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Project Report

Project Title: Analysis of Delmarva fox squirrel (*Sciurus niger cinereus*) benchmark population data (1991-1998)

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Abstract: This report summarizes Delmarva fox squirrel (DFS) population performance between January 1991 and May 1998 on seven "benchmark" study sites: Blackwater National Wildlife Refuge (NWR), Chincoteague NWR, Hayes Farm, Lecompte Wildlife Management Area (WMA), Wye Island Natural Resource Management Area, Prime Hook NWR and Assawoman WMA. There were 3,386 nest-box inspections and 8,489 trap days, for a total of 11,875 sampling events. There were 1,441 captures of 956 individual fox squirrels. Adults and subadults were captured equally in live traps and nest boxes; 80% of juveniles were captured in nest boxes. Nest boxes provided the most efficient sampling procedure. Squirrel abundance, measured as the number of individuals observed per 100 sampling days, varied both between study sites and between years by a factor of ~2-4. Annual turnover typically ran 50-80%, with abundance in one year poorly correlated with abundance in the previous year. Each population performed in a manner typical of eastern fox squirrel populations: each occurred at relatively low density (<< 1/ha), each included adult animals of both sexes (~1♂♂:1♀♀), each had a mix of age classes, each exhibited reproduction on an annual basis, and each appeared to recruit young into the population in most years. Except for cataracts in several Chincoteague animals, most individuals appeared to be healthy and robust. There was no inter-site movement, but several Chincoteague squirrels moved ≥ 2 km between study areas. There was some evidence of a negative relationship between DFS abundance and gray squirrel abundance. These results both indicate the value of the benchmark monitoring program and suggest several possibilities for future DFS population monitoring, experimentation and analysis.

I. Introduction

The second revision of the Delmarva Fox Squirrel Recovery Plan designated seven "benchmark" populations for annual monitoring over at least a five-year period (Delmarva Fox Squirrel Recovery Team 1993). The objective was to acquire long-term data on Delmarva fox squirrel (DFS, *Sciurus niger cinereus*) population trends, condition and performance through repeated, systematic sampling using a standard monitoring protocol. This protocol was designed to reveal DFS abundance, population structure (by age and sex), reproductive activity and movement on each site. The seven benchmark sites included Hayes Farm, Blackwater National Wildlife Refuge (Jarrett Tract), Blackwater National Wildlife Refuge (Egypt Road), Eastern Neck National Wildlife Refuge, Wye Island Natural Resource Management Area, Lecompte Wildlife Management Area, and Chincoteague National Wildlife Refuge. Monitoring was initiated on each site in either 1991 or 1992.

This report summarizes the population information collected on the benchmark sites through spring 1998. The current analysis (1) provides a summary and comparison between sites for basic sampling data such as the number of captures recorded per year and the number of individuals observed; (2) compares the apparent efficacy of different sampling procedures; (3) provides statistical comparisons of DFS abundance between sites through time and between study areas on Blackwater and Chincoteague; (4) examines the statistical relationship between squirrel abundance in adjacent years; and (5) examines the statistical relationship between DFS abundance and the abundance of other, sympatric squirrel species.

II. Benchmark Sites

Data are reported here for seven sites (Table 1). Eastern Neck has been deleted from the analysis because of infrequent sampling and few animals. The Jarrett and Egypt Road tracts are treated as isolated study areas within the Blackwater site. Egypt Road is a hardwood timber stand; Jarret is a loblolly pine (*Pinus taeda*) stand.

The DFS population on Chincoteague was established through translocation in the early 1970s. Five study areas are recognized on Chincoteague: Old Fields, White Hills, Wildlife Loop, Lighthouse Ridge and Woodland Trail. Old Fields is isolated by several kilometers of marshland and scrub woodland, but the other areas are contiguous, separated only by roads, ponds and non-forested habitat. Furthermore, all except Old Fields have been heavily affected by recurrent outbreaks of the southern pine beetle (*Dendroctonus frontalis*) during the 1980s and 1990s. Several hundred hectares of forest habitat have been lost on Chincoteague because of these pest outbreaks, tree mortality and the resulting forest clearing.

Two non-benchmark sites in Delaware to which the DFS recently has been translocated are included here to provide a comparison between natural and translocated populations. Thirteen DFS were released on Assawoman WMA in 1984 and 1985; 18 were released on Prime Hook NWR in 1986 and 1987. Four study areas (Field 309, Entrance Woods, Jefferson Farm and Willman's) are recognized on Prime Hook.

III. Methods and Procedures

A standard protocol for capturing and handling animals and recording data was developed for the benchmark monitoring (Appendix C, Delmarva Fox Squirrel Recovery Team 1993). A combination of nest-box inspections and live trapping was used for capturing animals (Appendix E, Delmarva Fox Squirrel Recovery Team 1993). Nest box inspections typically were performed January through March, with trapping in March through May. Subadults and adults were doubly ear-tagged for permanent identification, examined for gender, reproductive condition and general physical condition, weighed and released at the point of capture. Animals found to have lost one or both ear tags were retagged. Juvenile squirrels were not handled or tagged unless they were old enough to have hair and their eyes were open. Gray squirrels (GS, *Sciurus carolinensis*) and southern flying squirrels (SFS, *Glaucomys volans*) that were captured during nest box inspections were released without being ear-tagged.

There were 3,386 nest box inspections and 8,489 trap days between January 1991 and May 1998, for a total of 11,875 sampling events (Table 2). Nest-box inspections comprised 29% of overall sampling effort; live trapping comprised 71%. Sampling effort varied greatly between sites and even between years within some sites. The variability was especially great on the non-benchmark sites Prime Hook and Assawoman, rendering comparisons of these sites with the others particularly speculative.

Trapping and/or nest box inspections were conducted on Blackwater and Chincoteague prior to the start of benchmark monitoring. Two individuals on Blackwater and 18 on Chincoteague were ear-tagged in 1989-90 and subsequently were recaptured during the benchmark study. These individuals were classified as "new captures" at the time of first capture during the benchmark study. Their pre-1991 capture histories were used, however, in the calculation of observed life spans.

The standard protocol was unevenly implemented. Particularly during 1991-93, there was substantial variation in animal handling procedures and data recording. Not all sites used the same data form or the same recording notation. Not all data forms were checked for internal consistency. There were frequent cases of missing data (e.g., reproductive condition), observation errors (e.g., tag-reading mistakes), recording errors (e.g, incorrect fates) and inconsistency in the application of diagnostic criteria (e.g., the definition of "subadult") on the data sheets.

The current analysis required that the information for each site be put into a standard format for data entry and analysis. This involved recoding every observation of every squirrel onto a standard data form (Appendix 1). Inconsistencies and errors that had gone unnoticed in the annual data summaries became readily apparent when a complete capture history was developed for each individual. A portion of the capture records data file is included here for purposes of illustration (Appendix 2). The standardized data also made it possible to synonymize doubly retagged animals (i.e., animals that were retagged after having lost both of their original ear tags). Synonymy was assigned only to animals of the same gender that were captured at the same (or adjacent) trap/nest box within a 16-month period. Inconsistencies, errors and synonymies were resolved where possible, and always in a conservative manner. Data may have been lost in the process of standardizing the information for each site, but none was created.

The data summaries presented here generally agree with the annual summaries prepared for the sites. The biologists responsible for collecting the benchmark data were invited to provide editorial feedback on the standardized data in June 1998. Errors noted at that time were corrected. Any remaining inconsistencies result from the editing and decision-making involved in standardizing the information.

Statistical comparisons between sites and areas treat years as replicates, rather than as repeated factors. The monitoring design simply does not facilitate the desired repeated-measures hypothesis testing. Furthermore, the correlation analyses presented here may incorporate a degree of autocorrelation. Correlation coefficients are presented, therefore, as descriptive statistics, without reference to probability values.

IV. Results

(A) Capture Summaries

There were 1,441 captures (Table 3) of 956 individual fox squirrels (Table 4). These 956 individuals included 755 tagged (Table 5) and 201 untagged (Table 6) animals. The 755 tagged squirrels included 691 animals tagged as subadults or adults (Table 7) and 64 tagged as juveniles (Table 8). The number of individual squirrels varied from 85 to 202 per year (Table 9). The average individual was captured only 1.5 times (range 1-14). One hundred squirrels were retagged during the study (Table 10), including 70 single retags and 30 double retags. Five doubly retagged individuals were synonomized with previously tagged squirrels. Only 11 squirrels were found dead during the study, almost all in nest boxes (Table 11). Recapture rates of tagged squirrels were very low , so that most adults and subadults were captured only in traps (50.9%) or in nest boxes (41.0%); only 8.2% were captured in both traps and boxes (Table 12). As many as three adult/subadult animals were found together in a nest box on occasion. Most juveniles (81.0%) were captured in nest boxes (Table 13).

There were 827 gray squirrel captures on four sites: Blackwater (66), Hayes Farm (165), Lecompte (199) and Wye Island (397). GS was captured in every year on each site. Approximately 80% of GS captures were in nest boxes, with as many as six squirrels in a box. There were 87 southern flying squirrel captures on three sites: Blackwater (64), Lecompte (9) and Wye Island (14). SFS was captured in every year on Blackwater and Wye Island, but in only three years (1993, 1994 and 1996) on Lecompte. All of these captures were in nest boxes, with as many as four individuals in a box. It seems likely that many GS and SFS captures went unrecorded. Chincoteague is the only site from which these species were known to be missing at the outset of the study.

(B) Squirrel Abundance

Inter-site and inter-annual variability in sampling effort complicated comparisons of squirrel abundance between sites and between study areas within a site. Abundance is thus compared on the basis of the number of individual squirrels observed per 100 units of sampling effort (i.e., per 100 trap days or per 100 nest box inspections). Average, abundance varied both between study sites and between years by a factor of ~2-4. Abundance was compared among the seven sites using a one-way analysis of variance with site as a fixed effect, years treated as replicates, and site variances assumed to be heterogeneous. Abundance varied significantly among sites ($F_{6,43}$ = 18.08, $p < 0.001$, Figure 1). Tukey-adjusted multiple comparisons revealed that average abundance was higher on Blackwater (17.0 individuals per 100 sample days) than on Hayes Farm (6.4; t_{43} = 9.18, adjusted $p < 0.001$) and Wye Island (7.0; t_{43} = 8.37, adjusted $p < 0.001$). Squirrel abundance also was higher on Chincoteague (24.6) than on Hayes Farm (6.4; t_{43} = 3.36, adjusted $p = 0.025$) and Wye Island (7.0; t_{43} = 3.25, adjusted $p = 0.033$).

There appears to be a modest trend for average abundances to be higher in the early years (1991-94) and lower more recently (1995-98, Figure 1). The trend seems to be particularly pronounced on Chincoteague where a 1994-95 outbreak of southern pine beetles resulted in the loss of several hundred hectares of DFS habitat. Only Hayes Farm, which had very low DFS abundance to begin with, showed a progressive increase in abundance over the study period. There also appears to be approximate synchrony among sites with "good" years being good on most sites (e.g., 1994) and "bad" years being bad on most sites (e.g., 1997).

The translocated Assawoman population has survived, but appears not to have expanded significantly since the mid-1980s. Juveniles have been observed in only two of the benchmark years, and the number of tagged adults observed in a given year has never equaled 50% of the number of released animals. The Prime Hook population, on the other hand, has expanded since the initial release. Juveniles have been observed in five of six benchmark sample years, and the number of individual squirrels observed each year has equaled or exceeded 50% of the number of squirrels released initially.

Average abundance was consistently higher on Egypt Road (22.1 individuals per 100 sampling days) than on the Jarrett Tract (10.7) on Blackwater (paired $t_6 = 4.452$, $p = 0.004$; Figure 2). Average abundance was highly variable among areas on Chincoteague (Figure 3), but the differences were not statistically significant when tested with a one-way analysis of variance with area as a fixed effect, years treated as replicates, and site variances assumed to be homogeneous ($F_{4,26} = 1.20$, $p = 0.334$). Although the data do not allow a rigorous test, it appears from Figure 3 that average abundances have been lower on all areas following the pine beetle outbreak of 1994-95. Furthermore, average annual DFS abundance (= number of squirrels observed per 100 sampling days) has declined substantially on Chincoteague during the 1995-98 period compared with 1991-94. The percentage decline on Chincoteague has been 67%, compared with declines of 8%, 30%, 58% and 9% on Blackwater, Wye Island, Prime Hook and Assawoman, respectively. Abundance has actually increased by 65% and 21% on Hayes Farm and Lecompte, respectively, during this period. The Chincoteague decline is even more pronounced if only the number of adults and subadults observed per 100 sampling days is considered. Adults and subadults have declined 63%, compared with declines of 5% and 11% on Blackwater and Prime Hook, respectively, and increases of 45%, 39%, 4% and 380% on Hayes Farm, Lecompte, Wye Island and Assawoman, respectively, during 1995-98.

Using the largest number of individuals ever observed per 100 days of sampling on a site and the areas listed in Table 1, the estimated maximum population densities were 0.42 squirrels per hectare on Blackwater, 0.04 on Chincoteague, 0.16 on Hayes Farm, 0.12 on Lecompte, 0.10 on Wye Island, 0.33 on Prime Hook and 0.30 on Assawoman. Although this variability is possible, it seems unlikely. It is more reasonable to conclude that the population sampling was insufficient to achieve complete enumeration, particularly on Chincoteague. Based on an intensive trapping and nest-box study on Woodland Trail between September 1988 and May 1989, Larson (1990) estimated a density of 0.39 DFS per hectare. This number is high relative to the current Chincoteague figure (0.04), but in line with the other estimates for benchmark sites having good-to-excellent DFS habitat. However the calculation is performed, these DFS populations exist at low density.

(C) Comparison of Sampling Procedures

The number of individuals observed per 100 nest box inspections was positively correlated with the number of individuals observed per 100 trap days (r = 0.63, Figure 4). Much of this correlation, however, was due to an extreme value recorded for the Wildlife Loop area on Chincoteague in 1996. When this point was eliminated from the analysis, the correlation dropped to 0.28. This same pattern of variability was observed for both males and females. Finally, the same patterns also were evident when only the number of adults and subadults observed per 100 sampling days were used in the analysis. Nest boxes and traps are not interchangeable as sampling devices for the DFS when sampling is infrequent and short-term. In fact, when the number of individuals observed by each sampling procedure (Table 12, 13) is adjusted for sampling effort for each procedure (Table 2), capture rates were much higher in nest boxes than in traps for both adults/subadults

($\chi^2 = 87.859$, df = 1, $p < 0.001$) and juveniles ($\chi^2 = 187.927$, df = 1, $p < 0.001$). Nest-box inspections are far and away the most efficient way to sample DFS populations.

(D) Reproduction

Fifty-four females were captured in nest boxes along with one or more juveniles assumed to be their young (Table 14). Most of the females observed with young were tagged (43); only nine were unidentified. One juvenile was found in a nest box with an adult male. The 48 litters that were actually counted in the nest included 104 young, for an average of 2.2 juveniles per litter.

A total of 117 lactating females were captured during the study, with at least one lactating female observed every year on Blackwater and Prime Hook. Female number 70005 (Prime Hook) was found with litters in weeks 51 (3 young), 63 (2) and 76 (3). Female number 70014 (Prime Hook) was found with litters in weeks 88 (2) and 100 (1). Ten females were observed to be lactating in each of 2 years, five in each of 3 years and one in each of 4 years. It appears that not every adult female breeds every year.

Juveniles were observed somewhere in every month between January and July. There were conspicuous peaks of juvenile abundance in February (32.7% of juveniles observed), March (33.3%) and April (25.5%;Table 15). Only 6% of juveniles were captured during May through July.

(E) Age Structure

Most populations were composed of animals classified as adults, with relatively small percentages of subadults and juveniles (Figure 5). Apparent inconsistency in the application of age-class criteria render further age-class analysis speculative.

(F) Sex Ratio

Both male and female DFS were captured on every site in every year. The annual male:female sex ratio for subadult and adult animals varied from 0.79 to 1.48, but the overall ratio across sites and years (1.09) was not significantly different from 1.00 ($\chi^2 = 1.158$, df = 1, $p > 0.05$). The annual male:female sex ratio for the few juveniles for which gender was determined (63) varied from 0.67 to 4.00, but the overall ratio across sites and years (1.17) was not significantly different from 1.00 ($\chi^2 = 0.400$, df = 1, $p > 0.05$).

(G) Observed Life Span

Observed life span is the number of months between the first and last (or most recent) captures of an individual on a site. It represents a minimal estimate of residency on a site. Most individuals were captured only once, and very few were captured more than five times. Observed life spans ranged from 1 month (on all sites) to 86 months (on Blackwater and Wye Island). The maximum observed life span was ≥ 48 months on all sites. Average life spans ranged from 2.8 months on Lecompte (n= 172 individuals) to 9.6 months on Blackwater (n= 224) and 9.7 months on Assawoman (n=11). Life spans were heavily skewed toward the low end on every site (Figure 6). Most animals were observed only once or twice; a few were observed repeatedly over an extended period of time. Tagged animals were observed to evade detection for periods of up to 36 months between captures; eventual recaptures were always relatively near the point of initial capture.

Males appeared to be resident longer on some sites (e.g., Chincoteague: males 7.8 months vs females 5.3 months), females on others (e.g., Blackwater: males 9.6 months vs females 12.4 months). There was therefore no consistent pattern of gender differences. Overall, average observed life span was 6.9 months for males and 6.0 months for females.

Fifty-two squirrels evaded detection for extended periods of time (≥ 21 months) after being tagged. Thirty evasive males went an average of 31.3 months between successive captures (range 21-85 months). Twenty-two evasive females went an average of 29.8 months between successive captures (range 21-47). Seven of these evasive animals made directional movements to a different area on Chincoteague. Each of the others eventually was recaptured in the vicinity of the point of first capture.

(H) Movement

No inter-site movements of DFS were observed. There were, however, 22 directional movements between study areas on Chincoteague, based on recaptures of tagged squirrels. None of the movements were observed directly. The minimum straight-line distances involved in these movements ranged from ~0.5 to ~ 8.0 km. Most of these movements were between adjacent areas connected by continuous forest cover. Seven, however, were between areas no closer than ~2.0 km and having substantial intervening non-forested habitat. Four movements between Lighthouse Ridge and the Sow Pond section of White Hills (~2.5 km), between the B-Pool North section of Wildlife Loop and the Turnaround (~8.0 km), between C-Dike section of Wildlife Loop and the Turnaround (~6.0 km), between White Hills and Woodland Trail (~3.0 km) are particularly noteworthy.

During intensive observations on Chincoteague during late summer and autumn of 1990, Larson and Dueser (unpublished) reported the dispersal of one (out of 95 tagged animals) radio-collared adult female DFS from the Office portion of Lighthouse Ridge to Woodland Trail, a distance of 1.6 km. In a subsequent experiment, Larson and Dueser observed that adult and subadult DFS displaced 1.3-1.9 km from their home ranges returned home within 1.5-2.5 hours if the return route were through continuous forest or within a few hours to 73 days if the route included non-forested habitat.

(I) Condition and Pathology

The standard protocol included gross external evaluation of squirrel health and condition. Although dozens of observations of fleas, ticks and minor abrasions were recorded, relatively few pathological conditions were reported. As in the past, there were occasional references to cataracts in the eyes of Chincoteague squirrels.

(J) Population Turnover

Population turnover is estimated as the annual ratio of new individuals observed (Table 5) to total individuals observed (Table 4), i.e., as the percentage of squirrels observed on a site in a given year that were new captures. The percentage of new individuals was highly variable (range 22% - 100%), but generally high (overall average 80%). Site averages ranged from 50% for Assawoman to 89% for Hayes Farm and 86% for Blackwater. Most annual site populations were composed almost entirely of new individuals. Although the DFS is relatively long-lived, and many individuals were recaptured in the same vicinity for several years, turnover of residents was very high on most sites in most years. It is likely that the sampling regimes employed on the benchmark sites are insufficient to achieve anything approaching complete enumeration.

(K) Interannual Abundance Relations

The statistical relationship between population abundance in year t (N_t) and abundance in year t+1(N_{t+1}) was described with simple correlation analysis. This relationship was examined separately for abundance estimates based on nest boxes and live traps, with data entered at the level of the area. N_t was poorly correlated with N_{t+1} for both nest boxes ($r = 0.15$, Figure 7) and live traps ($r = 0.39$, Figure 8). The same patterns were evident when female abundance was considered separately ($r = 0.15$ boxes and 0.36 traps). The correlations tended to be slightly higher for males for both boxes (0.31) and traps (0.54). As suggested by the amount of inter-annual variability evident in Figure 1 (above), N_{t+1} is relatively poorly correlated with N_t.

As a further description of inter-annual relations, this analysis was repeated for the population abundances of subadult and adult animals of known gender in years t (N_t) and t+1 (N_{t+1}). N_t was poorly correlated with N_{t+1} for both nest boxes ($r = 0.28$) and live traps ($r = 0.37$). The same patterns were evident when female abundance was considered separately ($r = 0.21$ boxes and 0.35 traps). The correlations tended to be slightly higher for males for both boxes (0.34) and traps (0.59). Again, population size at time t+1 is relatively poorly correlated with population size at time t.

(L) Interspecific Abundance Relations

Gray squirrels and flying squirrels were captured on several of the benchmark sites. Gray squirrels typically equaled or exceeded the DFS in abundance, while flying squirrels were captured relatively infrequently. The interspecific abundance relationships between the DFS and each of these potential competitors was described with simple correlation analysis. Each analysis was run two ways: with all sites/areas included, and with sites/areas having no gray (or flying) squirrels excluded. The relationship between DFS abundance and gray squirrel abundance was weakly negative (r= -0.005, Figure 9), and the relationship between DFS and flying squirrel abundance was weakly positive (0.16, Figure 10). These relationships were somewhat stronger when the zero-gray (-0.39) and zero-flying squirrel sites (0.43) were excluded.

This negative correlation between DFS and GS abundance suggests that the presence of gray squirrels on a site may inhibit DFS population performance/abundance. On the other hand, previous analysis of the extensive nest-box data collected by Vagn Flyger in the 1970s (unpublished) revealed a positive, rather than negative, correlation between DFS abundance and GS abundance (Dueser unpublished). The nature of this interspecific relationship remains elusive.

V. Discussion

The second revision of the Delmarva Fox Squirrel Recovery Plan established several criteria for reclassifying the DFS from endangered to threatened. One of these criteria is showing that the seven benchmark populations are "stable or expanding based on at least five years of data" (Delmarva Fox Squirrel Recovery Team 1993:41). What can we say about population stability or expansion based on the past eight years?

(1) All of the benchmark populations persisted over the course of the study. No population declined steadily or went extinct during the period of study. Even the recently translocated populations on Prime Hook and Assawoman seem to be well-established.

(2) All of the benchmark populations performed during this time in a manner typical of eastern fox squirrel populations. Each occurred at relatively low density, each included adult animals of both sexes, each had a mix of age classes, each exhibited reproduction on an annual basis, and each appeared to recruit young into the population in most years.

(3) All of the benchmark populations exhibited variability through time. For the most part, this was a "stabilizing" pattern of variability in which declines were followed by increases and vice versa. Only Hayes Farm exhibited sustained (if modest) growth. This temporal variability reflects variation in habitat quality through time, variation in population structure through time and stochastic variation related to sampling.

(4) Similarly, the benchmark populations exhibited variability between sites. In terms of average abundance per unit of sampling effort, Blackwater, Chincoteague and Lecompte are excellent DFS sites. Hayes Farm and Wye Island are good sites. Prime Hook and Assawoman appear to be excellent translocation sites. This spatial variability reflects both inter-site variation in habitat quality and stochastic variation related to population sampling.

(5) There was also variability between study areas on Blackwater. DFS abundance was consistently higher on Egypt Road than on the Jarrett Tract. Based on what we know about DFS ecology and distribution (Delmarva Fox Squirrel Recovery Team 1993), the hardwood forest of Egypt Road would be expected to provide better habitat (and support greater squirrel abundance) than the pine forest of Jarrett Tract – just as was observed. There was also variability among areas on Chincoteague, but these differences were obscured by variability through time.

(6) Finally, all of the benchmark populations exhibited high annual turnover, with approximately 80% of the individuals observed in any given year being new captures. The sampling almost certainly did not provide complete enumeration.

The benchmark populations are alive and well after 5-8 years of study, but they are highly variable through space and time. Based on the number of individuals observed per 100 sampling days, average abundance varies between sites by a factor of ~2-4. Average abundance varies between areas on Blackwater by a factor of ~2. Much of the variability between sites and areas is probably due to differences in habitat quality (e.g., ratio of hard mast species to soft mast), although some must be attributable to sampling effects. Based on the number of individuals observed per 100 sampling days, average abundance also varies between years by a factor of ~2-4. Furthermore, abundance in one year is poorly predicted by abundance in the previous year. This temporal variability is difficult to explain, but may be driven by temporal variability in habitat quality such as food availability (particularly spring soft mast), weather during the breeding season (particularly precipitation) or the abundance of predators (particularly hawks and owls), as well as sampling variability. The benchmark sites are represented in the data set each year by a relatively small number of tagged squirrels, and small numbers can bounce around in time and space because of small, local sources of influence and random variability. The fact that the patterns of variability in these data are relatively consistent suggest that regional influences are relatively important for these populations. It should be possible to design a regional recovery (i.e., management) strategy.

Based on these observations, the Recovery Team may want to consider several possible lines of action:

(1) The observation of high rates of turnover, occasional long-distance movements and relatively long potential life spans suggest that the DFS has the potential to colonize unoccupied but suitable habitat contiguous to occupied sites. The Recovery Team may want to determine the rate at which such colonization (and perhaps range expansion) is actually occurring on unoccupied sites.

(2) The Chincoteague population may be declining coincident with habitat loss resulting from an outbreak of southern pine beetles in the mid-1990s. The Recovery Team may want to work with the Refuge to develop a plan for habitat restoration. At a minimum, the Chincoteague monitoring should be revised to include systematic grid- or plot- based trapping similar to that at Blackwater, to provide more reliable density estimates.

(3) The benchmark experimental design is inadequate to the task of explaining population variability through space and time. In reality, it was designed to reveal long-term trends rather than the details of population dynamics. Continuing the benchmark monitoring is certain to yield useful insights into population trends (and perhaps, at some point, extinction), and would be easy to justify. A few adjustments might be warranted in the protocol to more closely approximate complete enumeration, particularly on Chincoteague.

(4) On the other hand, the Recovery Team may want to consider the reallocation of the substantial benchmark effort among a variety of possibilities. The Recovery Team may want to consider replacing the current monitoring program with:

(A) a more intensive monitoring program with replicate study areas and seasonal sampling on one or two sites (e.g., on Blackwater and Chincoteague),

(B) a manipulative experiment designed to test for density-dependence in juvenile survival, recruitment and dispersal (e.g., on Blackwater),

(C) a large-scale experiment designed to examine the response of DFS populations to different types of timber harvest and silvicultural management,

(D) a manipulative experiment designed to test for competition between the DFS and the gray squirrel (e.g., on Hayes Farm, Lecompte or Wye Island),

(E) an extensive sampling program designed to determine the location and persistence of other, less well-known DFS populations, or

(F) a combination of continued nest-box checks on the existing benchmark sites and trapping on other, non-benchmark sites.

Given the relative efficiency of nest-box inspections, the Recovery Team may want to consider relying on this procedure for routine DFS population monitoring. There may be animals that will never be captured with any single sampling procedure, but the information return per unit effort is truly impressive for nest boxes. Nest boxes may require a period of acclimation of several months or more after installation, but they produce information at a prodigious rate thereafter – and with relatively little ongoing expense. Trapping can be implemented with only a few days of preparation on a site, but typically is productive only in certain seasons -- and only with a significant investment of time and effort. Anytime efficiency is a critical concern, nest-box inspections appear to offer a distinct advantage.

Given the expense of trapping, the time and effort available for DFS trapping studies might be better invested on other, non-benchmark sites, including the 36 occupied and 18 unoccupied sites reported by Taylor (1976) and the 30 pine forest sites reported by Guy Willey (1989, unpublished). The presence/absence of the DFS on most of these sites has never been confirmed through trapping or direct observation. It would take 2-3 years to cover these sites with a reasonable trapping program, but the resultant data could reveal a lot about the colonization/ extinction/ persistence of isolated populations. Population persistence remains a central question about the current status of the DFS.

The Recovery Team may want to consider one other approach to assessing the status of the DFS recovery process. Is the DFS dispersing to unoccupied sites at a detectable rate? Are small DFS populations persisting? If the Recovery Team believes the answer to either of these questions is "no," an intense, highly manipulative recovery program will be required, with extensive translocations, long-term monitoring and large-scale, restrictive habitat conservation planning. If the answer to both of these questions is "yes," a much simpler recovery approach may be warranted, with an emphasis on relatively low-key habitat conservation planning. If it further turned out that many of the occupied and/or colonized sites are located in bottom land forest habitat, the recovery process might be even simpler yet. Much of this habitat is already protected by one or more of the management and land-use regulations enacted to protect the Chesapeake Bay watershed. An effective recovery program in this case might be as "simple" as habitat conservation planning and enforcement of existing land-use regulations. Such a recovery strategy would reduce both the need for intensive population manipulation and the potential for conflicts with alternative land uses in upland habitats. Let me emphasize that this possible recovery strategy is not dictated by the results of the current study, but would be consistent with these results.

It remains for the Recovery Team to determine how to proceed. Nothing will be lost, and much might be gained, by continuing to monitor the benchmark sites. On the other hand, if at least a portion of the monitoring effort could be shifted away from current sites, there might be more to be gained from other activities. The more extensive approach suggested in (E) and (F) above could easily be combined with a genetics study. Moncrief, Cockett and Dueser (unpublished) recently demonstrated that sympatric DFS and GS can be distinguished unambiguously on the basis of microsatellite genetic markers. Assuming these markers are detectable in hair -- and there is no compelling reason to question this -- it may be feasible in the near future to combine passive sampling using nest boxes or bait stations with genetic profiling to detect the presence of DFS on a site and perhaps even to estimate relative abundance. It would be difficult to overstate the importance of this capability to monitoring and documenting the recovery of the Delmarva fox squirrel.

Whatever priorities the Recovery Team might set, they might want to consider the recommendations of Appendix 3 as they plan the next round of field work.

VI. Acknowledgments

I deeply appreciate the dedicated effort of the state and federal biologists who collected the benchmark data. Irvin Ailes (Chincoteague), Bill Giese (Blackwater), Ken Reynolds (Assawoman and Prime Hook) and Glenn Therres (Hayes Farm, Lecompte, Wye Island) merit special mention. I particularly appreciate the willingness of the biologists and the Recovery Team to entrust these data to my care and keeping. The Recovery Team suggested many stimulating questions for the data. Keren Giovengo, Mary Parkin and Nancy Moncrief greatly helped in refining the questions. John Porter of the University of Virginia designed the critical data management and error checking software. Patricia Pennock did a remarkable job of entering the data. Susan Durham and Jaime Jimenez of Utah State University provided important statistical advice. Enid Kelley generously assisted with preparing the final report. Finally, my wife Joan kept me supplied with coffee and good cheer during the seemingly endless task of transcribing the data. This work was supported by U.S.F.W.S. contract 5141070512 A and NSF grants BSR-8702333-06, DEB-9211772 and DEB-9411974 to the University of Virginia. This is a contribution from the Virginia Coast Reserve Long-Term Ecological Research Program.

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Appendix 1: Standard data form for entry of benchmark population data.

Delmarva Fox Squirrel Population Monitoring: Study Site________________________________ Page ___ of _____

Observers______________________ Dates_____________ No. traps/boxes__________ Weather__________________

Site Number	Grid Number	Month of Study	Trap Day	Trap=1, Box=2	Trap or Box Number	Right Ear Tag Number	Left Ear Tag Number	Retag = 1	Fate code	Age A=1, S=2, J=3	Sex M=1, F=2	Testes A=1, I=2, S=3	Vagina C=1, O=2	Nipple N=1, P=2, L=3	Pregnant = 1	Body Mass in Grams	Cond. E=1, G=2, W=3	No. of Young	Comments?

Fate codes: 1 = New capture, released; 2 = Recapture, released; 3 = Recapture this trapping period, released; 4 = Recapture, dead; 5 = New capture, dead; 6 = Recapture, changed grid; 7 = Released untagged or tag not read

Age: A=1=Adult; S=2=Subadult; J=3=Juvenile Testes: A=1=Abdominal; I=2=Inguinal; S=3=Scrotal Vagina: C=1=Closed; O= 2=Open Nipples: N=1=Non-pigmented, P=Pigmented, L=3=Lactating

Condition: E=1=Excellent (heavy coat, clear eyes, active) G=2=Good, W=3=Weak (conditional release)

Appendix 2: The following two pages list the standardized data for entries 83-103 in the CAPTURES data file. Lines 84-90 summarize the capture history for animal number (animno) 12330. This animal was first captured (line 84, fate = 1) on the Egypt Road tract (plotno = 2) on Blackwater National Wildlife Refuge (siteno = 1) in March 1991 (month = 39). The first capture occurred in nest box (trorbox = 2) number 21 (trpnum = 21). The animal received right ear tag 2330 (rtag) and left ear tag 2329 (ltag). It was classified as an adult (age = 1) male (sex = 1), and it weighed 1150 grams (bmass). This animal was next captured (fate = 2) in trap number 12 (trorbox = 1) in April 1991 (month = 40). It was then captured again (fate = 3) the following day (trapday = 2) in trap 11. This animal was not captured again until it was retagged (retag = 1) as a recapture (fate = 2) in April 1992 (month = 52) with new left tag 2470. It subsequently was captured again (fate = 2) in April 1993 (month = 64), February 1994 (month = 74) and April 1994 (month = 76). Animal number 12330 was never seen again after that date.

	animno	siteno	plotno	month	trapday	trorbox	trpnum	rtag	ltag	retag	fate	age	sex	testes	vagina	nipple	preg	bmass
83	12327	1	2	76	1	1	43	2328	2327	.	2	1	1	.	.	.	.	1020
84	12330	1	2	39	1	2	21	2330	2329	.	1	1	1	.	.	.	.	1150
85	12330	1	2	40	1	1	12	2330	2329	.	2	1	1	.	.	.	.	1150
86	12330	1	2	40	2	1	11	2330	2329	.	3	1	1	.	.	.	.	[illegible]
87	12330	1	2	52	2	1	31	2330	2470	1	2	1	1	.	.	.	.	[illegible]
88	12330	1	2	64	1	1	21	2330	2470	.	2	1	1	.	.	.	.	1100
89	12330	1	2	74	1	2	21	2330	2470	.	2	1	1	.	.	.	.	1100
90	12330	1	2	76	1	1	22	2330	2470	.	2	1	1	.	.	.	.	1100
91	12331	1	2	40	1	1	51	2331	2332	.	1	1	2	.	.	.	.	1200
92	12333	1	2	40	1	1	41	2333	2334	.	1	2	2	.	.	.	.	1050
93	12333	1	2	52	1	1	64	2333	2334	.	2	1	2	.	.	.	.	.
94	12337	1	2	40	1	1	63	2337	2335	.	1	1	1	.	.	.	.	1100
95	12337	1	2	51	1	2	63	2337	.	.	2	1	1	.	.	.	.	1150
96	12338	1	2	40	1	1	64	2339	2338	.	1	1	1	.	.	.	.	1050
97	12338	1	2	40	3	1	54	2339	2338	.	3	1	1	.	.	.	.	1050
98	12340	1	2	40	1	1	65	2341	2340	.	1	1	2	.	.	3	.	1150
99	12340	1	2	52	2	1	54	2471	2340	1	2	1	2	.	.	3	.	1025
100	12340	1	2	52	3	1	66	2471	2340	.	3	1	2	.	.	3	.	1025
101	12342	1	2	40	1	1	68	2342	2343	.	1	1	2	.	.	.	.	1150
102	12342	1	2	40	3	1	66	2342	2343	.	3	1	2	.	.	.	.	1150
103	12344	1	2	40	1	1	57	2345	2344	.	1	1	1	.	.	.	.	1200

Table 2 (continued)

Site	Year	Number of nest boxes checked	Number of trap days*	Total effort (trapping + box checks)
Wye Island	1991	50	250	300
	1992	49	150	199
	1993	49	150	199
	1994	44	150	194
	1995	45	150	195
	1996	43	150	193
	1997	41	150	191
	1998	41	150	191
	Sum	*362*	*1300*	*1662*
Prime Hook	1991	0	0	0
	1992	30	0	30
	1993	73	1446	1519
	1994	73	0	73
	1995	75	0	75
	1996	72	0	72
	1997	73	0	73
	1998	75	0	75
	Sum	*471*	*1446*	*1917*
Assawoman	1991	0	0	0
	1992	20	0	20
	1993	20	575	595
	1994	0	0	0
	1995	20	0	20
	1996	20	0	20
	1997	20	232	252
	1998	20	0	20
	Sum	*120*	*807*	*927*
Total sampling effort		*3386*	*8489*	*11875*
Percent of effort		29%	71%	

* 1 trap day = 1 trap operated for 1 day

Table 3: Number of Delmarva fox squirrel captures each year between 1991 and 1998.

Site	Year								Totals
	1991	1992	1993	1994	1995	1996	1997	1998	
Blackwater	50	70	64	60	57	81	50	75	507
Chincoteague	28	35	54	64	31	76	89	39	416
Hayes Farm	--	7	10	9	14	13	16	17	86
Lecompte	6	28	19	42	23	36	18	28	200
Wye Island	24	17	18	18	18	13	9	7	124
Prime Hook	--	9	27	32	9	5	9	--	91
Assawoman	--	6	1	--	4	4	2	--	17
Totals	108	172	193	225	156	228	193	166	1441

-- indicates missing data for that site and year

Table 4: Number of individual Delmarva fox squirrels observed, including both tagged and untagged (unidentified) animals.

Site	Year								Totals
	1991	1992	1993	1994	1995	1996	1997	1998	
Blackwater	29	33	28	20	25	40	18	29	222
Chincoteague	21	26	44	51	22	54	57	27	302
Hayes Farm	--	7	10	7	11	12	14	13	74
Lecompte	6	24	18	35	18	31	16	23	171
Wye Island	20	17	17	14	16	8	6	6	104
Prime Hook	--	9	13	28	9	4	9	--	72
Assawoman	--	6	0	--	3	2	0	--	11
Totals	76	122	130	155	104	151	120	98	956

-- indicates missing data for that site and year

Table 5: Number of new Delmarva fox squirrels each year

Site	Year								Totals
	1991	1992	1993	1994	1995	1996	1997	1998	
Blackwater	27	29	22	18	18	29	18	27	188
Chincoteague	17	15	26	37	21	44	49	22	231
Hayes Farm	–	7	10	6	10	11	9	12	65
Lecompte	6	19	14	25	17	27	16	21	145
Wye Island	17	8	12	9	14	8	6	6	80
Prime Hook	–	2	11	8	4	4	9	–	38
Assawoman	–	3	0	–	3	2	0	–	8
Totals	67	83	95	103	87	125	107	88	755

– indicates missing data for that site and year

Table 6: Number of untagged (unidentified) Delmarva fox squirrels observed each year.

Site	Year								Totals
	1991	1992	1993	1994	1995	1996	1997	1998	
Blackwater	2	4	6	2	7	11	0	2	34
Chincoteague	4	11	18	14	1	10	8	5	71
Hayes Farm	–	0	0	1	1	1	5	1	9
Lecompte	0	5	4	10	1	4	0	2	26
Wye Island	3	9	5	5	2	0	0	0	24
Prime Hook	–	7	2	20	5	0	0	–	34
Assawoman	–	3	0	–	0	0	0	–	3
Totals	9	39	35	52	17	26	13	10	201

– indicates missing data for that site and year

Table 7: Number of new subadult and adult Delmarva fox squirrels tagged each year.

Site	Year								Totals
	1991	1992	1993	1994	1995	1996	1997	1998	
Blackwater	23	25	21	14	17	29	18	27	174
Chincoteague	17	13	22	37	21	34	41	20	205
Hayes Farm	--	7	10	6	10	11	9	12	65
Lecompte	6	19	14	25	17	26	16	21	144
Wye Island	17	8	11	8	13	8	6	6	77
Prime Hook	--	2	7	3	2	1	6	--	21
Assawoman	--	1	0	--	3	1	0	--	5
Totals	63	75	85	93	83	110	96	86	691

-- indicates missing data for that site and year

Table 8: Number of new juvenile Delmarva fox squirrels tagged each year.

Site	Year								Totals
	1991	1992	1993	1994	1995	1996	1997	1998	
Blackwater	4	4	1	4	1	0	0	0	14
Chincoteague	0	2	4	0	0	10	8	2	26
Hayes Farm	--	0	0	0	0	0	0	0	0
Lecompte	0	0	0	0	0	1	0	0	1
Wye Island	--	0	1	1	1	0	0	0	3
Prime Hook	--	0	4	5	2	3	3	--	17
Assawoman	--	2	0	--	0	1	0	--	3
Totals	4	8	10	10	4	15	11	2	64

-- indicates missing data for that site and year

Table 9: Total number of individual Delmarva fox squirrels observed each year, including new captures, recaptures of animals tagged in a previous year and untagged (unidentified) animals. These numbers approximate the minimum number of squirrels known to be alive on a site in a given year.

Site	Year								Totals
	1991	1992	1993	1994	1995	1996	1997	1998	
Blackwater	31	47	51	45	43	59	38	49	363
Chincoteague	28	35	53	64	25	63	73	38	379
Hayes Farm	--	7	10	9	14	13	16	17	86
Lecompte	6	26	19	37	22	36	18	28	192
Wye Island	20	17	17	16	18	11	8	7	114
Prime Hook	--	9	14	31	9	5	9	--	77
Assawoman	--	6	1	--	4	4	2	--	17
Totals	85	147	165	202	135	191	164	139	1228

-- indicates missing data for that site and year

Table 10: Number of Delmarva fox squirrels retagged each year.

Site	Year								Totals
	1991	1992	1993	1994	1995	1996	1997	1998	
Blackwater	1	7	10	7	6	7	6	8	52
Chincoteague	1	5	2	2	0	6	7	3	26
Hayes Farm	--	0	0	0	0	1	1	0	2
Lecompte	0	0	2	1	2	2	0	1	8
Wye Island	0	0	1	2	1	0	1	0	5
Prime Hook	--	0	2	1	1	0	1	--	5
Assawoman	--	0	0	--	1	1	0	--	2
Totals	2	12	17	13	11	17	16	12	100

-- indicates missing data for that site and year

Table 11: Number of Delmarva fox squirrel fatalities observed each year.

Site			Last Fate		Totals
			Recapture, dead	New capture, dead	
Blackwater	Year	1991	0	1	1
	Total		0	1	1
Chincoteague	Year	1993	1	0	1
		1994	0	4	4
		1996	1	0	1
	Total		2	4	6
Lecompte	Year	1994	1	0	1
		1996	0	1	1
	Total		1	1	2
Wye Island	Year	1997	1	0	1
	Total		1	0	1
Prime Hook	Year	1996	0	1	1
	Total		0	1	1
Totals			4	7	11

Table 12: Capture types (trap, box, both) for subadult and adult Delmarva fox squirrels of known gender.

Year		Capture Types			Totals
		Trap only	Box only	Both trap and box	
1991	Count	34	29	8	71
	% within year	47.9%	40.8%	11.3%	100.0%
1992	Count	51	427	10	104
	% within year	49.0%	41.3%	9.6%	100.0%
1993	Count	53	65	6	124
	% within year	42.7%	52.4%	4.8%	100.0%
1994	Count	46	80	14	140
	% within year	32.9%	57.1%	10.0%	100.0%
1995	Count	73	37	5	115
	% within year	63.5%	32.2%	4.3%	100.0%
1996	Count	74	56	19	149
	% within year	49.7%	37.6%	12.8%	100.0%
1997	Count	93	35	13	141
	% within year	66.0%	24.8%	9.2%	100.0%
1998	Count	69	52	4	125
	% within year	55.2%	41.6%	3.2%	100.0%
Totals	Count	493	397	79	969
	% within year	50.9%	41.0%	8.2%	100.0%

Table 13: Capture types (trap, box, both) for Delmarva fox squirrel juveniles of known gender

Year		Capture Types			Totals
		Trap only	Box only	Both trap and box	
1991	Count		8	3	11
	% within year		72.7%	27.3%	100.0%
1992	Count	2	7	1	10
	% within year	20.0%	70.0%	10.0%	100.0%
1993	Count	5	5		10
	% within year	50.0%	50.0%		100.0%
1994	Count	1	13		14
	% within year	7.1%	92.9%		100.0%
1995	Count	2	5		7
	% within year	28.6%	71.4%		100.0%
1996	Count		14		14
	% within year		100.0%		100.0%
1997	Count	1	10		11
	% within year	9.1%	90.9%		100.0%
1998	Count		2		2
	% within year		100.0%		100.0%
Totals	Count	11	64	4	79
	% within year	13.9%	81.0%	5.1%	100.0%

Table 14: Number of Delmarva fox squirrel females observed in a nest box with juveniles.

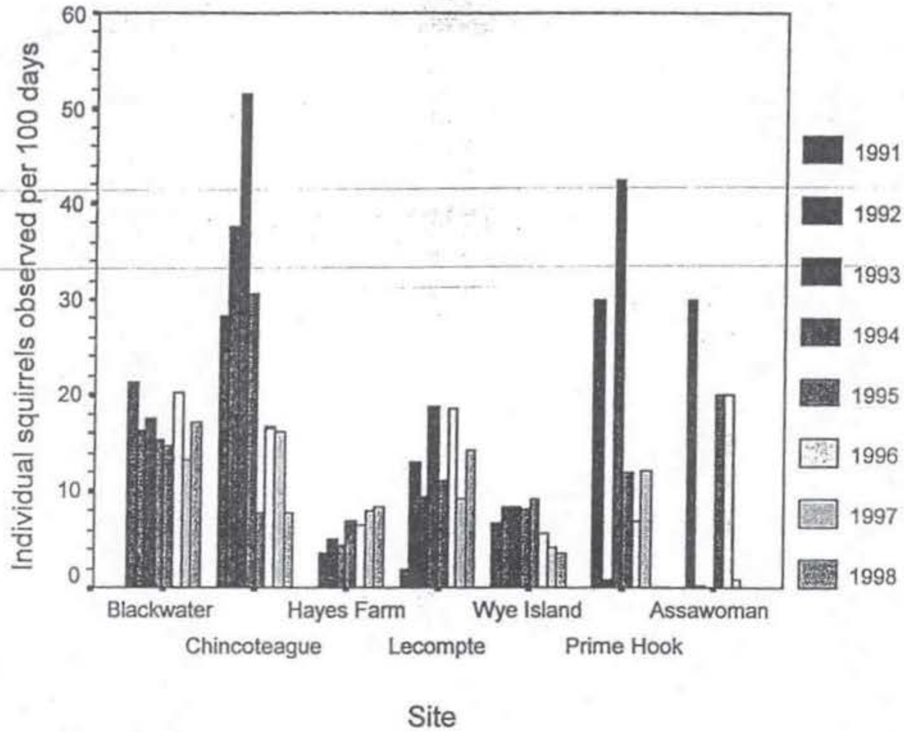
Site	Year								Totals
	1991	1992	1993	1994	1995	1996	1997	1998	
Blackwater	0	2	4	0	2	0	0	0	8
Chincoteague	2	5	3	0	0	3	0	0	13
Hayes Farm	--	0	0	0	0	0	2	1	3
Lecompte	0	2	1	5	1	1	0	1	11
Wye Island	1	0	0	1	1	0	0	0	3
Prime Hook	--	2	2	6	2	2	1	--	15
Assawoman	--	1	0	--	0	0	0	--	1
Totals	3	12	10	12	6	6	3	2	54

– indicates missing data for that site and year

Table 15: Number of Delmarva fox squirrel juveniles observed in each month.

Site		Month							Totals
		April	Feb	Jan	July	June	March	May	
Blackwater	Count	3	8				7		18
	% within site	16.7%	44.4%				38.9%		100%
Chincoteague	Count	1	25	4	2	3	13		48
	% within site	2.1%	52.1%	8.3%	4.2%	6.3%	27.1%		100%
Hayes Farm	Count		6						6
	% within site		100%						100%
Lecompte	Count		7				14		21
	% within site		33.3%				66.7%		100%
Wye Island	Count	1	8				3	2	14
	% within site	7.1%	57.1%				21.4%	14.3%	100%
Prime Hook	Count	36				2	13	1	52
	% within site	66.2%				3.8%	25.0%	1.9%	100%
Assawoman	Count	1					5		6
	% within site	16.7%					83.3%		100%
Totals	Count	42	54	4	2	5	55	3	165
	% within site	25.5%	32.7%	2.4%	1.2%	3.0%	33.3%	1.8%	100%

Figure 1: Number of individual Delmarva fox squirrels observed per 100 sampling days (i.e., per 100 box checks or per 100 trap days).



*Selected figures from "**Project Report, Analysis of Delmarva fox squirrel (Sciurus niger cinereus) benchmark population data (1991-1998)**" Dr. Raymond D. Deuser, Utah State University, Logan, UT 84322-5210, January 19, 1999.*

Figure 1: Number of individual Delmarva fox squirrels observed per 100 sampling days (i.e., per 100 box checks or per 100 trap days).

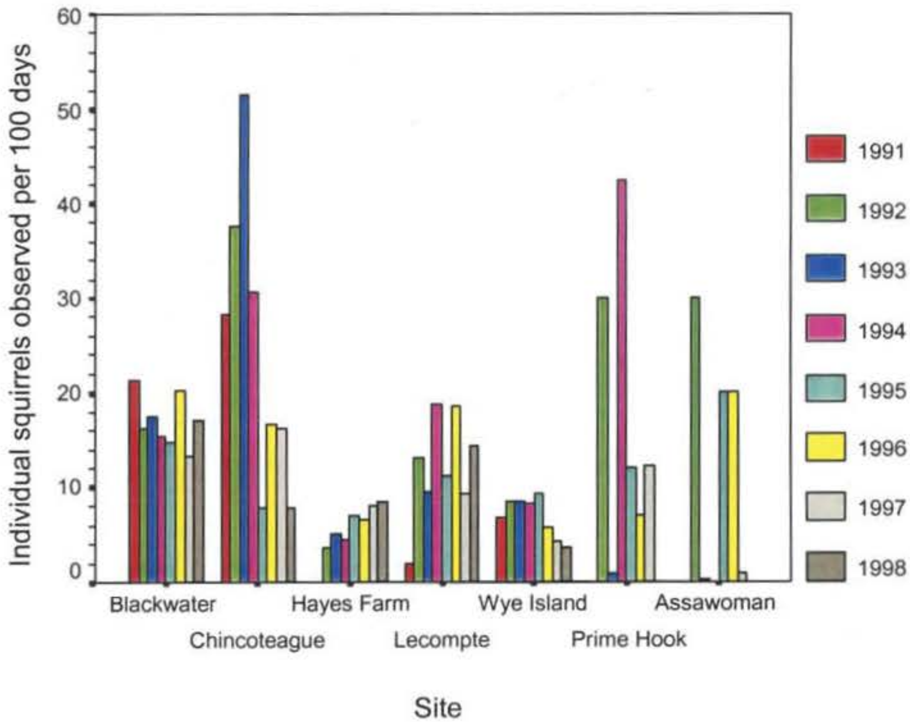


Figure 2: Number of individual Delmarva fox squirrels observed per 100 sampling days on two study areas on Blackwater National Wildlife Refuge.

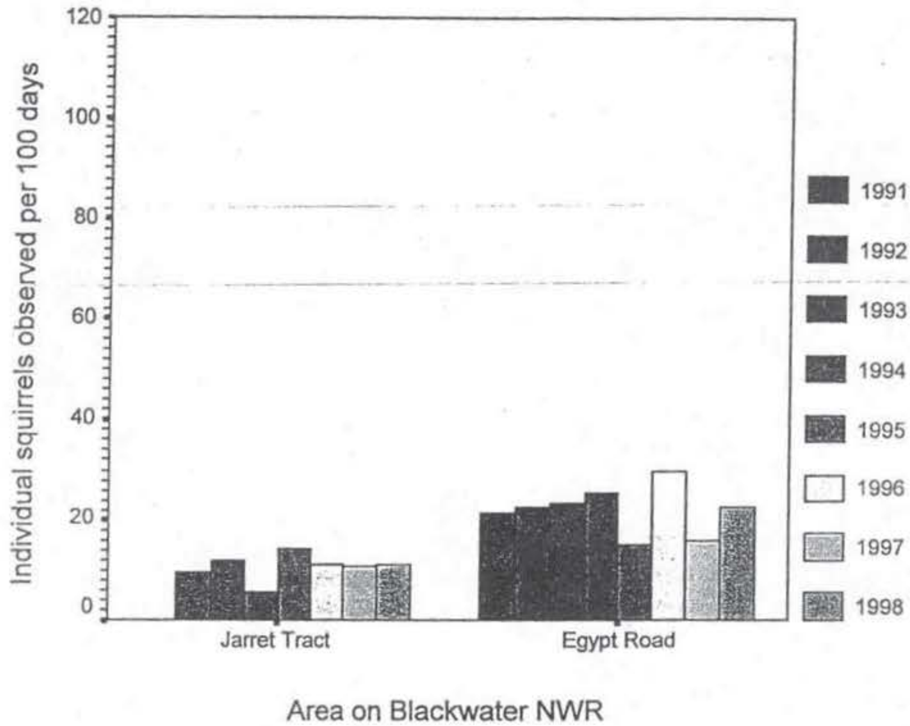


Figure 3: Number of individual Delmarva fox squirrels observed per 100 sampling days on five study areas on Chincoteague National Wildlife Refuge.

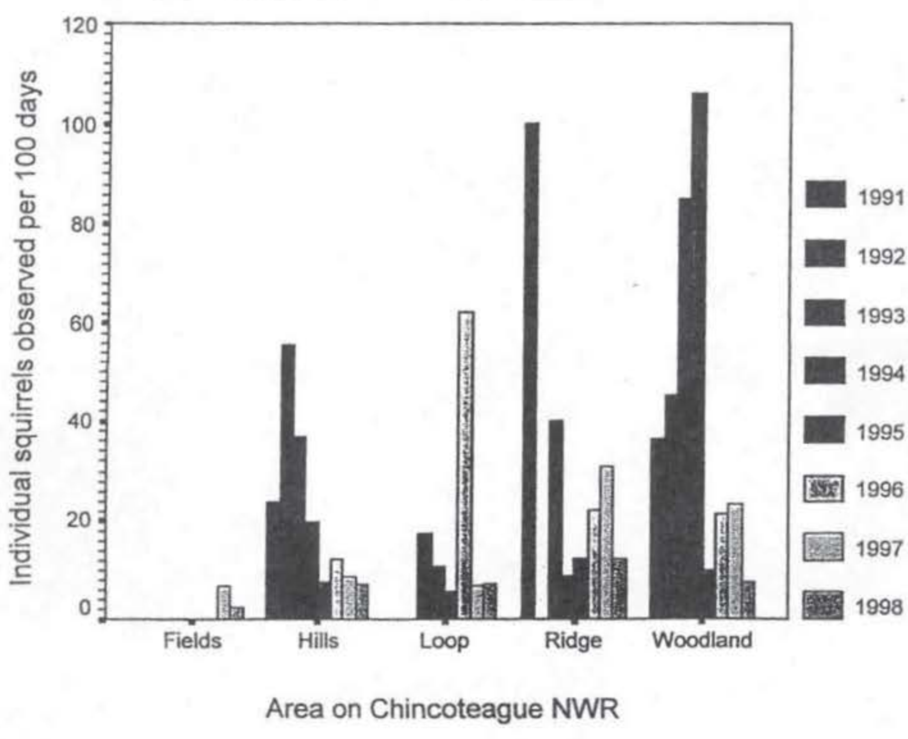


Figure 2: Number of individual Delmarva fox squirrels observed per 100 sampling days on two study areas on Blackwater National Wildlife Refuge.

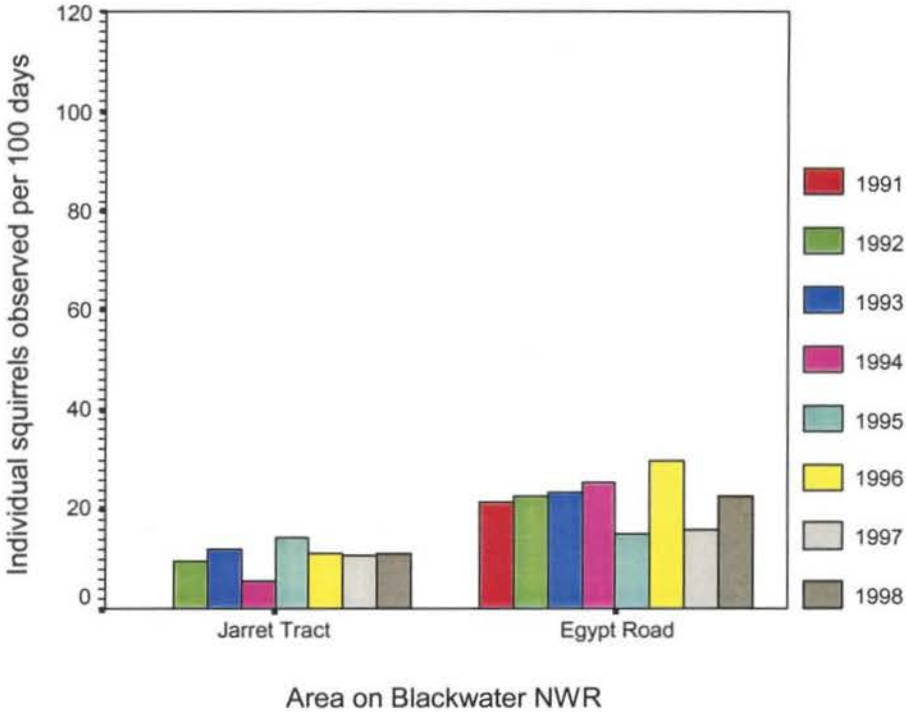


Figure 4: Comparison of sampling procedures on the benchmark study areas. Number of individual Delmarva fox squirrels observed per 100 trap days vs. number of individuals observed per 100 nest box checks.

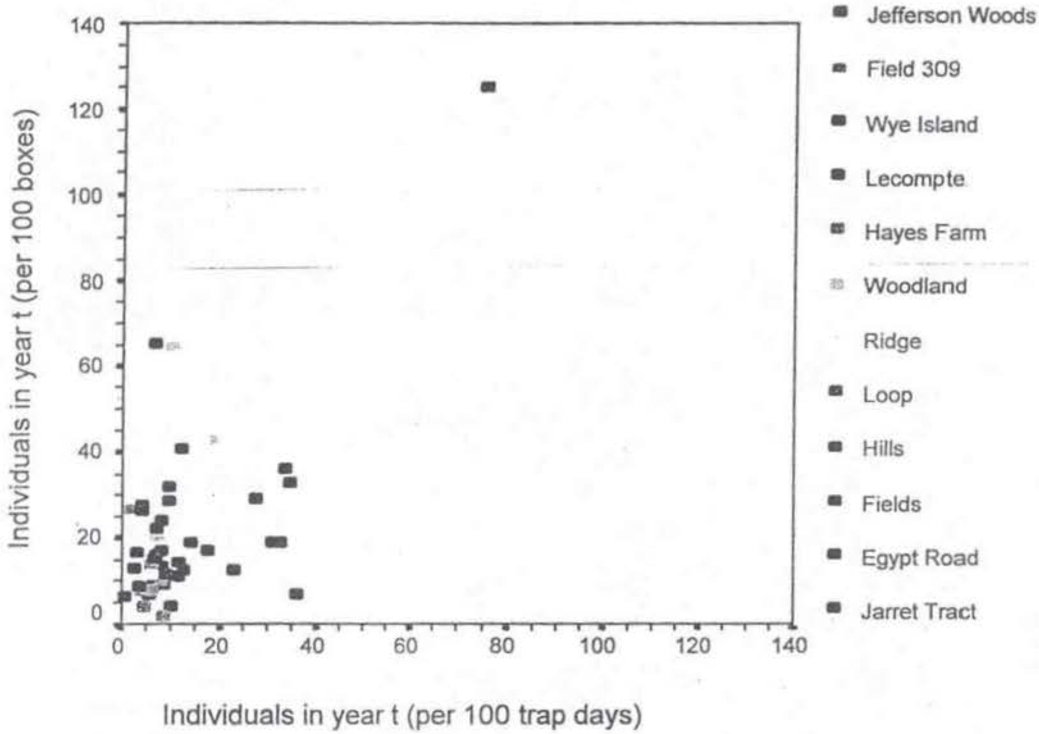


Figure 5: Delmarva fox squirrel population structure on seven benchmark study sites.

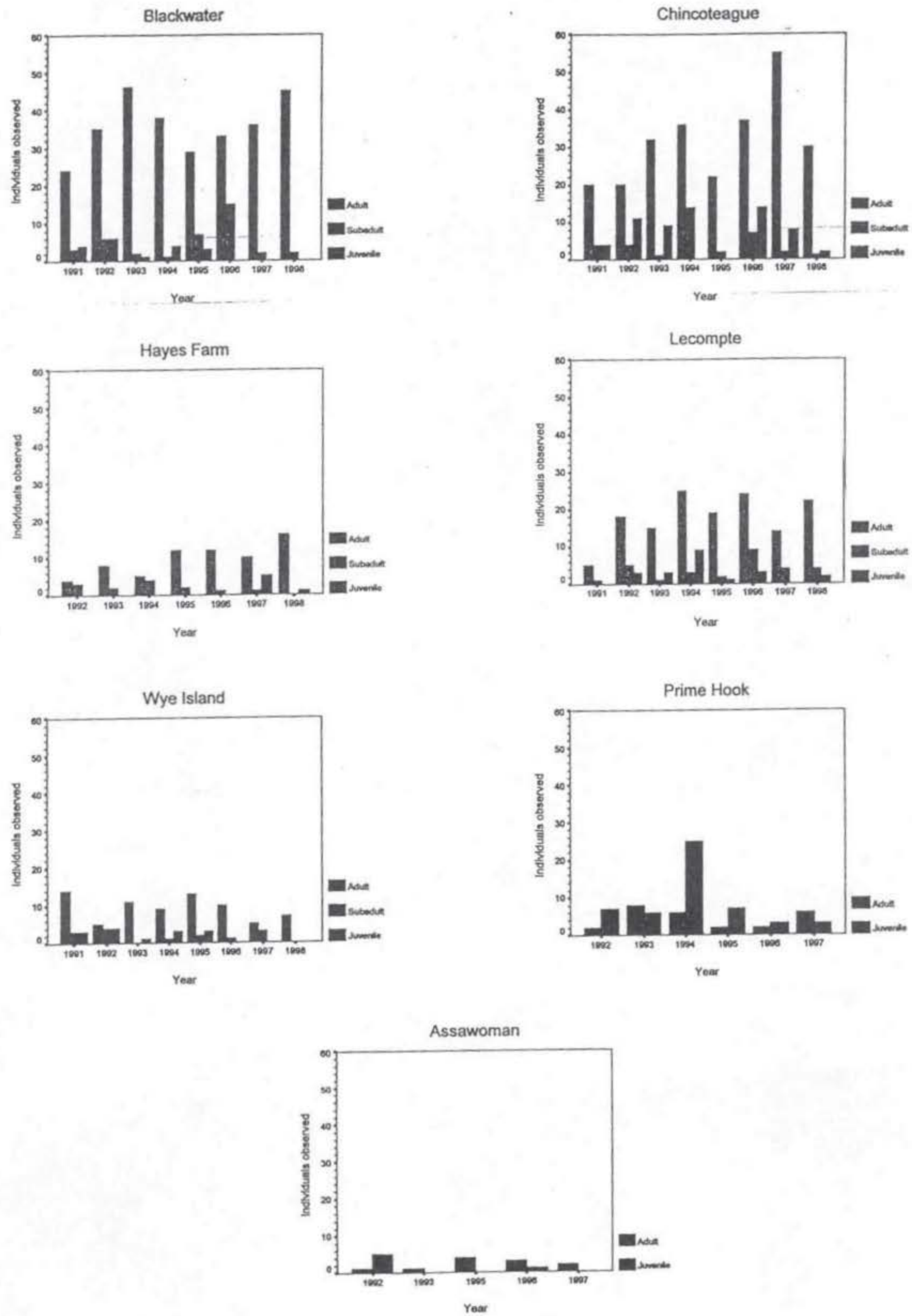


Figure 3: Delmarva fox squirrel population structure on seven benchmark study sites.

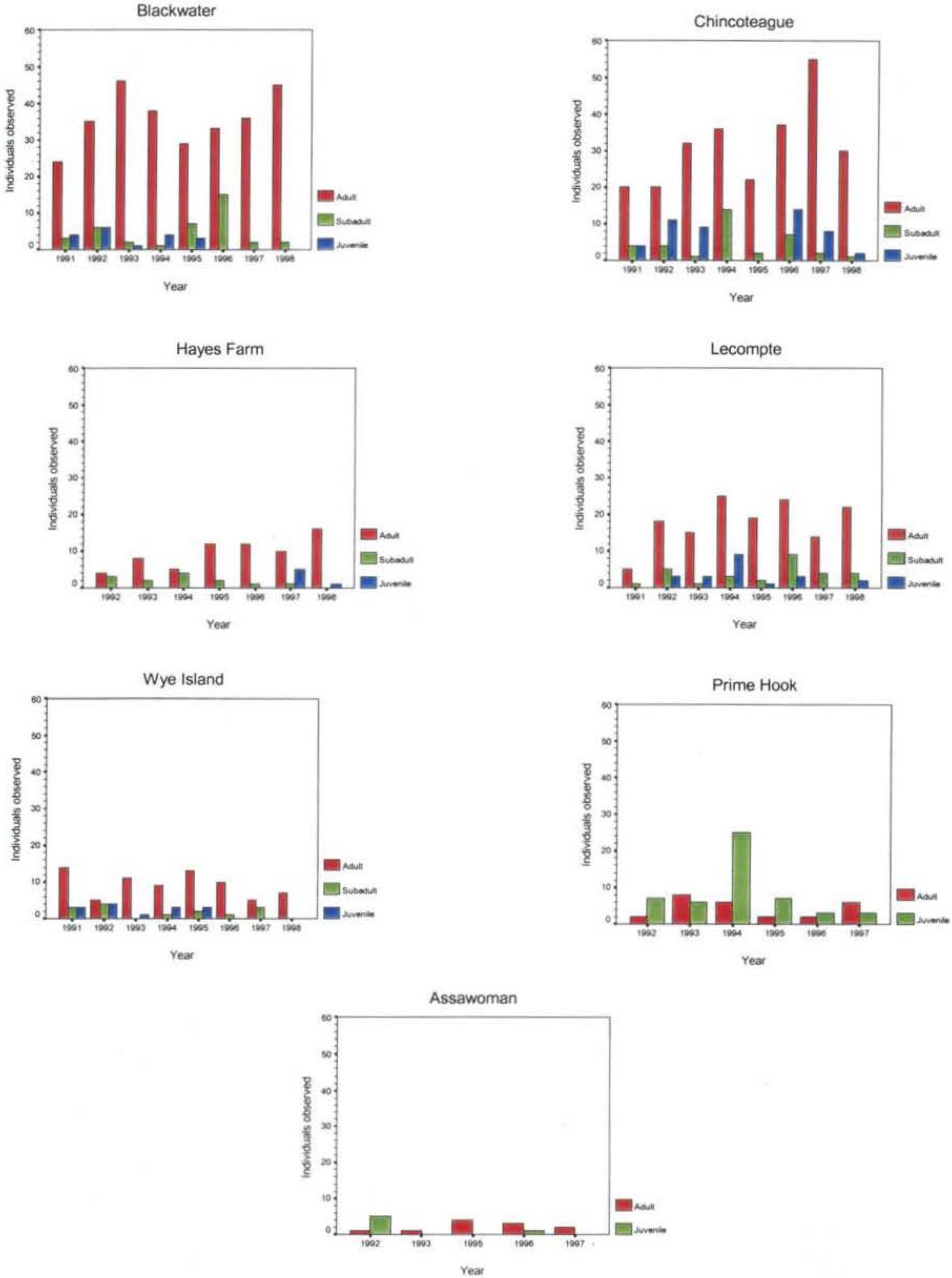


Figure 6: Observed life spans of Delmarva fox squirrels on seven benchmark study sites.

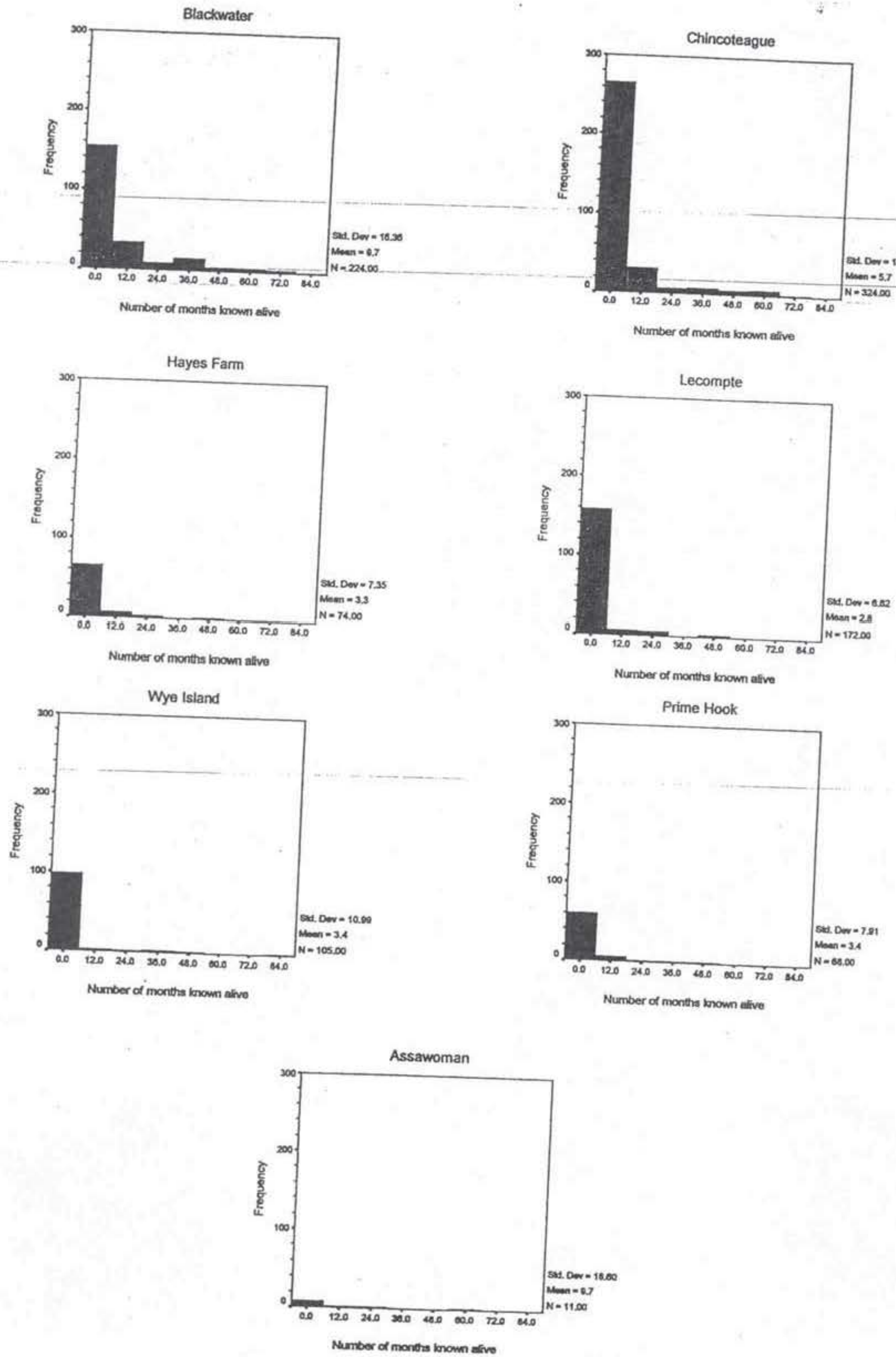


Figure 7: Relationship between the numbers of individuals observed in years t and t+1, per 100 nest box inspections, at the level of the study area.

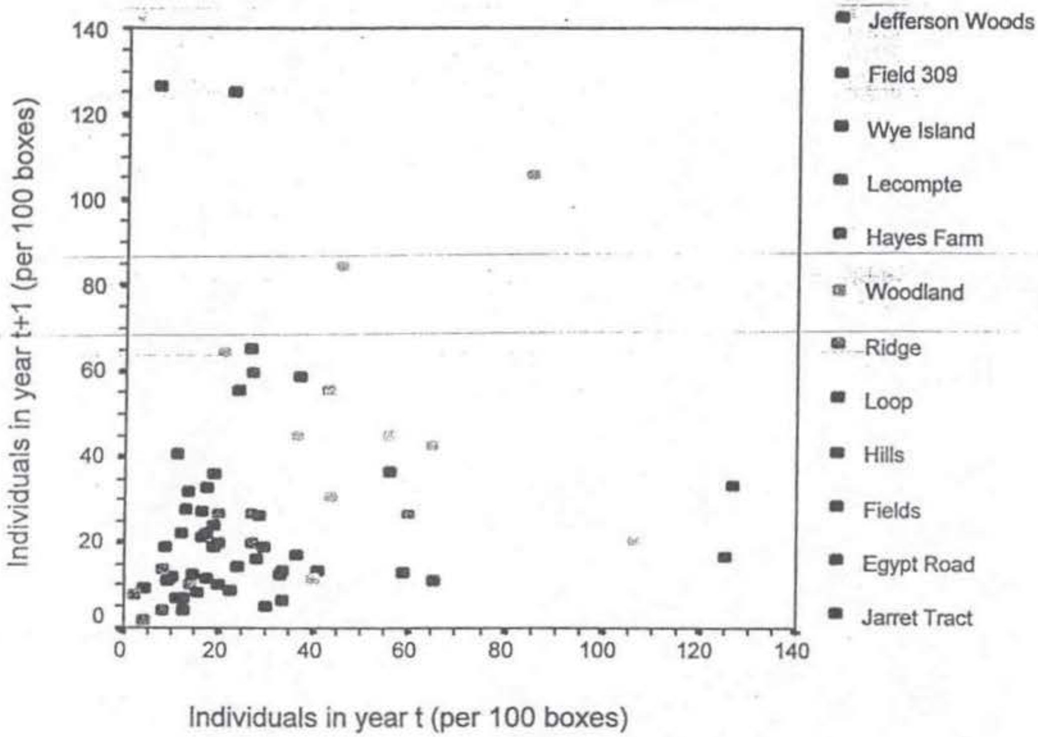
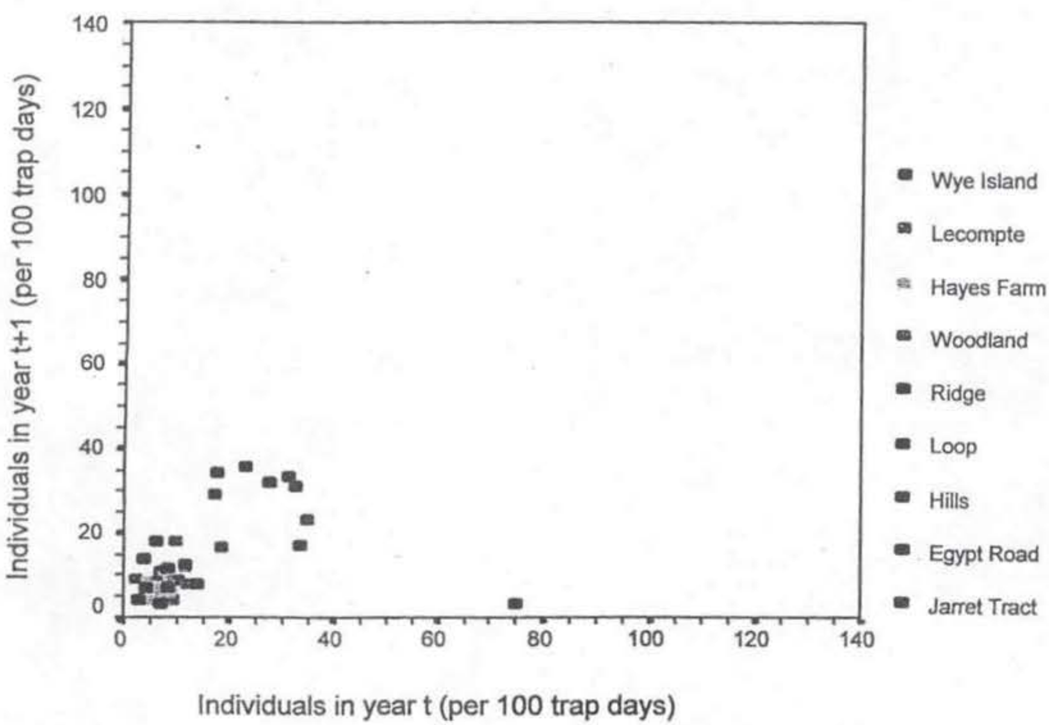


Figure 8: Relationship between the numbers of individuals observed in years t and t+1, per 100 trapping days, at the level of the study area.



	cond	young	parent	origobs	plotcode	monname	year	areano
83	2	.	.	211.00	102	April	1994	102
84	.	.	.	15.00	102	March	1991	102
85	.	.	.	20.00	102	April	1991	102
86	2	.	.	37.00	102	April	1991	102
87	2	.	.	81.00	102	April	1992	102
88	2	.	.	140.00	102	April	1993	102
89	2	.	.	182.00	102	Feb	1994	102
90	2	.	.	217.00	102	April	1994	102
91	.	.	.	16.00	102	April	1991	102
92	.	.	.	18.00	102	April	1991	102
93	.	.	.	61.00	102	April	1992	102
94	.	.	.	21.00	102	April	1991	102
95	2	.	.	51.00	102	March	1992	102
96	.	.	.	22.00	102	April	1991	102
97	.	.	.	48.00	102	April	1991	102
98	.	.	.	23.00	102	April	1991	102
99	2	.	.	83.00	102	April	1992	102
100	2	.	.	99.00	102	April	1992	102
101	.	.	.	24.00	102	April	1991	102
102	.	.	.	46.00	102	April	1991	102
103	.	.	.	25.00	102	April	1991	102

Appendix 3: Comments and recommendations to improve the collection, analysis and interpretation of Delmarva fox squirrel population data on the benchmark study sites.

(1) Proceed quietly through the woods during nest-box checks.

(2) Minimize escapes and the release of untagged animals.

(3) Handle squirrels according to the standard protocol, including determining gender, reproductive condition, body mass, and general physical condition. Check pelage, eyes and energy (activity) level.

(4) Use standard field data sheet. The Recovery Team may want to consider adopting and/or modifying the data sheet presented in Appendix 1.

(5) Fill out data sheet completely, including date, study site, weather and observer(s).

(6) Use ear tags in sequence when possible. Distinguish between right ear and left ear when recording data. Record retags as such. Tag anything with ears.

The Recovery Team should discuss the possibility of switching to pit tags (implants) to eliminate tag loss and tag-reading errors.

(7) Do not use duplicate tags on a site.

(8) The Recovery Team should review and/or revise the age-class criteria for juveniles, subadults and adults, and these criteria should be applied uniformly.

(9) Record tare weight for any bag or animal handling device that may be weighed with the animal. Ensure that tare weight has been subtracted from recorded body mass.
Mass of squirrel = (mass of squirrel + bag) - mass of bag (i.e., tare weight)

(10) Review all data sheets for completeness and accuracy before storing them away or entering the data.

(11) Maintain a continuous, up-to-date capture history for each individual ever captured.

(12) Train and supervise volunteers closely.

(13) Write legibly, ensure completeness and accuracy of all field records, and store records securely. Maintain originals in your possession at all times.

(14) Maintain nest boxes in good repair at all times.

(15) Make sampling effort as constant as possible from year to year.

Table 1: Description of Delmarva fox squirrel population benchmark sites.

Sites/Areas	State	County	Area sampled (ha)	Contact
Blackwater NWR*	Maryland	Dorchester	—	W. Giese
Egypt Tract			20	
Jarrett Tract			20	
Chincoteague NWR	Virginia	Accomack	—	I. Ailes
Old Fields			180	
White Hills			530	
Wildlife Loop			180	
Lighthouse Ridge			88	
Woodland Trail			235	
Eastern Neck NWR	Maryland	Kent	—	M. Kaehny
Hayes Farm	Maryland	Dorchester	56	G. Therres
Lecompte WMA*	Maryland	Dorchester	153	G. Therres
Wye Island NRMA*	Maryland	Queen Annes	86	G. Therres
Prime Hook NWR	Delaware	Sussex	—	K. Reynolds
Field 309			20	
Entrance Woods			20	
Jefferson Farm			18	
Willman's			26	
Assawoman WMA	Delaware	Sussex	20	K. Reynolds

* NWR = National Wildlife Refuge; WMA = Wildlife Management Area; NRMA = Natural Resource Management Area

Table 2: Sampling effort on benchmark population sites (1991-98).

Site	Year	Number of nest boxes checked	Number of trap days*	Total effort (trapping + box checks)
Blackwater	1991	58	87	145
	1992	116	174	290
	1993	116	174	290
	1994	116	174	290
	1995	116	174	290
	1996	116	174	290
	1997	111	174	285
	1998	113	174	287
	Sum	*862*	*1305*	*2167*
Chincoteague	1991	99	0	99
	1992	93	0	93
	1993	103	0	103
	1994	105	104	209
	1995	94	224	318
	1996	119	257	376
	1997	110	339	449
	1998	127	357	484
	Sum	*850*	*1281*	*2131*
Hayes Farm	1991	0	0	0
	1992	50	150	200
	1993	50	150	200
	1994	50	150	200
	1995	50	150	200
	1996	50	150	200
	1997	50	150	200
	1998	50	150	200
	Sum	*350*	*1050*	*1400*
Lecompte	1991	50	250	300
	1992	49	150	199
	1993	49	150	199
	1994	46	150	196
	1995	45	150	195
	1996	44	150	194
	1997	44	150	194
	1998	44	150	194
	Sum	*371*	*1300*	*1671*