, 2397-82036, and 2397-82099. The fourth chick was too small to carry a band.

<u>Female 10</u>

This bittern was captured with a dip net on Red Lake Farm on 9 July 1997. It was marked with band 1026-22952. When captured, it was incubating 5 eggs. The nest was discovered by Red Lake DNR personnel on 25 June and contained 2 eggs. The nest was revisited on 17 June and contained 2 chicks and 3 eggs, one of the eggs was in the pipping stage. Female 10 was present at this time. The nest was later visited by Red Lake personnel and all chicks are believed to have fledged.

<u>Juvenile 1</u>

This bittern was captured with a dip net on the north end of Lansing-Parker Pool on 10 July 1996. It was marked with band 2397-82014 and a radio transmitter, frequency 151.290 MHz. Sex was unknown. Juvenile 1 moved to Madsen Pool between 18 and 22 July; however, too few relocations were available for a reliable home-range estimate.

Mean location of available relocations = 720707 E, 5355576 N. Juvenile 1 migrated from Agassiz NWR at the end of the summer, 1996.

Juvenile 2

This bittern was captured with a dip net next to Ditch 11 in Agassiz Pool on 31 July 1996. It was marked with band 1026-22943. Sex was unknown.

Juvenile 3

This bittern was captured with a dip net 150 m north of the water-control structure between Agassiz and Lansing-Parker Pools on 1 August 1996. It was marked with band 1026-22944. Sex was unknown.

Juvenile 4

This bittern was captured with a dip net near Cormorant Island on 4 August 1996. It was marked with band 1026-22945. Sex probably male as weight was 822 g.

Juvenile 5

This bittern was captured with a dip net in the northwest corner of Pool 8 on 8 August 1996. It was marked with band 1026-22947 and a yellow patagial tag "11". Sex was unknown.

APPENDIX D

SUMMARY OF AMERICAN BITTERN HOME-RANGE ESTIMATES

Table 13. Seasonal home-range estimates (ha) of radio-marked American bitterns at Agassiz NWR, 1996-97. Three methods of home-range estimation were used.

		K – default[a]		K – best-fit[b]		MCP[c]	
	Season	Home-range[d]	Core-area[e]	Home-range	Core-area	Home-range	# Locations
Male 2	1996 breeding	165.0	10.6	165.0	10.6	106.3	39
	1996 post-breeding	49.2	5.2	48.0	5.1	24.7	38
	1997 breeding	---	---	---	---	---	---
	1997 post-breeding	63.0	4.5	60.8	4.5	27.7	41
Male 3	1996 breeding	95.4	19.7	95.4	19.7	133.5	17
	1996 post-breeding	104.4	12.6	103.2	12.6	60.1	25
	1997 breeding	---	---	---	---	---	---
	1997 post-breeding	---	---	---	---	---	---
Male 4	1996 breeding	93.6	23.9	93.6	23.9	66.5	34
	1996 post-breeding	---	---	---	---	---	---
	1997 breeding	---	---	---	---	---	---
	1997 post-breeding	---	---	---	---	---	---
Male 5	1996 breeding	78.6	7.2	78.6	7.2	28.5	22
	1996 post-breeding	---	---	---	---	---	---
	1997 breeding	---	---	---	---	---	---
	1997 post-breeding	---	---	---	---	---	---

Table 13 (cont.).

Male 6	1996 breeding	1006.0	115.1	1006.0	115.1	488.2	18
	1996 post-breeding	49.9	13.6	49.9	13.6	43.2	15
	1997 breeding	---	---	---	---	---	---
	1997 post-breeding	---	---	---	---	---	---
Male 7	1996 breeding	87.2	12.2	87.2	12.2	51.1	27
	1996 post-breeding	---	---	---	---	---	---
	1997 breeding	---	---	---	---	---	---
	1997 post-breeding	---	---	---	---	---	---
Male 8	1996 breeding	112.2	16.0	112.2	16.0	67.4	26
	1996 post-breeding	---	---	---	---	---	---
	1997 breeding	---	---	---	---	---	---
	1997 post-breeding	---	---	---	---	---	---
Male 9	1996 breeding	104.5	6.2	97.9	5.4	50.7	44
	1996 post-breeding	85.2	9.2	85.2	9.2	45	16
	1997 breeding	---	---	---	---	---	---
	1997 post-breeding	---	---	---	---	---	---
Male 10	1996 breeding	151.1	16.7	151.1	16.7	60.3	22
	1996 post-breeding	---	---	---	---	---	---
	1997 breeding	57.6	8.3	62.3	8.5	39.8	35
	1997 post-breeding	32.6	2.0	21.5	1.9	24.6	34
Male 11	1996 breeding	245.2	13.3	174.3	13.3	237.4	26
	1996 post-breeding	307.5	39.2	296.3	38.1	143.4	37
	1997 breeding	428.2	6.1	428.2	6.1	209.4	31
	1997 post-breeding	769.9	141.3	769.9	141.3	351.5	39

Table 13 (cont.).

Male 12	1996 breeding	313.2	69.8	313.2	69.8	163.9	27
	1996 post-breeding	131.1	16.7	147.2	16.1	122.8	32
	1997 breeding	89.6	11.1	89.6	11.1	46.3	23
	1997 post-breeding	292.4	10.9	270.6	10.7	145.2	46
Male 13	1996 breeding	170.7	14.2	116.1	14.0	157.5	19
	1996 post-breeding	128.4	16.2	97.6	14.5	71.3	24
	1997 breeding	---	---	---	---	---	---
	1997 post-breeding	---	---	---	---	---	---
Male 14	1996 breeding	185.0	23.9	179.2	24.1	62.5	26
	1996 post-breeding	190.0	58.0	180.2	48.9	148.6	30
	1997 breeding	370.3	52.1	393.0	44.4	203.6	27
	1997 post-breeding	46.5	8.9	46.5	8.9	26.8	15
Male 18	1996 breeding	---	---	---	---	---	---
	1996 post-breeding	---	---	---	---	---	---
	1997 breeding	304.7	33.7	287.2	35.1	185.0	28
	1997 post-breeding	118.7	4.1	115.6	4.2	64.6	39
Male 19	1996 breeding	---	---	---	---	---	---
	1996 post-breeding	---	---	---	---	---	---
	1997 breeding	40.8	4.3	40.8	4.3	26.3	36
	1997 post-breeding	39.1	13.6	39.1	13.6	35.6	16
Male 20	1996 breeding	---	---	---	---	---	---
	1996 post-breeding	---	---	---	---	---	---
	1997 breeding	---	---	---	---	---	---
	1997 post-breeding	---	---	---	---	---	---

Table 13 (cont.).

Female 1	1996 nesting	34.4	3.5	31.9	3.6	18.5	27
	1996 post-nesting	---	---	---	---	---	---
	1997 nesting	---	---	---	---	---	---
	1997 post-nesting	---	---	---	---	---	---
Female 6	1996 nesting	---	---	---	---	---	---
	1996 post-nesting	---	---	---	---	---	---
	1997 nesting	---	---	---	---	---	---
	1997 post-nesting	86.0	13.5	86.0	13.5	50.7	28

[a]Estimates made with the adaptive kernel method using default bandwidths.
[b]Estimates made with the adaptive kernel method using bandwidths providing the best-fit 95% polygon.
[c]Estimates made with the minimum convex polygon method.
[d]Home-range = 95% polygon.
[e]Core-area = 50% polygon.

APPENDIX E

AMERICAN BITTERN SEASONAL HOME-RANGE ESTIMATES

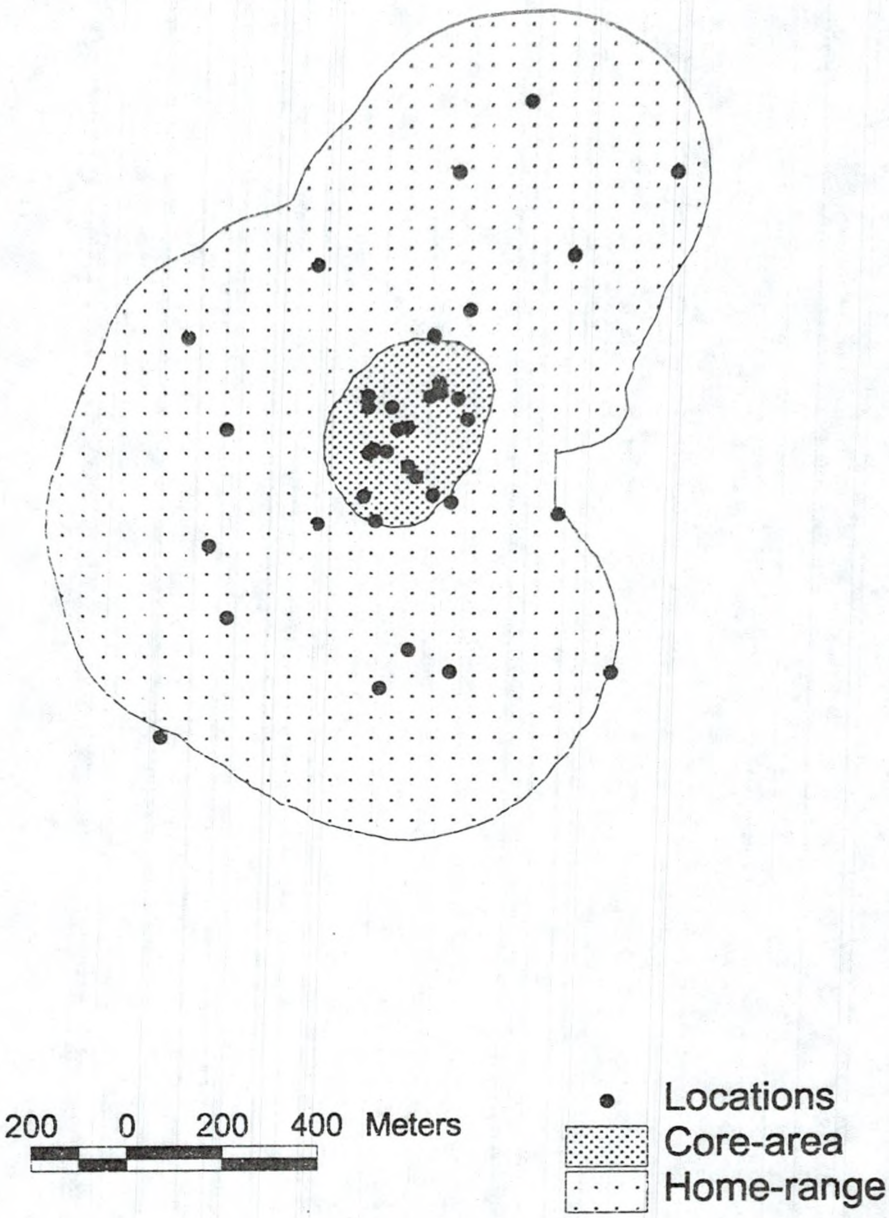

Figure 6. Breeding home-range for male 2, 1996.

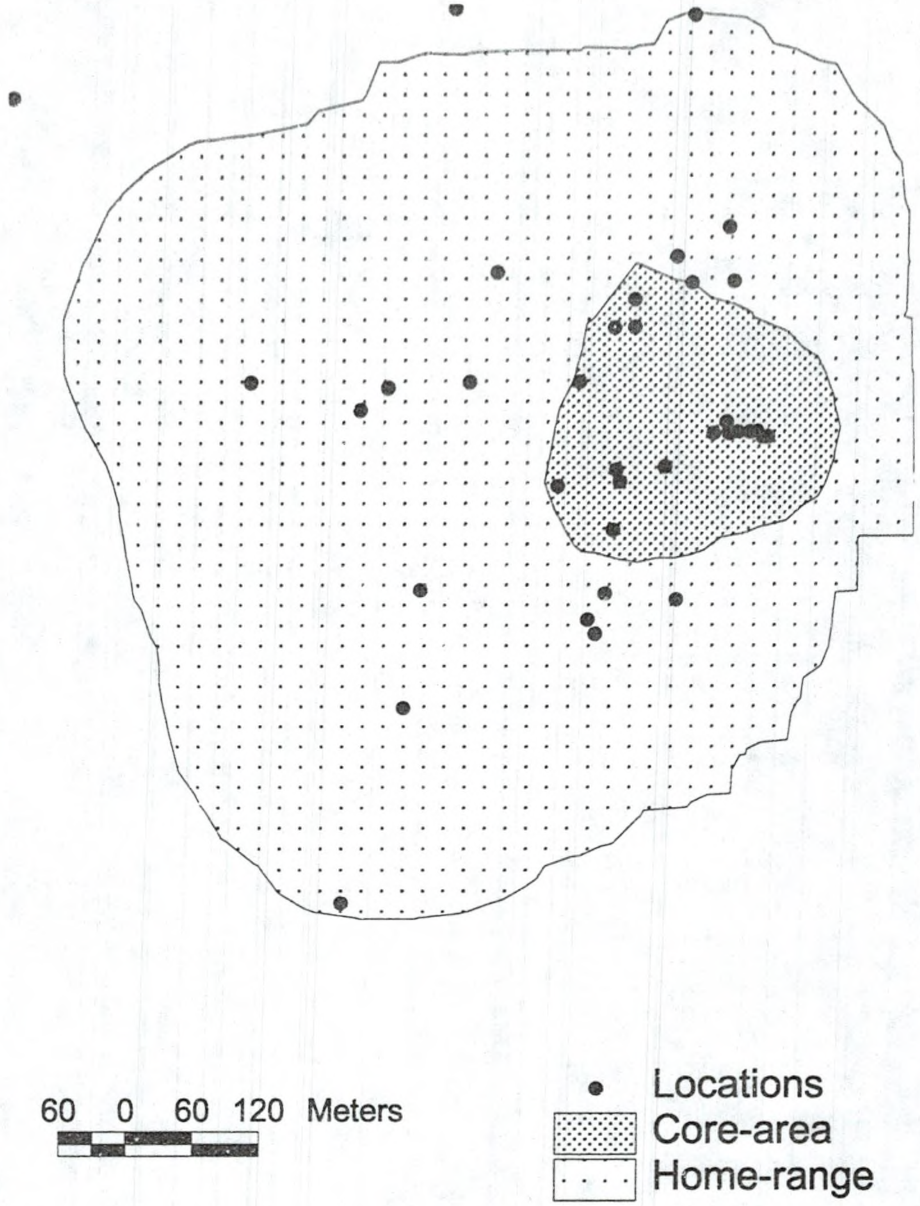

Figure 7. Post-breeding home-range for male 2, 1996.

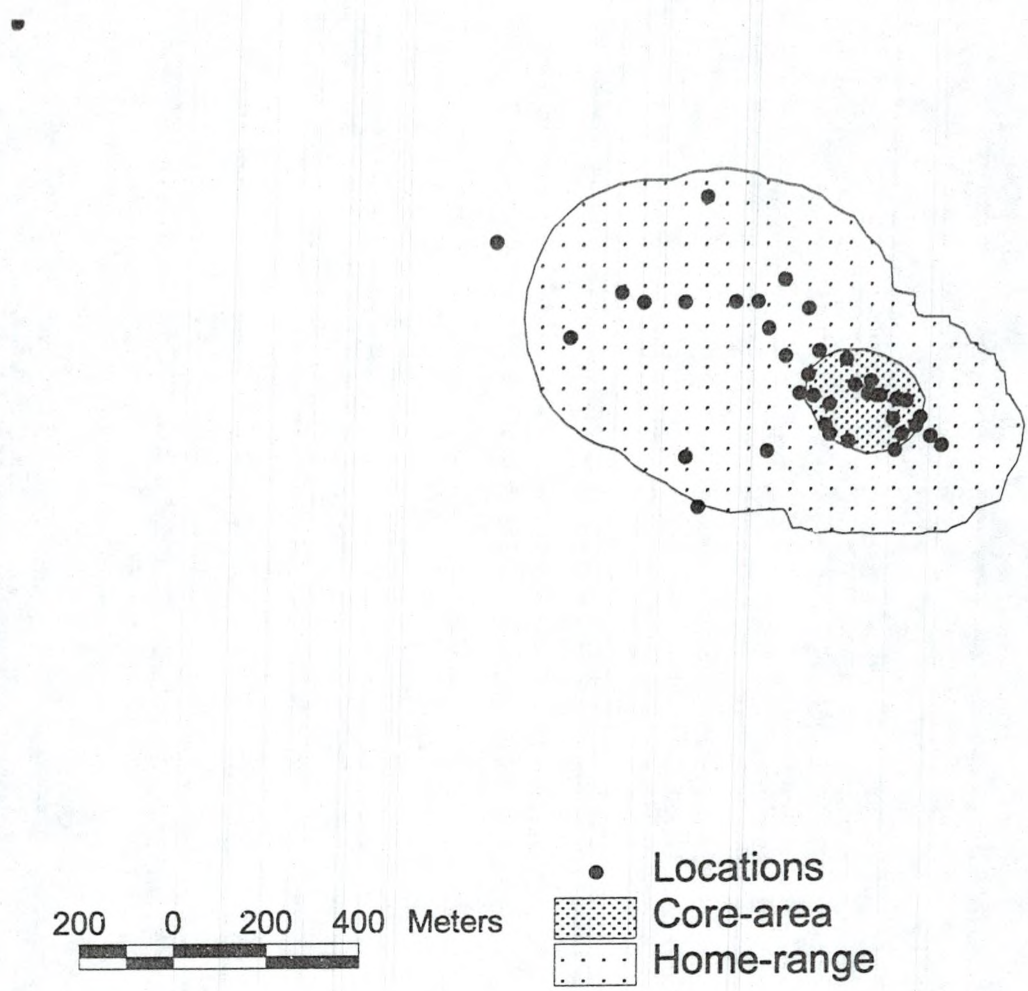

Figure 8. 1997 post-breeding home-range for male 2, 1997.

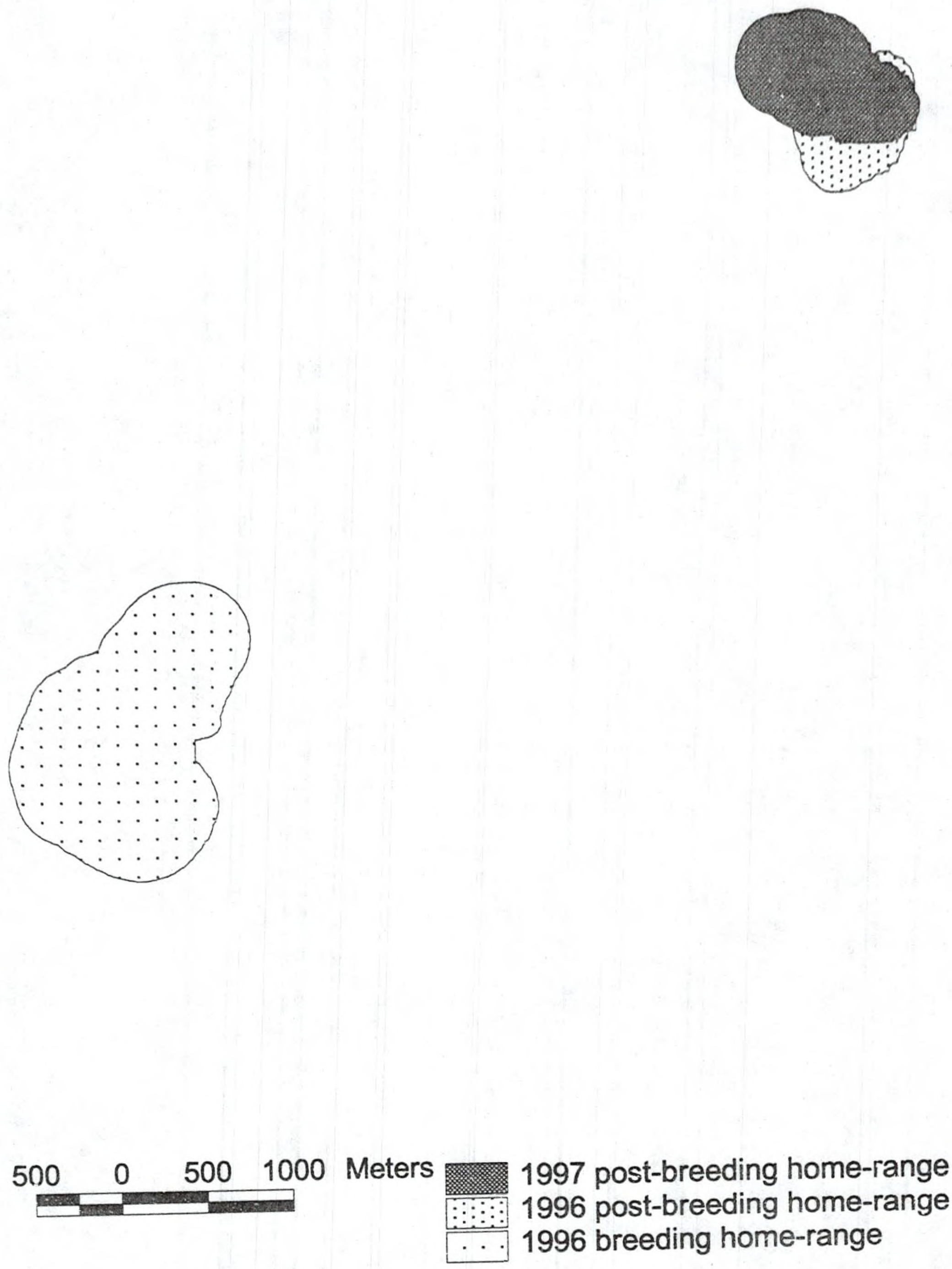

Figure 9. Three seasonal home-range estimates for male 2.

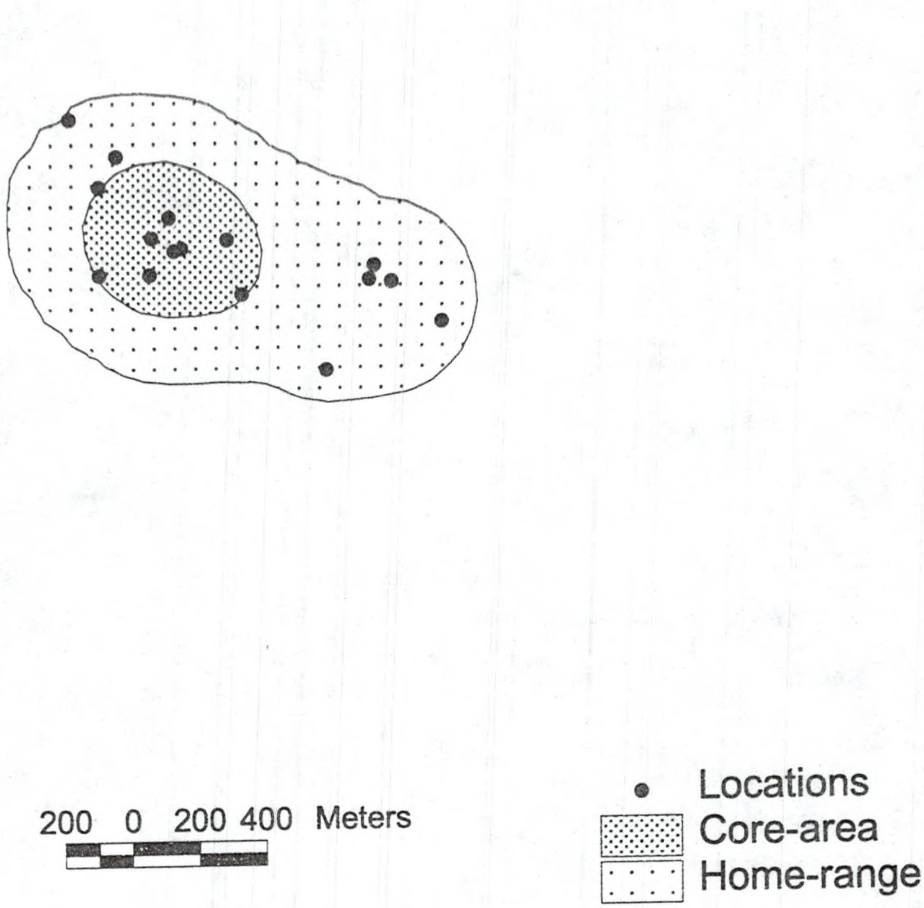

Figure 10. Breeding home-range for male 3, 1996.

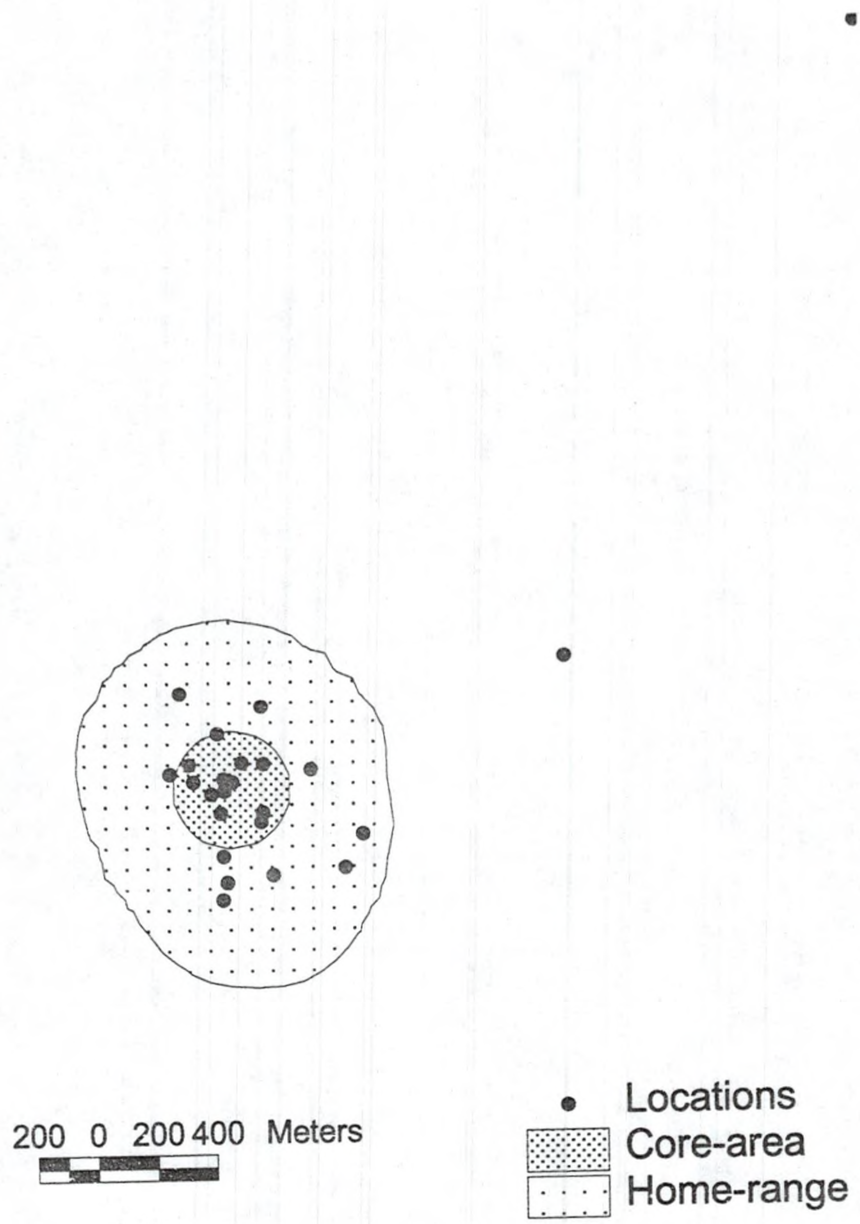

Figure 11. Post-breeding home-range for male 3, 1996.

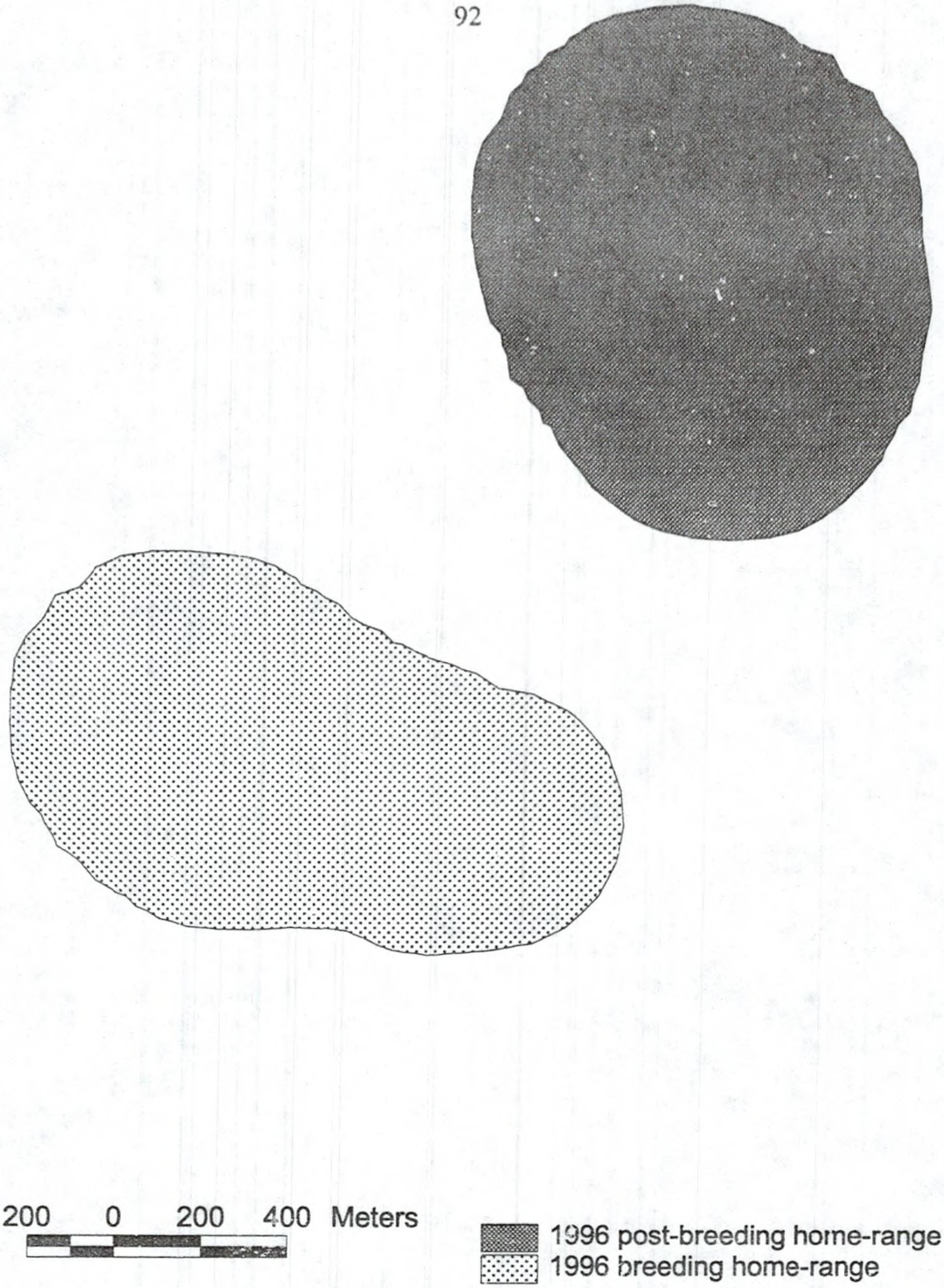

Figure 12. Seasonal home-ranges estimates for male 3, 1996.

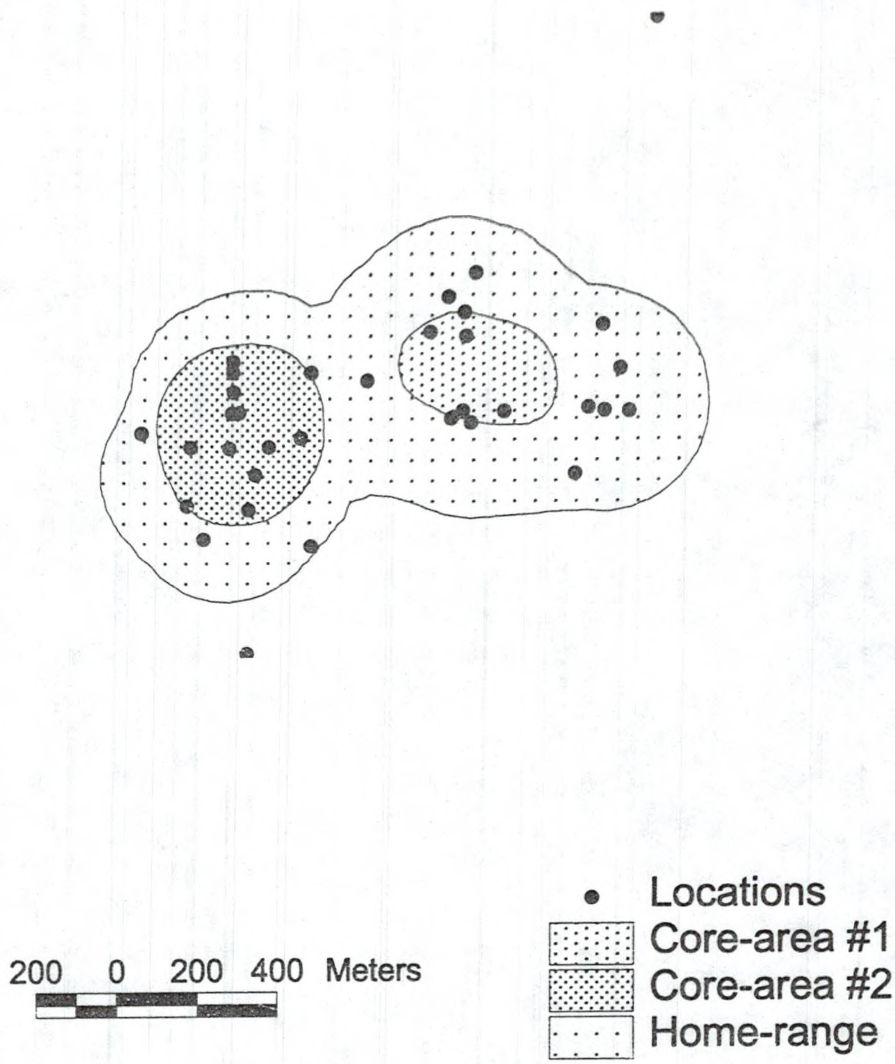

Figure 13. Breeding home-range for male 4, 1996.

Figure 14. Breeding home-range for male 5, 1996.

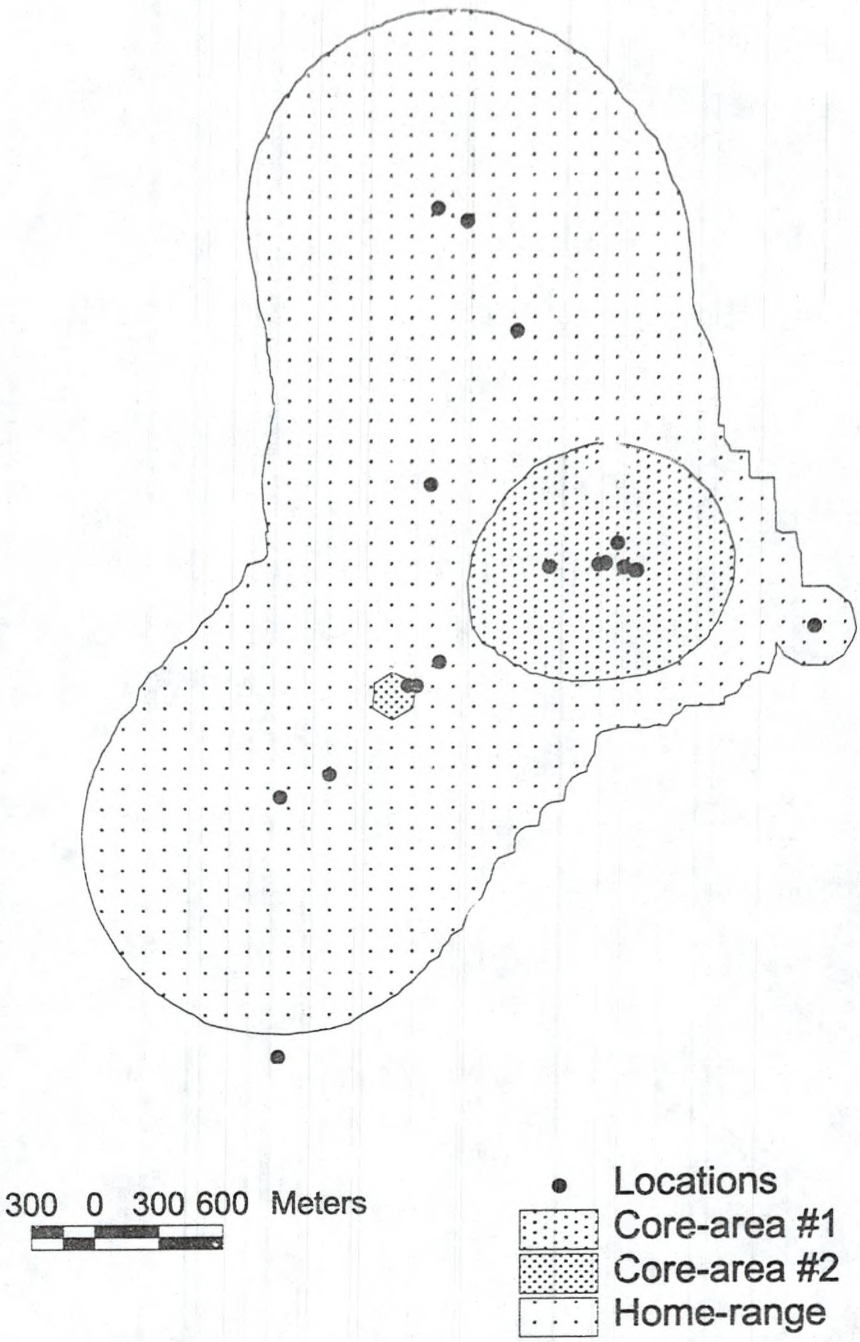

Figure 15. Breeding home-range for male 6, 1996.

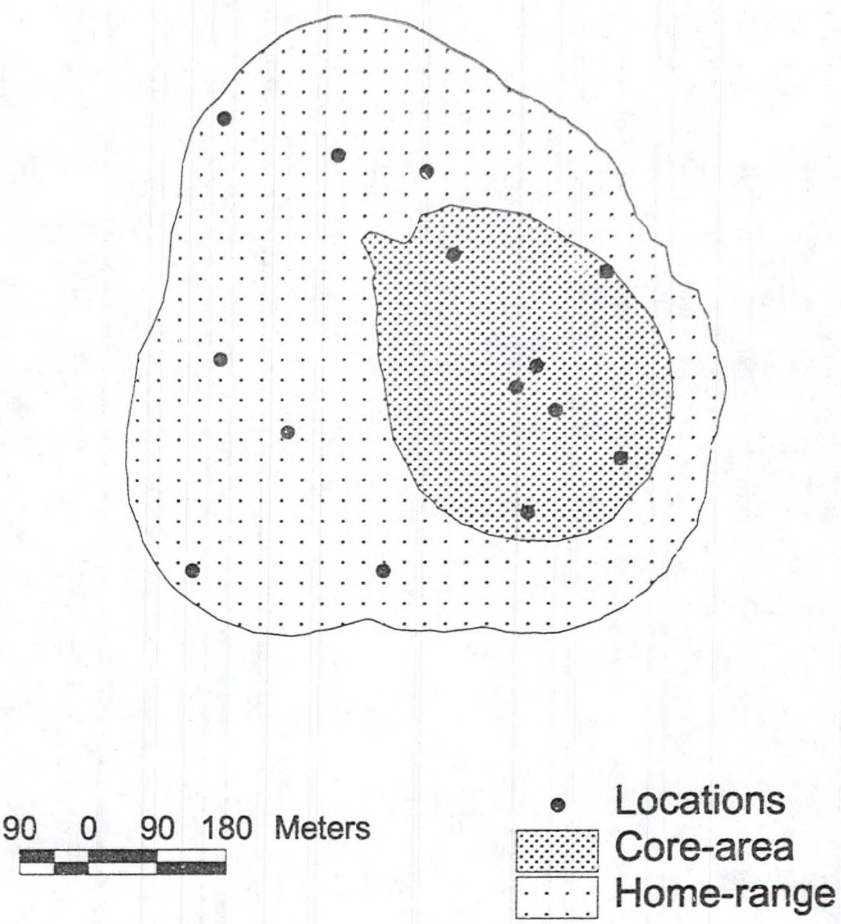

Figure 16. Post-breeding home range for male 6, 1996.

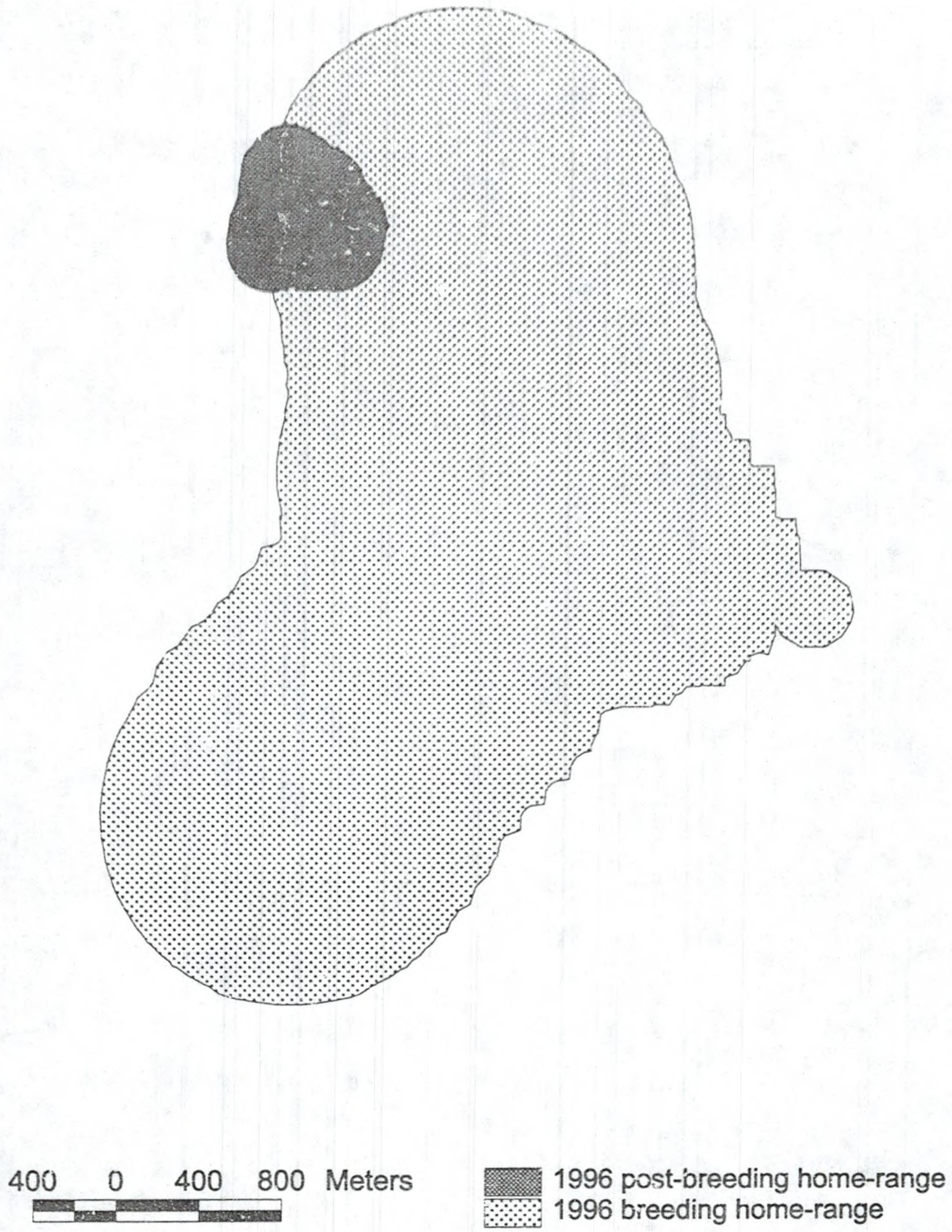

Figure 17. Seasonal home-range estimates for male 6, 1996.

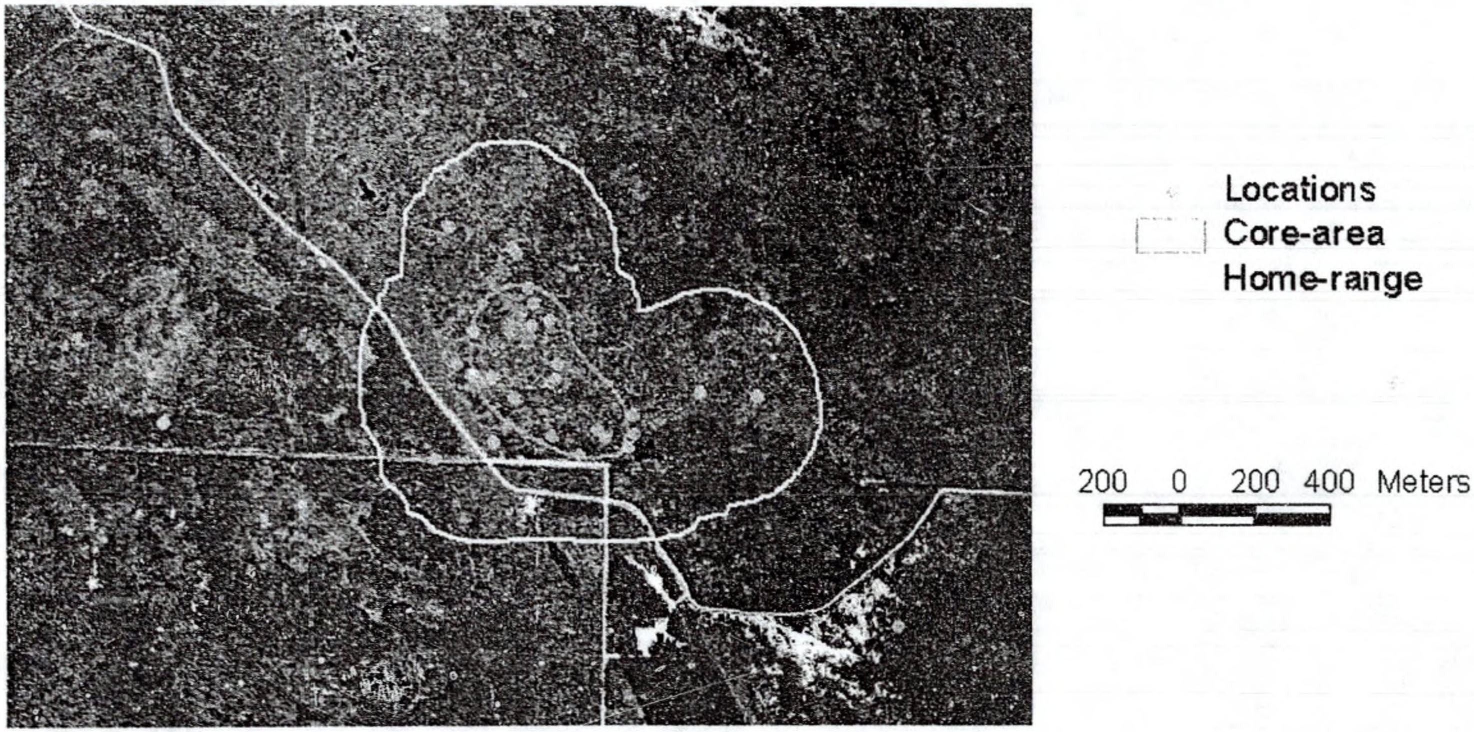

Figure 18. Breeding home-range for male 7, 1996. Photograph 43 taken in August 1996.

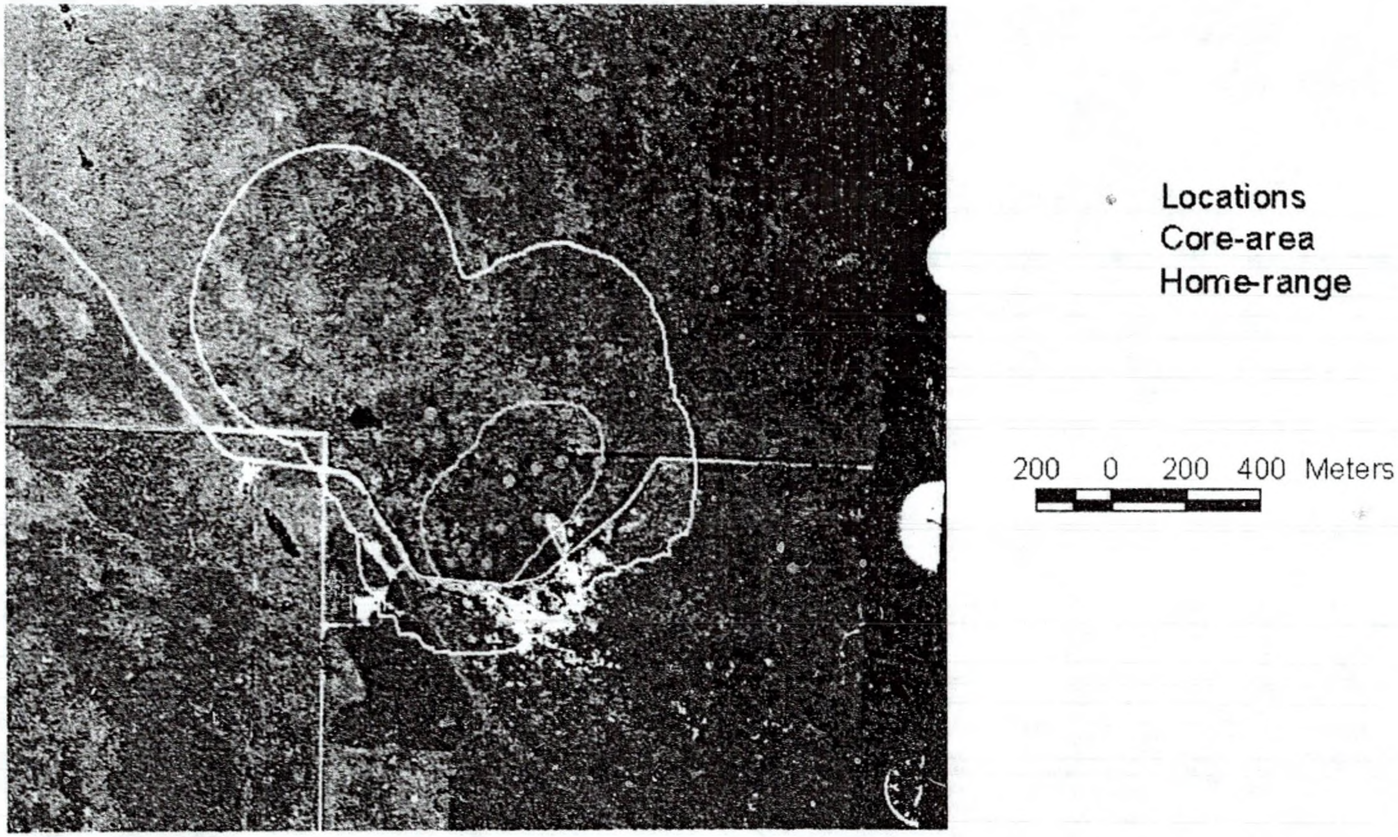

Figure 19. Breeding home-range for male 8, 1996. Photograph 43 taken in August 1996.

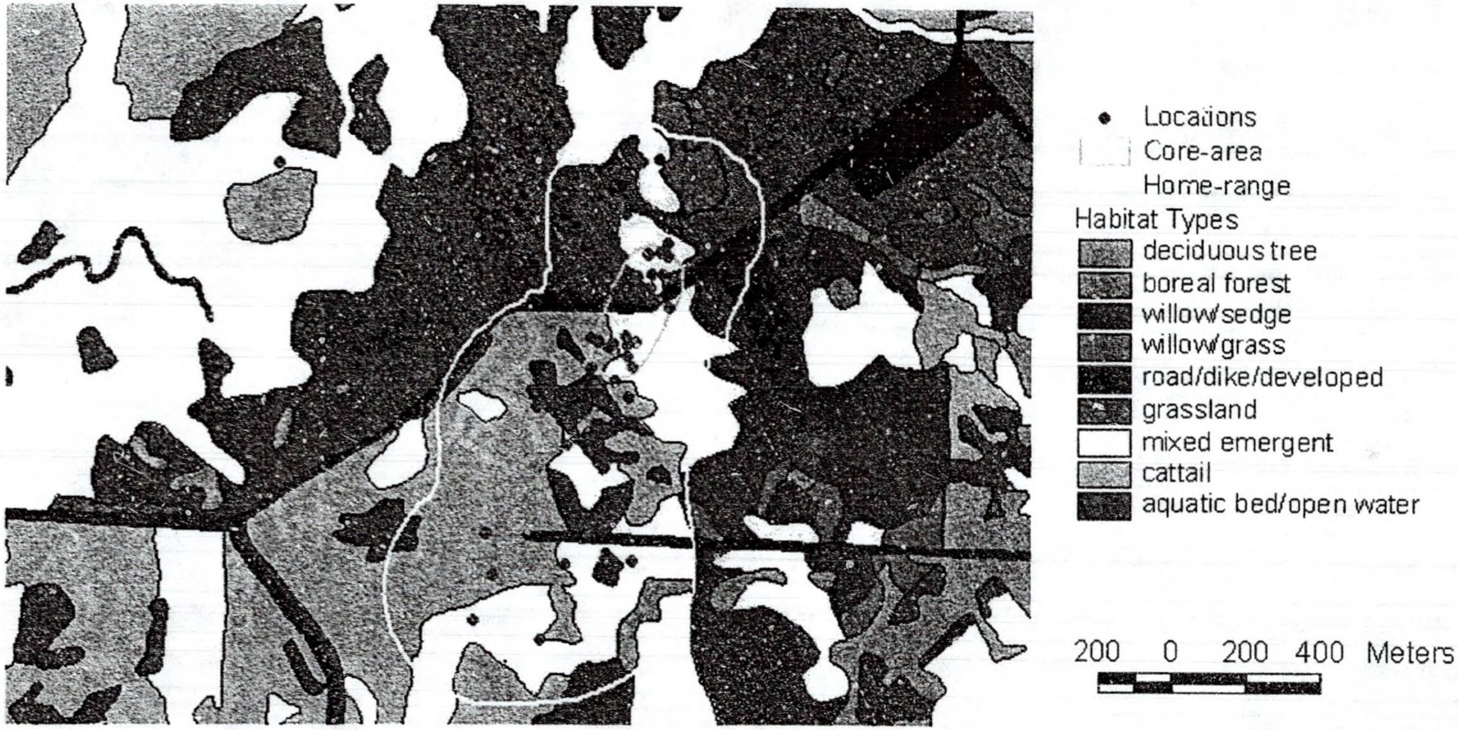

Figure 20. Breeding home-range for male 9, 1996.

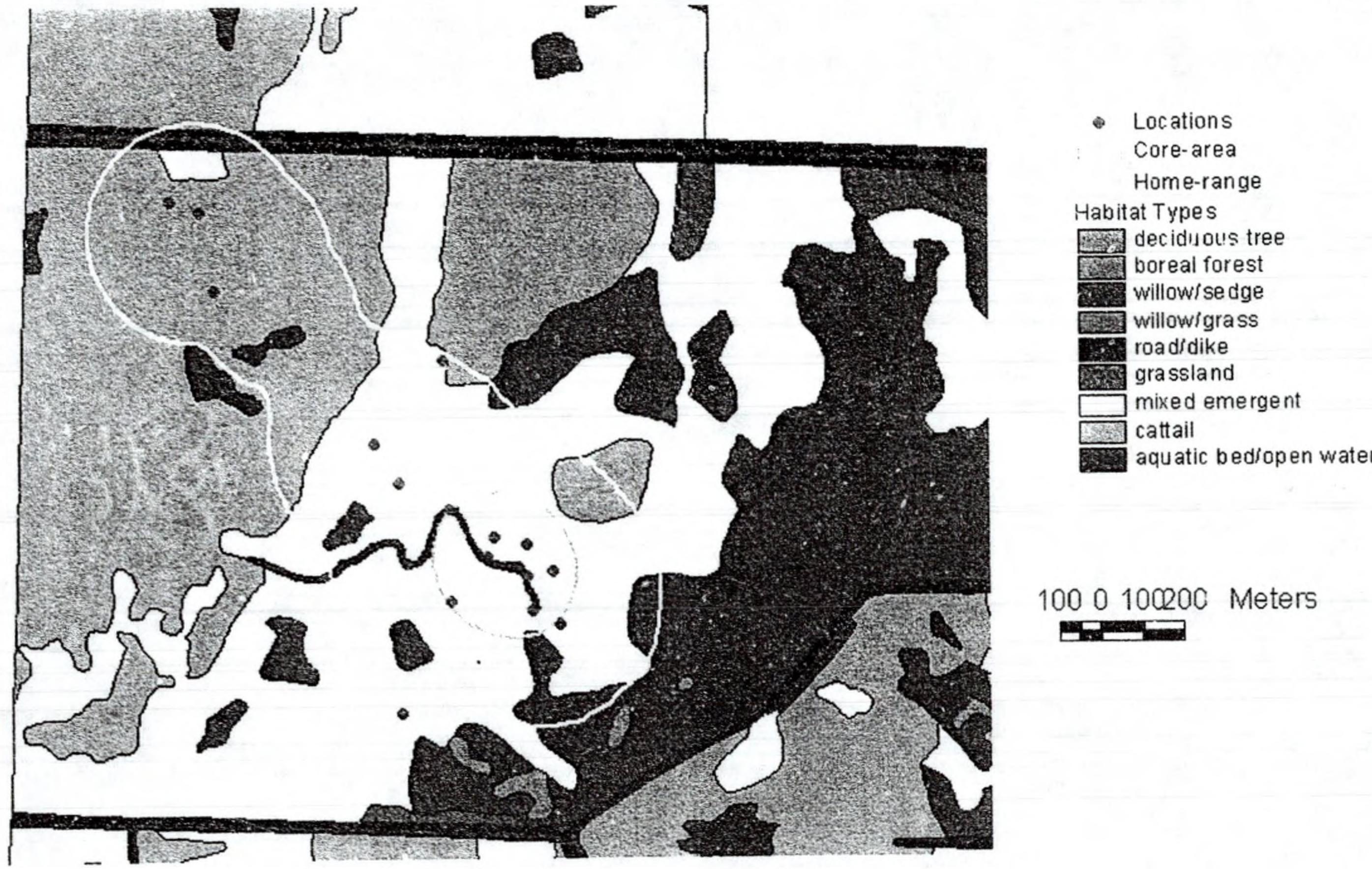

Figure 21. Post-breeding home-range for male 9, 1996.

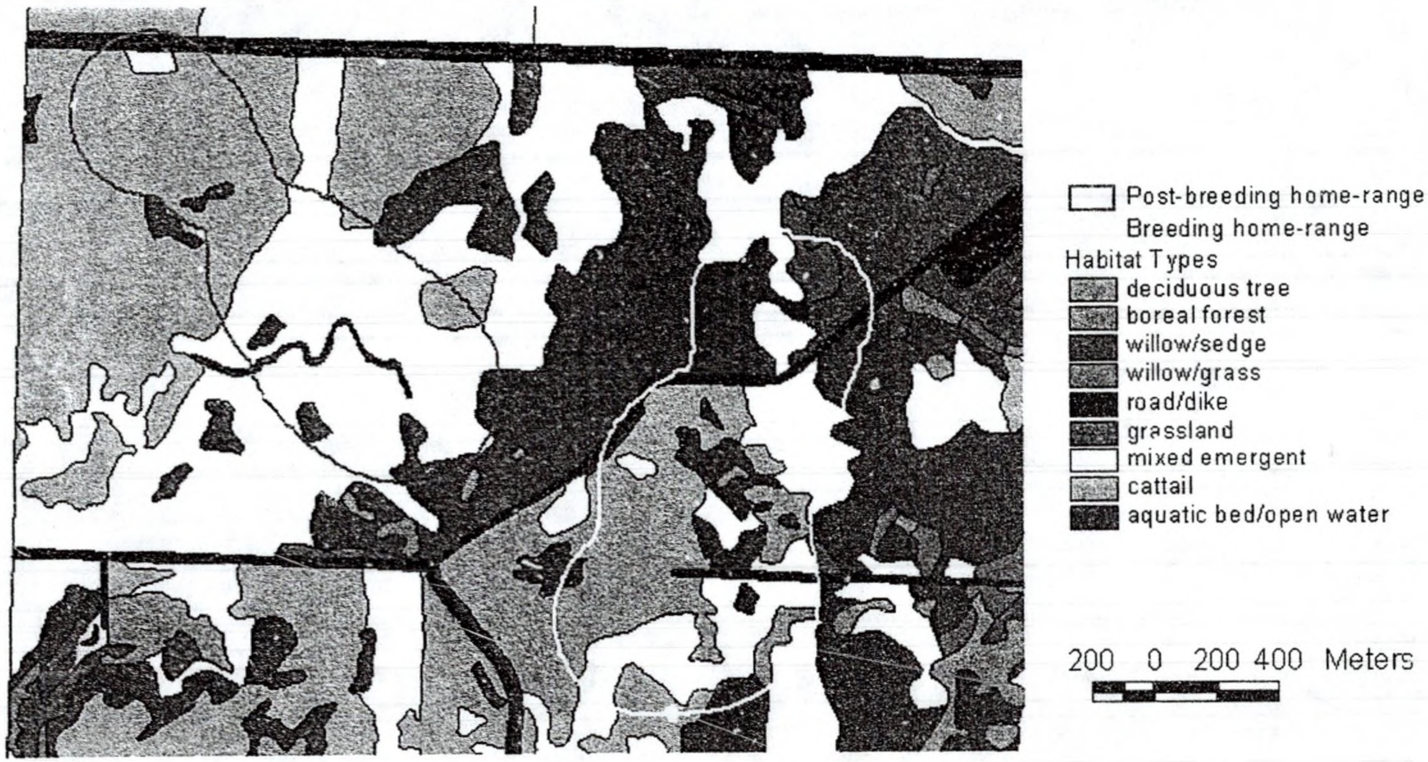

Figure 22. Seasonal home-range estimates for male 9, 1996.

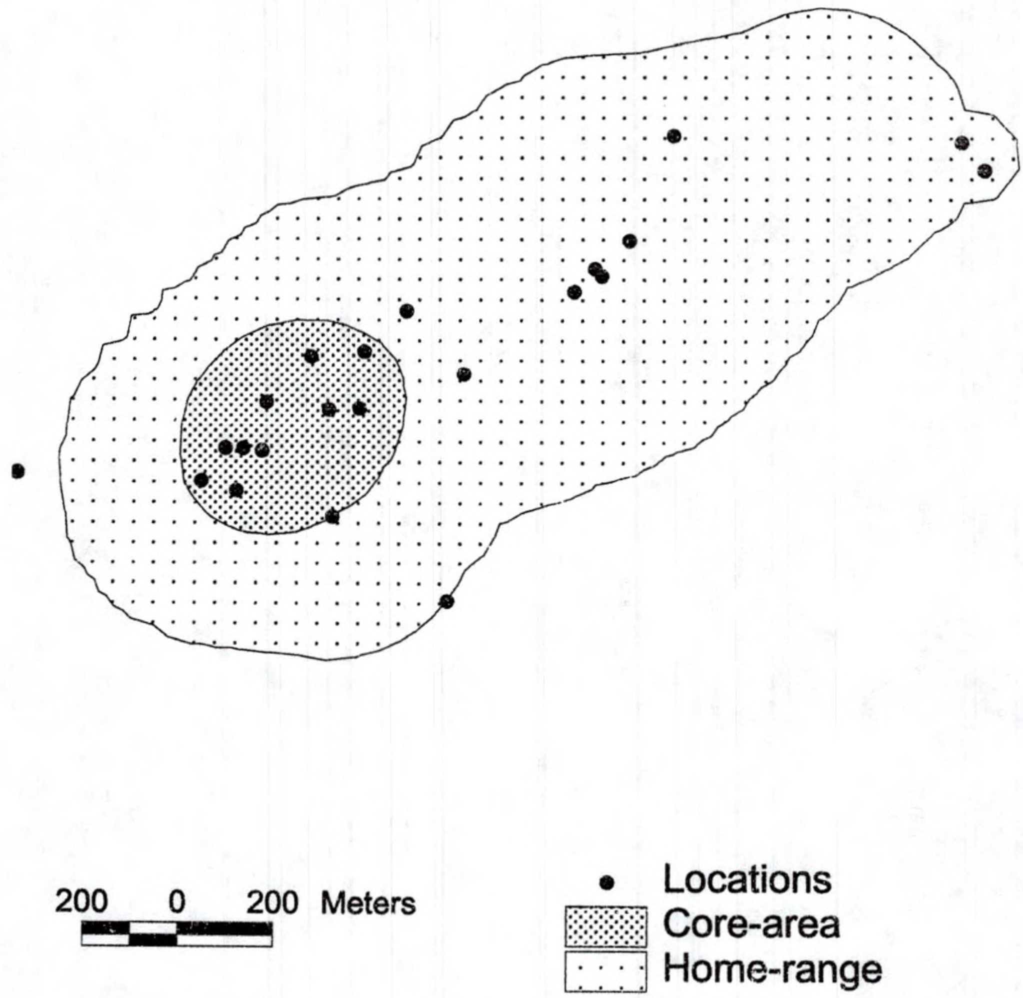

Figure 23. Breeding home-range for male 10, 1996.

Figure 24. Breeding home-range for male 10, 1997. Photograph 43 taken in August 1996.

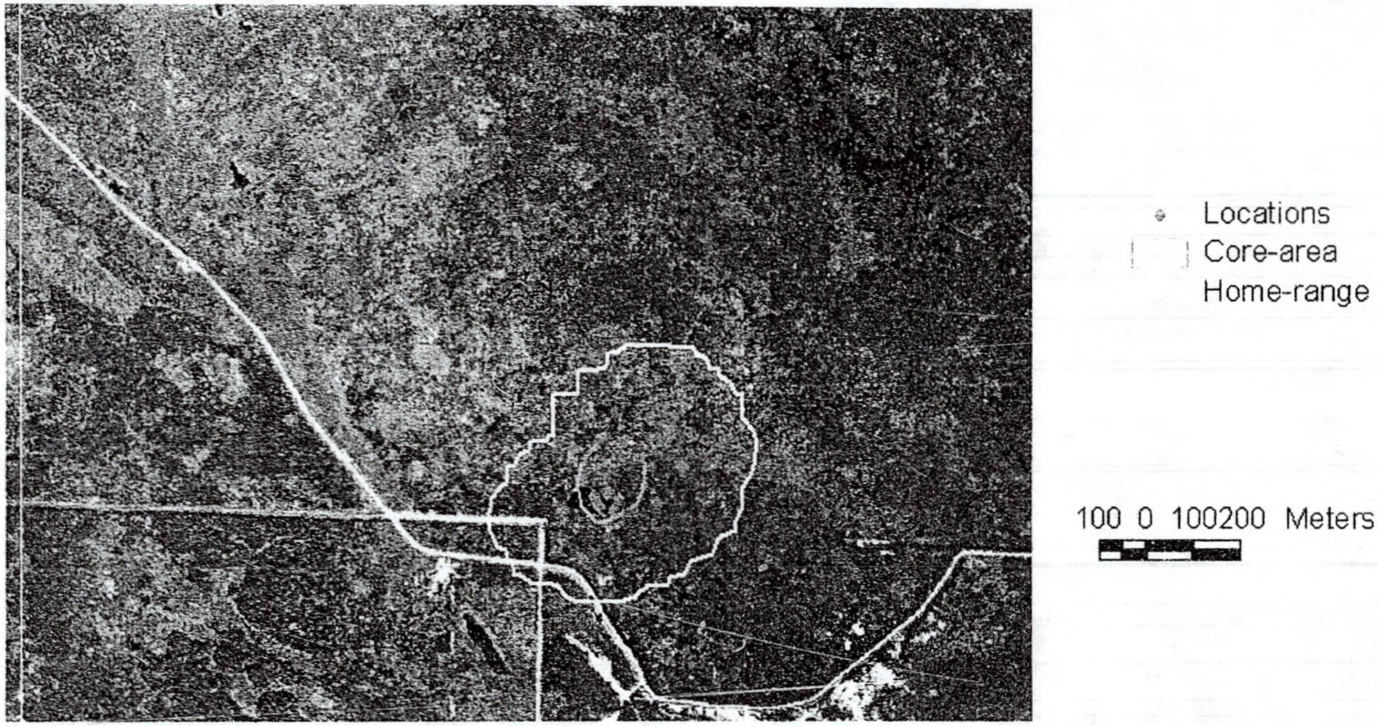

Figure 25. Post-breeding home-range for male 10, 1997. Photograph 43 taken in August 1996.

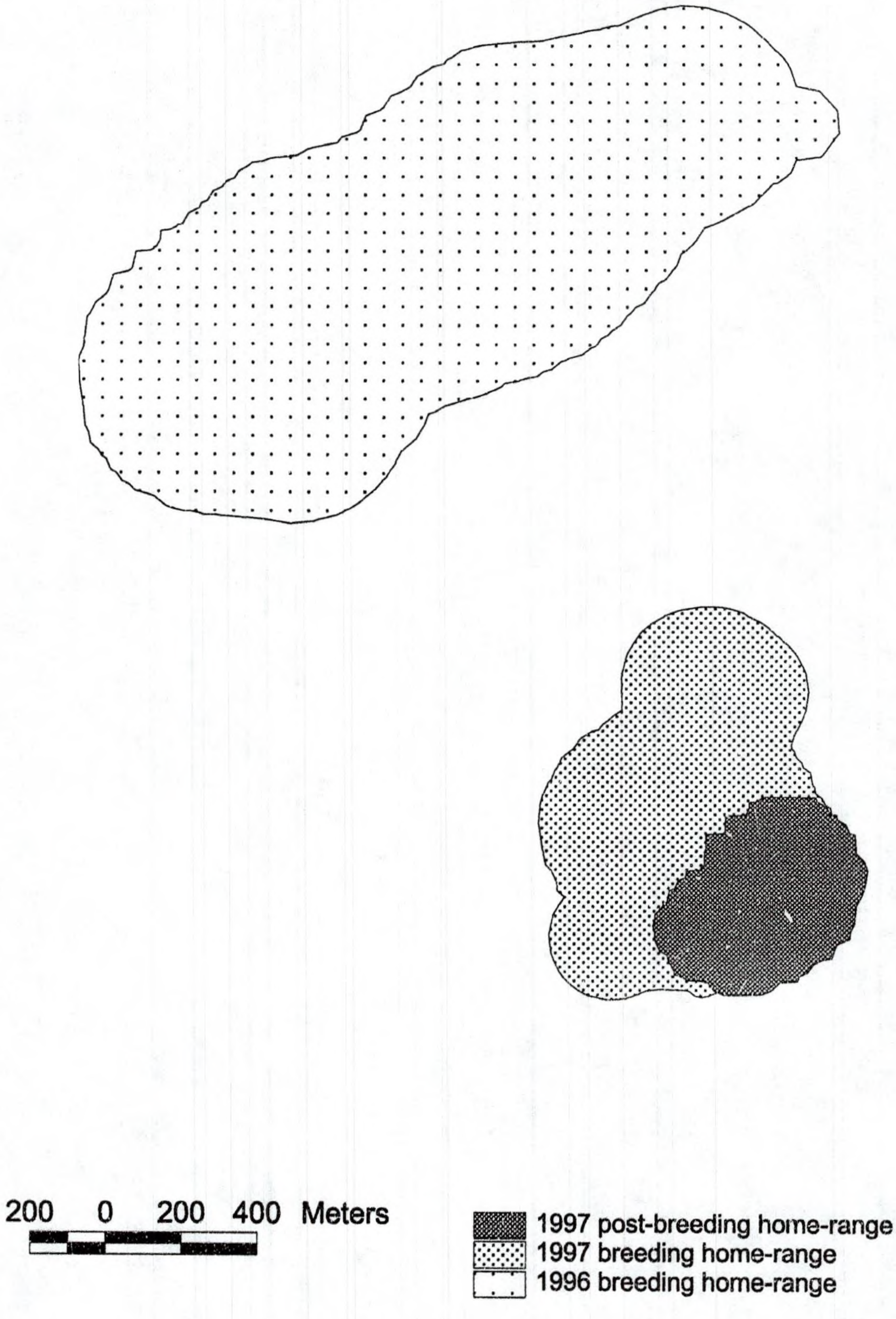

Figure 26. Three seasonal home-range estimates for male 10.

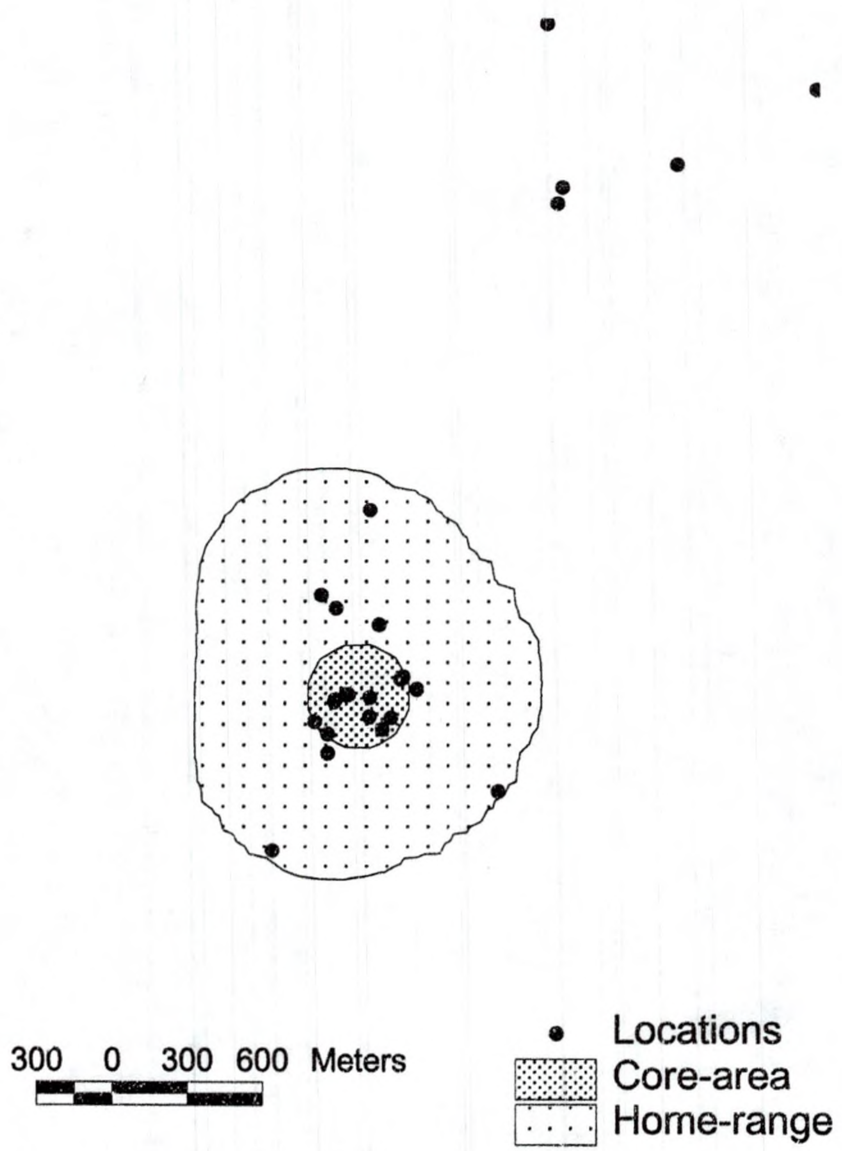

Figure 27. Breeding home-range for male 11, 1996.

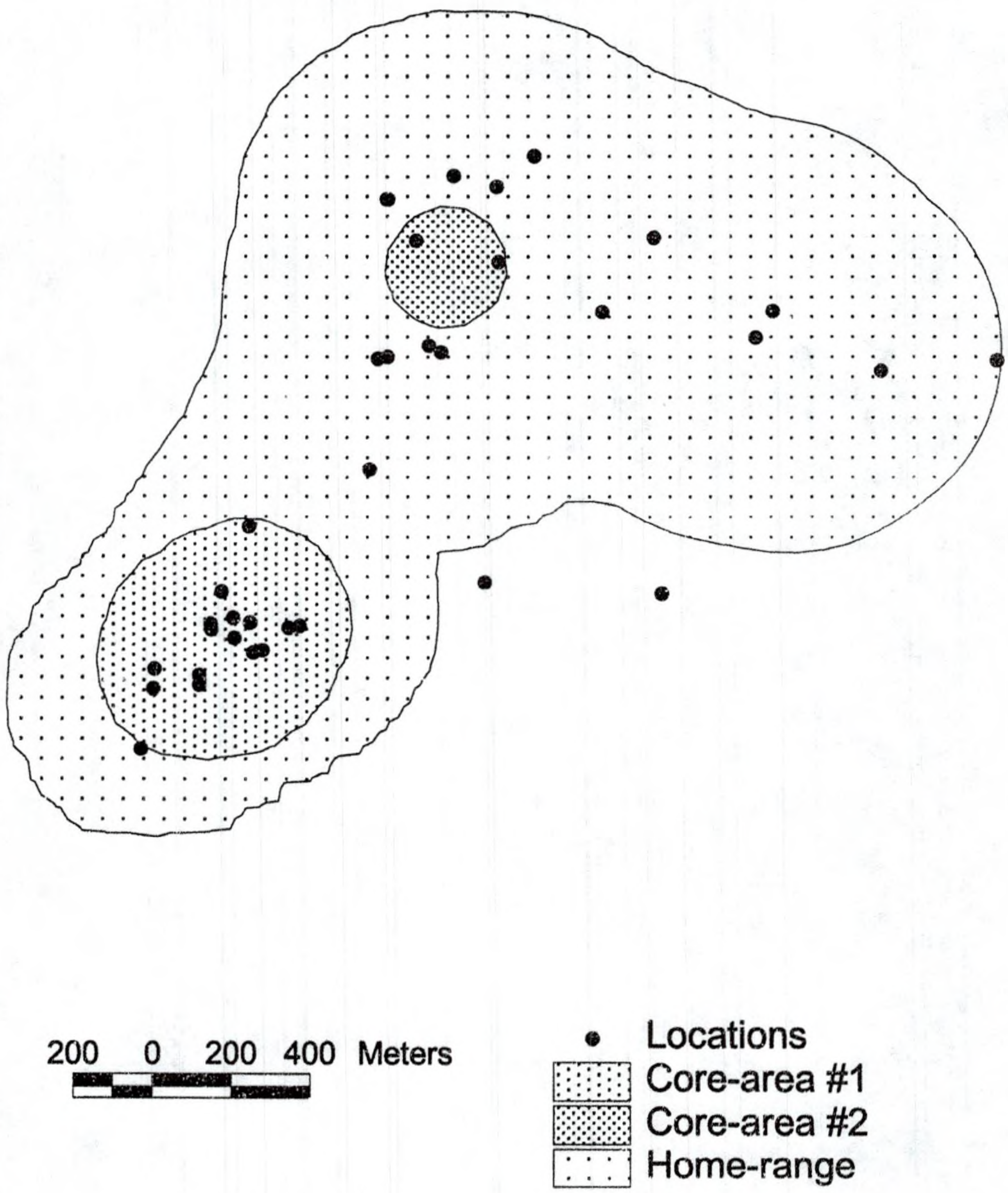

Figure 28. Post-breeding home-range for male 11, 1996.

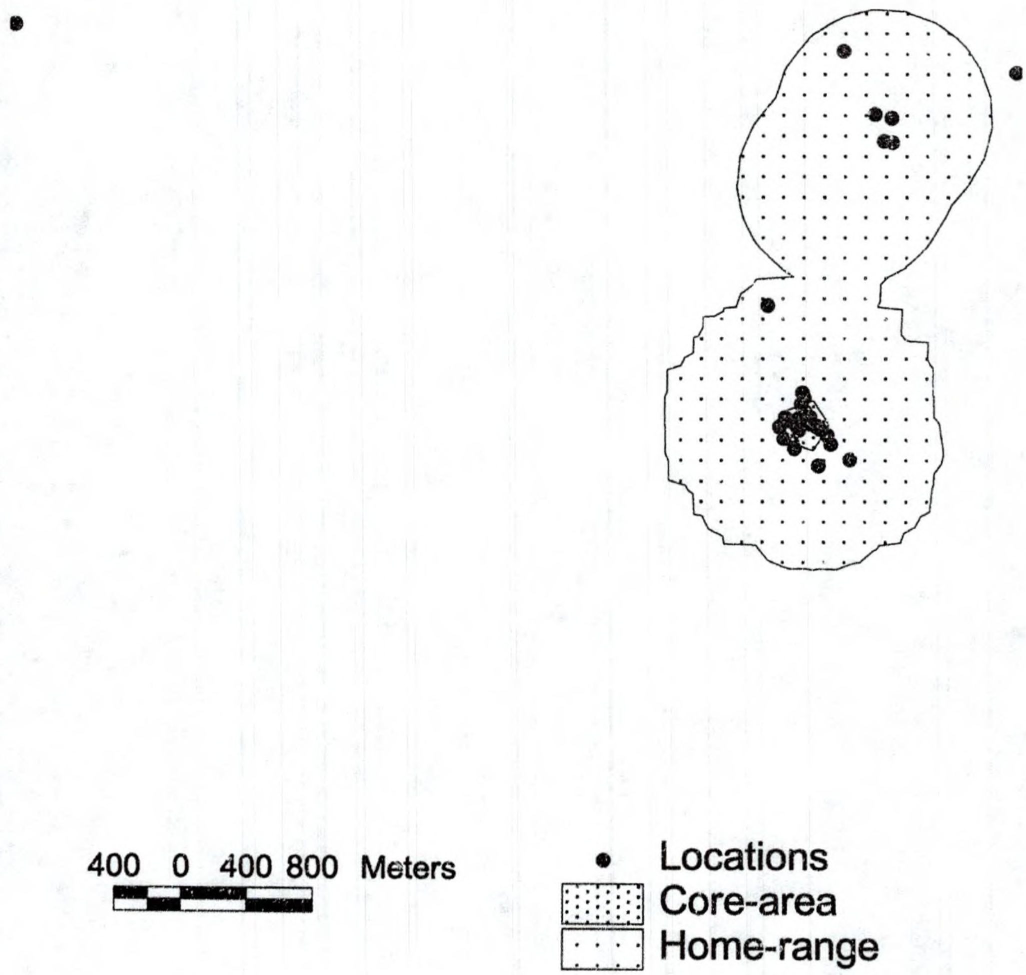

Figure 29. Breeding home-range for male 11, 1997.

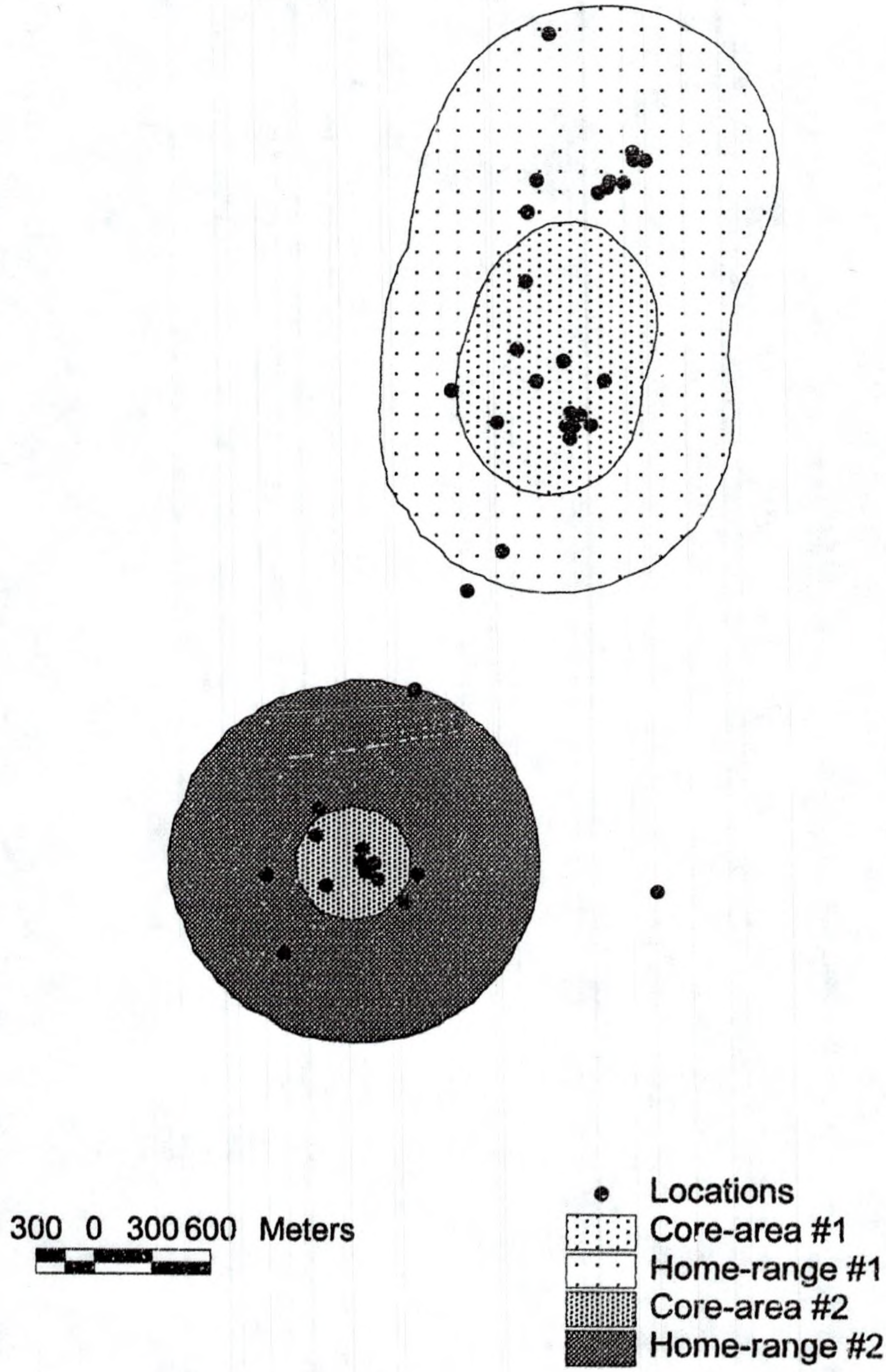

Figure 30. Post-breeding home-range for male 11, 1997.

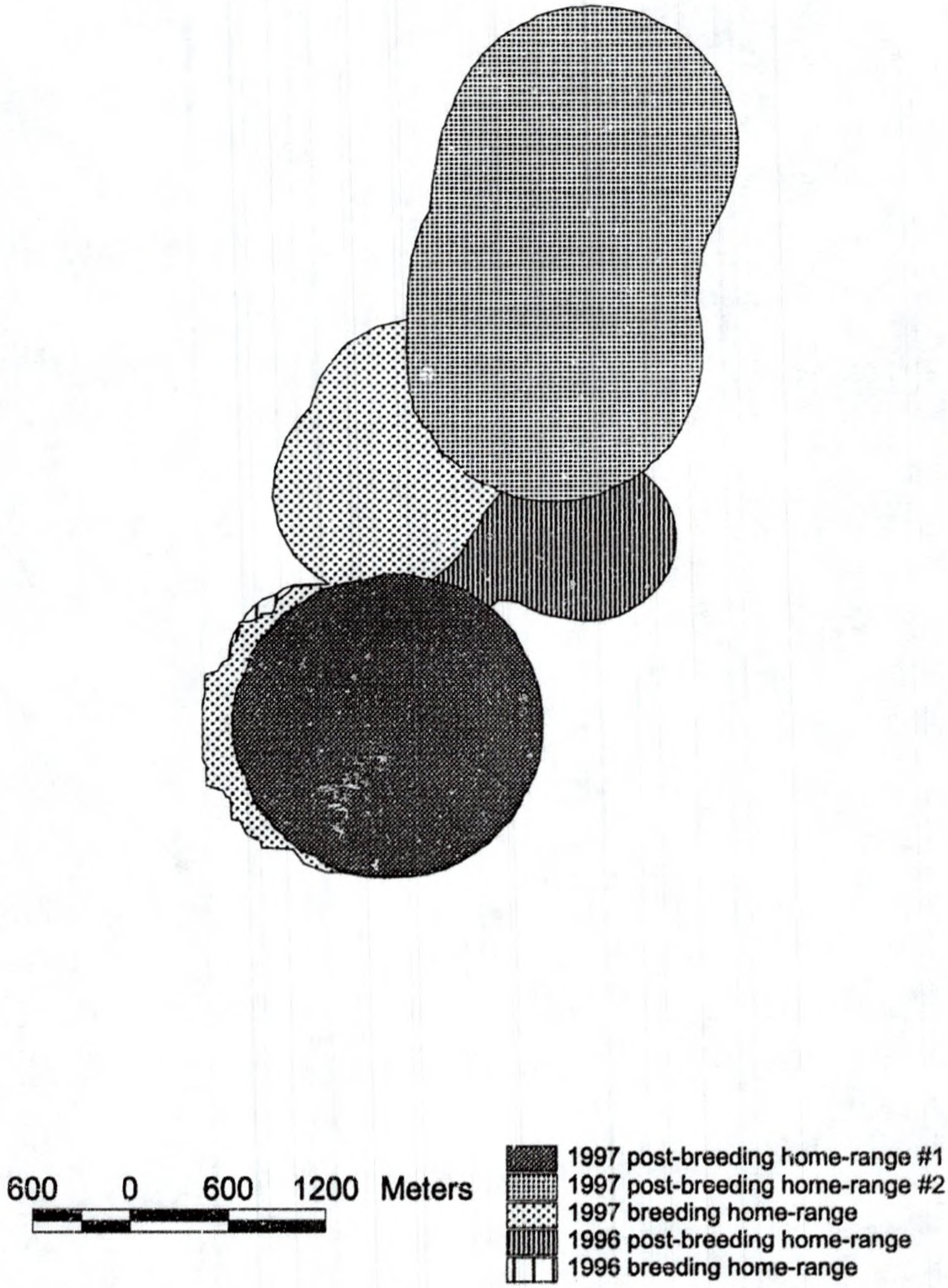

Figure 31. Four seasonal home-range estimates for male 11.

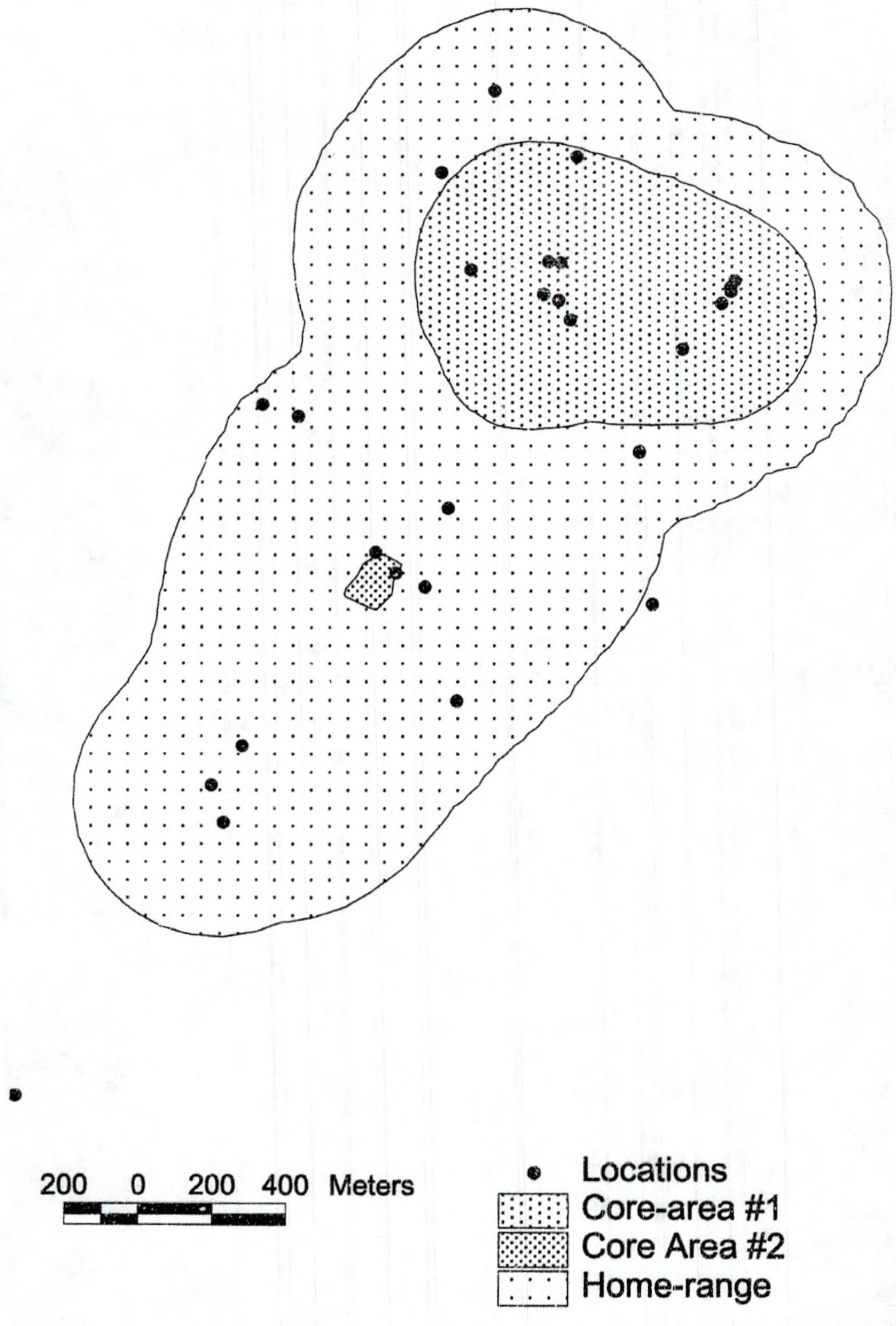

Figure 32. Breeding home-range for male 12, 1996.

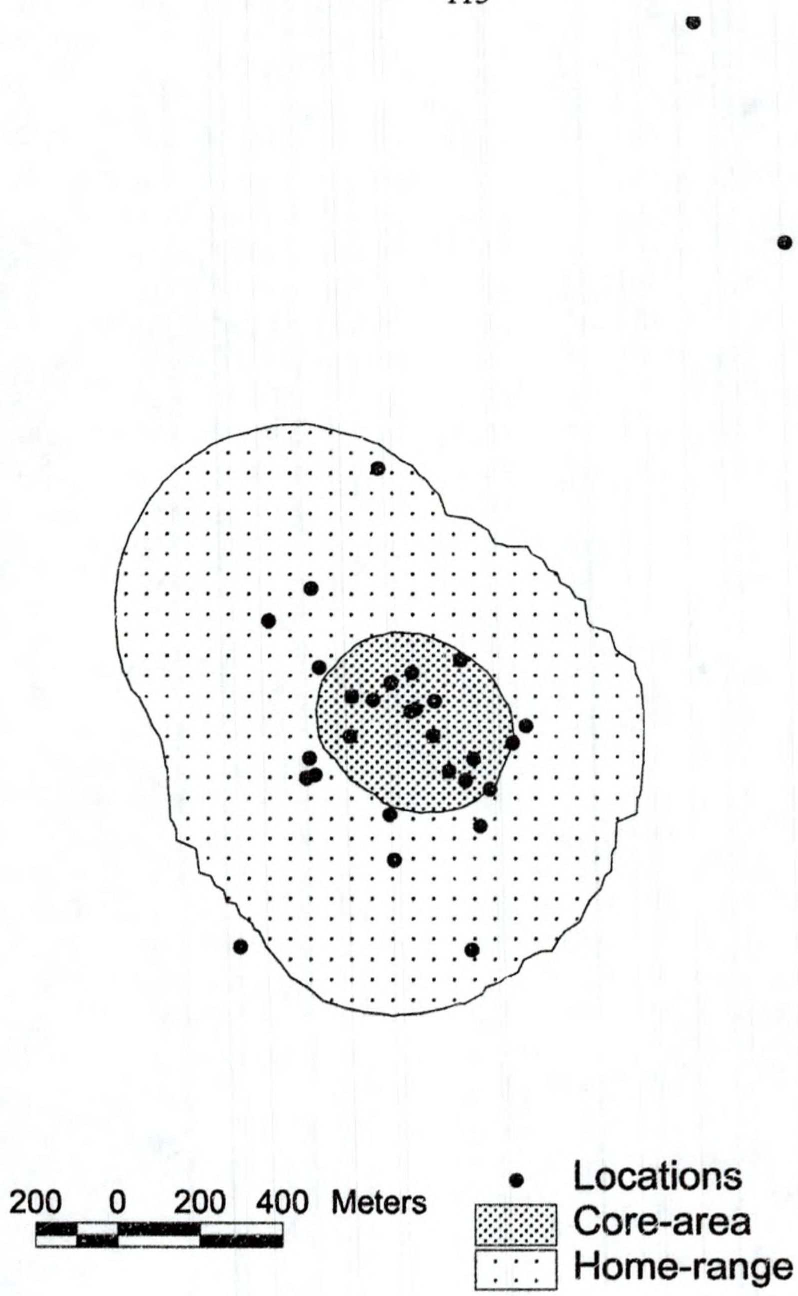

Figure 33. Post-breeding home-range for male 12, 1996.

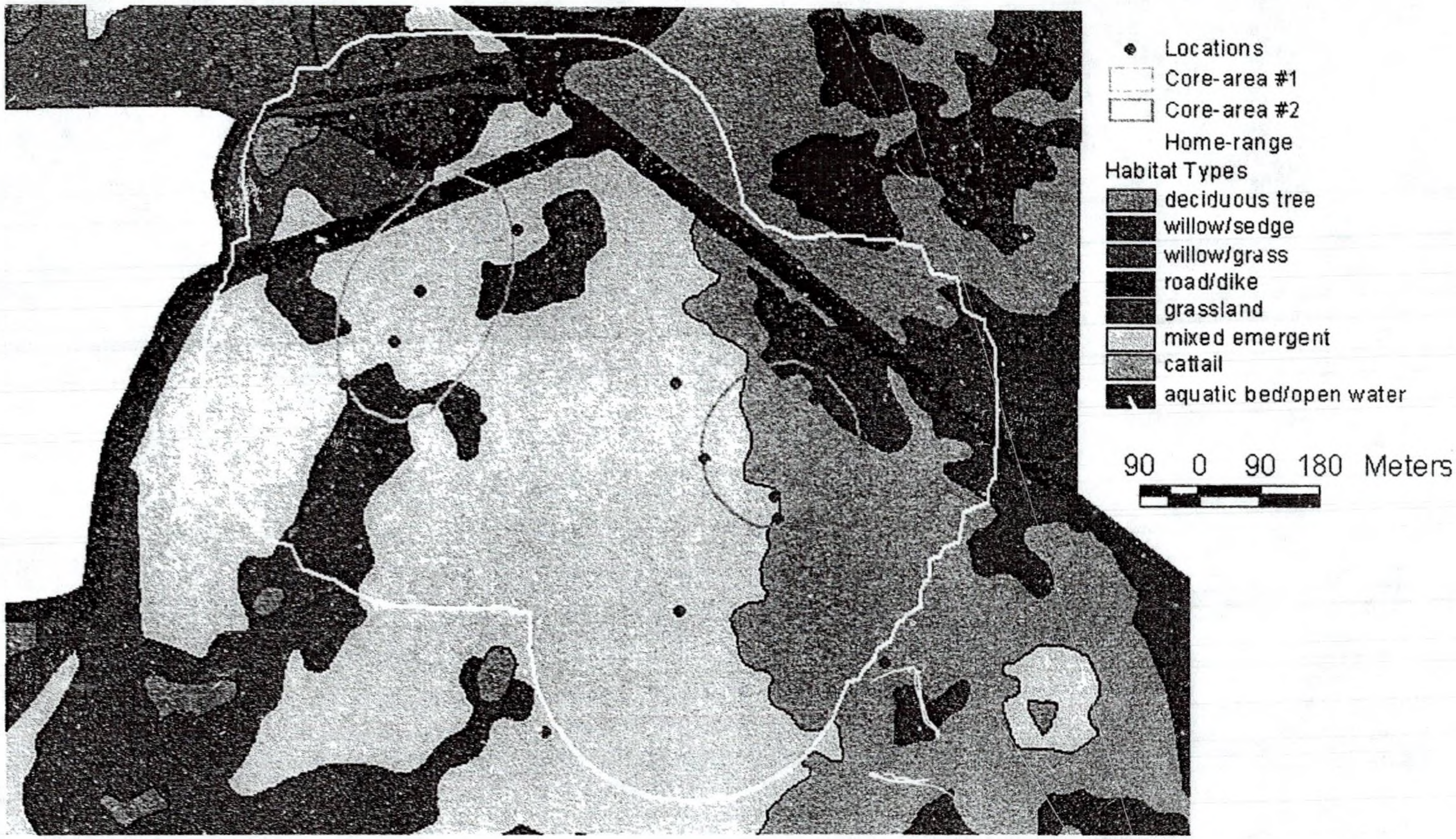

Figure 34. Breeding home-range for male 12, 1997.

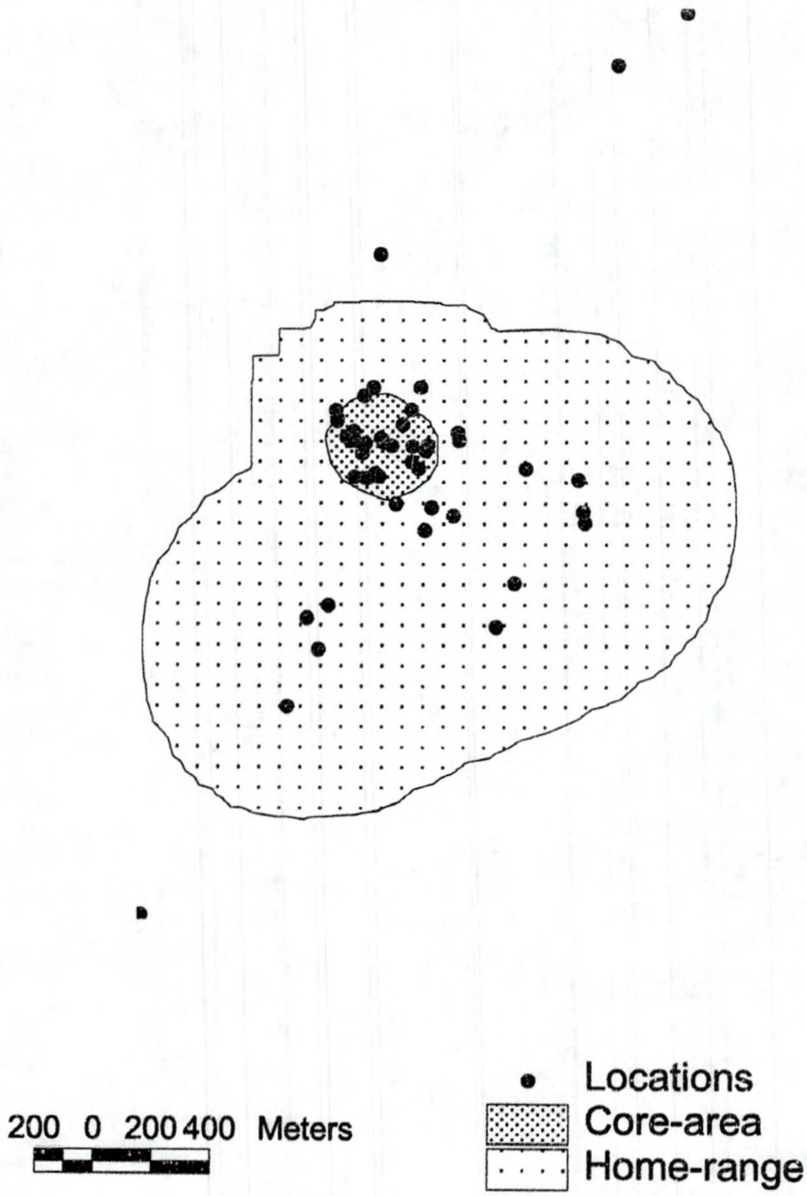

Figure 35. Post-breeding home-range for male 12, 1997.

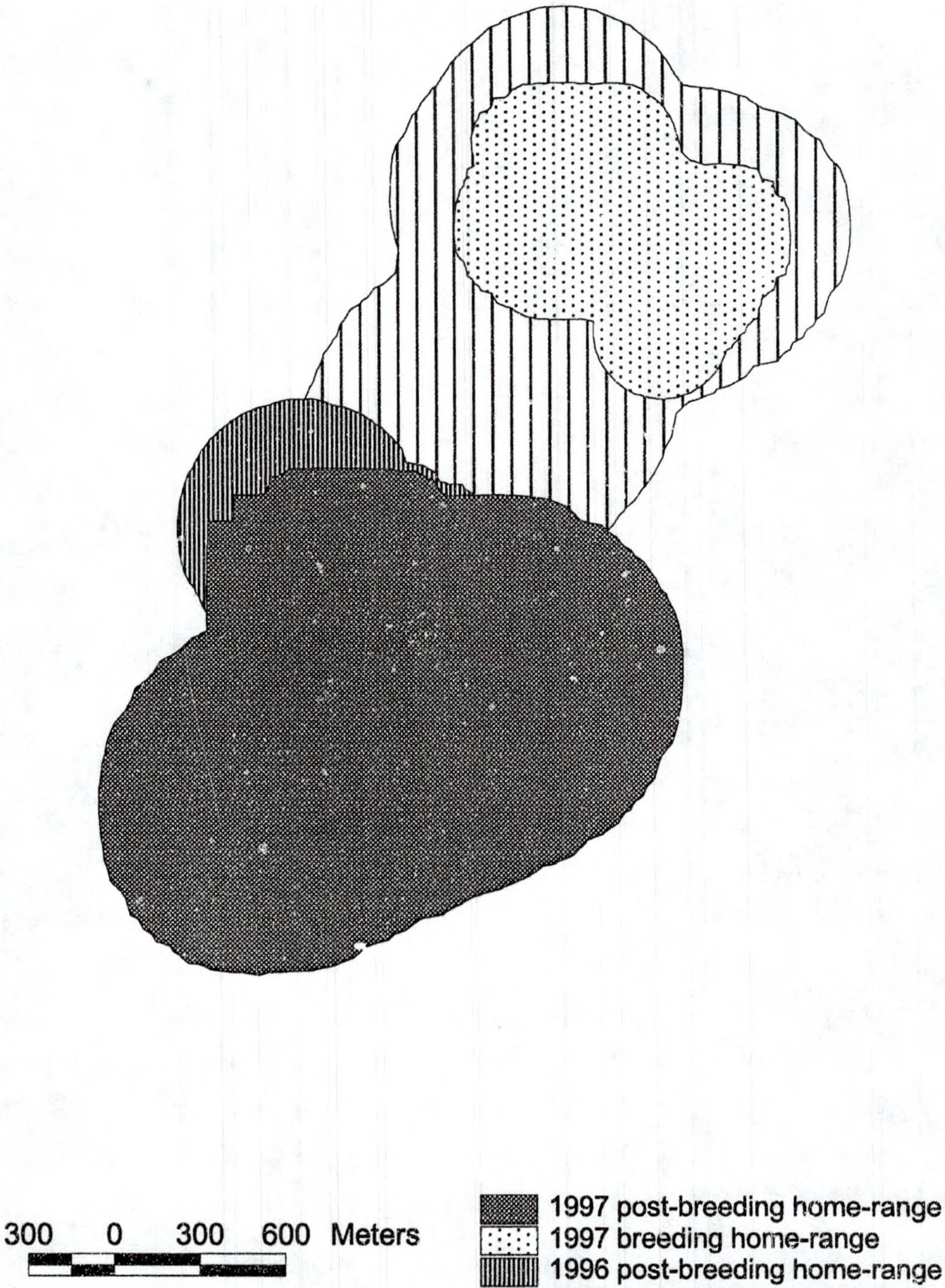

Figure 36. Four seasonal home-range estimates for male 12.

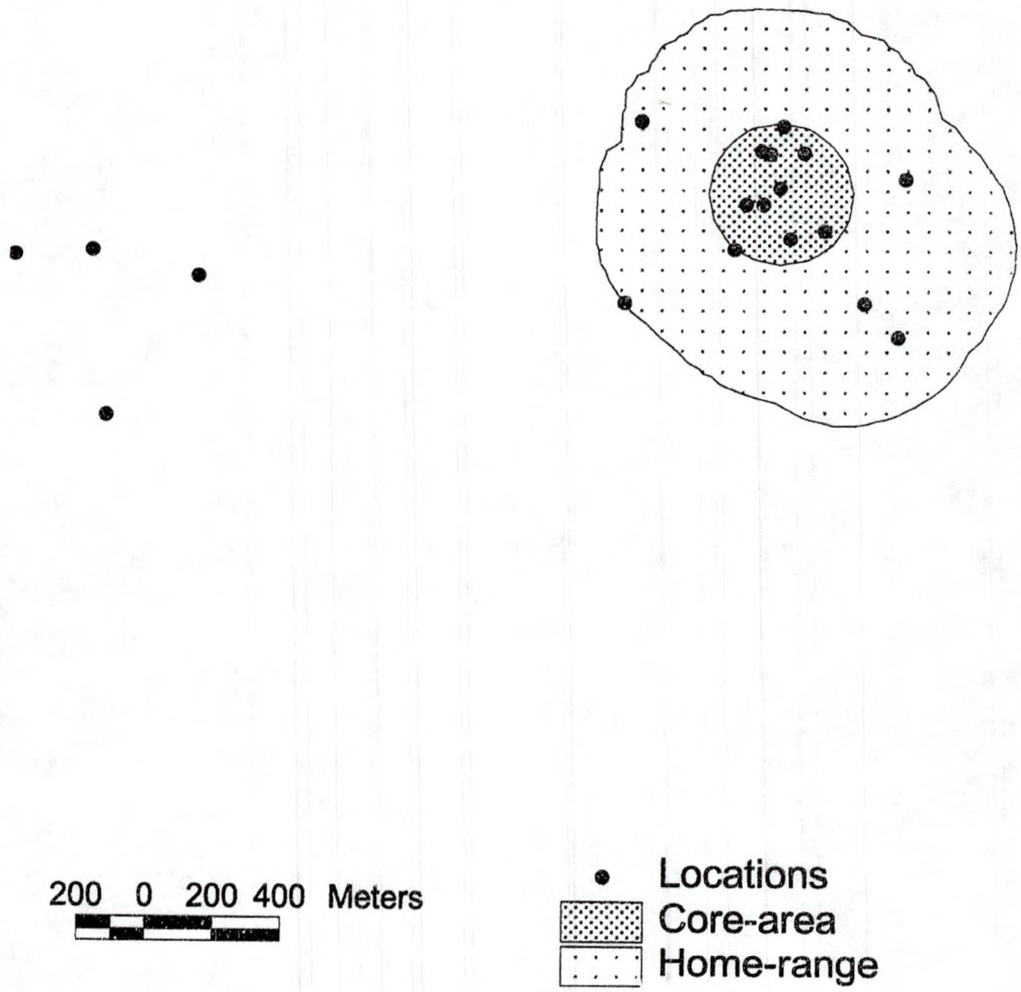

Figure 37. Breeding home-range for male 13, 1996.

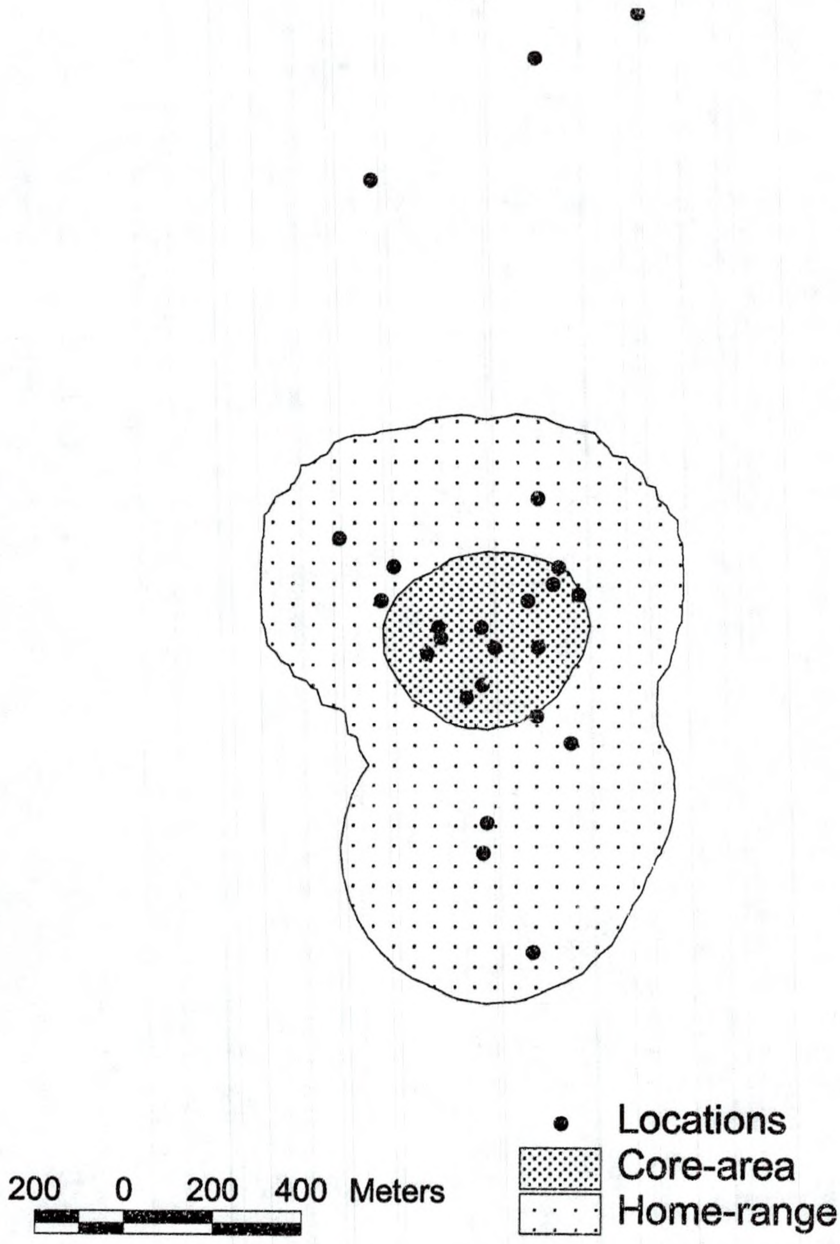

Figure 38. Post-breeding home-range for male 13, 1996.

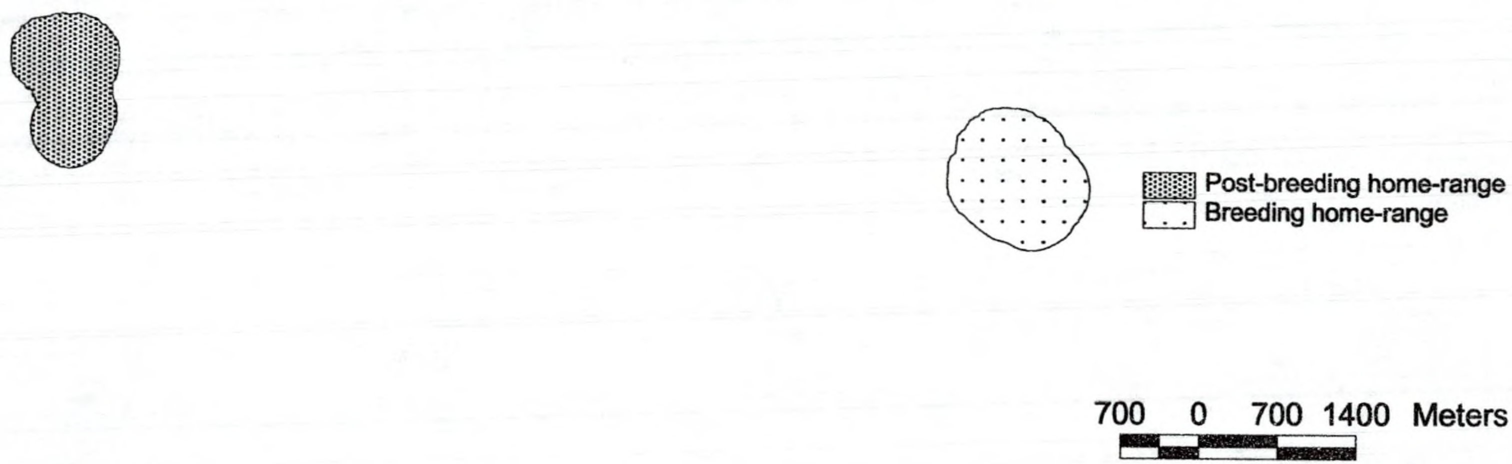

Figure 39. Seasonal home-range estimates for male 13, 1996.

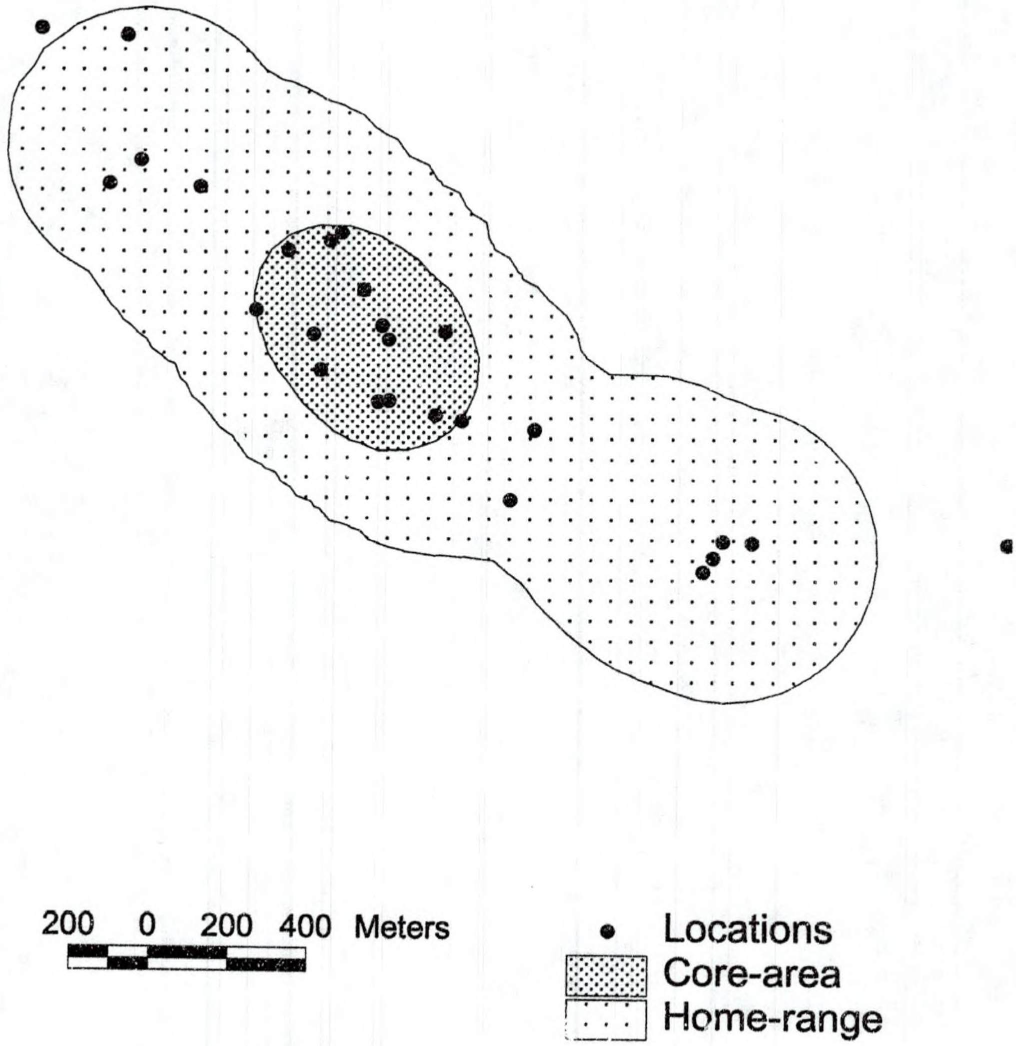

Figure 40. Breeding home-range for male 14, 1996.

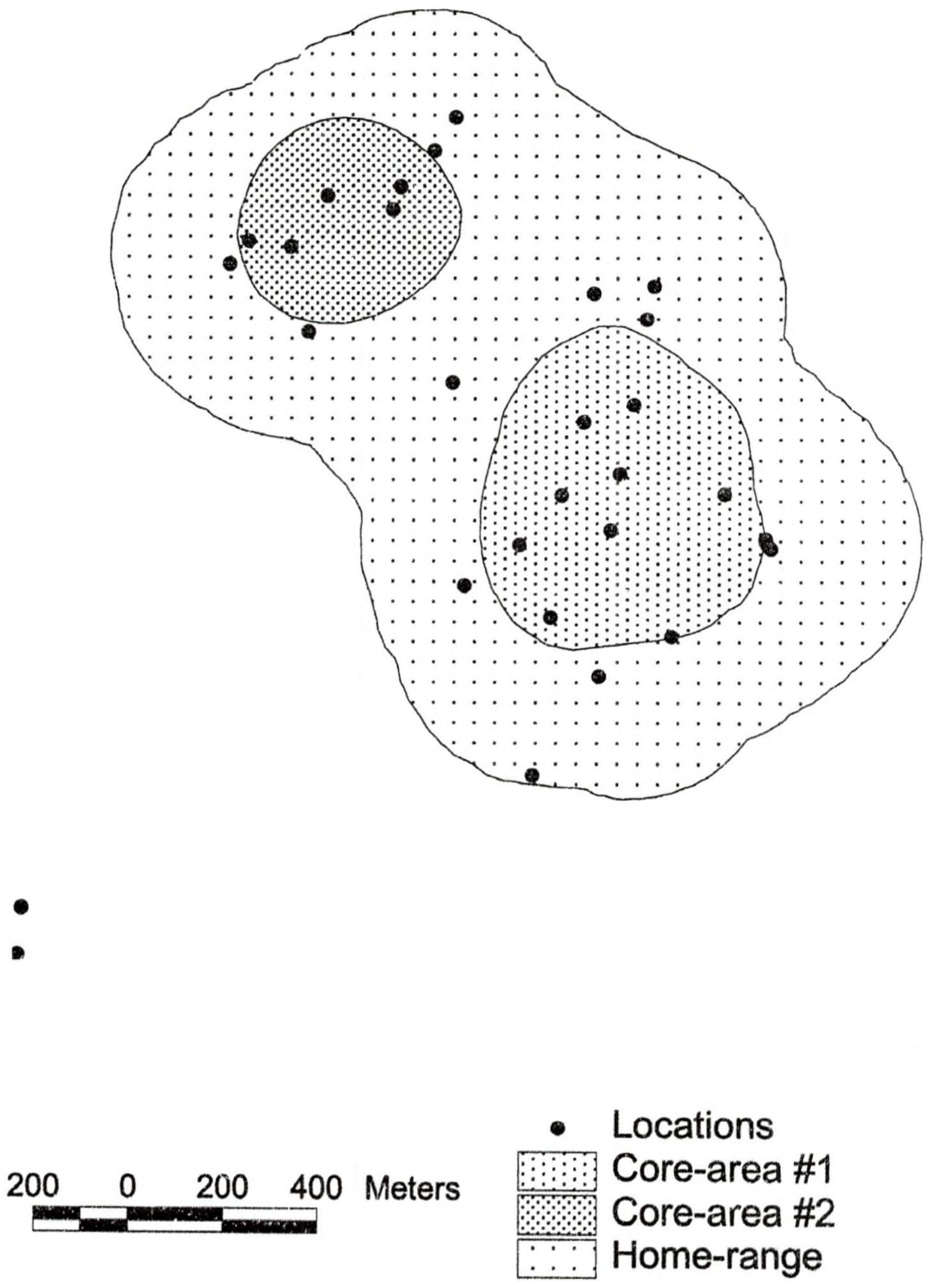

Figure 41. Post-breeding home-range for male 14, 1996.

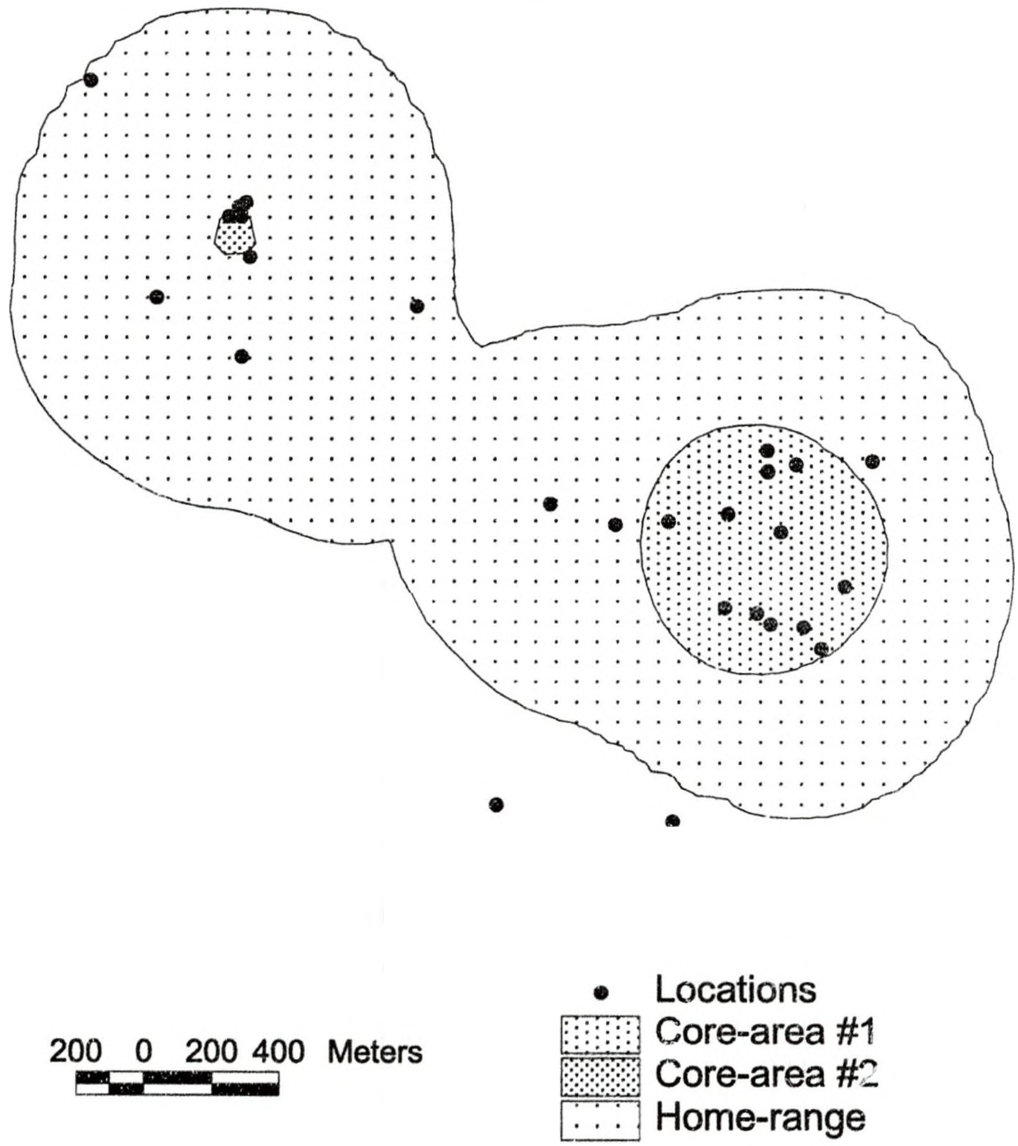

Figure 42. Breeding home-range for male 14, 1997.

Figure 43. Post-breeding home-range for male 14 in Northwest Pool, 1997. Photo 12 taken in August 1996.

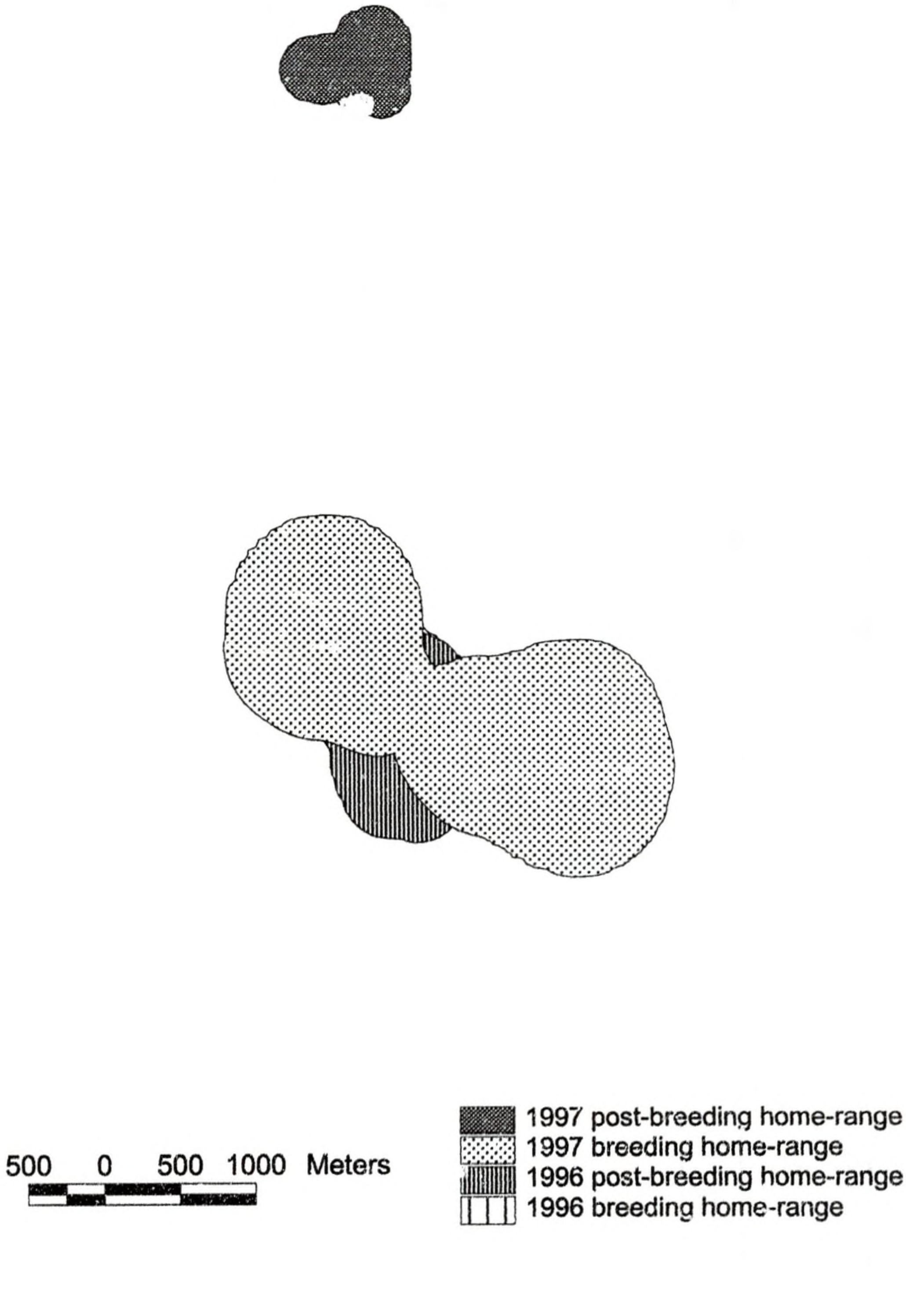

Figure 44. Four seasonal home-range estimates for male 14.

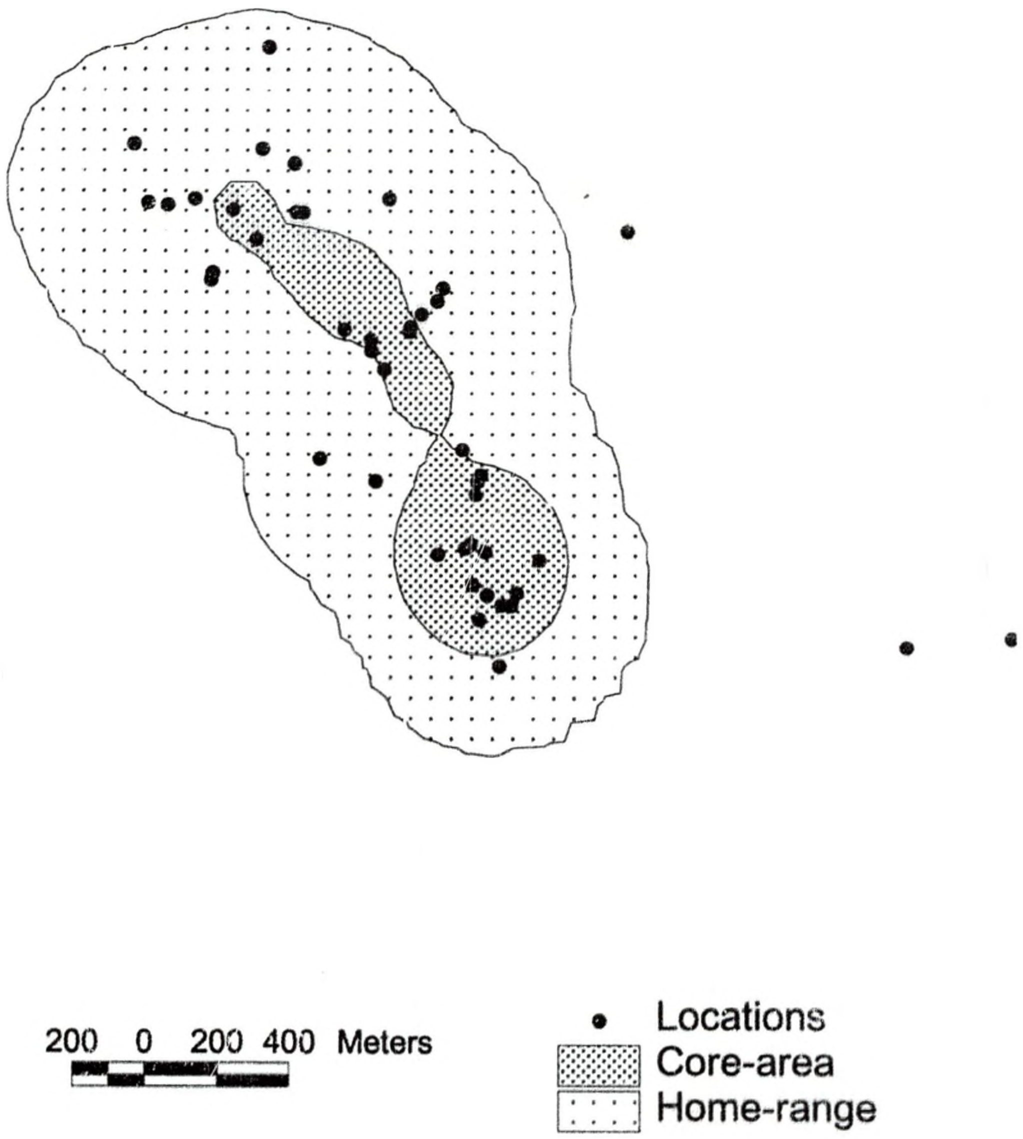

Figure 45. Breeding home-range for male 15, 1996.

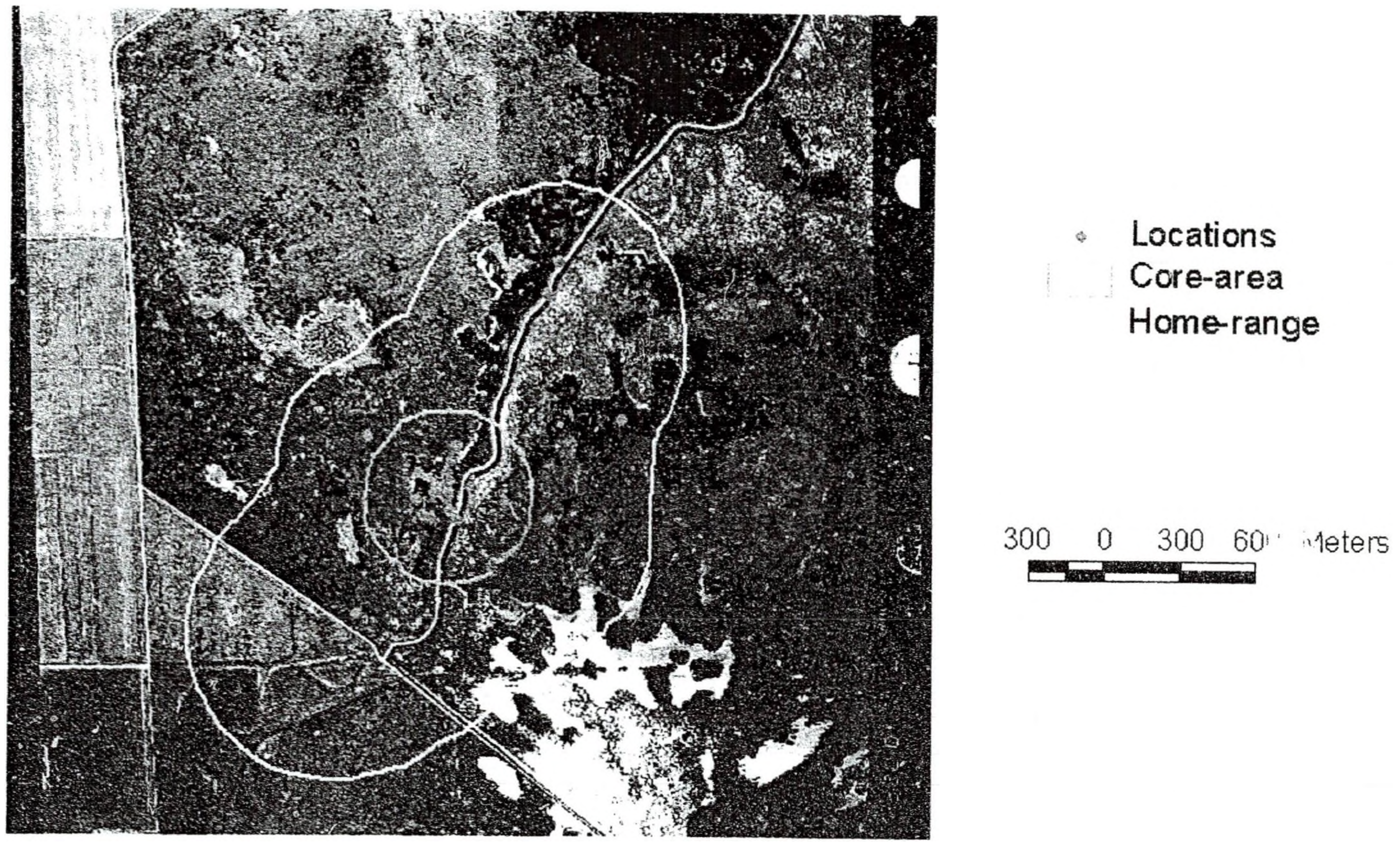

Figure 46. Breeding home-range for male 18, 1997. Photograph 29 taken in August 1996.

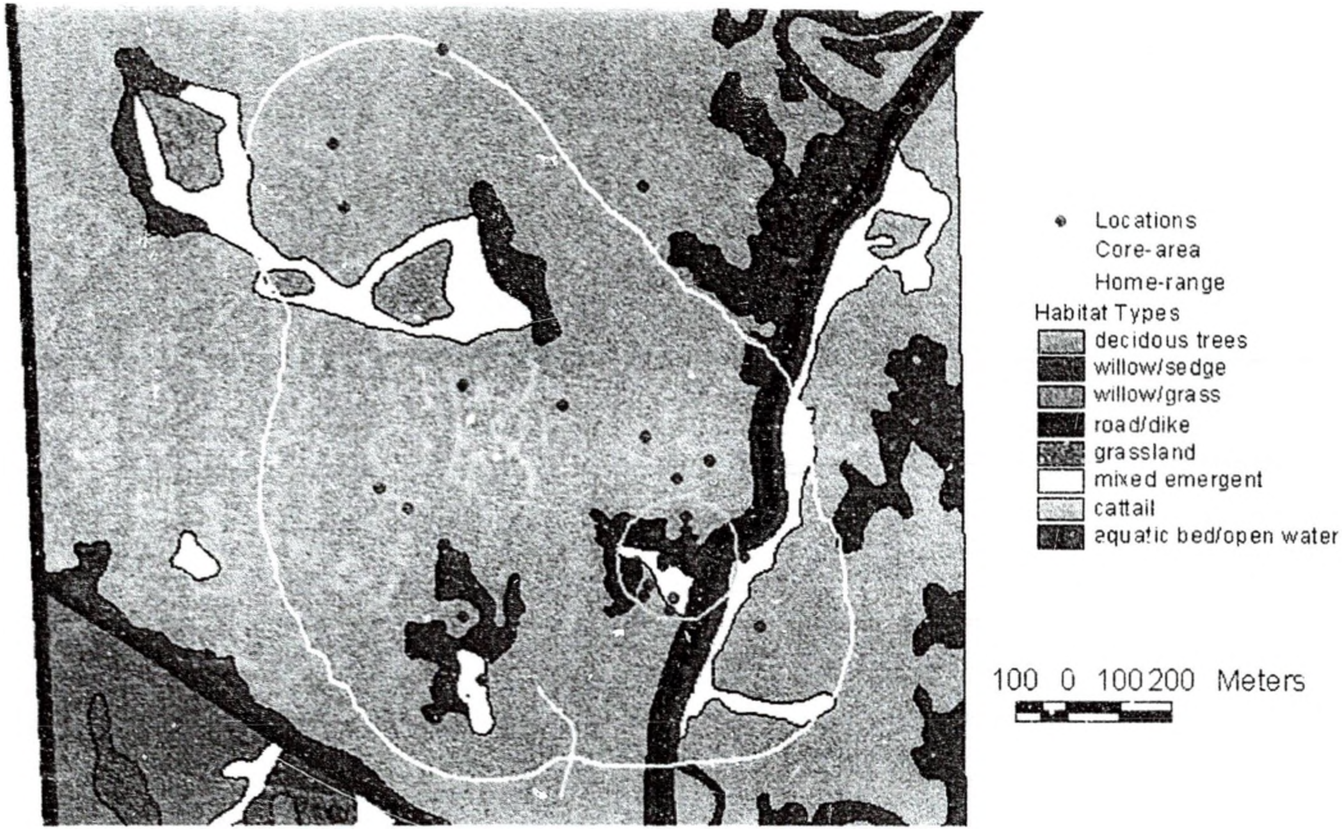

Figure 47 Post-breeding home-range for male 18, 1997

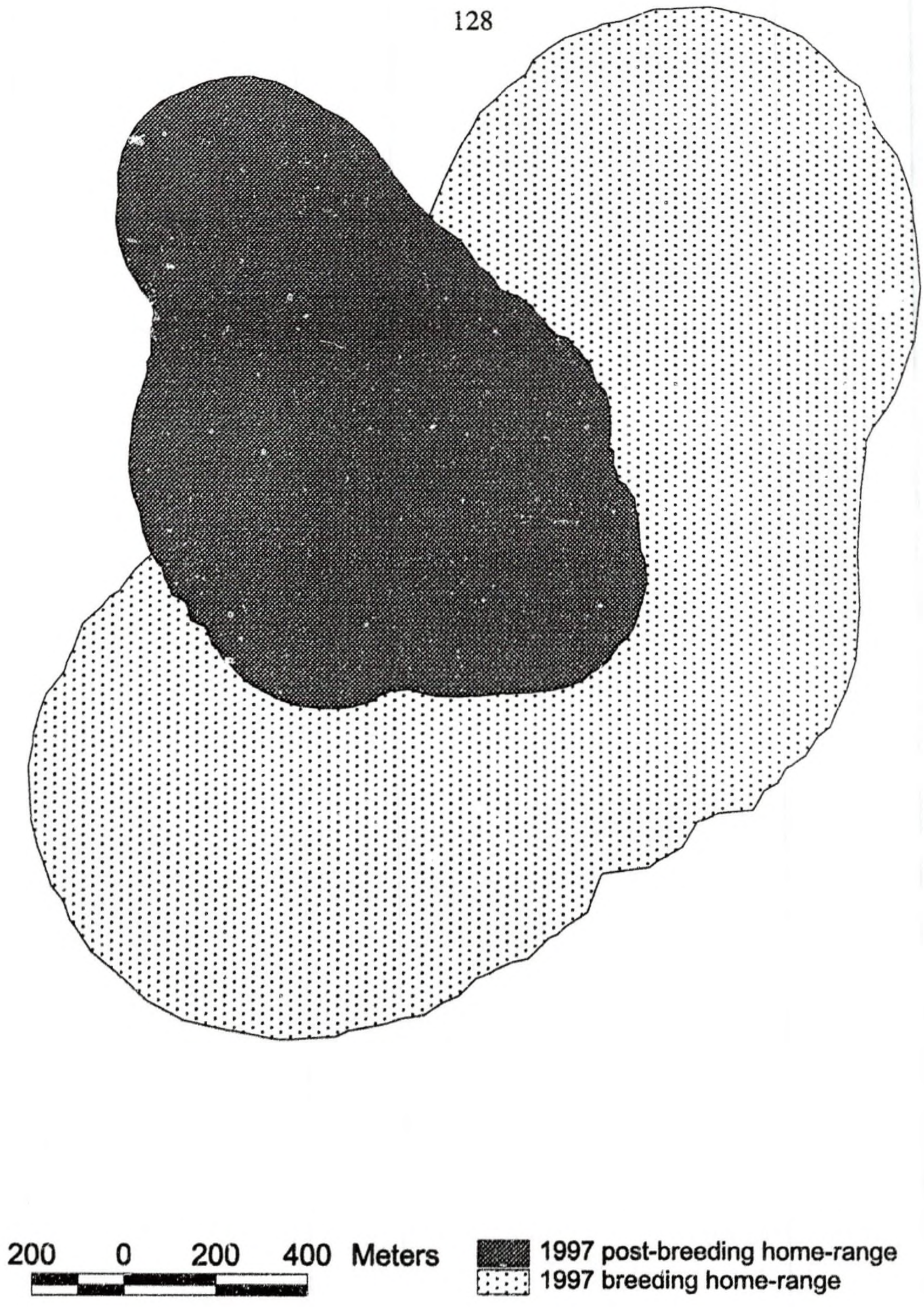

Figure 48. Seasonal home-range estimates for male 18, 1997.

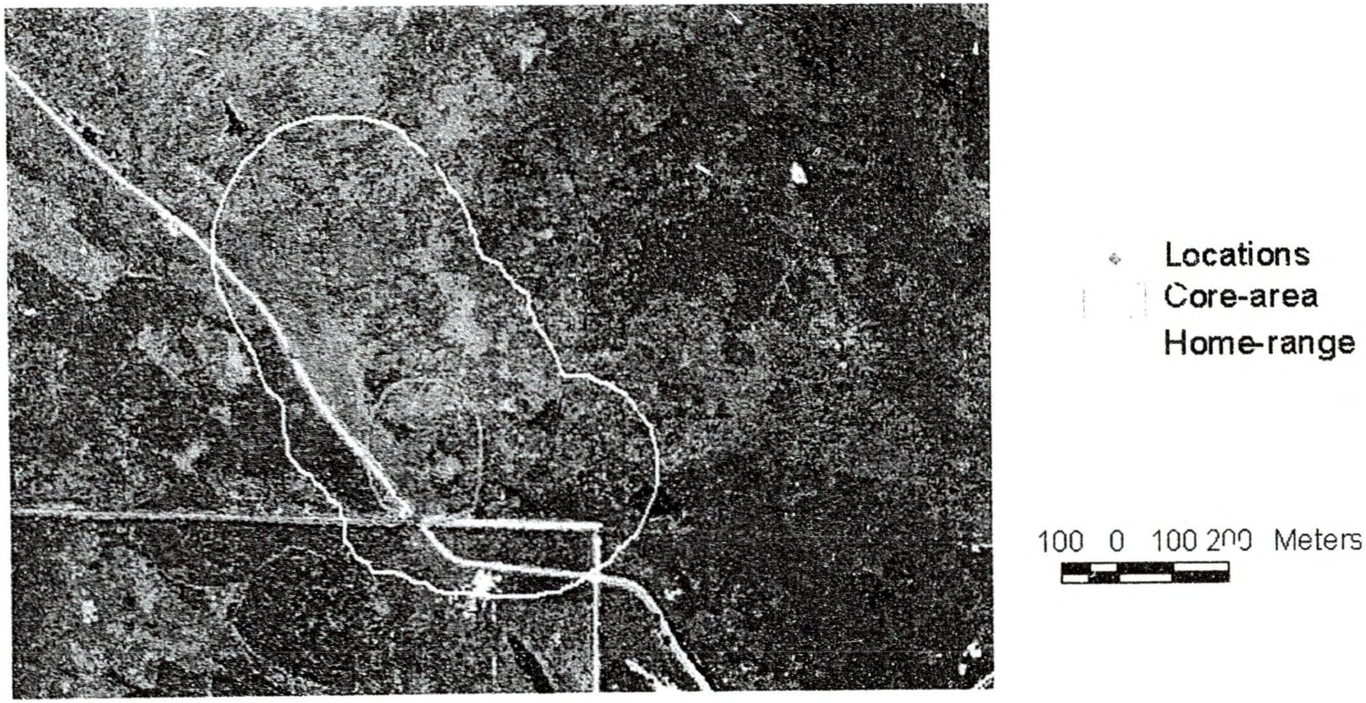

Figure 49. Breeding home-range for male 19, 1997. Photograph 43 taken in August 1996.

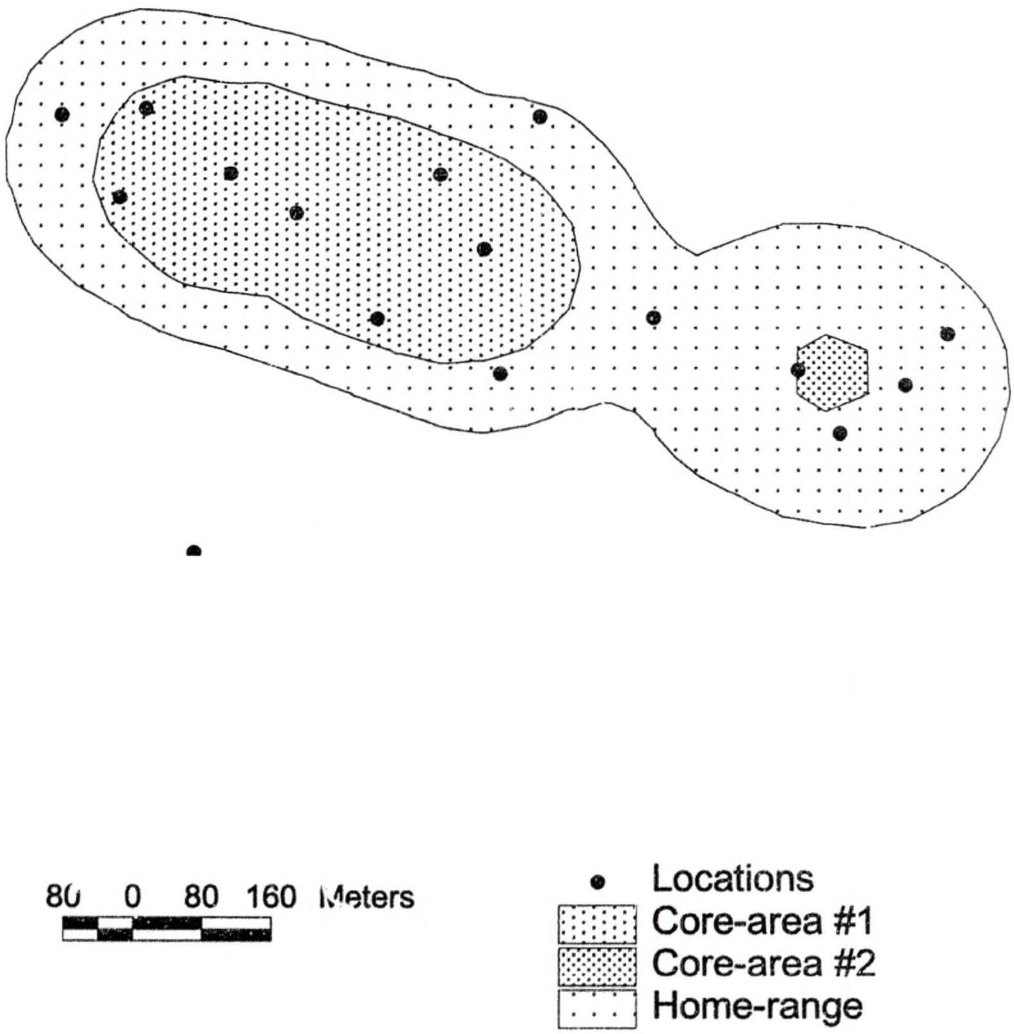

Figure 50. Post-breeding home-range for male 19, 1997.

Figure 51. Seasonal home-range estimates for male 19, 1997.

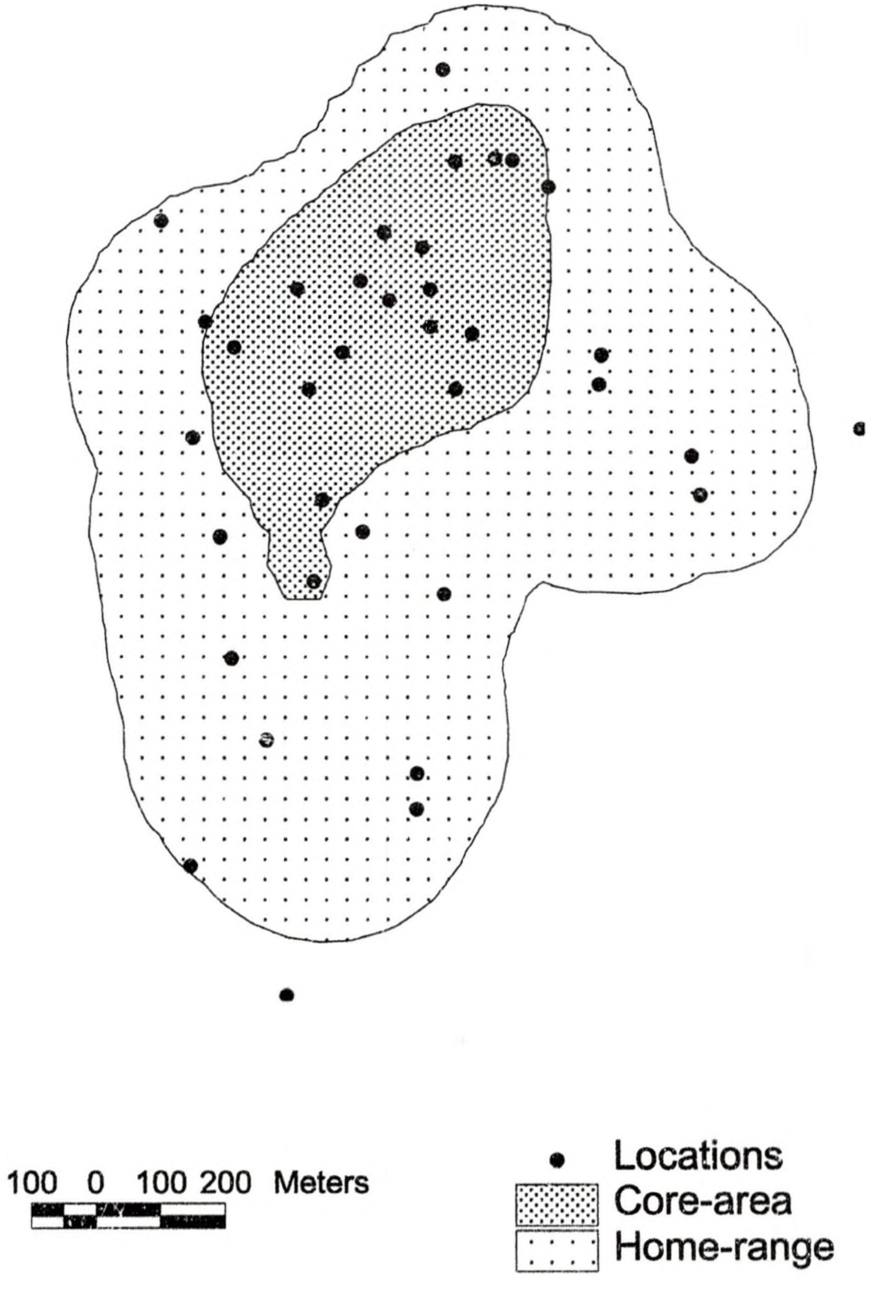

Figure 52. Post-breeding home-range for male 20, 1997.

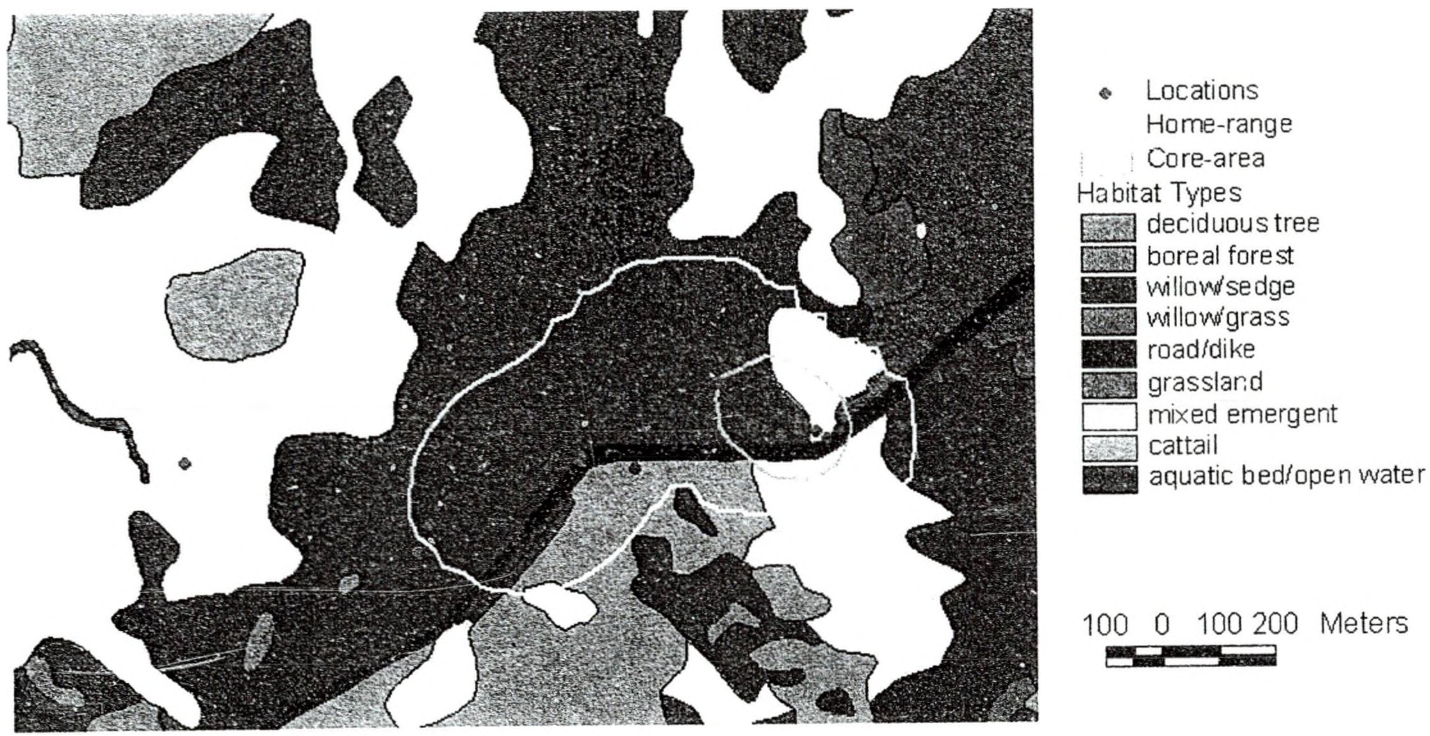

Figure 53. Home-range of female 1 during first nesting attempt, 1996.

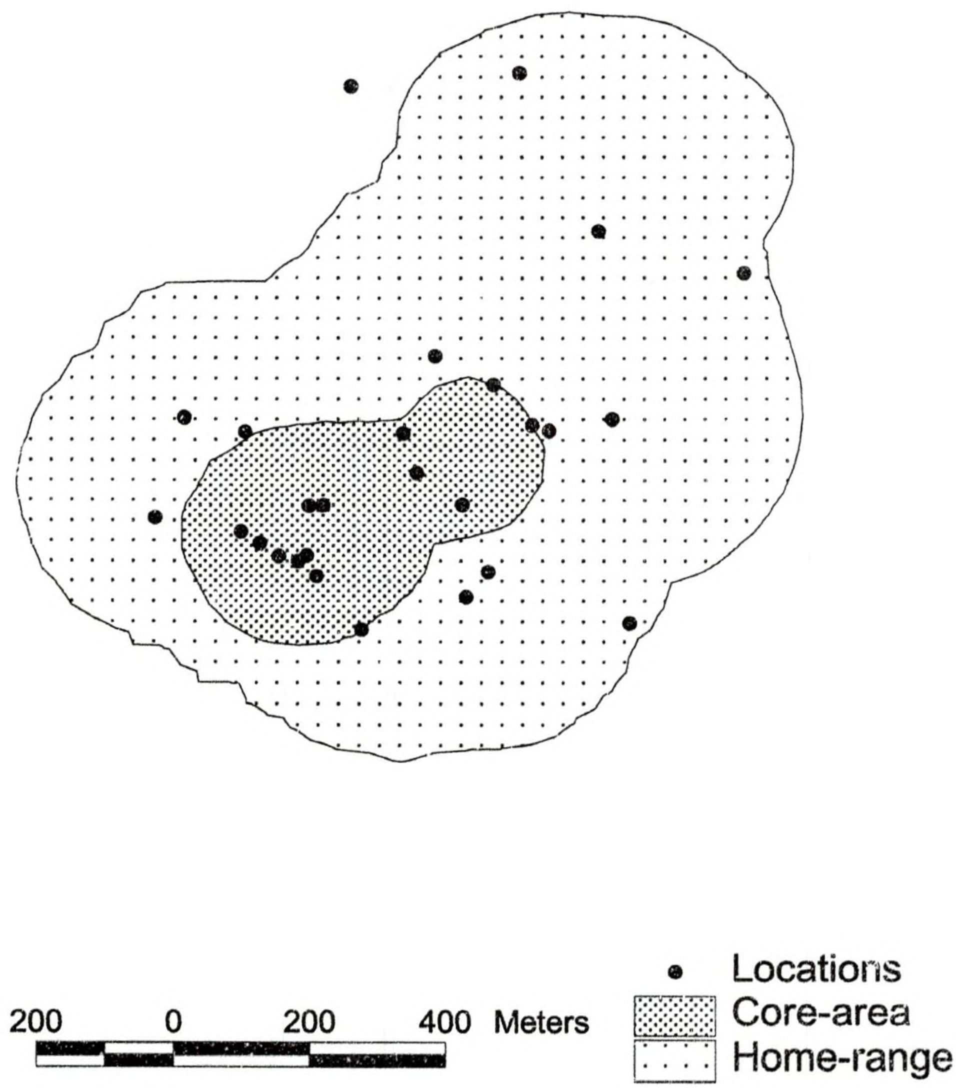

Figure 54. Post-nesting home-range for female 6, 1997.

LITERATURE CITED

Amstrup, S. C. 1980. A radio-collar for game birds. J. Wildl. Manage. 44:214-217.

Bent, A. C. 1926. Life histories of North American marsh birds. U.S. Natl. Mus. Bull. no. 135. Washington, D.C.

Brininger, W., Jr. 1996. Ecology of the American bittern. M.S. Thesis., St. Cloud State Univ., Minn. 70 pp.

Brown, M., and J. J. Dinsmore. 1986. Implications of marsh size and isolation for marsh bird management. J. Wildl. Manage. 50:392-397.

Byers, C. R., R. K. Steinhorst, and P. R. Krausman. 1984. Clarification of a technique for analysis of utilization-availability data. J. Wildl. Manage. 52:544-548.

Campbell, B., and E. Lack (eds). 1985. A dictionary of birds. Buteo Books. Vermillion, S.D. 670 pp.

Chepko-Sade, B. D., and Z. T. Halpin (eds.). 1987. Mammalian dispersal patterns. The Univ. of Chicago Press. Chicago, Ill. 342 pp.

Dahl, T. E. 1990. Wetland losses in the United States 1780's to 1980's. U. S. Fish and Wildl. Serv., Washington, D.C. 21 pp.

Davies, W. E., Jr. 1993. Black-crowned night-heron *in* The Birds of North America, No. 74 (A. Poole and F. Gill, eds.). Philadelphia: The Academy of Natural Sciences; Washington, D.C.: The American Ornithologist's Union.

Duebbert, H. F., and J. T. Lokemoen. 1977. Upland nesting of America bitterns, marsh hawks, and short-eared owls. Prairie Nat. 9:33-40.

Environmental Systems Research Institute, Inc. 1996. ArcView GIS. 350 pp.

Frederickson, L. H., and F. A. Reid. 1986. Wetland and riparian habitats: a nongame management overview. pp. 59-96 *in* J. B. Hale, L. B. Best, and R. L. Clawson, eds. Management of nongame wildlife in the Midwest: a developing art. Proc. Symp. 47th Midwest Fish Wildl. Conf., Grand Rapids, Mich.

Frederickson, L. H., and T. S. Taylor. 1982. Management of seasonally flooded impoundments for wildlife. U.S. Fish and Wildl. Serv. Res. Pub. 148. Washington, D.C. 29 pp.

Gibbs, J. P., and S. M. Melvin. 1992. American bittern, *Botaurus lentiginosus*. pp. 51-69 *in* K. J. Schneider and D. M. Pence, eds. Migratory nongame birds of management concern in the Northeast. U. S. Fish and Wildl. Serv., Newton Corner, Mass. 400 pp.

_____, _____, and F. A. Reid. 1992. American bittern *in* The Birds of North America, No. 18 (A. Poole, P. Stettenheim, and F. Gill, eds.). Philadelphia: The Academy of Natural Sciences; Washington, D.C.: The American Ornithologists' Union.

Greenwood, P. J. 1980. Mating systems, philopatry and dispersal in birds and mammals. Animal Behaviour 28:1140-1162.

Gould, J. H. 1991. Seasonal use of Conservation Reserve Program fields by white-tailed deer in east-central South Dakota. M.S. Thesis., South Dakota State Univ., Brookings. 40 pp.

_____, and K. J. Jenkins. 1993. Seasonal use of Conservation Reserve Program fields by white-tailed deer in east-central South Dakota. Wildl. Soc. Bull. 21:250-255.

Hands, H. M., R. D. Drobney, and M. R Ryan. 1989. Status of the American bittern in the northcentral United States. Rep. to the U. S. Fish and Wildl. Serv., Ft. Snelling, Minn. 13 pp.

Hanowski, J. M., and G. J. Niemi. 1986. Habitat characteristics for birds species of special concern. Unpubl. rep. to Minn. Dep. Nat. Res., St. Paul, Minn. 50 pp.

Harris, S., W. J. Cresswell, P. G. Forde, W. J. Trewhella, T. Woolard, and S. Wray. 1990. Home-range analysis using radio tracking data - a review of problems and techniques particularly as applied to the study of mammals. Mamm. Rev. 20:97-123.

Immelmann, K. 1971. Ecological aspects of periodic reproduction. pp. 341-389 *in* D. S. Farner and J. R. King, eds. Avian biology. Academic Press, New York, N.Y.

Jensen, W. F. 1988. Summer and fall ecology of mule deer in the North Dakota badlands. Ph.D. Dissertation. Univ. of North Dakota, Grand Forks. 220 pp.

Kenward, R. 1987. Wildlife radio tagging. Academic Press, Inc., San Diego, Calif. 222 pp.

Klett, A. T., H. F. Duebbert, C. A. Faanes, and K. F. Higgins. 1986. Techniques for studying nest success of ducks in upland habitats in the Prairie Pothole Region. U. S. Fish and Wildl. Serv. Res. Pub. 158. 23 pp.

Kie, J. G., J. A. Baldwin, C. J. Evans. 1994. Calhome electronic user's manual. U. S. For. Serv., Fresno and Albany, Calif. 19 pp.

Korschgen, C. E., K. P. Kenow, W. L. Green, D. H. Johnson, M. D. Samuel, L. Sileo. 1996. Survival of radio-marked canvasback ducklings in northwestern Minnesota. J. Wildl. Manage. 60:120-132.

Lawson, E. J. G., and A. R. Rodgers. 1997. Differences in home-range size computed in commonly used software programs. Wildl. Soc. Bull. 25:721-729.

Loft, E. R., J. W. Menke, J. G. Kie, R C. Bertram. 1987. Influence of cattle stocking rate on the structural profile of deer hiding cover. J. Wildl. Mange. 51:655-664.

Manci, K. M., and D. H. Rusch. 1988. Indices to distribution and abundance of some inconspicuous waterbirds at Horicon Marsh. J. Field Ornithol. 59:67-75.

Meilke, P. W., Jr., and K. J. Berry. 1982. An extended class of permutation techniques for matched pairs. Commun. Stat. 11:1197-1207.

Middleton, D. S. 1949. Close proximity of two nests of American bitterns. Wilson Bull. 51:83-85.

Mohr, C. O. 1947. Table of equivalent populations of North American mammals. Amer. Midland Nat. 37:223-249.

Mousley, H. 1939. Home life of the American bittern. Wilson Bull. 51:83-85.

Nams, V. O. 1990. Locate II user's guide. Pacer Computer Software. Truro, N.S. 84 pp.

Naugle, D. E., J. S. Gleason, J. A. Jenks, K. F. Higgins, P. W. Mammenga, and S. M. Nusser. 1997. Factors influencing wetland use by Canada geese. Wetlands 17:552-558.

Neu, C. W., C. R. Byers, and J. M. Peek. 1974. A technique for analysis of utilization-availability data. J. Wildl. Manage. 38:541-545.

Palmer, R. S. 1962. Handbook of North American birds, Vol. 1. Yale Univ. Press, New Haven, CT. 567 pp.

Provost, M. W. 1947. Nesting of birds in the marshes of northwest Iowa. Amer. Midland Nat. 38:485-503.

Robel, R. J., J. N. Briggs, A. D. Dayton, and L. C. Hulbert. 1970. Relationships between visual obstruction measurements and weight of grassland vegetation. J. Range Manage. 23:295-297.

Sampson, F. B., and F. L. Knopf (eds.). 1996. Prairie conservation. Island Press. Washington, D.C. 339 pp.

Sauer, J. R., J. E. Hines, G. Gough, I. Thomas, and B. G. Peterjohn. 1997. The North American breeding bird survey results and analysis. Version 96.3. Patuxent Wildl. Research Center. Laurel, Md.

Schoen, J. W., and M. D. Kirchhoff. 1985. Seasonal distribution and home-range patterns of Sitka black-tailed deer on Admiralty Island, southeast Alaska. J. Wildl. Manage. 49:96-103.

Sokal, R. R., and F. J. Rohlf. 1995. Biometry. W. H. Freeman and Co. New York. 887 pp.

Southern, W. E. 1971. Evaluation of a plastic wing-marker for gull studies. Bird Banding 42:88-91.

Stoleson, S. H., and S. R. Beissinger. 1997. Hatching asynchrony, brood reduction, and food limitation in a neotropical parrot. Ecological Monographs 67:131-154.

Svedarsky, W. D. 1992. Observation on nesting of the American bittern in northwest Minnesota. Prairie Nat. 24:241-250.

Tate, J., Jr. 1986. The blue list for 1986. Amer. Birds 40:227-236.

Telfair, R. C. II. 1994. Cattle egret *in* The Birds of North America, No. 113 (A. Poole and F. Gill, eds.). Philadelphia: The Academy of Natural Sciences; Washington, D.C.: The American Ornithologist's Union.

Toepfer, J. E., J. A. Newell, and J. Monarch. 1988. A method for trapping prairie grouse hens on display grounds. pp. 21-31 *in* A. P. Bjugstad ed. Prairie chickens on the Sheyenne National Grasslands. U.S. Dept. Agric. For. Serv. Gen. Tech. Rep. RM-159.

U. S. Fish and Wildl. Serv. 1987. Migratory nongame birds of management concern in the United States: the 1987 list. Office of Migratory Bird Manage., Washington, D.C. 25 pp.

_____. 1995. Migratory nongame birds of management concern in the United States: the 1995 list. Office of Migratory Bird Manage., Washington, DC. 22 pp.

Vesall, D. B. 1940. Notes on the nesting habits of the American bittern. Wilson Bull. 52:207-208.

Watmough, B. R. 1978. Observations on nocturnal feeding by night herons *Nycticorax nycticorax*. Ibis 120:356-358.

Weller, M. W., and L. H. Frederickson. 1974. Avian ecology of a managed glacial marsh. The Living Bird 12:269-291.

_____, and C. E. Spatcher. 1965. Role of habitat in the distribution and abundance of marsh birds. Spec. Rep. No. 43, Iowa State Univ. Agric. and Home Econ. Exp. Sta., Ames. 31 pp.

White, G. C., and R. A. Garrott. 1990. Analysis of wildlife radio-tracking data. Academic Press, Inc., San Diego, Calif. 383 pp.

Wilkinson, L., M. Hill, J. P. Welna, and G. K. Birkenbeuel. 1992. SYSTAT for windows: Statistics, Version 5 Edition. SYSTAT, Inc. Evanston, Ill. 750 pp.

Worton, B. J. 1989. Kernel methods for estimating utilization distribution in home-range studies. Ecology 70:164-168.

_____. 1995. Using monte-carlo simulation to evaluate kernel-based home-range estimators. J. Wildl. Mange. 59:794-800.