FLORIDA GRASSHOPPER SPARROW MANAGEMENT NEEDS

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Abstract: A banding study investigating habitat, home range, movements, and survival of Florida grasshopper sparrows (Ammodramus savannarum floridanus) was conducted to determine management needs. The subspecies was classified as endangered in 1986 because of its restricted distribution, loss of habitat, and population decline. Pastures occupied by grasshopper sparrows were burned on a 2-3-year rotation. All vegetation variables except shrub cover were strongly influenced ($P < 0.001$) by time post-burn. Most (87%) variation of the post-burn time effect was in positive differences in means of vegetation density, percent litter cover, and vegetation height and in a negative difference in mean percent forb cover. Florida grasshopper sparrow home range size increased linearly with post-burn time ($P \leq 0.27$). Frequent burning encouraged habitat compositions associated with greater densities of sparrows. Sizes of 30 home ranges averaged 1.77 ha and ranged from 0.57 to 4.82 ha. Adults were highly sedentary, and the subspecies appears to be nonmigratory. Annual survival rate for adult males was 0.59, and mean life expectancy was 1.95 years. Study results do not support the hypothesis that suitable habitat is ephemeral and individual sparrows move as habitat improves or deteriorates. However, grasshopper sparrows may alter home range size in response to fire and ensuing changes in prairie physiognomy and floristics. Approximately 1.77 ha of treeless prairie should be allocated per breeding pair. Population density was 0.08 territories/ha, indicating that a minimum viable colony of 50 breeding pairs (U. S. Fish and Wildlife Service 1988) may require >600 ha. Sites managed for grasshopper sparrows should be treeless. A low (<70 cm), sparse (<10% cover) growth of saw palmetto (Serenoa repens) and shrubs should be provided and an open substrate (>20% bare ground) maintained. We recommend prescribed fire on a 2-3 year rotation to sustain suitable habitat. Burning should occur between August and February to avoid the nesting period. Preliminary information on population dynamics may be helpful in evaluating recovery efforts. Information is needed on Florida grasshopper sparrow breeding success and winter ecology.

INTRODUCTION

The grasshopper sparrow (Ammodramus savannarum) is a widely distributed grassland bird (Friedmann et al. 1950, Bond 1960, De Schauensee 1964, AOU 1983) typical of mixed-grass prairies (Cody 1985:192), cultivated grasslands (Smith 1968), and more mesic tallgrass conditions (Wiens 1973a, Rotenberry 1985). Patterns of grasshopper sparrow habitat use have been associated with components of vegetation composition and structure induced by cultivation (Goode and Dumbach 1943, Smith 1963), grazing (Wiens 1973a, Skinner 1975, Bock and Webb 1984, Rotenberry 1985), mowing (Frawley and Best 1991), prescribed fire (Delany et al. 1985, Bock and Bock 1987), and seral stage (Johnston and Odum 1956; Whitmore 1979a,b). Sparrow occurrence and density usually is positively correlated with percent bare ground and negatively correlated with percent litter cover, vegetation density, and percent shrub cover (Smith 1968, Wiens 1973b, Wray et al. 1982, McNair 1984, Vickery 1991, sources cited above). Habitat affinities may be related to the species' foraging and nesting requirements (Whitmore 1981). Of the four subspecies of grasshopper sparrows in North America, only the Florida subspecies (A. s. floridanus) is nonmigratory (Smith 1968, Stevenson 1978; but see Bailey 1925:102 and Phillips et al. 1964:194).

The Florida grasshopper sparrow was classified as endangered in 1986 because of its restricted distribution, loss of habitat, and population decline (Federal Register, Vol. 51, No. 147, 1986). The subspecies is endemic to the southcentral prairie region of Florida and early reports implied a large and widespread population (Howell 1932, Nicholson 1936). Recent surveys suggest a decline in numbers and distribution, with habitat loss being the greatest threat to the sparrow (U.S.Fish and Wildlife Service 1988). Much of the native prairie in Florida has been converted to improved pasture (Davis 1980) or reduced by agriculture and phosphate mining (Callahan et al. 1990). No critical habitat was designated because suitable areas (see Delany et al. 1985) seem ephemeral, and Florida grasshopper sparrows were thought to move in response to range management (or neglect) as habitat improves or deteriorates (Delany and Cox 1986). Specific habitat and minimum area requirements of floridanus, however, are not known. The subspecies could be down-listed as threatened if 50-100 breeding pairs become established at each of 10 secure, discrete sites throughout its former range; or delisted if 25 such sites are established (U.S. Fish and Wildlife Service 1988). It is yet to be determined what constitutes a discrete site. Colonies (breeding aggregations) can cover several km^2 and be separated by 11-48 km (Nicholson 1936, pers. observ.). No information is available on the dispersal and movements of Florida grasshopper sparrows.

Grassland birds often exhibit fluctuations in ranges and population densities as they "track" resources in an inherently unstable habitat (Cody 1985:197). Site tenacity and variables outside the locale (i.e., during migration), however, confound direct relationships between habitat quality and population density (Van Horn 1983, Rotenberry 1986, Wiens and Rotenberry 1985). Hence, the response of grassland birds to habitat perturbations is usually delayed and unpredictable (Wiens et al. 1986). On a smaller scale, intraspecific variation in the territory size of grassland sparrows (Wiens et al. 1985, Reid and Weatherhead 1990), shifts in location (Petersen and Best 1987), and settlement patterns (Best and Rodenhouse 1984) may evince habitat quality. Features of vegetation structure (Smith and Shugart 1987) and composition (Rotenberry 1985) may indicate resource availability (e.g., food or potential nest sites), providing proximate cues that determine individual habitat selection (Hilden 1965, Brush and Stiles 1986) and territory size (Seastedt and MacLean 1979).

We monitored individual movements, home range, habitat use, and survival within a colony of Florida grasshopper sparrows. Movements and variation in home range size were related to features of the vegetation and range management. We examined the hypothesis that suitable habitat is ephemeral (i.e., becomes unusable prior to significant successional changes) and that sparrows move or alter home range size in response to habitat manipulation (principally prescribed fire). This information was obtained to assess habitat quality and recommend strategies to manage the population. These data also provide an opportunity to examine a population of presumably nonmigratory grasshopper sparrows.

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STUDY AREA

Most of the 5609 km^2 area of dry prairie in Florida is located within 75 km north and west of Lake Okeechobee (Davis 1980, Kautz 1991) (Fig. 1). Robertson and Kushlan (1974) and Webb (1990) discuss geologic and climatic influences of the early Pleistocene that may have produced this relict ecosystem and subsequent subspeciation of floridanus. The topography is flat and soils are typically acidic sands (Abrahamson and Hartnett 1990). The climate of southcentral Florida is humid-subtropical. Average annual rainfall is 130 cm (Winsberg 1990:159). The grass, saw palmetto (Serenoa repens), and shrub community is interspersed with other habitat types and is described by Hartman (1978) and Abrahamson and Hartnett (1990). By definition, the prairie includes $\leq$ 15 percent pine (Pinus spp.) cover (Kautz 1991). Consequently, cleared and thinned forests in the region are included because the remaining understory resembles saw palmetto prairie (Davis 1943). Milleson et al. (1980) describe prairie improvements for cattle grazing.

The study was conducted on the 430-km^2 U.S. Air Force Avon Park Bombing Range in Highlands and Polk counties, Florida (Fig. 2). The military installation serves primarily as a training range for fighter aircraft and Florida Army National Guard maneuvers. Approximately 2000 ha of prairie and improved grassland are located in and around target areas. Pastures were managed for cattle and leased to ranchers who maintain 4,000 animal units.

Study efforts were concentrated within a 700-ha prairie that contained a colony of Florida grasshopper sparrows. This area included possible native prairie (unpubl. timber survey, c. 1917) dominated by saw palmetto, dwarf oak (Quercus minima), pineland threeawn (Aristida stricta), bluestems (Andropogon spp.), and yellow-eyed grass (Xyris spp.); scattered cypress domes; and small (<4 ha) hypericum (Hypericum spp.) ponds. Soils are poorly drained Malabar and Oldsmar fine sands (USDA Soil Conservation Service, 1989). The prairie was bordered by pine plantations, improved pastures, and freshwater marsh. A 1-lane, paved road (Kissimmee Road) divided the study area into the "Kissimmee Road", "Delta Trail", and "Morgan Hole" pastures to the north and "O-Q Range" to the south. The study area contained parts of these four management units that ranged from 309-1152 ha. Units were burned with a head fire (burned with the wind) and backfired (10-20 m) on leeward sides on a 2-3 year rotation between December and mid-March. All management units were grazed by cattle at 1 animal per 8.7-28.3 ha. Cattle used most units for $\leq$21-day periods followed by longer periods of exclusion. A second colony of grasshopper sparrows was located 11 km southeast of the study area. U.S. Air Force personnel conducted annual surveys for Florida grasshopper sparrows using methods similar to those described by Delany et al. (1985).

METHODS

Home Range Mapping

Ninety-nine grasshopper sparrows were marked from 21 March 1989 - 27 June 1992 with numbered, aluminum, U.S. Fish and Wildlife Service bands (size 1) and a unique pair of colored (red [R], blue [B], yellow [Y], mauve [M], pink [P], green [G], orange [O], stripe [S], white [W], and black [Z]), plastic leg bands (size XF). Color bands were placed on the right tarsometatarsus and read top to bottom to identify individuals (i.e., red over blue = RB). Capture methods are described by Delany et al. (1992) (Appendix 1). The sex of adult sparrows was determined during the breeding season (March-June) by the presence of a cloacal protuberance (male) or its absence and the presence of a brood patch (female). Age (juvenile or adult) was determined by plumage (Smith 1968). Subspecies were identified according to Mearns (1902). Weight was obtained with a 50-g Pesola spring balance calibrated in 0.5g intervals. Wing chord was measured to the nearest 0.5 mm with a ruler and end stop. Birds were released at the site of capture. Latitude and longitude coordinates of most banding locations were recorded from a portable LORAN-C. Capture locations also were plotted on large-scale (1:2,400) aerial photographs. Details such as saw palmetto patches, fences, ditches, and fire lines were explicit ground references and permitted accurate plotting (estimated to within 2 m). Observations of banded sparrows were made with a variable 20-45x spotting scope. Resightings and recaptures of marked sparrows over the course of the study also were used to detect movements, estimate survival, and determine locations outside the breeding season. Female grasshopper sparrows were secretive, and we recorded few observations. As a consequence, they were omitted from most of the analysis.

A sample of 30 home ranges was represented by 21 color-marked males. Sparrows were observed for 1- to 4-hour periods during all stages of the breeding cycle. Mating status was determined by the capture of a female within a territory or by the recurrent presence of a nonaggressive conspecific in consort with the male. Locations of undisturbed individuals were recorded at 5-minute intervals (during which time a sparrow could cross its home range) to reduce chances of autocorrelation (Swihart and Slade 1985a). Most individuals were visited weekly from April-June. Observations were made between sunrise and 1300. Individual home ranges, as defined by Burt (1943), were determined by recording locations (69-134, $\bar{x}$=84) on the aerial photographs. Locations were converted to Cartesian (x,y) coordinates by digitizing them on a Houston Instrument True Grid 8024 pad. Schoener ratios (Schoener 1981, Swihart and Slade 1985b) were calculated to test for independence between consecutive locations. Program Home Range (Ackerman et al. 1989) was used for 3 estimates of home range size: convex polygon (Southwood 1966), harmonic mean (Dixon and Chapman 1980), and Fourier transform (Anderson 1982).

Habitat Analysis

Eight features of the vegetation composition and structure were measured within home ranges of male grasshopper sparrows. The sampling scheme and calculations follow Whitmore (1981) and Delany et al. (1985). Measurements were made at point subsamples and 1-m^2 plots located at the center of the home range and 10 m from the center at each of the 4 cardinal directions. Point subsample measurements (5/home range) included height of the nearest saw palmetto and vertical density, the total number of vegetation contacts with a 7-mm diameter metal rod placed vertically into the vegetation; effective height was the highest contact recorded. The percentage cover (total vertical projection) by each of grasses, forbs, shrubs, litter, and bare ground was determined from measurements at 1-m subsections of a transect adjacent to point subsamples. Plant species occurrence was recorded in a 1-m^2 circular plot centered at each point subsample. Plant names follow Wunderlin (1982). Pastures were approximately 3, 12, or 24 months post-burn by the onset of grasshopper sparrow breeding. Samples are from 10 home ranges in each post-burn stage.

Data Analysis

Banding and resighting data on 53 male sparrows initially captured as adults were examined. We used program JOLLY (Pollock et al. 1990) to estimate the survival and capture probabilities of the Cormack-Jolly-Seber (CJS) mark- recapture model (Cormack 1964, Jolly 1965, Seber 1965). Adult mean life expectancy was calculated as -1/log (ϕ), where ϕ represents annual survival probability (Seber 1982:4).

Measurements of both wing chord and body weight were available for 25 males and 8 females. Bartlett's test was used to test whether variances of individual measurements (Steele and Torrie 1980: 471) or covariance matrices of measurement pairs (Morrison 1976) were homogeneous with respect to sex. Gender means of wing chord and body weight were compared with a t-test. A linear discriminant function (Johnson and Wichern 1982:466) was estimated assuming equal prior assignment probabilities and misclassification costs. For this small sample, we followed Lachenbruch's (1975) jackknifing procedure for unbiased estimation of misclassification rate.

The analysis of pasture management, vegetational structure and composition (physiognomy), and home range size proceeded in 2 steps. First, we determined whether the physiognomy of sampled points within home ranges responded to the effect of time (months) since burning. Next, we estimated the response of territory size (ha) to the effects of time post-burn and to that component of physiognomy not related to time post-burn. The models are represented as:

(1) physiognomy = post-burn + error(1)

(2) home range size = post-burn + error(1) + error(2),

where error (1) is that part of physiognomy that cannot be accounted for by time since burning. Error(2) is residual error for home range size after accounting for post-burn and error(1) variability.

For model (1), we used multivariate analysis of variance (MANOVA) to examine the effect of post-burn time (POSTBURN) on the 8 physiognomic variables. POSTBURN was treated as a factor with 3 discrete levels. All 5 subsamples of each home range were used in the analysis, but variance due to home ranges within treatment levels was used as the error term for hypotheses involving POSTBURN.

Total variance for the POSTBURN effect was decomposed into a linear contrast that tested the overall increase or decrease in the physiognomic variables with increasing post-burn time, and into a quadratic contrast that tested whether linear trends between successive time periods were constant. The physiognomic variable DENSITY was square-root transformed ($[\text{no. contacts} + 0.5]^{0.5}$) and ground cover compositional variables were arc-sine transformed ($\sin^{-1} [\% \text{ cover}/100]^{0.5}$) prior to analysis to achieve variance stability and approximate normality.

Prior to fitting model (2), we standardized all physiognomic variables (i.e., centered and scaled each variable to a mean of 0.0 and a standard deviation of 1.0) so they would be comparable with respect to measurement scale. We centered data values to POSTBURN means (i.e., subtracted from each the appropriate POSTBURN mean of standardized values) to remove the effect of post-burn time and averaged these values over all subsamples within each home range to obtain composite physiognomic values. The matrix of physiognomic values was factored into its principal components to assess multicollinearity among the variables and to find a small, independent, interpretable set of habitat components that accounted for most ($\geq$70%) of the variability in the 8 physiognomic variables. We plotted component loadings for each pair of components for interpretation.

Variability of home range size estimates was inconsistent among post-burn times, and estimates included possible outlying values. We rank-transformed 95% area values of territory size estimates provided by the minimum convex polygon (CP95), harmonic mean (HM95), and Fourier transform (FT95) methods. Analysis of ranks of data rather than data values themselves is analogous to the use of classical nonparametric methods, but the applications are easier and more flexible (Conover and Iman 1981).

Rank-transformed values of CP95, HM95, and FT95 were analyzed in a 1-way ANOVA with the 3-level POSTBURN effect. Linear and quadratic contrasts of rank means among levels of POSTBURN were tested. Scores for the 8 physiognomic factors were added as covariates to the ANOVA both individually in turn and simultaneously to test for additional variability due to physiognomic effects not related to post-burn time. No significant reduction in variability due to the addition of these components would indicate that no measurable influence of physiognomy, apart from that determined by post-burn time, on home range size. We also tested for a difference in mean ranks of home range size with respect to mating status for each estimation method of home range size.

Pastures under a single post-burn time varied year to year, and we assumed that physiognomic characteristics within a post-burn level were consistent with respect to pastures and years. We also assumed that home ranges set up by the same bird in a single pasture during different years (i.e., different times post-burn) constituted independent samples.

RESULTS AND DISCUSSION

Banding

Based on breeding behavior and plumage characteristics (Mearns 1902), 73 banded grasshopper sparrows were identified as floridanus (Fig. 3). These included 53 males, 17 females, and 3 juveniles of undetermined sex. Breeding activity (singing) was observed as early as 4 March and most pair formation was completed by 1 April.

Grasshopper sparrows were monogamous. Vocalizations and displays were similar to those described by Smith (1959), except that no aerial songs were observed. Males captured by 15 March had a conspicuous cloacal protuberance, and females had brood patches by 25 April. Juveniles (YW, MW, and GW) were banded between 6-26 June and estimated to be about 20 days old. Singing decreased during June, and the breeding season appeared to terminate by July. Study methods did not appear to adversely influence breeding grasshopper sparrows. Observations of breeding chronology reported here generally agree with data from oological collections (reviewed by McNair 1986). No information was obtained on breeding success.

Five ticks were found on 3 grasshopper sparrows (3% prevalence). Two Gulf coast tick (Amblyomma maculatum) nymphs (Rocky Mountain Laboratory, No. 119585) were removed from an adult male Florida grasshopper sparrow (RM) on 19 April 1989. Two bird tick (Haemaphysalis chordeilis) nymphs were removed from WR, and a larva was removed from WM (National Veterinary Services Laboratories, No. T1403) on 13 February 1992. The sex and subspecies of WR and WM were not determined.

Tick neurotoxins may cause paralysis and death in some passerines (Pitts and Hayes 1990), however, it is not known if this is a significant source of mortality in wild populations. Although toxin is present in the saliva of the Gulf coast tick (D. J. Forrester, Univ. Fla., pers. commun.), the Florida grasshopper sparrow host appeared to be in good health.

Appendix 2 lists banding information for grasshopper sparrows. Four sparrows lost $\geq$ one plastic band. All were recaptured and the bands replaced. Pink bands faded 2 months after application and were difficult to identify.

Incidental mist net captures included bobwhite quail (Colinus virginianus), sedge wren (Cistothorus platensis), yellowthroat (Geothlypis trichas), Eastern meadowlark (Sturnella magna), red-winged blackbird (Agelaius phoeniceus), rufus-sided towhee (Pipilo erythrophthalmus), savannah sparrow (Passerculus sandwichensis), Henslow's sparrow (Passerherbulus henslowii), and Bachman's sparrow (Aimophila aestivalis). There was no net mortality.

Morphometrics.—Normal probability plots and bivariate scatterplots (Fig. 4) suggest that sparrow body measurements followed univariate and bivariate normal distributions. Tests of variance homogeneity were not rejected for variables individually ($P \geq 0.237$) or for the variable pairs ($P = 0.702$). Thus, variance information could be pooled over sexes. Wing chord and weight were highly distinguished by sex (Table 1, Fig. 4).

The estimated discriminant function was

$$y = 106.169 - 2.12403 \text{ chord} + 1.11419 \text{ weight}.$$

If the sample means represent the population means for gender, an individual would be classified as female for values of $y \geq 0$ and as male otherwise. The probability of any measurement pair being correctly classified as female is determined by

$$P_f = \exp(y)/[1 + \exp(y)].$$

Twelve percent of the males (3 of 25) and 12.5% of females (1 of 8) were incorrectly classified (Fig. 4), producing an average 12.3% misclassification rate.

Similar phenotypical differences in measurements between sexes have been reported for other sparrows (Werner 1975, Piper and Wiley 1991). Measurements of Florida grasshopper sparrow wing length were somewhat shorter than those reported by Mearns (1902) (♂ = 63 mm, n=1; ♀ = 61 mm, n=2). Caveats concerning the measurement and interpretation of body sizes of birds (Clark 1979, Rising and Somers 1989) certainly apply to our data.

Survival and longevity.—The CJS model provided a good fit to the adult male sparrow data ($\underline{P}$ = 0.375). Survival and capture (resighting) rates did not vary over the course of the study (P = 0.153), thus years could be pooled to obtain greater precision in the estimates.

Adult survival rate (0.59) for male Florida grasshopper sparrows (Table 2) was at the upper range reported for adult passerines (Lack 1954, Ricklefs 1973). Because migration can contribute to mortality (Breitwisch 1989), we expected a higher annual survival rate in this resident population. Sources of mortality were not determined. The mean life expectancy for sparrows $\geq$1 year old (Table 1) approached the 3.08 year longevity record reported for the species (Klimkiewicz and Futcher 1987). One individual banded (No. 902-63010) as an adult on 18 April 1989 and resighted on 28 June 1992, exceeded the longevity record by $\geq$1 year. Because male Florida grasshopper sparrows were highly sedentary and easy to locate during the breeding season, we believe our estimates of survival and longevity are accurate.

Assuming fledgling survival rate is 25% of adult survival (Wray et al. 1982), an annual recruitment of 5.4 fledglings per pair is needed to maintain a stable population (see Ricklefs 1973:399) of grasshopper sparrows at this location. The species is double-brooded (Smith 1968), and annual productivity can reach 10.9 young per pair(Wray et al. 1982). Mean clutch size estimated from oology slips for 51 Florida grasshopper sparrow egg sets was 3.71 (McNair 1986). The relatively high survival rate and longevity of adult Florida grasshopper sparrows, together with high reproductive potential, may facilitate the recovery of populations remaining in good breeding habitat (see Delany et al. 1985). However, continued habitat loss will further isolate sedentary populations and jeopardize those that depend on immigration for stability.

Habitat

Dominant plant species and compositional differences in the floristics of the 3 post-burn stages were noted (Table 3). Home ranges did not include trees, and sparrows avoided areas of even widely scattered pines (<1 tree/ha).

Individually, all variables except percent shrub cover were strongly influenced by post-burn time (Table 4, Fig. 5). Means of shrub height, vegetation height, vegetation density, percent grass, and percent litter all increased with post-burn time. Means of percent forbs and percent bare ground both decreased with post-burn time. The trends were linear except for the height variables; mean height increases between 12 and 24 months post-burn were not as great as increases between 3 and 12 months.

Time since burning strongly influenced the ensemble of physiognomic variables (Wilks' λ = 0.065; 16, 40 df; $\underline{P}$ < 0.001). Most (87%) of the total variation of the burn effect was in positive differences in means of shrub height, density, percent litter, and vegetation height (in order of importance) and in a negative difference in means of percent forbs, a result consistent with the univariate contrasts.

We detected a moderate degree of multicollinearity among composite physiognomic values within burning time regimes (condition index = 9.1, Rawlings 1988:276), suggesting that associations between physiognomy and home range size may be unreliably depicted if these values are used as covariates. Cumulative proportions of physiognomic variability accounted for by principal components 1-6 were 31%, 53%, 68%, 82%, 90%, and 96%, respectively. Specific physiognomic variables were strongly associated with the first 3 principal component axes and thus enabled interpretations of these components. Component 1, which placed great positive weights on density and vegetation height, intermediate positive weight on percent grass cover, and intermediate negative weights on shrub height, percent litter cover, and percent shrub cover, may have indicated overall vegetation density. The second component, overall vegetation cover, had intermediate positive loadings on percent shrub and grass cover and a great negative loading on percent bare ground. The third component was heavily weighted by percent forb cover and probably represented forb availability. Components 4-8 could not be interpreted.

Florida grasshopper sparrow distribution is closely associated with the dry prairie plant community (Fig. 1), which historically may have been maintained by recurrent lightning fires. The original habitat of floridanus was considered atypical for the species because the sparrow seemed to prefer saw palmettos and dwarf oaks to "grassy areas" (Howell 1932). Because of possible climatic restrictions (McNab and Edwards 1980), saw palmetto does not occur within the range of other grasshopper sparrows. Compared to the eastern race (A. s. pratensis) (see Whitmore 1981), habitat used by floridanus was similar in the proportion of grass cover. The subspecies apparently finds habitat conditions produced by range management on the study area acceptable.

Movements

Most (21) resighted or recaptured males occupied the same home ranges (breeding territories) during successive years. Sparrows were usually within 50 m of their original capture site. One male occupied the same home range for 4 consecutive years, and six occupied the same home ranges for 3 consecutive years. Four males reoccupied a home range following absence for a year. After an intervening fire, locations of 11 males corresponded generally with locations the previous year. Male MW moved 2.0 km, the longest observed movement, from his natal site to a territory the following spring. Information on natal dispersal is limited to this individual. Other movements outside the previous year's home range were by males GY (183m), MP (366m), and BM (570m). GY and MP were unmated prior to moving. The mating status of BM was undetermined. BM and GY established new breeding territories on sites vacated by males RM and SS, respectively. MP and MW established breeding territories on previously unoccupied sites. Between 18-28 June 1992, PW moved 549 m from that year's breeding territory and winter location in the Delta Trail Pasture to O-Q Range where he was observed singing and attempting to displace an unbanded male. PW was the only sparrow to move to a location that was at a different post-burn stage (12 to 3 months). There was no evidence of population exchange with the nearest known colony. All observed sparrow movements occurred within the colony area and across prairie habitat. Trees may have an isolating influence on Florida grasshopper sparrows. Sparrow movements demonstrated no obvious response to the burning schedule. However, observations of settlement by new (unbanded and probably 1-year-old) sparrows were more frequent on pastures 3 months post-burn. Dispersing juveniles may settle preferentially in areas recently burned

Sparrows were captured in the Delta Trail Pasture during 357 net-hours (total hours x 18.3-m sections of mist net) between 20 November-13 February to determine locations outside the breeding season. Of 27 unbanded grasshopper sparrows captured, 14 were overwintering pratensis, 8 were probably floridanus, and 5 were an undetermined subspecies. Two banded Florida grasshopper sparrows were captured on 23 January 1992. PW was recaptured 15 m east of his 17 April 1992 banding location, and PZ was recaptured 135 m west of his 22 April 1991 banding location. Both were breeding adult males on territories when originally banded. WY was banded (subspecies and sex undetermined) on 13 February 1992. This individual was recaptured on 10 June 1992 in O-Q Range 274 m southwest of its original location and identified as a breeding male floridanus. Males apparently remain on the breeding territory throughout the year. Prior evidence that the subspecies was nonmigratory was limited to 2 specimens (USNM, Nos. 341353 and 341455) collected in Osceola County in January 1937 and identified as floridanus (R. B. Clapp, U.S. Natl. Mus., pers. commun.).

Home Range

Home range during the breeding season was the defended territory that contained all sparrow activity. Territories were maintained by singing from perches near the perimeter. Singing occurred throughout the day but was more frequent from sunrise to 0900 hours and for about 15 minutes before sunset. Singing was usually responsitory, and there were few observations of intraspecific aggression. Resident males were successful in removing conspecific intruders with an aerial chase. Red-wing blackbirds and eastern kingbirds (Tyrannus tyrannus), however, temporarily supplanted some grasshopper sparrows at singing perches. Grasshopper sparrow home range boundaries were stable throughout the breeding season. There was little overlap, and most adjacent home ranges were separated by $\geq$30 m. Home range boundaries of Florida grasshopper sparrows near trees were $\geq$75 m from edges of cypress domes or pine plantations. Home ranges were not uniformly distributed within the study area with some areas occupied more consistently. Territorial aggregations within the colony (e.g., Fig. 6) may be related to features of the habitat or may reflect a social tendency of the species. Most new males (ZM, WY, ZY, and unbanded individuals) established territories between resident males or on the edge of a breeding aggregation (Fig. 6).

Elevated singing perches were an important structural feature of the vegetation for grasshopper sparrows and delineated most home range boundaries. Territorial males were usually prominently exposed on dead stems of staggerbush (Lyonia fruticosa) and tarflower (Befaria racemosa) which were $\leq$0.9 m higher than the surrounding vegetation. Similarly, home range boundaries often included parts of a fence line (fenceposts and fence wires) or the shrub edge of a pond.

Sizes (100% CP) of 30 home ranges (Appendix 3) averaged 1.77 ha (SD:0.96) and ranged from 0.51 - 4.82 ha. The median home range size was 1.56 ha. The average home range size was larger than estimates reported for A. s. pratensis in Wisconsin (0.81 ha) (Wiens 1973b), Pennsylvania (0.82 ha) (Smith 1963), and Iowa (1.38 ha) (Kendeigh 1941). Schoener (1981) ratios calculated for each sparrow indicated that locations were not independent ($t^2/r^2 \leq 1.05$). Many successive locations were an iteration of perch use and autocorrelation probably cannot be avoided. Except for FT95 (P = 0.160), rank-transformed home range size increased linearly with post-burn time ($P \leq 0.027$, Table 5, Fig. 7). There was no evidence that trends were curved ($P \geq 0.28$, Table 5). No set of residual physiognomic factor scores added to the ANOVA model either individually (CP95: $P \geq 0.299$; HM95: $P \geq 0.060$; FT95: $P \geq 0.243$) or simultaneously (CP95: $P = 0.982$; HM95: $P = 0.288$; FT95: $P = 0.898$) provided a significant reduction in variance for any home range size variable. Wiens (1973b) also found that, within one treatment, no single vegetation feature was related to the territory size of pratensis. For all estimates for floridanus, the mean rank of home range size of mated males ($n = 25$) was greater than that of unmated males ($n = 5$), but the difference was significant only for the FT95 estimate ($P = 0.011$; $P = 0.159$ for CP95 and $P = 0.429$ for HM95).

Variation in territory size may reflect food availability (Brown 1964, Schoener 1968). During the breeding season, the diet of grasshopper sparrows consists of insects and other invertebrates, with grasshoppers (Acrididae) being the most important food (Howell 1932, Wiens 1973a, Wiens and Rotenberry 1979, Joern 1988). Evans (1984) found that as prairie sites diverge in fire history, they diverge also in grasshopper assemblages. Changes in vegetation density also may affect the foraging ability of ground-dwelling birds (Whitmore 1981, Cody 1985:195). Variation in home range size among Florida grasshopper sparrows may be a spatial response to the relative abundance and availability of food. Some variation could be related to different "topographies" presented by singing perches (Reid and Weatherhead 1988).

Population Density.—Annually 26-43 territories ($\bar{x} = 34.75$) were located on the study area (0.05 territories/ha) (D. R. Progulske, U.S. Air Force, pers. commun.) Single survey counts, however, included only 60% of the known territories in some pastures. Our adjusted estimate of population density on the study area was 0.08 territories/ha. Florida grasshopper sparrow density was much lower than ranges reported for pratensis (0.12-0.93/ha) (Goode and Dumbach 1943, Johnston and Odum 1956, Wiens 1973b, Whitmore 1979a, Wray et al. 1982, Frawley and Best 1991) and A. s. ammolegus (9-14 individuals/2.5 ha) (Bock and Webb 1984). Relatively low densities (0.04 territories/ha) of Florida grasshopper sparrows were also discovered in a colony 22 km northeast of the study area (P. B. Walsh, unpubl. rep. Fla. Game and Fresh Water Fish Comm.). Sparrows in that colony were more dense (0.08 territories/ha) on areas 6-7 months post-burn, and less dense (0.02 territories/ha) on areas >43 months post-burn.

The relatively low densities of floridanus may reflect the overall habitat quality for the species in Florida. We speculate that contraction and expansion of home range sizes and that dispersal of juveniles within a colony cause changes in population densities in some pastures.

CONCLUSIONS

We found that Florida grasshopper sparrow habitat included a wide range of physiognomic and floristic characteristics consistent with the known preferences and natural history of the species (sources cited above). Time since burning was strongly associated with physiognomic characteristics and home range size. As time post-burn increased, sparrow home ranges were larger and characterized by taller and denser vegetation, greater coverage by litter and grass, and decreasing coverage by forbs and bare ground. Rates of change in most physiognomic components became slower over time. Frequent burning encouraged habitat compositions associated with greater densities of grasshopper sparrows in this population. Grasshopper sparrows may alter home range size in response to habitat manipulation and ensuing changes in prairie vegetation. These relationships however, do not necessarily imply cause and effect in terms of population changes. Underlying ecological explanations are unclear but may be related to food resource abundance and availability. Stochastic variation in population size also may influence grasshopper sparrow density and home range size. When subjected to prevailing range management and within the temporal boundaries of this study, grasshopper sparrow habitat was not ephemeral.

We found that adult Florida grasshopper sparrows were highly sedentary and observed no movements that were clearly associated with features of the habitat or range management. Study results and information obtained from other colonies in Florida do not support the hypothesis that individual sparrows move from pasture to pasture as habitat improves or deteriorates (Delany and Cox 1986).

Evidence provided here indicates that the subspecies is nonmigratory. Measures of wing length and body weight were good indicators of gender. Estimates of survival and assumptions of productivity indicate that annual recruitment of 5.4 fledglings per pair is needed to maintain a stable population of grasshopper sparrows on the study area.

MANAGEMENT AND RESEARCH IMPLICATIONS

Most sites occupied by Florida grasshopper sparrows are currently managed for cattle (Delany et al. 1985, Delany and Cox 1986), and burning is the most common practice used by south Florida cattlemen to improve their pastures (Lewis 1964). Burning also is used as a wildlife management tool where prairie occurs on public property. Burning causes immediate and significant changes in prairie physiognomy and floristics, and successional changes after the exclusion of fire also are rapid (Delany et al. 1985, this study). How Florida grasshopper sparrows respond to these temporal and spatial variations in habitat have important management implications. The Florida subspecies is a little-known grasshopper sparrow, and basic ecological information is needed before management options can be assessed (U. S. Fish and Wildlife Service 1988). Results from this study provide preliminary information that may be useful in managing grasshopper sparrow populations in Florida.

Suitable habitat for floridanus is localized and the known population occurs in 11 widely distributed and apparently isolated colonies (Delany and Cox 1986, Fla. Game and Fresh Water Fish Comm., unpubl. data). A specific conservation plan should be developed and implemented for each colony. Land use trends at occupied sites indicate continued habitat loss for the subspecies, as dry prairie is converted to improved pasture and farmland (Delany and Cox 1986). The sparrow may be slower to follow a shifting resource and more susceptible to habitat loss than more mobile (migratory) subspecies. Management of the sparrow should provide permanent areas of suitable habitat and maximize the density (and success) of breeding pairs. Compared to other grasshopper sparrows, densities may remain low, even under the best possible conditions. Because the dispersal ability of Florida grasshopper sparrows appears limited, management efforts should be concentrated at existing locations and adjacent areas (within 2 km). Management should accommodate the year-round needs of this resident sparrow.

Approximately 1.77 ha (mean home range estimate) of prairie habitat should be allocated to sustain a breeding pair. A 30 m buffer between pairs and 75 m around unsuitable habitat should be provided. Thus, the recovery plan (U. S. Fish and Wildlife Service, 1988) objective of a minimum viable colony of 50 breeding pairs would seem to require 164 ha of contiguous habitat. Home range size varied however, and "average values" should be viewed with caution (Wiens et al. 1985). Based on known population densities, > 600 ha may be needed. Pasture use indicates that a minimum of 50 ha of grassland may be required to qualify as potential habitat for floridanus (pers. observ.). Areas of critical habitat could be designated under some range management conditions (see below).

We encourage range managers to provide a low (<70 cm), sparse (<10% cover) growth of saw palmetto and shrubs. The grass and forb layer should contain ≥20 percent bare ground. Sites should be treeless. Intensive pasture improvements for cattle that remove all saw palmettos and native grasses may eliminate potential nest sites for the subspecies (Delany et al. 1985). Whitmore and Hall (1978) found that pratensis was adapting to reclaimed surface mines in West Virginia. Topsoiling, transplanting, and direct seeding of native plant species appears to be a viable and affordable method of restoring native prairies in Florida (Callahan et al. 1990) and may be a management tool for expanding potential habitat near some colonies.

Periodic fire is needed to maintain habitat. We recommend prescribed fire on a 2-3 year rotation. More frequent fires may temporarily benefit the sparrow by providing more open substrate, but consequent changes in the prairie plant community may have long term, detrimental effects. Reduced grasses and forbs have been observed on annually burned experimental plots on the study area (S. Penfield, U.S. Air Force, unpubl. data). Less frequent fires may allow the vegetation to reach a dense successional stage unusable by grasshopper sparrows. There is no evidence that smaller (<309 ha) prescribed fires on the study area would benefit the sparrow. Current patterns burn approximately 30 percent of the colony area annually and probably provide adequate refuges for temporarily displaced sparrows. Burning should occur between August and February to avoid the nesting period. Although Florida grasshopper sparrows probably evolved under conditions induced by seasonal (late spring-early summer) lightning fires, the current population may not be sufficiently large or widespread to withstand significant nest loss and maintain equilibrium.

Intervening trees should be removed from occupied pastures to increase potential habitat and prevent the isolation of sparrows. Establishment of pine plantations on native grasslands is discouraged. Florida grasshopper sparrows appear to tolerate current levels of military activity and low stocking rates of cattle on the study area. Grasshopper sparrow surveys should continue in order to monitor management efforts.

Florida grasshopper sparrow response to range management to improve nesting habitat (U.S. Fish and Wildlife Service 1988) may be slow and difficult to predict (see Wiens et al. 1986). Survival is an important component of the population characteristics often used to monitor endangered species (Dobson 1990:115). Preliminary information on the population dynamics of Florida grasshopper sparrows presented here may be helpful in evaluating recovery efforts.

The recovery plan (U.S. Fish and Wildlife Service 1988) provides for a captive breeding program if the population continues to decline. Pending recovery, the identification of sex of individual grasshopper sparrows outside the breeding season (when external characters are absent) may be important. We provide an alternative method of separating sex classes.

A similar banding study should be replicated for other colonies to make general statements about the efficacy of burning. Information on Florida grasshopper sparrow breeding biology is needed to fully assess habitat quality and determine if the sparrow is benefitting from management. Variation in home range size, vegetation structure, and food resources may have important consequences for breeding success and population stability. Information is needed on the winter ecology of the resident form and the impact of what appeared to be a high density of migratory sparrows. Pulliam and Parker (1979) found that resident grasshopper sparrows (A. s. ammolegus) were sometimes winter-food limited.

Our adjustments to survey counts should be verified. A correction factor may provide more accurate population estimates for Florida grasshopper sparrows and be an alternative to survey replications. Techniques and equipment developed during this study (Delany et al. 1992) may facilitate other work.

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Table 1. Comparison of body measurements of adult Florida grasshopper sparrows by sex, during the breeding season (March-June), 1989-1992, on the Avon Park Air Force Range, Highlands County, Florida.

	Female ($n=8$)		Male ($n=25$)			
Variable	$\bar{x}$	se	$\bar{x}$	se	t	P
Wing chord (mm)	57.88	0.30	60.74	0.25	6.06	<0.001
Weight (g)	18.38	0.39	17.17	0.21	2.83	0.008

Table 2. Estimates of survival, life expectancy, and capture (resighting) probability of color-marked adult male Florida grasshopper sparrows, Avon Park Air Force Range, Highlands County, Florida, 1989-1992.

	Survival rate		Adult mean life	Capture probability	
Year	ϕ	se (ϕ)	expectancy	p	se (p)
1989	0.437	0.100	1.21		
1990	0.668	0.146	2.48	0.868	0.121
1991				0.650	0.157
mean	0.552	0.085	1.68	0.759	0.199
pooled	0.598	0.066	1.95	0.770	0.093

Table 3. Frequency of occurrence (>10%) for plants at 30 Florida grasshopper sparrow home ranges in pastures at three post-burn stages. Avon Park Air Force Range, Highlands County, Florida, 9 May - 22 June. *n* = number of sample plots.

Species	3 months post-burn (*n*=50)	12 months post-burn (*n*=50)	24 months post-burn (*n*=50)	Percent Frequency (*n*=150)
pineland threeawn (*Aristida stricta*)	96.0	98.0	98.0	97.0
Dicanthelium (*Dicanthelium acuminatum*)	86.0	80.0	88.0	84.7
bog-buttons (*Lachnocaulon minus*), and hat pins (*Eriocaulon decangulate*)	84.0	82.0	78.0	81.3
dwarf-oak (*Quercus minima*)	92.0	72.0	80.0	81.3
yellow-eyed grass (*Xyris* spp.)	88.0	78.0	76.0	80.7
blustems (*Andropogon* spp.)	68.0	28.0	46.0	47.3
gopher apple (*Licania michauxii*)	48.0	42.0	12.0	34.0
dog fennel (*Eupatorium recurvans*)	38.0	28.0	20.0	28.7
pawpaw (*Asimina reticulata*)	10.0	18.0	26.0	27.0
beakrush (*Rhynchospora* spp.)	28.0	18.0	28.0	24.7
meadow beauty (*Rhexia* spp.)	38.0	10.0	12.0	20.0
saw palmetto (*Serenoa repens*)	10.0	12.0	36.0	19.3
St. Johns-wort (*Hypericum* spp.)	12.0	10.0	28.0	16.7
deer-tongue (*Carphephorus paniculatus*)	20.0	10.0	8.0	12.7
grass-leaved golden aster (*Heterotheca graminifolia*)	32.0	2.0	4.0	12.7
bachelor buttons (*Polygala* spp.)	10.0	16.0	6.0	10.7
robins's plantain (*Erigeron vernus*)	20.0	10.0	2.0	10.7
staggerbush (*Lyonia* sp.)	6.0	8.0	18.0	10.7

Table 4. Univariate results of the effect of time since burn on physiognomic variables measured at Florida grasshopper sparrow home ranges, March - June, 1989-1992, on the Avon Park Air Force Range, Highlands County, Florida.

	POSTBURN	Linear Contrast		Quadratic Contrast	
Variable	P	Direction	P	Direction	P
Shrub ht.	<0.001	+	<0.001	-	<0.001
Veg. ht.	0.001	+	0.001	-	0.076
Density	<0.001	+	<0.001	-	0.184
% Shrub	0.995	-	0.995	-	0.922
% Grass	<0.001	+	<0.001	+	0.717
% Forb	0.006	-	0.002	-	0.842
% Litter	0.001	+	<0.001	-	0.608
% Bare	<0.001	-	<0.001	-	0.690

Table 5. ANOVA results of Florida grasshopper sparrow rank-transformed home range estimates with respect to post-burn time on the Avon Park Air Force Range, Highlands County, Florida, 1989-1992.

		CP95		HM95		FT95	
Source	df	SS	P	SS	P	SS	P
POSTBURN	2	634.4	0.011	382.2	0.081	216.8	0.254
Linear	1	561.8	0.005	378.5	0.027	156.8	0.160
Quadratic	1	72.6	0.280	3.8	0.818	60.0	0.380
error	27	1613.1		1865.3		2030.7	

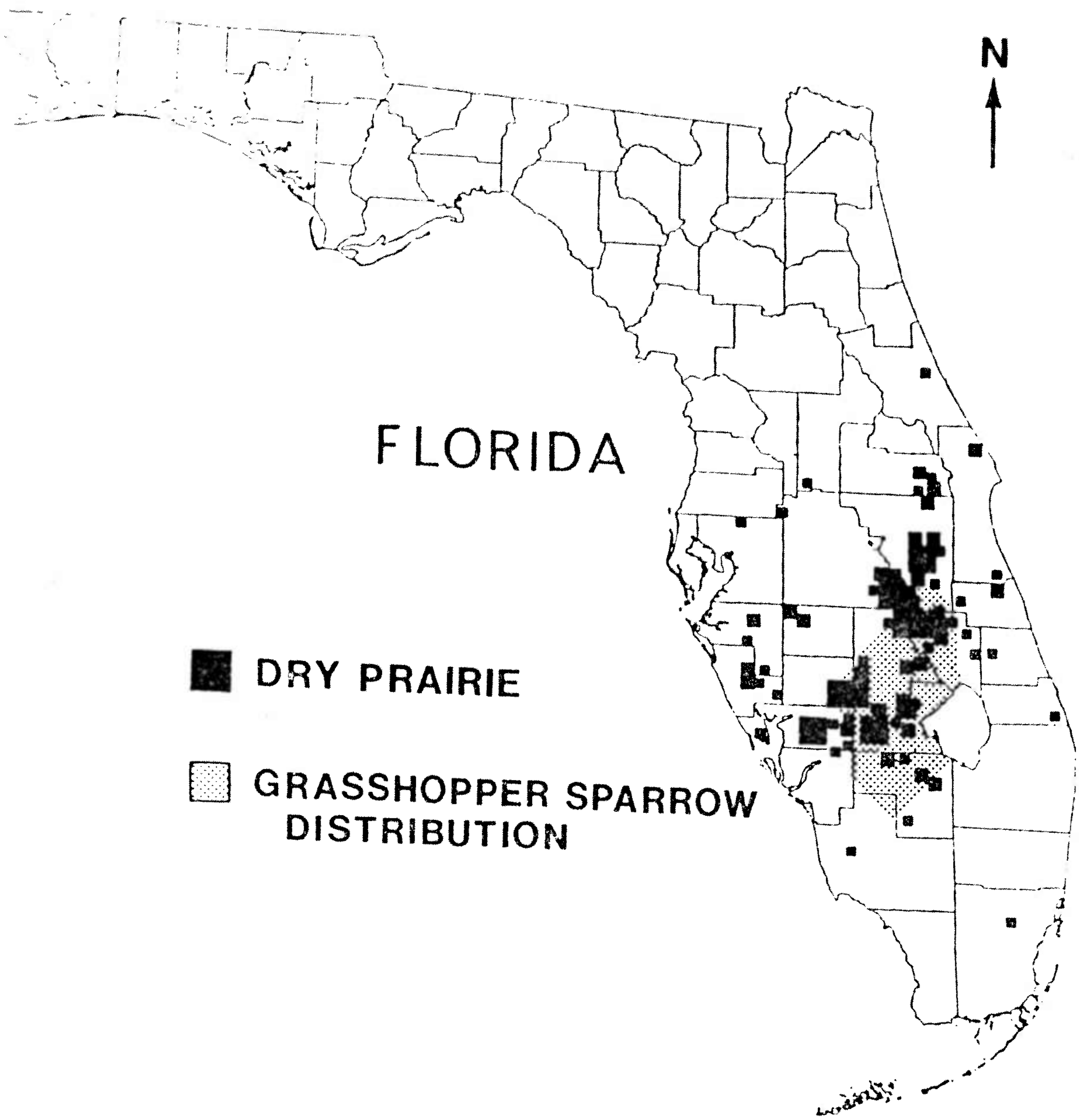

Fig. 1. Major areas of dry prairie land cover in Florida (1988 Landsat data) and Florida grasshopper sparrow distribution.

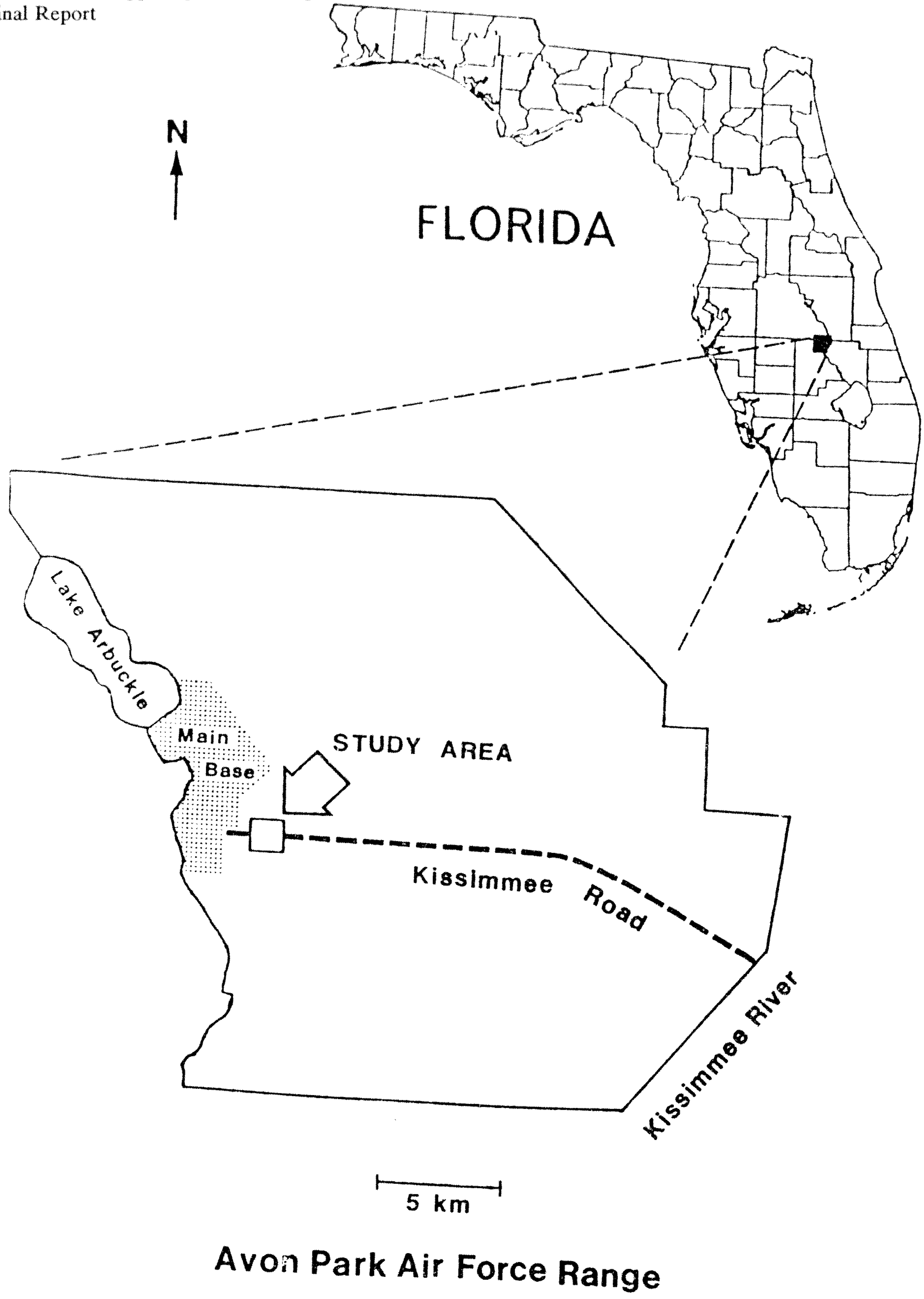

Fig. 2. Study area location on the Avon Park Air Force Range, Higlands and Polk counties, Florida.

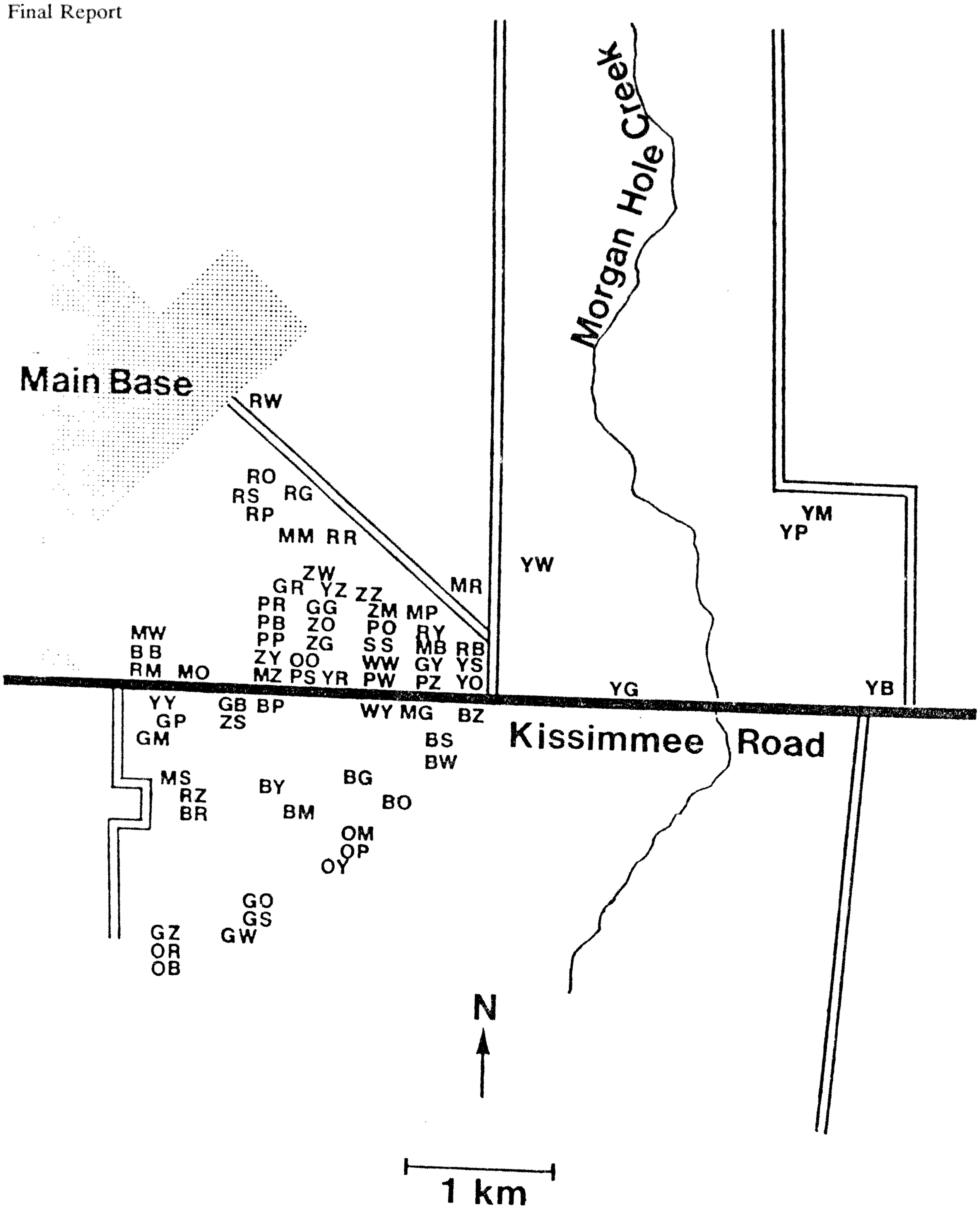

Fig. 3. Banding locations of color-marked Florida grasshopper sparrows on the Avon Park Air Force Range, Highlands and Polk counties, Florida, 1989-1992. Color codes of leg band pairs, read top to bottom to identify indivduals were: red (R), blue (B), yellow (Y), mauve (M), pink (P), green (G), orange (O), stripe (S), white (W), and black (Z).

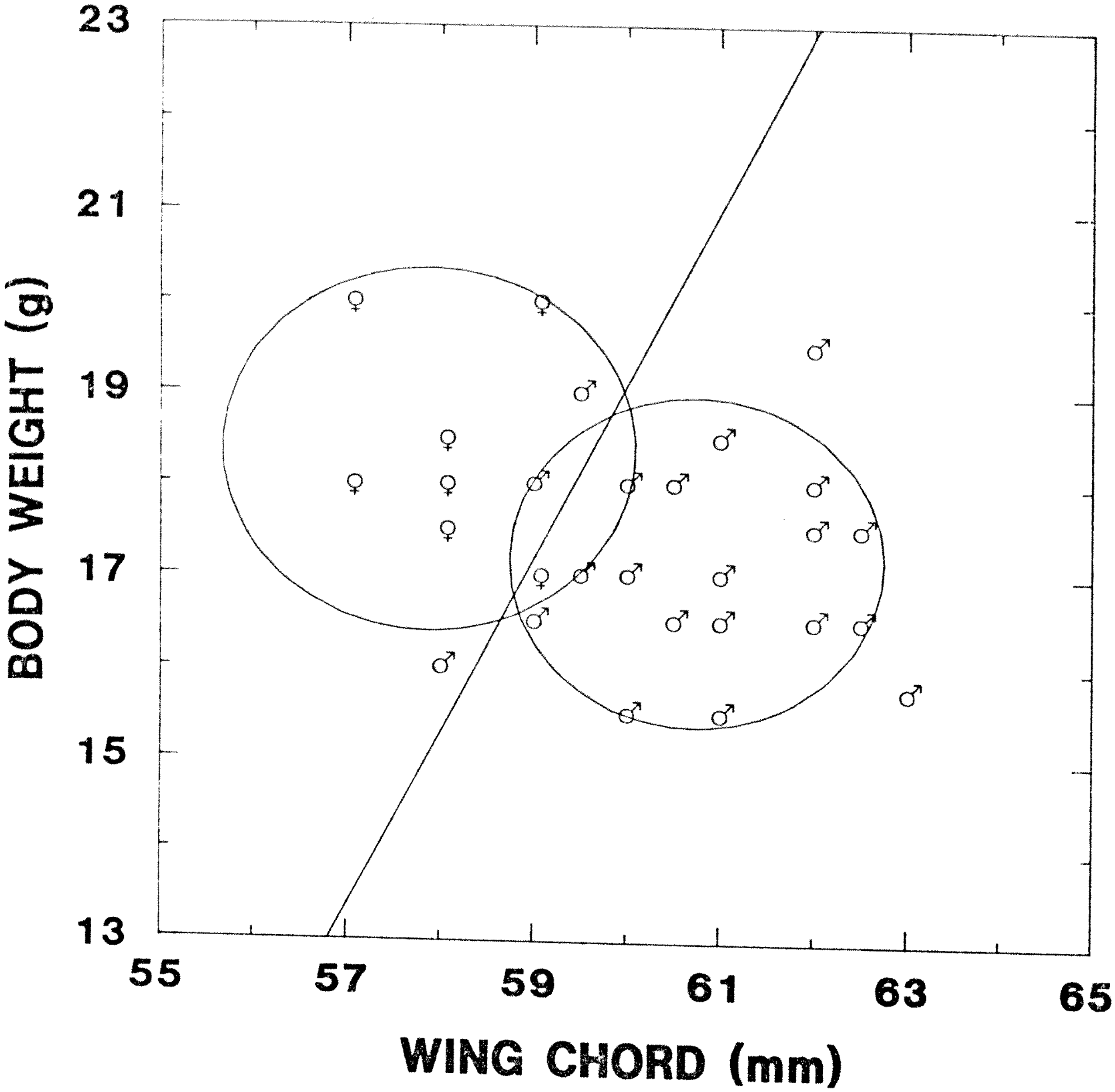

Fig. 4. Body weight (g) relative to wing chord (mm), by sex, with 50% prediction ellipse for adult Florida grasshopper sparrows on the Avon Park Air Force Range, Highlands County, Florida 1989-1992. Line represents weight and wing chord values yielding equal male/female classification probabilities.

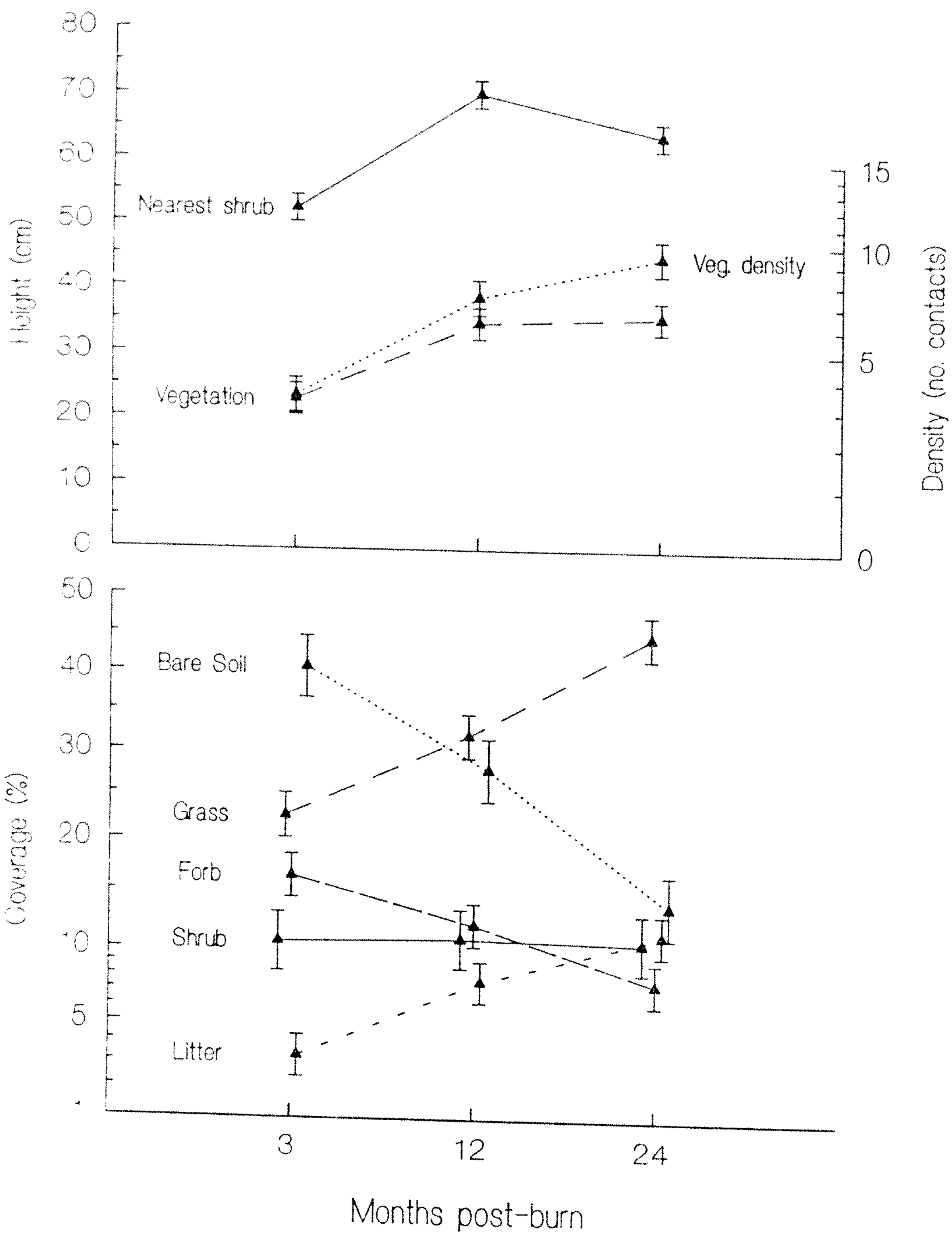

Fig. 5. Mean and standard error of physiognomic components on pastures at varying intervals since burning on the Avon Park Air Force Range, Highlands County, Florida, 1989-1992. Symbols representing percent cover means are staggered around time interval values for clarity.

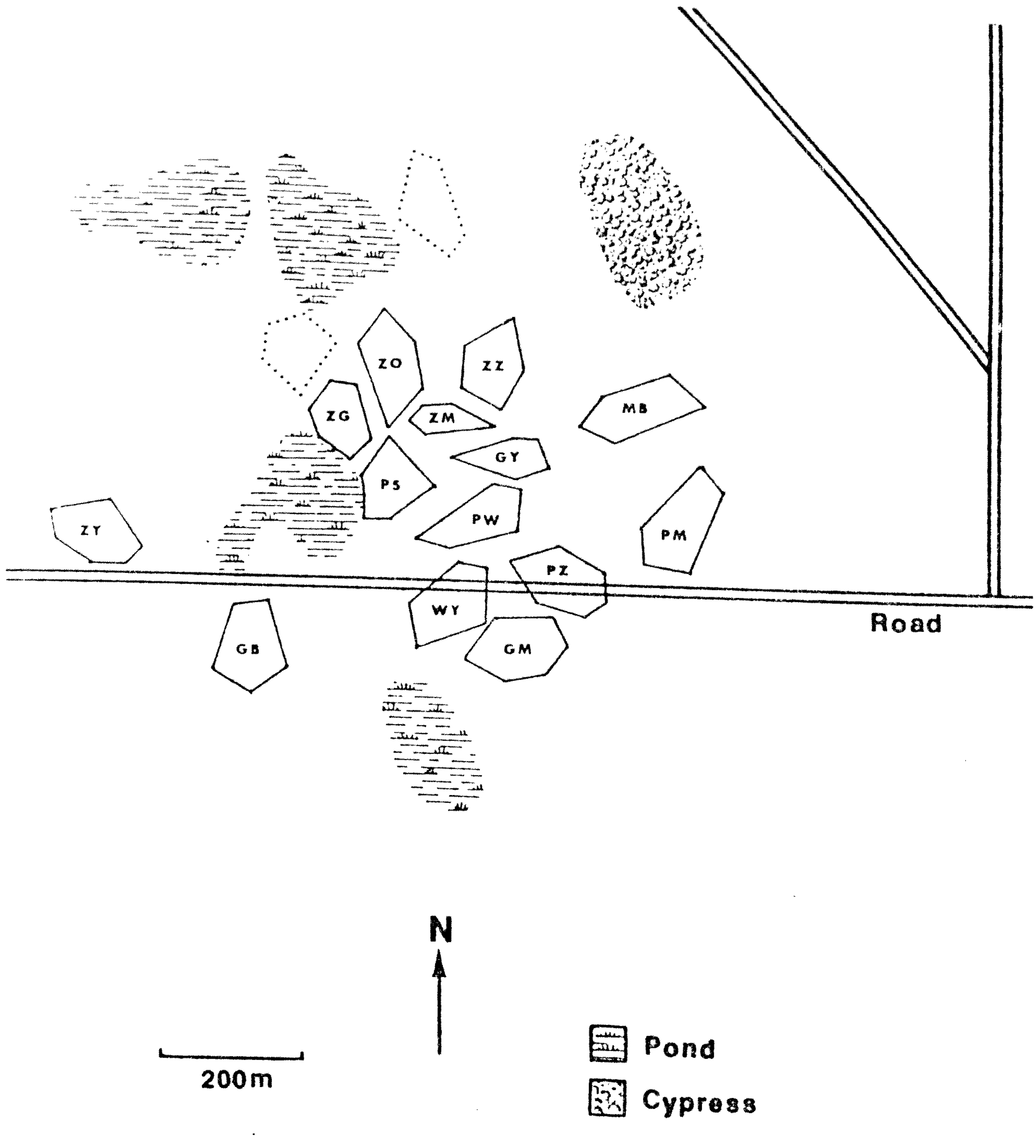

Fig. 6. Map of Florida grasshopper sparrow home range distribution along Kissimmee Road, Avon Park Bombing Range, Highlands County, Florida, March- June 1992. Dotted lines are approximate (unplotted) home ranges of unbanded males.

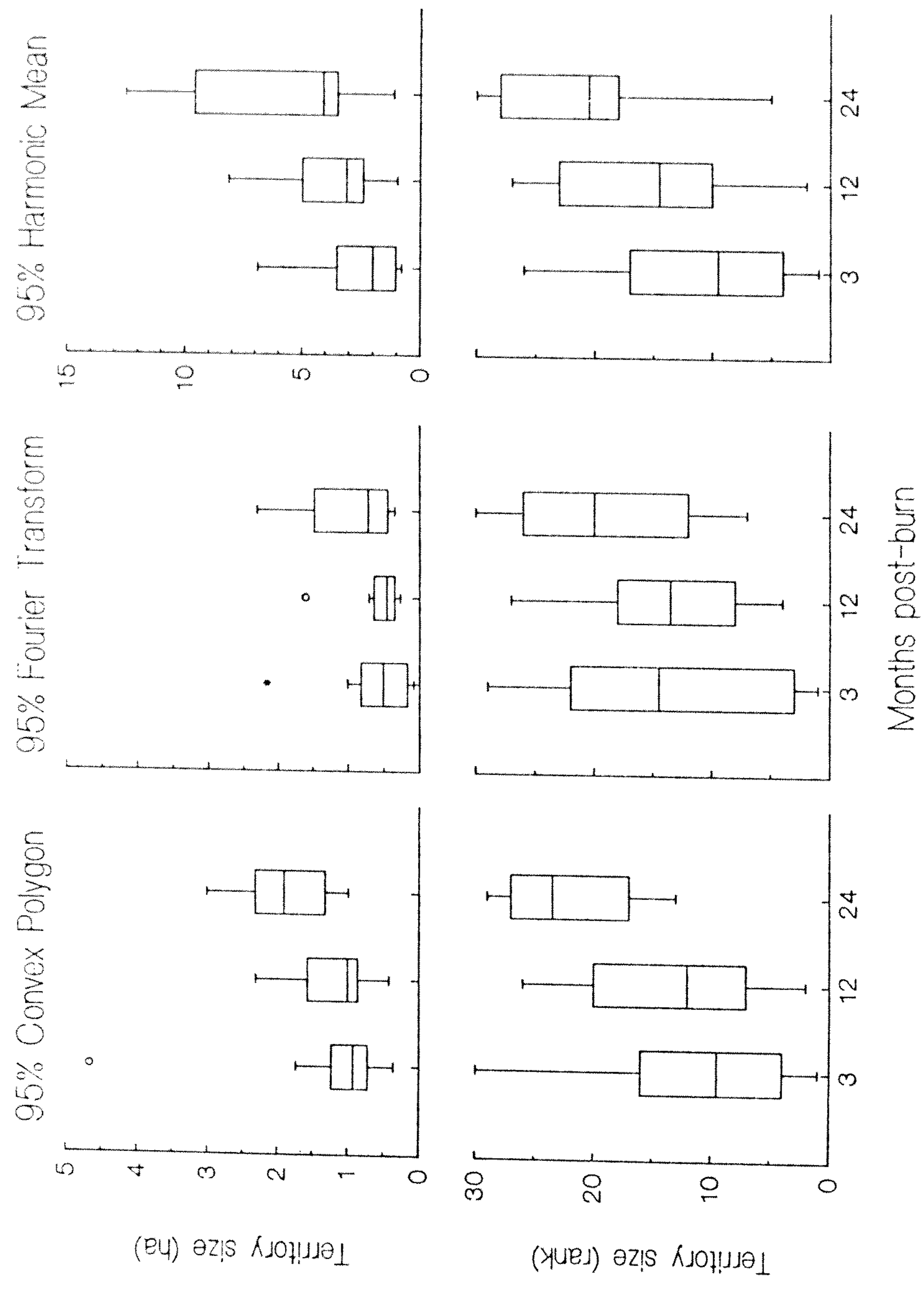

Fig. 7. Box plots of Florida grasshopper sparrow home range size (ha, top) and ranks of size (bottom) at varying intervals since burning (n = 10 per interval), on the Avon Park Air Force Range, Highlands County, Florida, 1989-1992, for 3 home range calculation methods. Note scale change for 95% harmonic mean (top right).

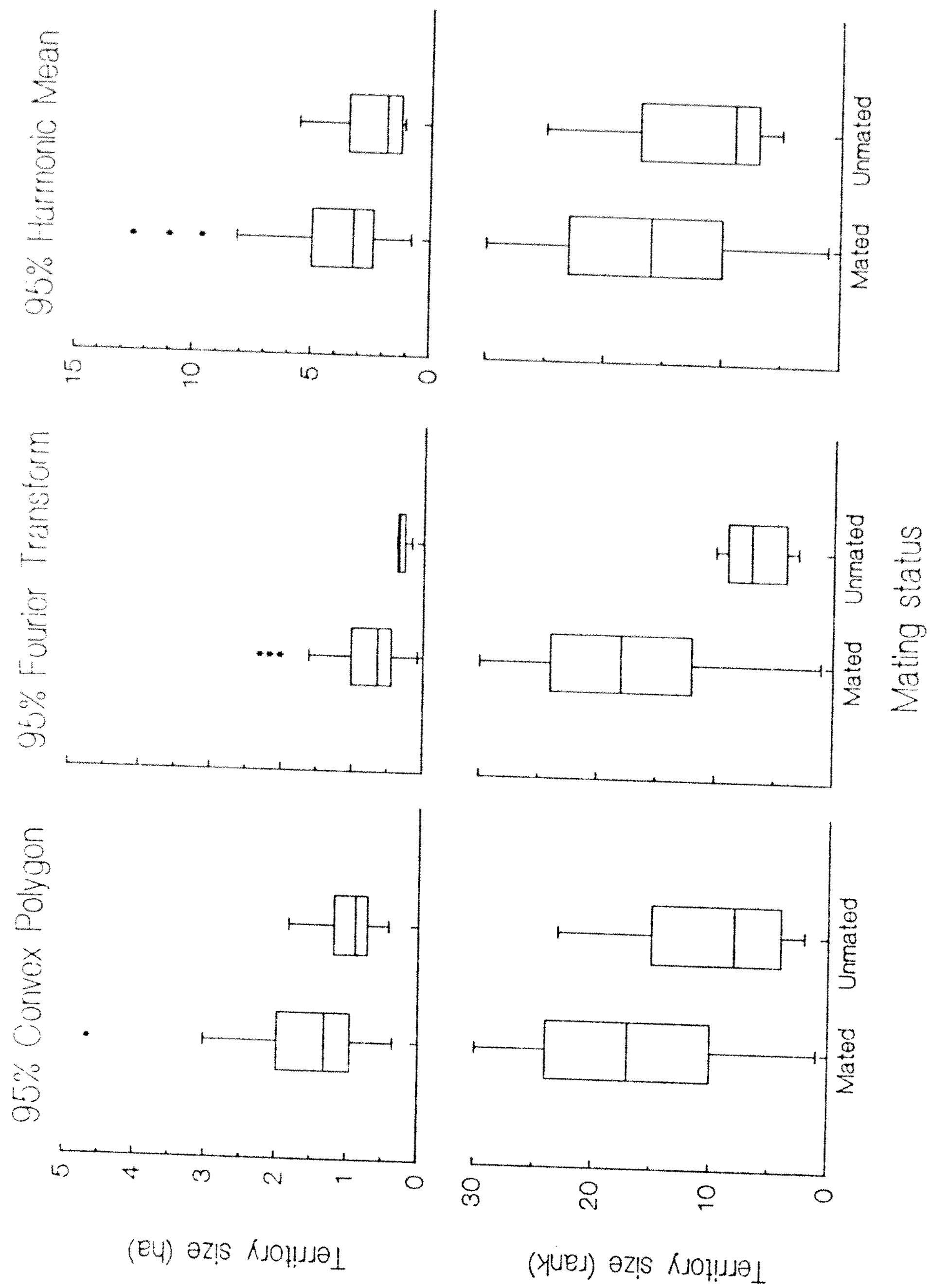

Fig. 8. Box plots of Florida grasshopper sparrow home range size (ha, top) and ranks of home range size (bottom) by mating status (mated, n = 25; unmated, n = 5), on the Avon Park Air Force Range, Highlands County, Florida, 1989-1992, for 3 territory size calculation methods. Note scale change for 95% harmonic mean (top right).

Appendix 1. Reprint of publication describing netting and banding equipment and techniques used during this study.

Netting and Banding Florida Grasshopper Sparrows

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INTRODUCTION

The Florida Grasshopper Sparrow *(Ammodramus savannarum floridanus)* was listed as endangered in 1986 (Federal Register 1986). The subspecies is endemic to the southcentral prairie region of the state, and most colonies (breeding aggregations) are located on native grasslands (Delany et al. 1985; Delany and Cox 1986) with compacted, sandy soils. Habitat loss is the principal cause of decline of the sparrow (U.S. Fish and Wildlife Service 1988). Much of the "native" prairie in Florida has been converted to improved pasture (Davis 1980) or reduced by phosphate mining (Callahan et al. 1990). The recovery plan for this subspecies (U.S. Fish and Wildlife Service 1988) identifies the need for basic information on habitat requirements, movements, and survival before the Florida Grasshopper Sparrow can be managed properly. A banding study was initiated in 1989 to obtain information necessary to manage the population. This paper describes mist netting techniques and reports preliminary banding results.

The study area was the U.S. Air Force Avon Park Bombing Range in Highlands and Polk Counties, Florida. The 430 km^2 military installation serves primarily as a training range for fighter aircraft and Florida Army National Guard maneuvers. The bombing range has a variety of plant communities in and around target areas, including native grasslands and forested areas. Most of the installation is leased for cattle grazing. A colony of Grasshopper Sparrows was studied within a 700 ha prairie dominated by saw palmetto *(Serenoa repens)*, dwarf oak *(Quercus minima)*, pineland threeawn *(Aristida stricta)*, bluestems *(Andropogon* spp.), and yellow-eyed grass *(Xyris* spp.).

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MATERIALS AND METHODS

As an alternative to commercially available mist net poles and pounders, we designed a step insertion pole (Figure 1), consisting of a 305 cm (10 foot) length of 2 cm (3/4 inch) diameter, galvanized electrical conduit. A 46 cm metal rod, 1.6 cm in diameter, was inserted 34 cm into the conduit and welded into place. The exposed 12 cm was sharpened to a point. One side (12 cm) of an L-shaped, 0.6 x 2.5 cm, flat metal bar was welded to the conduit to form a "step" 36 cm from the point. The cost per pole was $3.45 for materials and $8.50 for labor.

Usually, two to four people searched for singing male Grasshopper Sparrows by making visual and auditory observations while walking through the study area. The searchers carried one to two 18 m furled mist net(s) (3.2 cm mesh) mounted on two to four modified poles. Net loops were strung on the poles without attachments. When a sparrow was found, the poles were set into the ground by stepping on the horizontal bar, and the nets were unfurled. Neither guy wires nor center poles were needed to support the poles or nets. The nets were positioned between singing perches so the sparrow could be captured when flushed. Grasshopper Sparrows were marked with numbered, aluminum U.S. Fish and Wildlife Service bands and a unique combination of two colored, plastic leg bands (Figure 2). The split plastic bands were not glued shut. During the breeding season (March to June), the sex of adult sparrows was determined by the presence of a cloacal protuberance (male), or its absence and the presence of a brood patch (female). Age (juvenile or adult) was determined by plumage. Sparrows were released at the site of capture, and the process was repeated at the next occupied territory. One to five captures could be made in a morning. Capture locations and subsequent observations of marked sparrows were recorded on large scale (1:2,400) aerial photographs. Most banding occurred during the breeding season between sunrise and 0900 hours, when sparrows were most active.

RESULTS AND DISCUSSION

From 21 March 1989 to 20 November 1991, we banded 71 Grasshopper Sparrows during 86 netting attempts lasting 10 to 30 minutes each. The sample included 49 males, 15 females, and 7 individuals of undetermined sex. Only three sparrows less than one year old were captured. Of 38 males banded prior to the 1991 breeding season, we observed 17 on territories within 100 m of their capture location during succeeding years. The longest observed movement was a male that moved 2 km from his natal site to occupy a territory the following spring. Of 29 males banded during 1989, 11 were seen in 1990 and four were observed in 1991. Six of the nine males banded during 1990 were seen the following year. No banded females were recaptured or seen during succeeding years.

Two instances of plastic band loss were observed. One band was missing from a male one year post-banding, and two were missing from a male after two years. Both sparrows were recaptured and the bands replaced.

Our capture and banding activities did not appear to adversely influence breeding Grasshopper Sparrows. Most banded males resumed territorial behavior (singing) when released. Poles modified with the point and step attachments were inexpensive, easy to set, and provided a secure attachment for mist nets. The modified poles allowed rapid positioning of nets which minimized disturbance to breeding birds, and maximized the effectiveness of our efforts during the limited banding period. Techniques described here may facilitate similar studies on compacted substrates. Overlapping or glued plastic bands may be needed to improve band retention for Grasshopper Sparrows. Information from this study will be related to prairie management for cattle, and recommendations will be made to benefit the Florida Grasshopper Sparrow.

ACKNOWLEDGMENTS

D. Necker constructed the net poles. We gratefully acknowledge the field assistance of P. Ebersbach, C. Ford, D. Ford, R. Hooten, T. Logue, C. Olsen, Col. J. Rogers, S. VanHook, and V. Wallers. J.R. Brady, S.A. Nesbitt, and J.A. Rodgers, Jr. reviewed earlier drafts of this manuscript. This technique was developed while conducting Florida Game and Fresh Water Fish Commission research project No. 7513.

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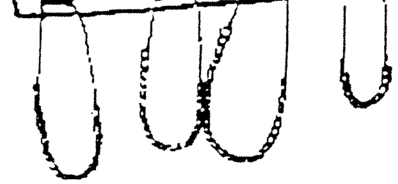

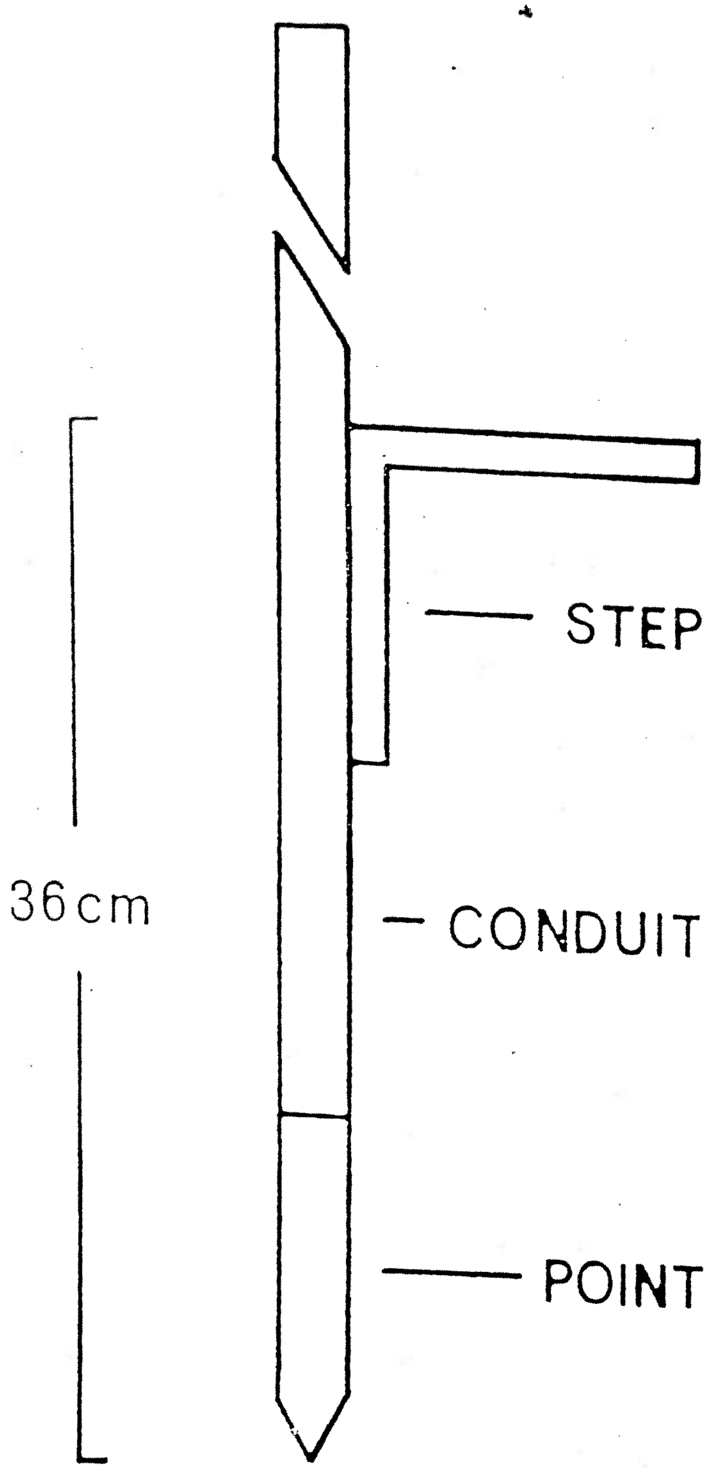

Figure 1. Diagram showing placement of step and point attachments to mist net pole.

Figure 2. A Florida Grasshopper Sparrow marked with aluminum and plastic leg bands.

Appendix 2. Grasshopper sparrow banding data, Avon Park Air Force Range, Highlands and Polk counties, Florida, 1989-1992. Color bands are red (R), blue (B), yellow (Y), mauve (M), pink (P), green (G), orange (O), stripe (S), white (W), and black (Z). Colors of pairs of bands affixed to the right tarsometatarsus are in order of top to bottom.

USFWS #	Color	Date	Sex	Location
920-63001	RR	3/02/89	♂	Ivey Grade
02	BB	3/28/89	♀	27°37.98', 81°20.13'
03	YY	3/29/89	♂	27°37.80', 81°20.14'
04	MM	3/29/89	♂	Ivey Grade
05	PP	4/12/89		27°37.99', 81°19.56'
06	GG	4/17/89	♀	27°38.00', 81°19.30'
07	OO	4/17/89	♂	27°38.00', 81°19.30'
08	SS	4/18/89	♂	27°38.01', 81°19.16'
09	WW	4/18/89	♂	27°38.01', 81°19.16'
10	ZZ	4/18/89	♂	27°38.14', 81°19.17'
11	RB	4/18/89	♂	27°38.00', 81°19.02'
12	RY	4/19/89	♀	27°38.00',81°19.02'
13	RM	4/19/89	♂	27°37.98', 81°20.13'
14	RP	4/25/89	♂	27°38.50', 81°19.45'
15	RG	4/25/89	♀	27°38.67', 81°19.44'
920-63016	RO	4/25/89	♀	27°40.18', 81°18.26'
17	RS	4/25/89	♂	27°40.18', 81°18.26'
18	RW	4/25/89	♂	Ivey Grade, runway
19	RZ	4/26/89	♂	27°38.20', 81°18.75'
20	BR	4/26/89	♂	27°37.68', 81°19.96'
21	BY	4/26/89	♂	27°37.54', 81°19.91'
22	BM	4/26/89	♂	27°37.42', 81°19.91'
23	BP	5/04/89	♂	27°37.84', 81°19.48'
24	BG	5/04/89	♂	27°37.67', 81°19.42'
25	BO	5/04/89	♂	27°37.73', 81°19.33'
26	BS	5/05/89	♂	27°37.86', 81°19.18'

USFWS #	Color	Date	Sex	Location
27	BW	5/05/89	♂	27°37.64', 81°19.06'
28	BZ	5/05/89	♂	27°37.84', 81°18.81'
29	YR	5/11/89	♀	27°38.01', 81°19.16'
30	YB	5/16/89	♂	27°38.?', 81°17.?'
31	YM	5/17/89	♂	27°38.61', 81°17.45'
32	YP	5/17/89	♂	27°38.61', 81°17.53'
33	YG	5/24/89♂	♂	27°37.93', 81°18.44'
34	YO	5/31/89	♀	27°37.91', 81°18.87'
920-63035	YS	5/31/89	♂	27°37.91', 81°18.87'
36	YM	6/07/89	?	Delta Trail
37	YZ	6/29/89	♂	27°38.03', 81°19.28'
38	MR	3/15/90	♂	27°38.14', 81°18.76'
39	MB	3/27/90	♂	27°38.03', 81°19.06'
40	MY	4/31/90	♂	27°33.48', 81°13.59'
41	MP	5/24/90	♂	27°38.09', 81°18.97'
42	MG	5/31/90	♂	27°37.81', 81°19.23'
43	MO	6/06/90	♂	27°37.95', 81°20.00'
44	MS	6/12/90	♂	27°37.66', 81°20.08'
45	MW	6/12/90	?	27°37.93', 81°20.13'
46	MZ	6/13/90	♀	27°37.99', 81°19.56'
47	PR	6/26/90	♂	27°37.99', 81°19.56'
48	PB	6/27/90	♂	27°38.07', 81°19.42'
49	PY	1/15/91	?	27°37.68', 81°19.96'
50	PM	1/15/91	?	27°37.68', 81°19.96'
51	PG	1/15/91	?	27°37.68', 81°19.96'
52	PO	4/15/91	♀	27°37.92', 81°19.23'
53	PS	4/17/91	♂	27°37.96', 81°19.33'
920-63054	PW	4/17/91	♂	27°37.92', 81°19.23'
55	PZ	4/22/91	♂	27°37.93', 81°19.22'

USFWS #	Color	Date	Sex	Location
56	GR	4/23/91	♀	27°38.01', 81°19.39'
57	GB	5/01/91	♂	27°37.54', 81°19.75'
58	GY	5/06/91	♂	27°37.99', 81°19.08'
59	GM	5/15/91	♂	27°37.81', 81°20.25'
60	GP	5/21/91	♂	27°37.80', 81°20.14'
61	GO	6/11/91	♀	27°37.50', 81°19.95'
62	GS	6/26/91	♂	27°37.50', 81°19.95'
63	GW	6/26/91	?	27°37.50', 81°19.95'
64	GZ	6/26/91	♀	27°37.50', 81°19.95'
65	OR	6/26/91	♀	27°37.50', 81°19.95'
66	OB	6/26/91	♂	27°37.50', 81°19.95'
67	OY	6/27/91	♂	27°37.50', 81°19.95'
68	OM	6/27/91	♀	27°37.50", 81°19.95'
69	OP	6/27/91	♂	27°37.50', 81°19.95'
70	OG	11/20/91	?	27°37.42', 81°19.91'
71	OS	11/20/91	?	27°37.42', 81°19.91'
72	OW	1/22/92	?	27°37.92', 81°19.23'
920-63073	OZ	1/22/92	?	27°37.92', 81°19.23'
74	SR	1/23/92	?	27°37.92', 81°19.23'
75	SB	1/23/92	?	27°37.92', 81°19.23'
76	SY	1/23/92	?	27°37.92', 81°19.23'
77	SM	1/23/92	?	27°37.92', 81°19.23'
78	SP	1/23/92	?	27°37.92', 81°19.23'
79	SG	2/13/92	?	27°37.92', 81°19.23'
80	SO	2/13/92	?	27°37.92', 81°19.23'
81	SW	2.13.92	?	27°37.92', 81°19.23'
82	SZ	2/13/92	?	27°37.92', 81°19.23'
83	WR	2/13/92	?	27°37.92', 81°19.23'
84	WB	2/13/92	?	27°37.92', 81°19.23'

USFWS #	Color	Date	Sex	Location
85	WY	2/13/92	?	27°37.92', 81°19.23'
86	WM	2/13/92	?	27°37.92', 81°19.23'
87	WP	2/13/92	?	27°37.92', 81°19.23'
88	WO	2/13/92	?	27°37.92', 81°19.23'
89	WG	2/13/92	?	27°37.92', 81°19.23'
90	WS	2/13/92	?	27°37.92', 81°19.23'
91	WZ	2/13/92	?	27°37.92', 81°19.23'
920-63092	ZR	2/13/92	?	27°37.92', 81°19.23'
93	ZB	2/13/92	?	27°37.92', 81°19.23'
94	ZY	3/27/92	♂	27°37.99', 81°19.56'
95	ZM	5/14/92	♂	27°38.14', 81°19.17'
96	ZG	5/14/92	♂	27°38.01', 81°19.39'
97	ZO	5/14/92	♂	27°38.01', 81°19.39'
98	ZS	6/28/92	♀	27°37.54', 81°19.75'
99	ZW	6/28/92	♀	27°38.01', 81°19.39'

Appendix 3. Home range plots of adult male Florida grasshopper sparrows (March - June) 1989-1992, on the Avon Park Air Force Range, Highlands County, Florida. Individual color code, size, and year are indicated followed by months of pasture post-burn (in parentheses). Sample size (n) is the number of locations obtained. The solid lines are 95% (outer) and 50% (inner) harmonic means. The dashed lines are 100% (outer) and 95% (inner) minimum convex polygons. Home range size (ha) is the area bounded by the 100% minimum convex polygon.

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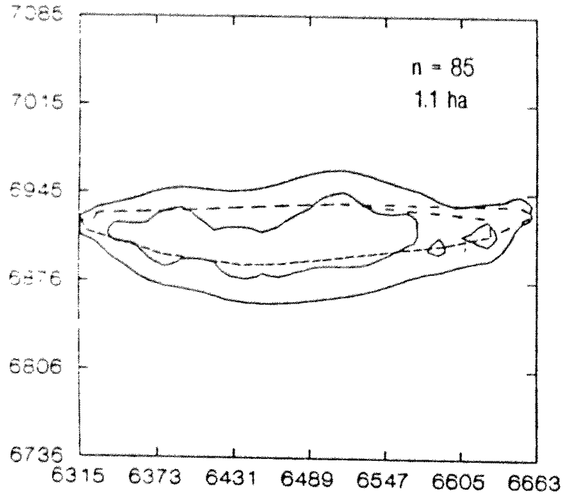

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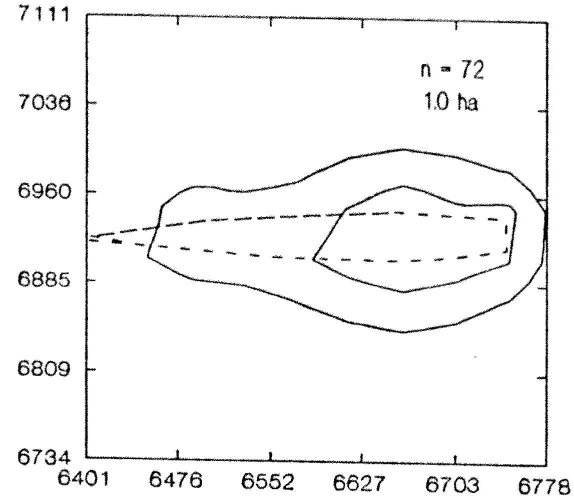

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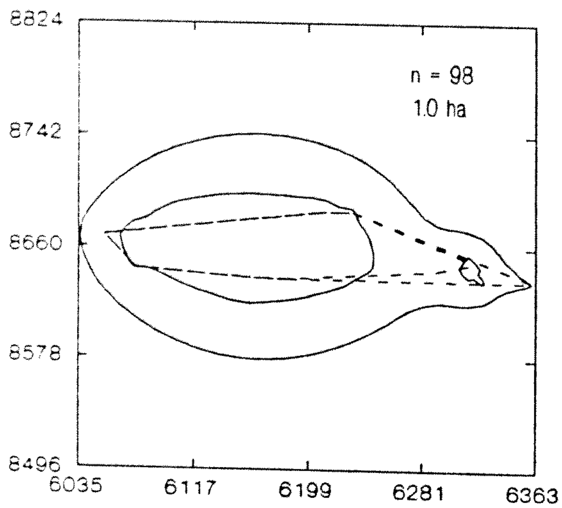

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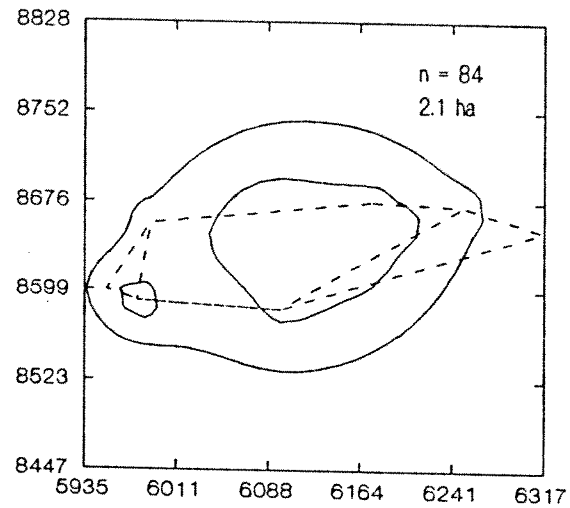

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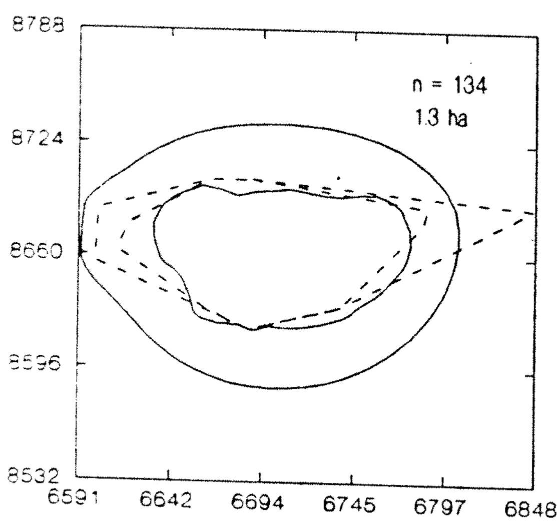

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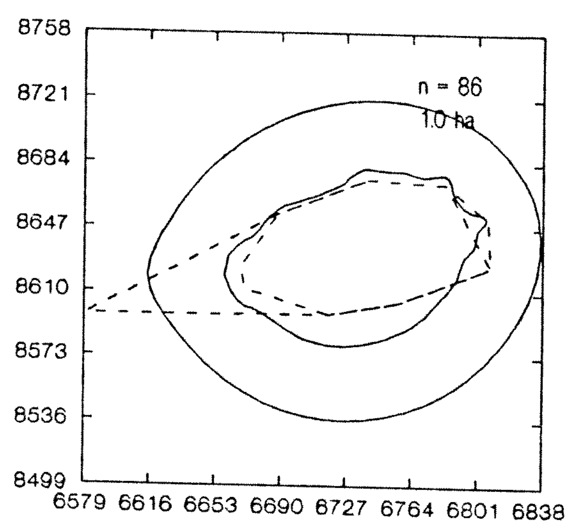

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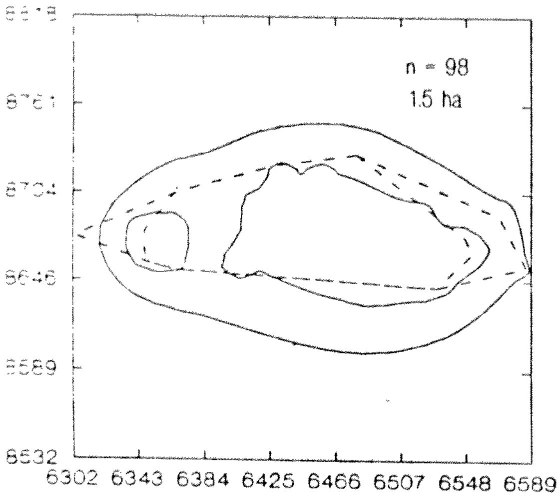

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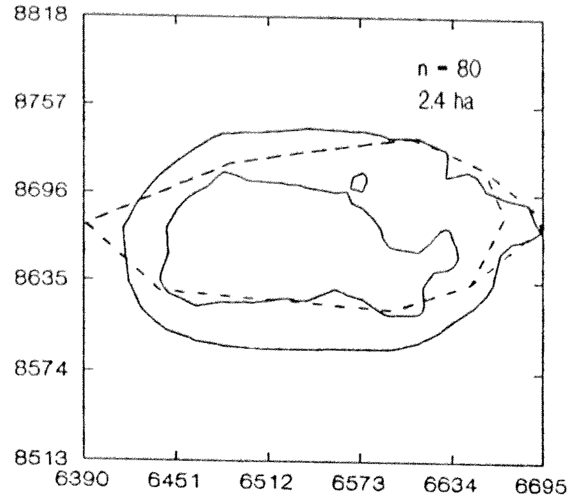

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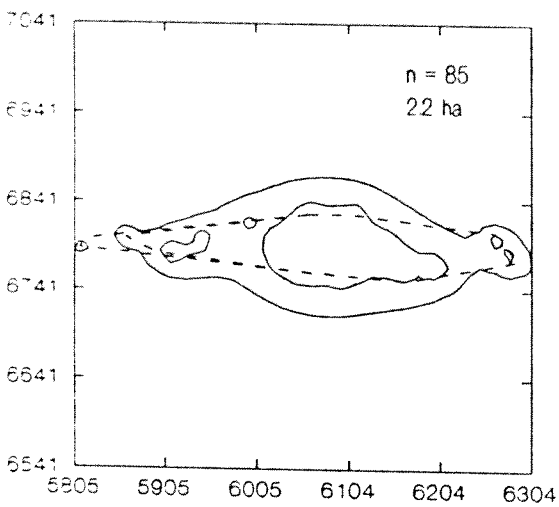

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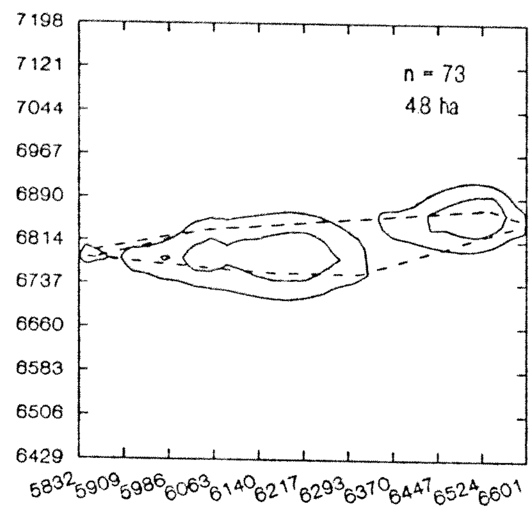

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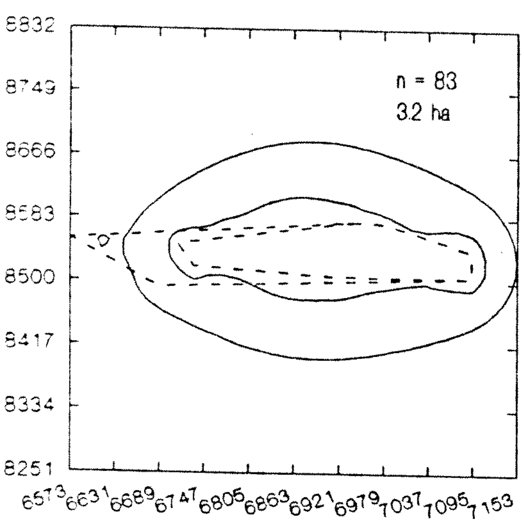

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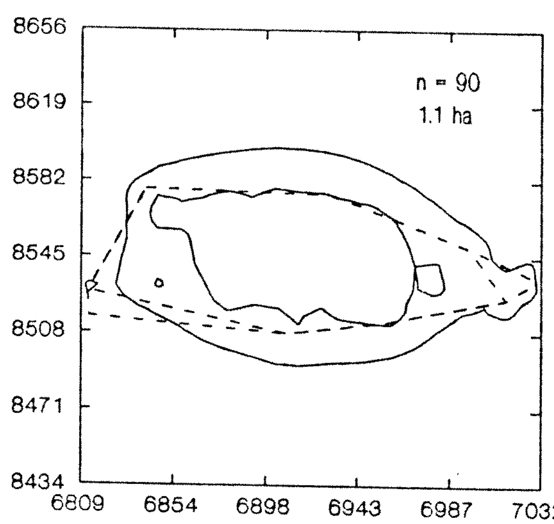

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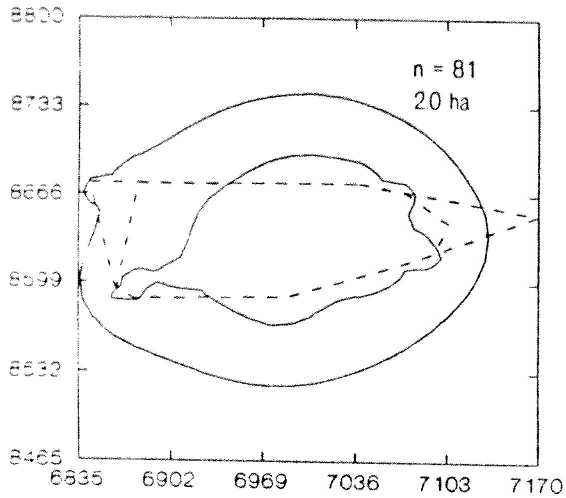

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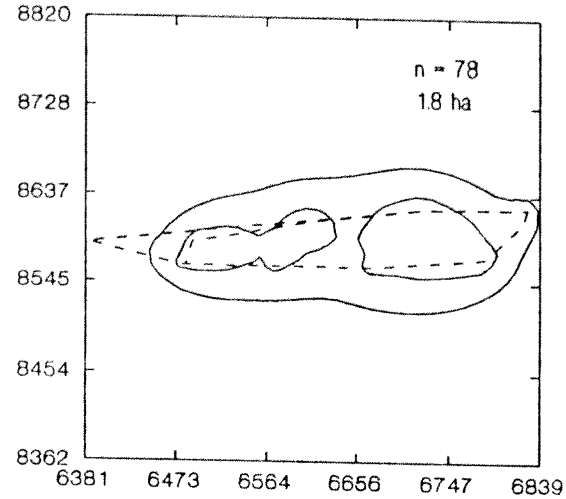

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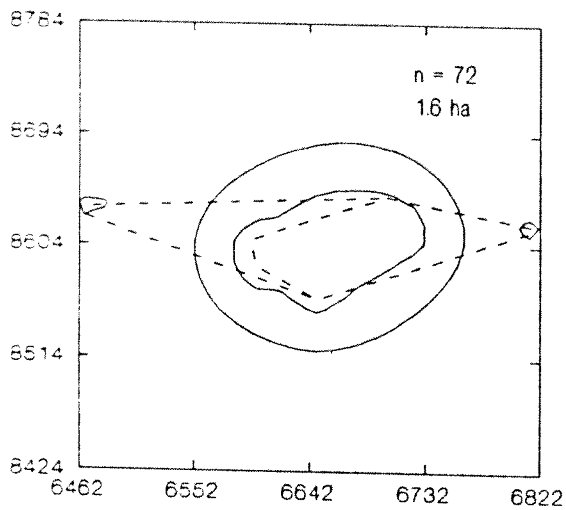

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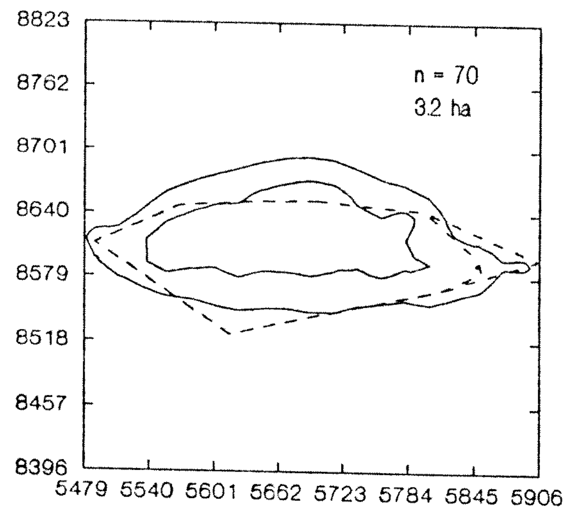

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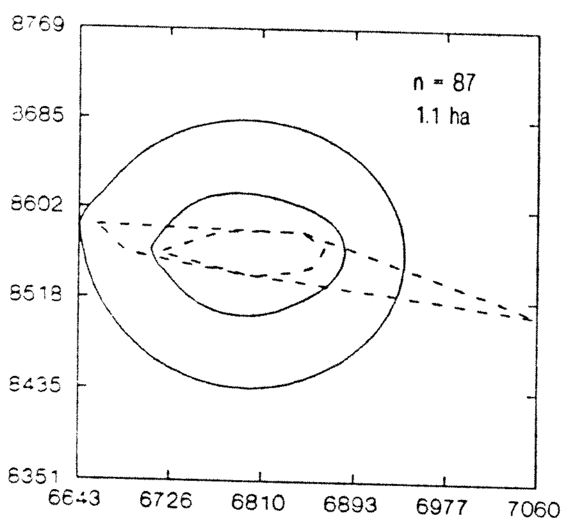

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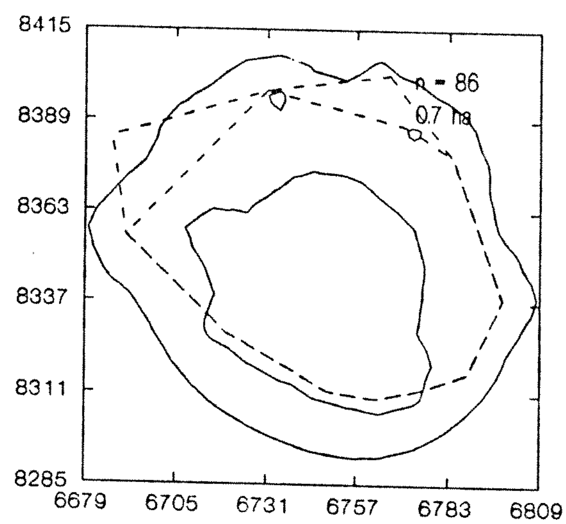

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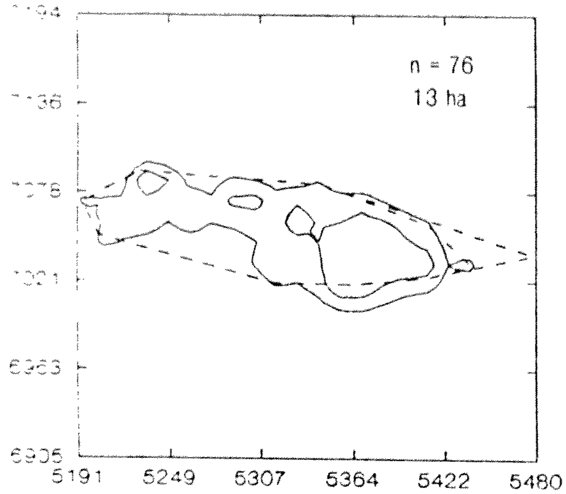

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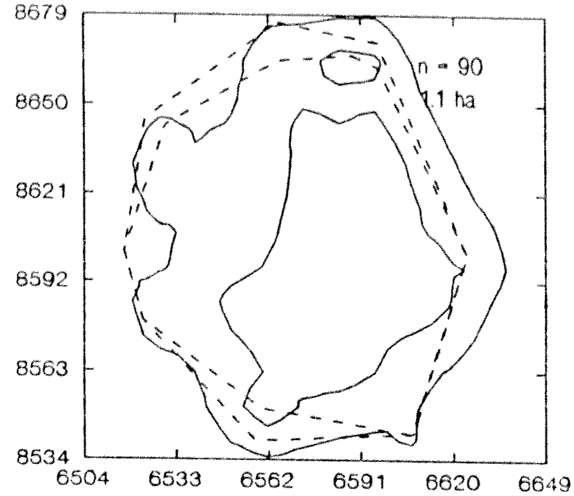

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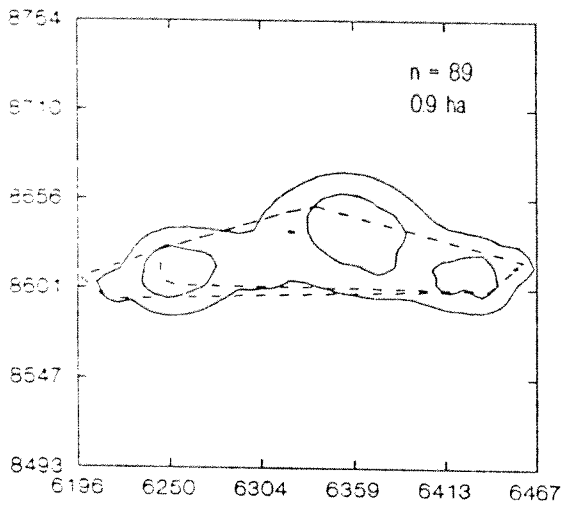

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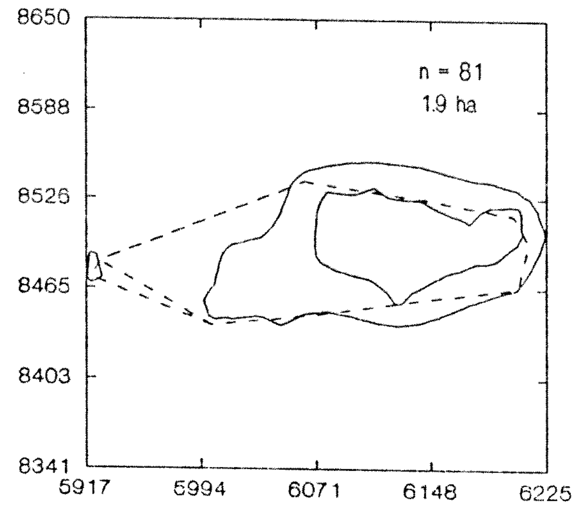

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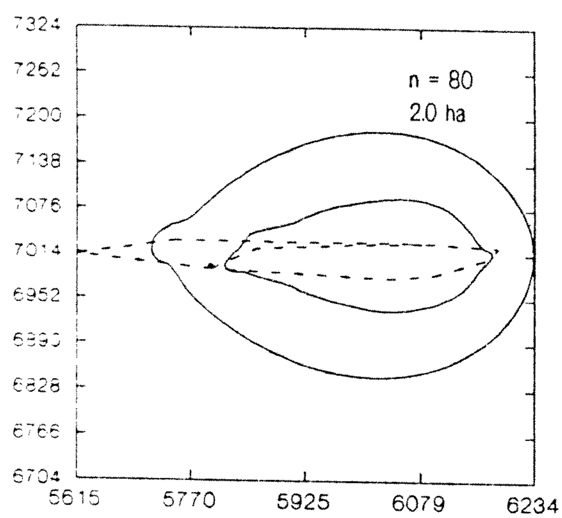

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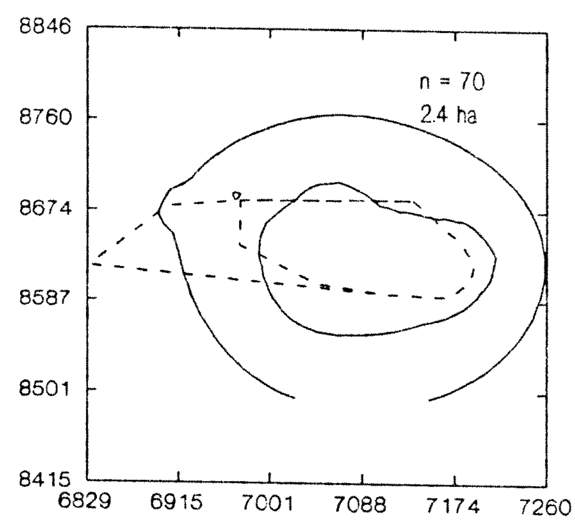

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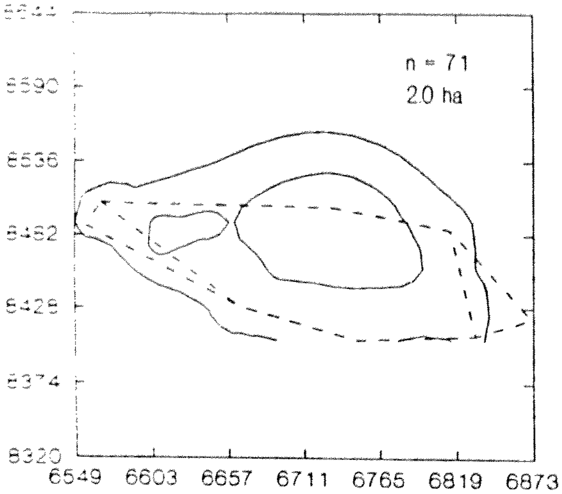

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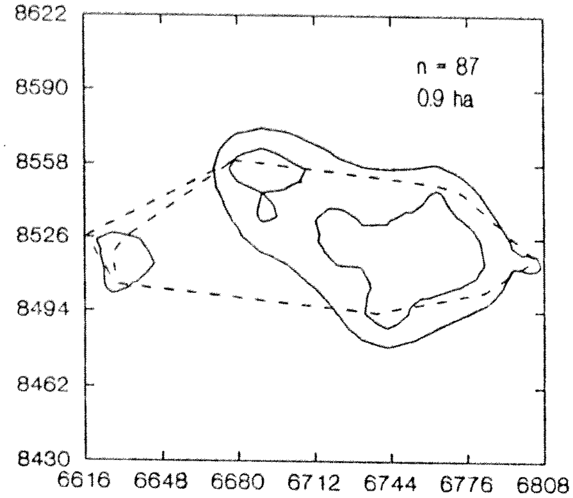

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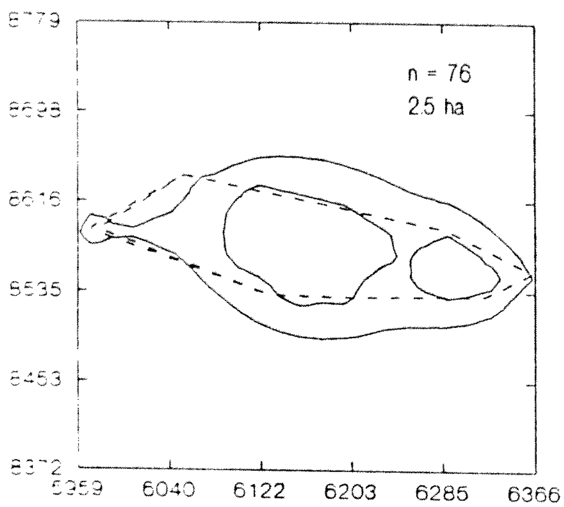

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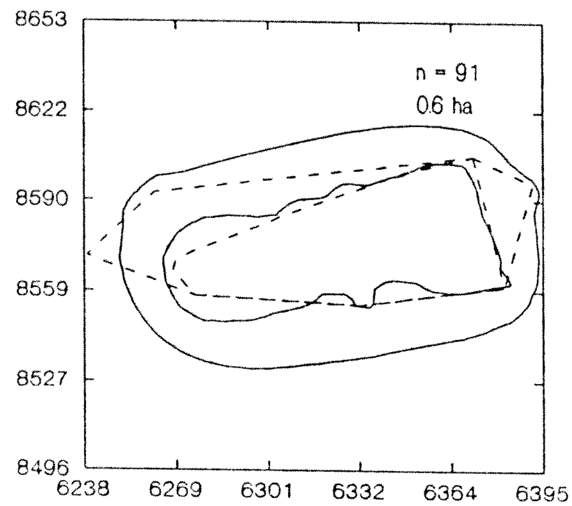

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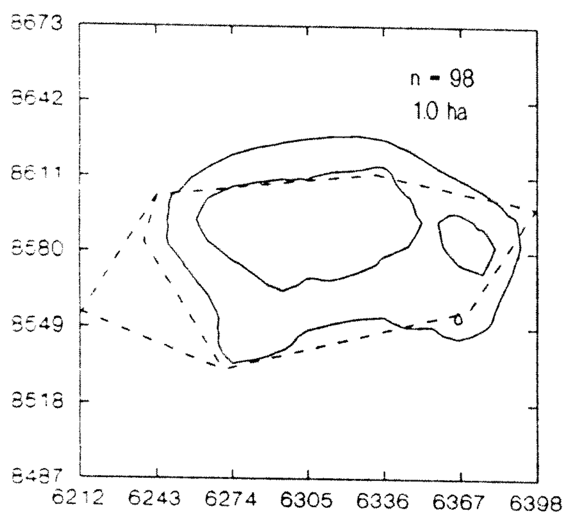

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