BIG CYPRESS DEER/PANTHER RELATIONSHIPS: DEER MORTALITY

by

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Abstract: Sixty-six white-tailed deer (Odocoileus virginianus) were captured in the Bear Island Unit of the Big Cypress National Preserve, 57 of which were radio-instrumented. Of the 26 marked deer that died, 10 were taken by bobcats (Felis rufus), 4 by Florida panthers (Felis concolor coryi), and 1 by an alligator (Alligator mississippiensis). Four died of other natural causes, 5 were harvested (3 legally, 2 illegally), and 2 died of unknown causes. Average doe home range size was 239 ha and 2 bucks ranged from 454-1560 ha. There were no differences in survival rates among 3 intervals: summer (1 May-31 Aug.), fall/hunting season (1 Sep.-31 Dec.), and spring (1 Jan.-30 Apr.). The average annual survival rate was 0.813 (95% CI- 0.68, 0.94) and 64% of the annual mortality was attributable to predation. A neonate mortality rate of 37.8% $\pm$ 16.1 can be inferred by examining pregnancy rates and number of fetuses from collected does and comparing to the fawn-rearing rate from observations of radio-instrumented does. Fawn mortality appeared to fluctuate with surface water levels (high water = high fawn mortality). Hunting activities had little to no impact on does, either in number of illegal kills (2) or by causing does to leave the Preserve (0). The population appeared to be stable with a net reproductive rate (R_0) of 0.97.

INTRODUCTION

This study was designed to evaluate the causes and rates of deer mortality, especially among does, for the purpose of better managing the deer resource. The Bear Island unit of the Big Cypress National Preserve (BCNP) was chosen as the study site because it supports the highest density deer herd on public lands (Schortemeyer et al. 1989) in occupied panther range, and at least 12 panthers have used Bear Island since 1986.

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STUDY AREA

Bear Island is the northernmost unit of the Big Cypress National Preserve and lies northeast of the intersection of State Road 84 (I-75) and State Road 29. The climate is sub-tropical savannah characterized by a hot, humid rainy season (May through September) and a mild dry season (October through April)(Duever et al. 1986). Average annual rainfall and temperature are 136.0 cm and 23° C, respectively. Major plant communities are herbaceous freshwater marshes, pinelands, mixed-species swamps, and hardwood hammocks.

METHODS

Capture Techniques

We captured deer in the herbaceous wetlands of Bear Island, primarily East Hinson Marsh, an area with relatively high numbers and good visibility of deer. We first attempted to capture deer in these open, flooded areas through use of an airboat and capture gun. After sunset, we launched our airboats and began to spotlight for the eyeshine of white-tailed deer. Once a deer was spotted, we pursued the animal in an attempt to shoot it with a tranquilizing dart. A combination of ketamine hydrochloride (muscle relaxer) and Rompum (tranquilizer) was used in the darts. Although we captured a few deer, we decided to explore other methods in an effort to decrease our capture time.

We also netted deer from a Bell Jet Ranger helicopter with a handheld net-gun (Coda Enterprises, Inc., Mesa, AZ.) (Barrett et al. 1982). The shooter was positioned behind the pilot with the helicopter doors removed, and secured by a safety harness allowing him to lean out of the aircraft. We used 1 other person as an additional spotter and to assist in securing the deer after netting. The preferred shooting zone was perpendicular to and below the helicopter and the shooter. This "window" ensured that the net and weights would not strike the skids or interfere with the rotors. The pilot was responsible for presenting the deer within this window which meant that the helicopter was flown sideways or "crabbing" toward the deer. Once a deer was netted, we bound the legs and placed a blind-fold over the eyes while the helicopter transported a second crew to the capture site. The second crew then worked with the deer while the helicopter crew resumed hunting.

Attempts at capturing young fawns (< 2 mos. of age) were made at night by spot-lighting for mother-fawn pairs or by making daytime searches of radio-instrumented does. Older fawns were captured from helicopters with the net-gun.

Most captured deer were fitted with mortality-sensing radio-collars and released within 20-30 minutes. However, those animals that were captured by darting required several hours to recover from the anesthesia. The drugged animals could not be left alone during this recovery period for fear that they would wander into water and not have enough muscular control to avoid drowning. Not all captured animals were collared; yearling bucks were eartagged only because of the expected growth in neck size as they matured. Fawns were fitted with special collars that were designed to either expand as the deer grew or to expand and eventually break away with time and growth. We used the expansion collars on female fawns, since at full expansion the circumference would accommodate adult doe neck size, and the breakaway types on male fawns. Animals were eartagged and lengths, weights, and girths recorded whenever conditions permitted.

Monitoring of Radio-Instrumented Deer

We used 2 methods to locate radio-collared animals: ground triangulation and aerial fixes. Ground triangulation involved obtaining 3 or more directions of best signals from different locations. When plotted, the intersection of these lines indicated the location of the study animal. We obtained aerial fixes in a Cessna 172 equipped with antennas on each wing. A switch box allowed us to listen to either or both antennas and determine whether the deer was to the left or right of the aircraft. By dropping altitude to < 150 m, we could pinpoint a deer's location by circling a small area that was defined by the best signal reception.

Our radio-collars emitted a signal pulse at the rate of approximately 1 per second. Some transmitters also were equipped with tip switches sensitive to head movements resulting in varying pulse rates. Each transmitter had a mortality switch that would double the pulse rate if the collar did not move for a pre-determined time span (in this case, we selected a 2 hour period), indicating that the subject animal was probably dead. We had only one instance in which we detected a mortality signal from a living deer.

When a mortality was detected, we located the carcass within hours. The area immediately surrounding the carcass was searched first for signs of predators or other causes of death. The carcass was then examined for possible trauma. If the carcass was fresh, it was subjected to a full necropsy to determine the condition of the animal prior to death and to identify the mortality agent.

We located collared deer once a week and checked for mortality signals 3 additional times a week in conjunction with panther flights. Habitat type, associations with other deer, presence of fawns or yearlings, and activity were noted when possible. We plotted our deer locations using the Cartesian-based Universal Transverse Mercator system which provided us with east-west and north-south coordinates. We defined the arithmetic center of a deer's home range as the average east-west and north-south coordinates. Home ranges were calculated as convex polygons using the McPaal (Stuwe and Blohowiak 1985) microcomputer program.

Habitat types and descriptions were adjusted from Davis (1943, see Appendix A) to correspond to the habitat types used by the Florida Department of Transportation's (FDOT) Geographic Information System (GIS). Differences between habitat use and availability were determined through chi-square analysis. If significant differences were found, we examined the influence of each habitat with Bonferroni comparisons of their individual chi-square values (Johnson and Wichern 1982:197). Individual chi-square values were considered significant when $P < \alpha$/no. of categories.

The year was divided into 3 seasons, fall or hunting season (1 September - 31 December), spring (1 January - 30 April), and summer (1 May - 31 August). Hunting season was defined by the period in which antlered deer could be harvested legally. The remainder of the year was divided equally between spring and summer with the summer interval beginning at the onset of rainy season (Duever et al. 1986). We used chi-square analyses to examine variation in seasonal habitat use.

We recorded activity patterns of deer with a radio receiver, digital processor, and chart recorder. Pulse rates of transmitters were physically recorded on pressure-sensitive chart paper as deer moved and motion switches were activated. By counting those pulse changes, we could estimate activity rates over time.

Survival/Mortality Rate Calculations

We calculated survival rates for deer by the formula:

$$S_i = [(X_i - Y_i)/X_i]^n$$

where S_i is the interval survival rate, X_i is the number of radio-transmitter days, Y_i is the number of animals dying during the interval, and n is the length of the interval in days (Trent and Rongstad 1974, Heisey and Fuller 1985). We used the same fall, spring, and summer seasons, defined previously, as our intervals for survival rate calculations.

Collection of Bobcat Scats

In order to clarify the proportion and seasonality of deer occurrence in bobcat (Felis rufus) diets, we opportunistically collected bobcat scats throughout Bear Island We assumed that these scats represented food items taken on the area because of bobcats' relatively small home ranges. Panther scats were not used because panthers often make large movements in short time periods and scats may be the result of kills made elsewhere. Scats were washed in a sieve and air-dried. Contents were identified macroscopically by examining bones, teeth, or claws and by comparing hair to known samples.

RESULTS AND DISCUSSION

We captured 66 deer and radio-instrumented 57 of these animals (Table 1). Four deer were captured in 7 airboat-darting nights (1 deer/10.5 hrs.), but one died from a capture stress and another died from a dart-inflicted broken femur resulting in a 50% mortality rate. We captured 60 deer by helicopter/netgunning (1 deer/1.3 hrs.) with only 1 probable mortality. This animal was found killed by a black bear 3 days post-capture. A necropsy of the partially-consumed and decaying carcass revealed no direct capture-related trauma but it was evident that the bear had inflicted wounds upon the deer prior to its death. We concluded that the bear killed the deer but could not rule out the possibility that the capture process contributed to the deer's vulnerability to predation. One other doe died from an attempt to collect blood by a cardiac puncture; this method was discontinued. Two fawns were hand-captured during daytime searches of radio-instrumented does.

Helicopter-netgunning proved to be a superior capture method for white-tailed deer in comparison to darting from airboats. The capture rate was increased 8-fold and we were able to release the deer within 20 minutes of capture. Since we used no drugs and the handling time was minimal, stress to the captured deer was minimized.

Successful helicopter-netgunning was dependent upon several factors the most obvious being availability of target animals. We hunted at dawn and dusk when white-tailed deer were more active. Expansive open areas were needed for helicopter maneuverability. We found that flooded marshes were well suited for this capture technique because water slowed deer escape and water helped cool the animal after its physical exertion.

Home Range and Habitat Use Characteristics

Doe home ranges varied from 76-961 ha. Large home ranges resulted from extensive movements (2-10 km) by 3 does outside of their typical use areas. Average home range size was 239 ha (excluding those outlier home ranges). Bear Island doe home ranges were within the range reported for upland habitats in Florida: 85 ha (Marchinton and Jeter 1967), 270 ha (Bridges 1968), and 342 ha (Smith 1970). Home ranges of 2 adult bucks were 454 and 1560 ha.

Home range arithmetic centers showed significant shifts between hunting and non-hunting seasons ($Z = 5.5$, $p < 0.01$). However, 95% of deer home range centers were less than 600m ($\bar{X}$ = 300m) apart between hunting season and the rest of the year (Fig. 1). None of these shifts were the result of does utilizing new areas but were shifts of activity centers within previously used areas. No radio-instrumented deer left the Big Cypress Preserve Wildlife Management Area during the hunting season indicating that hunting activities had little impact on deer home range use.

The shift of activity centers was probably the result of significant changes between summer and fall habitat use ($X^2 = 193.4$, df=6, $P<0.0001$) (Fig. 2). Two upland habitat types, hardwood hammocks and pine/palmetto, were used more ($X^2 = 43.3$ and

18.8, respectively; df=6, P< 0.00714) and freshwater marshes less (X^2 = 98.0) than expected in fall when compared to summer habitat use. This change coincides with mast production by live oaks (Quercus virginianus), laurel oaks (Quercus laurifolia), gallberry (Ilex glabra), and saw palmetto (Serenoa repens)(Halls 1977). Some studies have shown that deer will move to areas of denser hiding cover at the onset of hunting season (Pilcher and Wompler 1981, Kufeld et al. 1988). Besides mast production, hardwood hammocks and pine palmetto have more structural diversity than marshes so their utility as hiding cover may be greater.

Summer and spring habitat use differed significantly (X^2 = 96.2; df=6, P<0.0001), primarily the result of the way deer used thicket swamps and freshwater marshes (Fig. 2). Thicket swamps were used more and freshwater marshes less in spring with the pattern reversing in summer (i.e. less use of thicket swamps and more use of marshes) (X^2 = 18.1 and 47.3, respectively; df=6, P<0.00714). Since the majority of collared deer were does and spring is the fawning season, thicket swamps may have been used more than expected because of the excellent cover they provide for birthing and hiding fawns. Spring is the driest part of the year; marshes may have little palatable forage until summer rains allow regrowth of marsh vegetation.

Differences between spring and fall habitat use were significant (X^2 = 26.4; df=6, p=0.00019), however the differences could not be attributed to a particular habitat or combination of habitats (Fig. 2). The differences are more the result of small changes in the way deer used all habitats.

As a natural bias of the capture method, most collared deer were distributed in 2 distinct areas of Bear Island. These areas were expansive open areas that were suitable for helicopter pursuit of deer. East Hinson Marsh, covering some 2070 ha, was the most productive area for capturing deer. Freshwater marshes, which covered 50.6% of the area used by radio-collared deer (Fig. 3), were a mosaic of sawgrass, flag ponds, and wet prairies. Hardwood tree islands and cypress domes dotted the marsh interior with extensive hardwood hammocks, pinelands, and cypress/mixed hardwood swamps as borders. Interfaces between open marsh and forests were areas of shrub marsh, dominated by wax myrtle (Myrica cerifera), and thicket swamps. The 32 deer collared in East Hinson were found in freshwater marshes or hardwood hammocks 68.8% of the time (Fig 3). Deer in East Hinson used habitat in proportion to availability (P < 0.005) except for thicket swamps, which were used more than expected (X^2 = 76.7, P < 0.000714; df =6). Thicket swamps may be preferred because they offer excellent cover and browse.

The Okaloacoochee Slough in north Bear Island, where 17 deer were collared, was dominated by a combination of sawgrass ponds, flag marshes, and cypress swamps. Thicket swamps were found extensively between cypress and marsh habitats. Cypress and thicket swamps accounted for 71.6% of locations for the deer collared in this area (Fig. 4). The GIS habitat designations for the Okaloacoochee Slough were not accurate enough to calculate habitat availability so no habitat preferences could be determined.

White-tailed Deer Activity Patterns

Deer were most active at dusk (1600-1900 hours), and had 2 periods of greatest inactivity, 1 shortly after sunrise and the second in the early afternoon (Fig. 5). These 3 peaks or troughs were significantly different from the mean activity profile (P < 0.05). There was steady activity from midnight to sunrise, with very little variation between hourly activity estimates.

Fawning Success and Fawn Mortality

Gaining insight into how many fawns are born and survive through their first year is critical to understanding the dynamics of a population. If there are too few fawns produced or successfully reared to adulthood, a population will decline. In order for a population to remain stable over time, females need to replace themselves with a surviving female offspring. If females produce more than 1 replacement, the population can increase.

White-tailed deer fawns > 6 weeks old are able to travel with their mothers (Jackson et al. 1972); observations of does that successfully raise fawns to this age and beyond can be a measure of fawning success. These fawning success estimates can yield insight into neonate fawn mortality by calculating predicted fawning success based upon pregnancy rates and fetal counts.

Ten of 17 radio-instrumented does were observed with fawns of the year during spring 1991 for a 58.8% fawning success rate. Five-year averages for collected does in Bear Island show that 93.1% of does were pregnant with 1.2 fetuses/doe (McCown 1991). By applying these values to 1991's observations of fawning success, it is possible to estimate neonate fawn mortality. Of the 17 does with known fawning success, 15.8 should have been pregnant (17 x .931) and produced 19.0 fetuses (15.8 does x 1.2 fetuses/doe). This suggests a spring 1991 neonate fawn mortality of 47.0% [1-(10 observed fawns/19.0 estimated # of full-term fetuses)].

This neonate fawn mortality rate is comparable to 1988's 55.2% and much higher than 1989's and 1990's rates of 28.4% and 20.4% respectively. These fluctuations in neonate fawn mortality may be related to surface water levels during the spring fawning season. Peak fawn drop was 28 February which coincides with the driest time of the year (Fig. 6). During the springs of 1989 and 1990, freshwater marshes had no surface water except in artificial wells dug for livestock. In contrast, these same areas were inundated during the springs of 1988 and 1991. Low water conditions may have allowed does to avoid concentrating on higher ground for selecting birth sites and hiding neonates. This may have reduced the chances of fawn predation. The 4-year average neonate fawn mortality rate was 37.8% $\pm$ 16.1 SE.

We captured 13 fawns-of-the-year and affixed them with radio-collars. Two fawns were captured as neonates. Our neonate capture efforts were hampered by poor access to radio-collared does and the abundance of hiding cover which limited our ability to detect fawns. Capture methods for neonates were developed in areas with high density herds, good visibility, and easy access to fawns (Downing and McGinnes 1969, Bolte et al. 1970, Logan 1972, and Epstein et al. 1985). Of the 13 animals that began the 6 month to 1 year age interval, 12 survived. The only mortality was the result of bobcat predation. Apparently, fawns have a 92.1% chance of surviving to their first birthday once they are at least 6 months old.

Adult Mortality and Survival

Twenty-six radio-instrumented or ear-tagged deer (22 does) died between September 1986 and July 1991. Bobcats were the most important predators on white-tailed deer in Bear Island, preying upon at least 7 and perhaps as many as 10 deer (see discussion under Bobcat predation)(Fig. 7). Florida panthers killed 4 radio-collared deer and 1 was killed by an alligator (Alligator mississippiensis). Humans shot 3 deer legally, 2 were ear-tagged bucks and the third was a doe harvested off the Preserve during the antlerless season. Two other does were illegally killed during general gun season 1988. Four does died of natural (non-predator) causes; one suffered a broken leg, another suffered a broken jaw, and the third died of an unknown infectious agent and related pneumonia. The fourth deer died after twin fetuses became lodged in the birth canal and could not be expelled (D. Forrester, pers. comm.). This doe, dead for < 24hrs, was subsequently scavenged by a bobcat. Two deer died of unknown causes.

Age-at-death

We were able to determine age-at-death for 19 of the 22 doe mortalities by examining lower jaw tooth wear and replacement (Fig. 8). Bobcats and panthers did not appear to select deer on the basis of age. The average age of predator-killed does was 3.5 compared to an average age of 5.3 for does that died of other causes. This type of prey selection was not expected from these 2 cat species because each kills after short stalks of randomly encountered prey. Cursorial predators, such as wolves (Canis lupus) and spotted hyenas (Crocuta crocuta), tend to select heavily upon the very young, the very old, or compromised individuals (Kruuk 1972, Fuller and Keith 1980). Because these canids depend upon their ability to outrun prey, the advantages in selecting less fit animals are obvious. Most felids stalk and then rush their intended prey (Kruuk 1986, Young and Goldman 1946). The success of this hunting strategy is less dependent upon prey fitness and more dependent upon stalking cover and stealth. Hornocker (1970) found that mountain lions killed mule deer (Odocoileus hemionus) indiscriminately with respect to age but did select for young elk and mature bulls. This selectivity was attributed to prey behavior (bulls wintering on different, more vulnerable ranges) and young elk being more vulnerable on the basis of their size relative to that of adults. Although our sample size was small (n = 13), bobcats and panthers appeared to prey on white-tailed deer in proportion to their age distribution.

Bobcat predation

Bobcats seemed to kill adult deer through strangulation or strangulation in combination with excessive hemorrhaging in the neck area. Of the 10 deer that were killed by bobcats, 4 exhibited bite wounds to the ventral neck area. One of the 4 deer had large blood clots present under the skin of the neck area suggesting that bobcat bites may also damage large vessels and accelerate death. Claw marks were sometimes visible on the deer, perhaps evidence of the bobcat trying to maintain its grip on a struggling deer. One young doe (1.3 yrs. of age) was killed by bites that punctured its skull. This doe's skull had not completely ossified and therefore was not as hard as adult skulls. Other carcasses were too badly decomposed to determine precisely how they were killed; however, none of the skulls were damaged and no large bones were broken.

Two adult does killed by bobcats were recovered within 24 hrs. of death and were necropsied. One doe (4.5 yrs. of age) was in good physical condition with moderate levels of tail, heart, kidney, and pericardial fat, and was pregnant. The second doe (2.5 yrs. of age) was found to be in poor condition with little to no fat, and was not pregnant. This animal was first captured 6 weeks prior to death and did not appear to be in a weakened state.

There were no indications that either animal's health was compromised before predation occurred.

After making a large kill, bobcats dragged the carcass to the nearest cover. Seldom, however, did they move the carcass more than 10 m. In 1 instance, a deer was dragged about 5 m until it lodged against a saw palmetto stem and apparently could not be freed. Kills made in marshes were dragged into 1-2 m tall sawgrass. After feeding, bobcats completely covered the kill with whatever vegetation or leaf litter was available.

Because bobcats are small predators (9.1-13.6 kg. average), they are unable to consume large percentages of adult deer carcasses. In south Florida, kills remain palatable for only a few days because of heat and humidity so only 1 feeding may be possible. Bobcats fed on the large, meaty areas of the carcass (shoulders or hams), eating the muscle around large bones without dismembering or breaking the bones. Bobcats did not open the abdominal wall and did not gut the deer carcasses we observed. On 2 occasions (1 predation, 1 scavenging) the cats fed on the tissues of the lower abdomen completely consuming the mammary tissues. Both of these pregnant does died near the peak fawn drop (1 died of a birthing complication) so we speculate that the milk-producing tissues may be preferred as food.

As a result of the feeding habits of bobcats, deer carcasses remain relatively intact and articulated. Secondary feeders such as vultures, raccoons, a myriad of insects (fly maggots, carrion beetles), and bacteria quickly consume the remaining soft tissues, reducing the deer to a skeleton within 4-7 days. Three deer carcasses were found in this skeleton-only state, 2 of which had the skeletal remains of small fawns present. The fawns' skulls were crushed, long bones were broken, and their skeletons disarticulated. Although supporting sign such as tracks, scrape marks and feeding sites were missing, the carcasses were dragged a short distance and covered with vegetation/leaf litter and thus we suspected that these animals were preyed upon by bobcats. Panthers were ruled out because the rib cage of the does' carcasses were intact and no long bones were crushed.

Bobcat Food Habits

Our analysis of 87 scats did not demonstrate that deer were an important component of bobcat diets, occurring in only 4.6% of scats (Table 2). These results were similar to those reported by Maehr and Brady (1986) in a statewide analysis of bobcat food habits. Rodents (primarily Sigmodon spp.) and rabbits (Sylvilagus spp.) were the principal items in bobcat diets. All 4 occurrences of white-tailed deer were in the spring (mid-February to mid-April), which coincided with fawning season. One scat had fawn hooves present confirming that bobcats utilize a portion of the annual fawn production. Our telemetry data, however, indicated that bobcats also preyed upon adult deer and that the majority (5 of 10 kills) of this predation occurred during spring (Fig. 9).

Survival Rates of White-tailed Deer

White-tailed does, regardless of age, had an average survival rate of 0.813 (95% CI = 0.68, 0.94), meaning that 81% of all collared deer would survive any given year (Table 3). The annual mortality rate (1.0 - survival rate) was 0.187. There were no differences in survival rates among the 3 seasons (summer, hunting, and spring) nor within or between years.

When mortality was partitioned among bobcats and other causes, bobcat predation occurred at an average annual rate of 0.0856 (SE = 0.042) and was responsible for 45.9% of annual mortality. Overall, predation by Florida panthers and bobcats accounted for 64.0% of the annual mortality rate. Clearly, predation was the most important cause of mortality among female white-tailed deer.

Life Table Analyses for Adult Does

Life tables are abstract tools used in both tabular and graphic forms to model the age structure and survival patterns of a population. Because the fates of females determine how future populations will function, our analyses were restricted to white-tailed does. Life tables consist of 6 categories of information: age intervals (x = year interval of interest), number of animals present in each interval [f(x)], the proportion of animals that have survived from the first interval [l(x)], the probability of dying in each interval [d(x)], a mortality rate [q(x)], and a survival rate [p(x)] (Caughley 1977).

An ideal life table would represent a complete count of all animals during the season of births, with an exact record of all of the animals' ages. There is, however, no ideal way to collect these data. Our best estimates of the life table parameters were derived from ages at death of radio-instrumented does. If a doe was 5 years old at death, it follows that this same deer survived through age classes 1 through 4. By tallying the number of deer that survived through each age class, we constructed a hypothetical population [f(x)] of Bear Island adult does (Table 4). We assumed that all of the does were born at the same time (representing a single cohort) and that we followed each animal to its death. This back-tallying does not provide, however, an estimate of the number of newborn fawns that were present in the population. To estimate this number, we calculated how many fawns it would take to provide 19 yearlings the following year based on our earlier estimates of fawn mortality (37.8%) and 6 months old to 1 year mortality (7.9%). Our estimate of f(x = year 0) was calculated at 33.2 newborn fawns. Given this estimate of f(0), the rest of the table can be calculated.

There are 2 estimates, average age of doe deer and the average survival probability [p(x)], derived from the life table that can be compared to estimates calculated from field data. As part of the deer herd health and reproduction study (McCown 1991), a sample of doe deer was collected in Bear Island. These collections represented a sample of the age structure of live deer. The average age of collected does was 2.7 years, which was in close agreement with the life table estimate of 2.9 years. We calculated an average annual survival rate of 81% for radio-instrumented does in Bear Island, regardless of age class. The annual survival rate calculated from the life table by averaging the p(x) column was 75%. The close agreement between these estimates of average age and annual survival suggests that this life table is a close approximation of the real population.

One of the most useful depictions of life table analyses is a graph of the l(x) data (Fig. 10). The greatest mortality occurs during the first year of life with a steady attrition of does up to 8 years. No collared doe survived past this age. A comparable graph of the mortality rates q(x), follows a J-shaped curve that corresponds to a high mortality rate among the very young and the very old animals with low rates among middle-aged animals (Fig. 11). There is, however, an unexpected rise in mortality for 3 year-olds. The cause of this rise may be predation on does during the season of births. Eight does died during February and March (peak of fawn drop is 28 February), 7 of which were killed by bobcats and panthers (Fig. 9). Four of the 7 were 3 year-olds; interestingly, predation was the only known source of mortality for 3 year-olds. We speculate that does are more vulnerable to predation during the fawning season (63.4% of all predation occurs during spring) and, because the 3 year-old age class is one of the most represented, a rise in mortality rate may not be surprising.

By incorporating data on deer reproduction, fecundity estimates can be added to the life table. The needed additions are: B(x) = expected number of pregnant does, m(x) = number of female fetuses per pregnant adult female, and l(x)m(x) = the number of female offspring a female is expected to produce multiplied by the survival probabilities for that female. We assumed that m(x) was constant across all age classes based on data from collected does (McCown 1991). The sum of l(x)m(x) column is referred to as the net reproductive rate (R_0) or the number of female offspring that a female is expected to produce in her lifetime (Caughley 1977). When R_0 is much < 1.0, a population should decline because females are not replacing themselves; conversely, if R_0 is much > 1.0, a population should increase. In this case, $R_0 = 0.97$ which suggested that females were replacing themselves and the population is stable. The mean generation time = 3.6 years which means that, on average, a female has produced her replacement before her fourth birthday.

CONCLUSIONS

Hunting season activities had little impact on the Bear Island deer herd either in number of illegal kills of does (2) or in causing deer to leave the Preserve. No deer established a separate home range during hunting season and any shifts in home range activity centers could be the result of differing habitat use. Fall mast production or deer seeking thicker cover could explain the habitat use changes.

Bobcats were the primary mortality agent on adult female white-tailed deer, responsible for 45.9% of annual mortality. Predation by bobcats and panthers accounted for 64% percent of annual mortality and occurred more frequently in the spring, because does were more vulnerable during fawning. Adult doe mortality averaged 18%/year over 4 years with no significant seasonal variation.

The Bear Island deer herd was stable with females replacing themselves before their death and was at equilibrium with losses from predation and hunting. Fawn mortality seemed to fluctuate with spring surface water conditions (high surface water = high fawn mortality) so several successive springs of high surface water may lead to a short-term decrease in herd size. However, with the increase in fawn survivorship during drier springs, these short-term losses can be recovered and thus would not have any long-term impacts on the population.

Our data do not support contentions that hunting in Bear Island has adverse impacts upon the white-tailed deer population, and in particular, female deer. The deer herd provides a stable prey base for panthers and is not prone to wide fluctuations in survival patterns. If an increase in the deer herd is sought, more intensive land management would be necessary. This could involve habitat manipulations (burning or disking) or creating and maintaining food plots that would increase the nutrient base for supporting more deer.

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Table 1. Ages and sexes of white-tailed deer captured in Bear Island Unit, Big Cypress National Preserve, Sept. 1986 - March 1990.

	Fawns		Yearlings		Adults		Total
	male	female	male	female	male	female	
CAPTURED	6	9	2	7	3	39	66
COLLARED	4	9	0	7	2	35	57

Table 2. Number and percent occurrence of prey items found in 87 bobcat scats, Bear Island Unit, Big Cypress National Preserve, Collier County, Florida, September 1986 - February 1990.

	Number of Occurrences	% occurrence in scats
Rodent (Sigmodon spp.)	59	67.8
Rabbit (Sylvalagus spp.)	48	55.2
Bird	20	23.0
Ciconiformes	(2)	
Passeriformes	(6)	
Unknown	(12)	
White-tailed deer	4	4.6
Raccoon (Procyon lotor)	10	11.5
Turtle	1	1.1
Unknown	2	2.3

Table 3. Survival rates for radio-collared female white-tailed deer, Bear Island Unit, Big Cypress National Preserve, Florida, May 1987 to June 1991.

Interval	Number of deer	Number of deaths Yi	Number of radio-days Xi	Interval length (days) n	Interval survival Si	Annual survival
Summer87	15	1	1804	123	0.934	
Hunting87	14	1	1677	122	0.930	
Spring88	14	2	1598	121	0.859	0.746
Summer88	18	0	2214	123	1.000	
Hunting88	29	3	3404	122	0.898	
Spring89	26	3	2929	120	0.884	0.794
Summer89	22	0	2706	123	1.000	
Hunting89	31	3	3638	122	0.904	
Spring90	33	2	3894	120	0.940	0.850
Summer90	30	2	3541	123	0.933	
Hunting90	28	1	3310	122	0.964	
Spring91	25	1	2964	120	0.960	0.863
Average Annual Survival						0.813
95% confidence interval						(0.71, 0.92)

Table 4. Life and fecundity table for female white-tailed deer, Bear Island Unit, Big Cypress National Preserve, Collier County, Florida.

x	f(x)	l(x)	d(x)	q(x)	P(x)	B(x)	m(x)	l(x)m(x)
0	33.2	1.0	0.43	0.43	0.57			
1	19	0.57	0.03	0.05	0.95			
2	18	0.54	0.06	0.11	0.89	16.76	0.5586	0.302
3	16	0.48	0.21	0.44	0.56	14.90	0.5586	0.268
4	9	0.27	0.06	0.22	0.78	8.38	0.5586	0.151
5	7	0.21	0.06	0.29	0.71	6.52	0.5586	0.117
6	5	0.15	0.06	0.40	0.60	4.66	0.5586	0.084
7	3	0.09	0.09	1.0	0	2.79	0.5586	0.050
8	0	0						
					$\bar{X}$ = 0.75		R_0 = 0.97	

x = age class
f(x) = number of does
l(x) = survivorship = f(x)/f(0)
d(x) = mortality = l(x)-l(x+1)
q(x) = mortality rate = d(x)/l(x)
P(x) = survival rate = 1-q(x)

B(x) = expected number of pregnant does = f(x) x 0.931(pregnancy rate)
m(x) = # of female births per female = [B(x) x 0.5 x 1.2]/f(x)
where 0.5 = sex ratio
and 1.2 = litter size
l(x)m(x) = # of female births per surviving adult female

R_0 = net reproductive rate = sum of l(x)m(x)

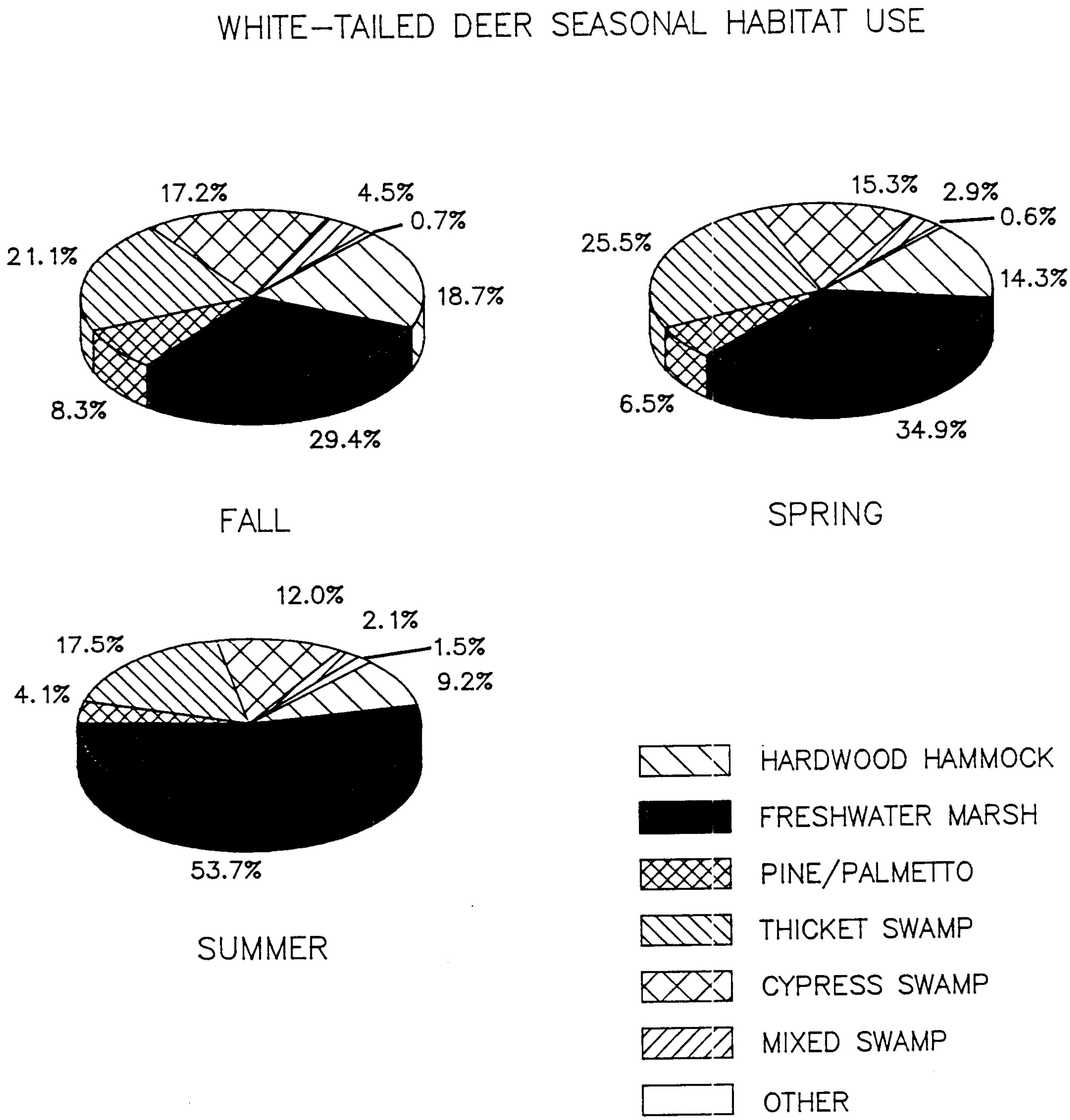

Fig. 2. Seasonal habitat use by white-tailed deer, Bear Island Unit, Big Cypress National Preserve during spring (1 Jan.-30 Apr.), summer (1 May-31 Aug.), and fall (1 Sep.-31 Dec.).

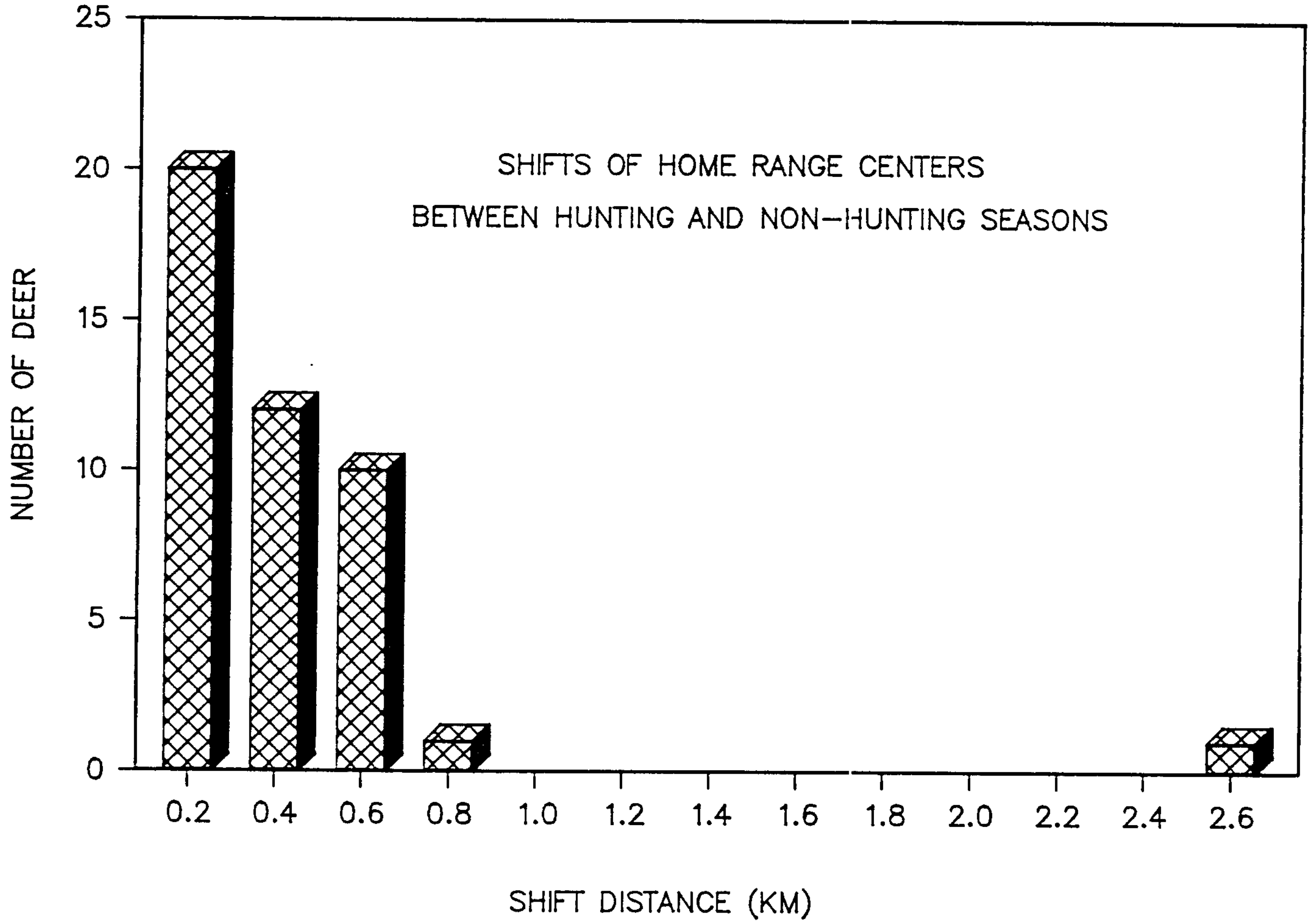

Fig. 1. Shifts of female white-tailed deer home range centers between hunting and non-hunting seasons, Bear Island Unit, Big Cypress National Preserve.

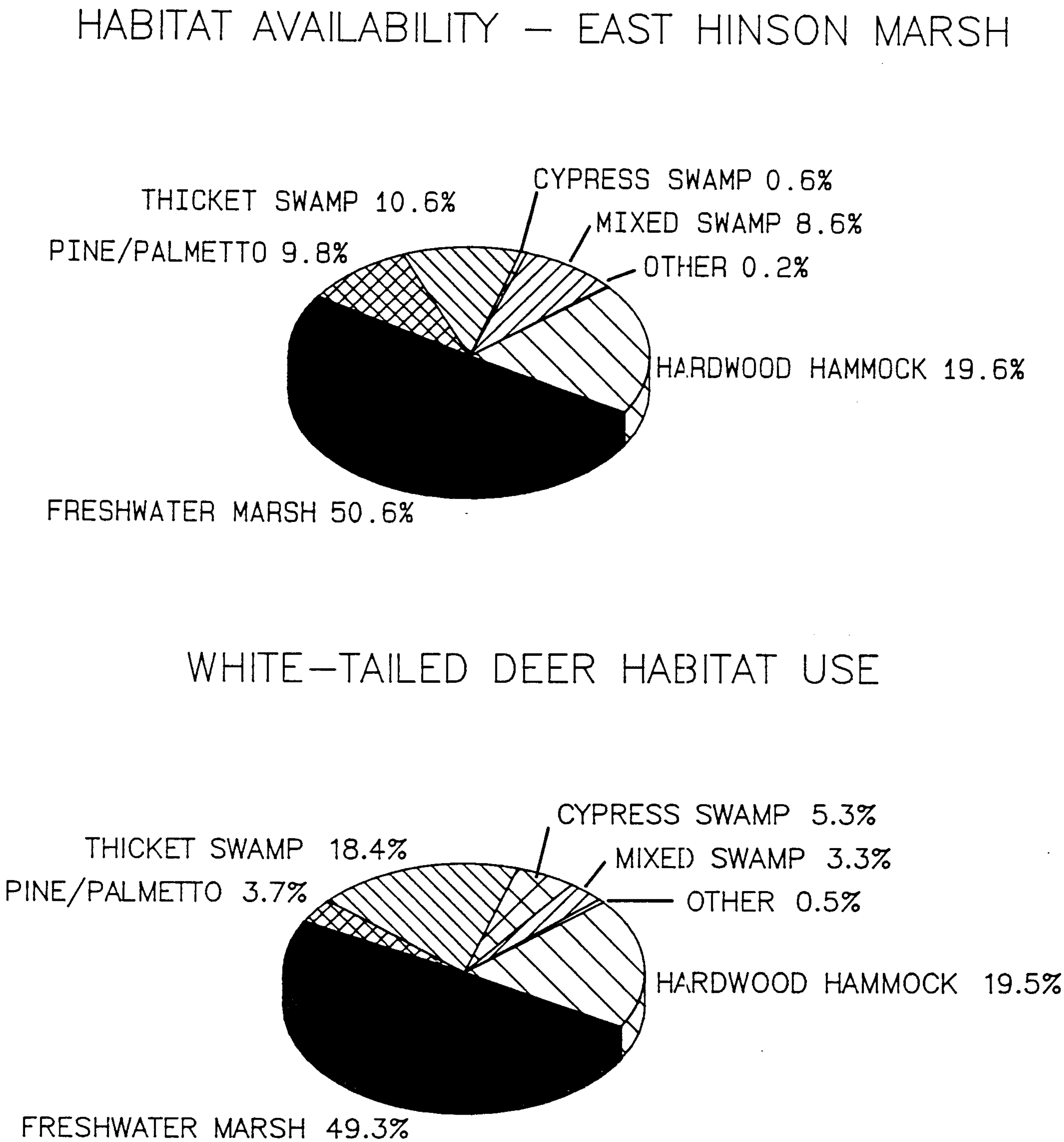

Fig. 3. Habitat availability and use by white-tailed deer in East Hinson Marsh, Bear Island Unit, Big Cypress National Preserve.

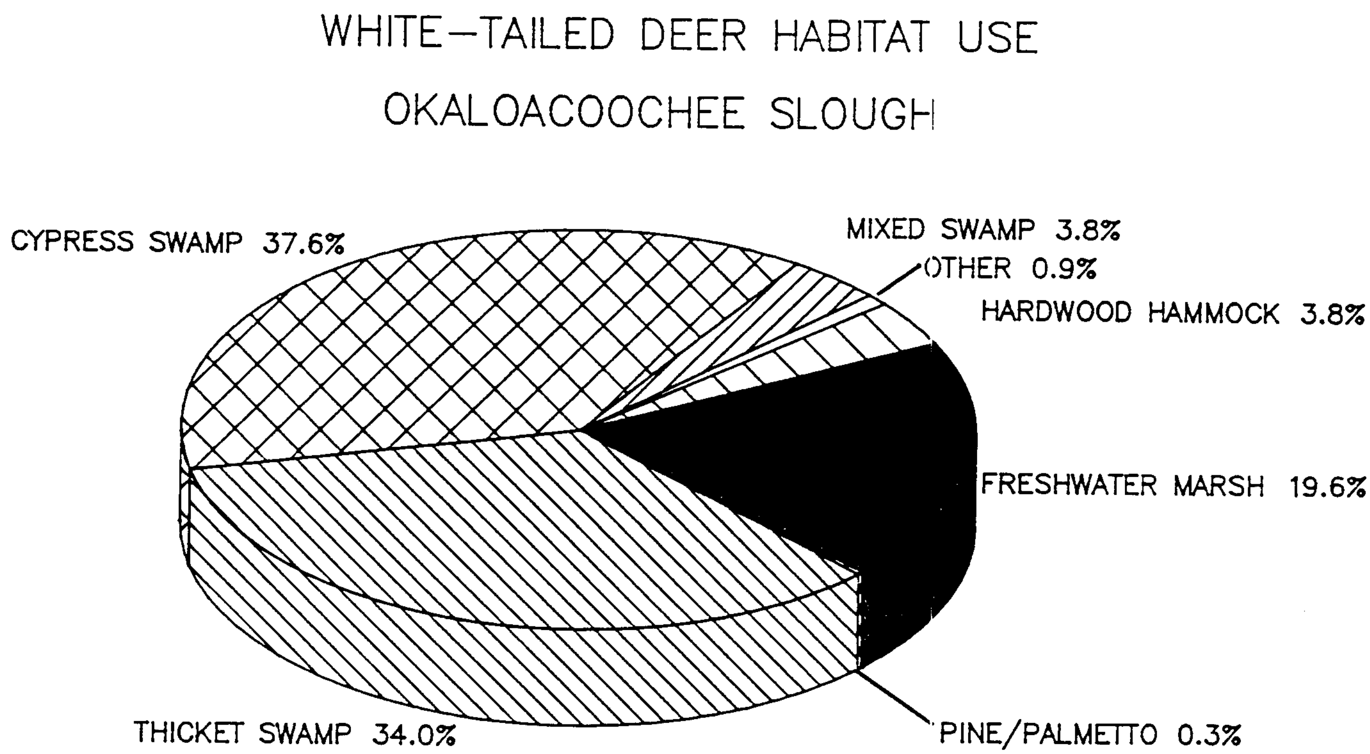

Fig. 4. Habitat use by white-tailed deer in Okaloacoochee Slough, Bear Island Unit, Big Cypress National Preserve.

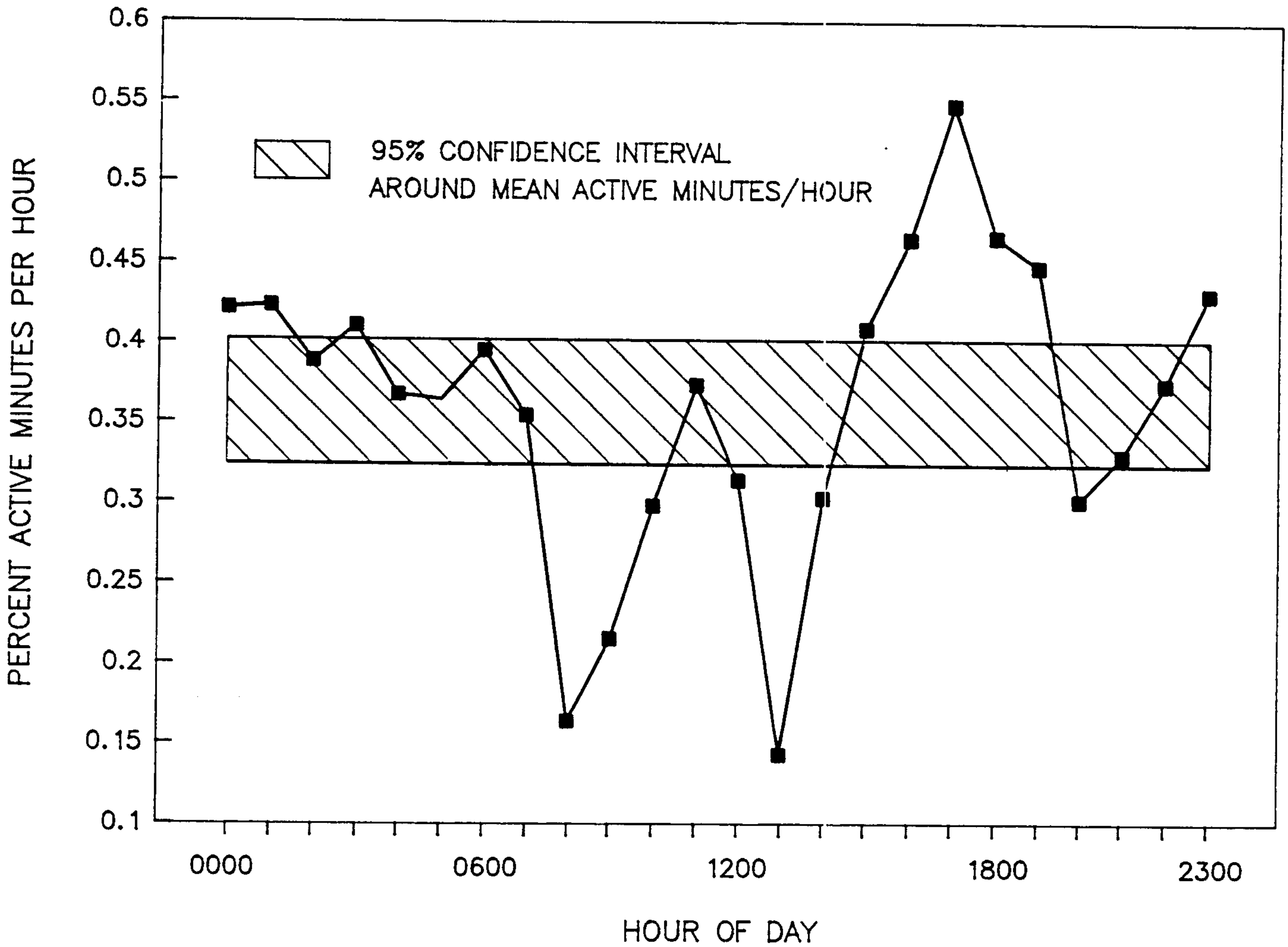

Fig. 5. Activity pattern of white-tailed deer, Bear Island Unit, Big Cypress National Preserve. Hatched area represents a 95% confidence interval around the mean percent active minutes/hr.

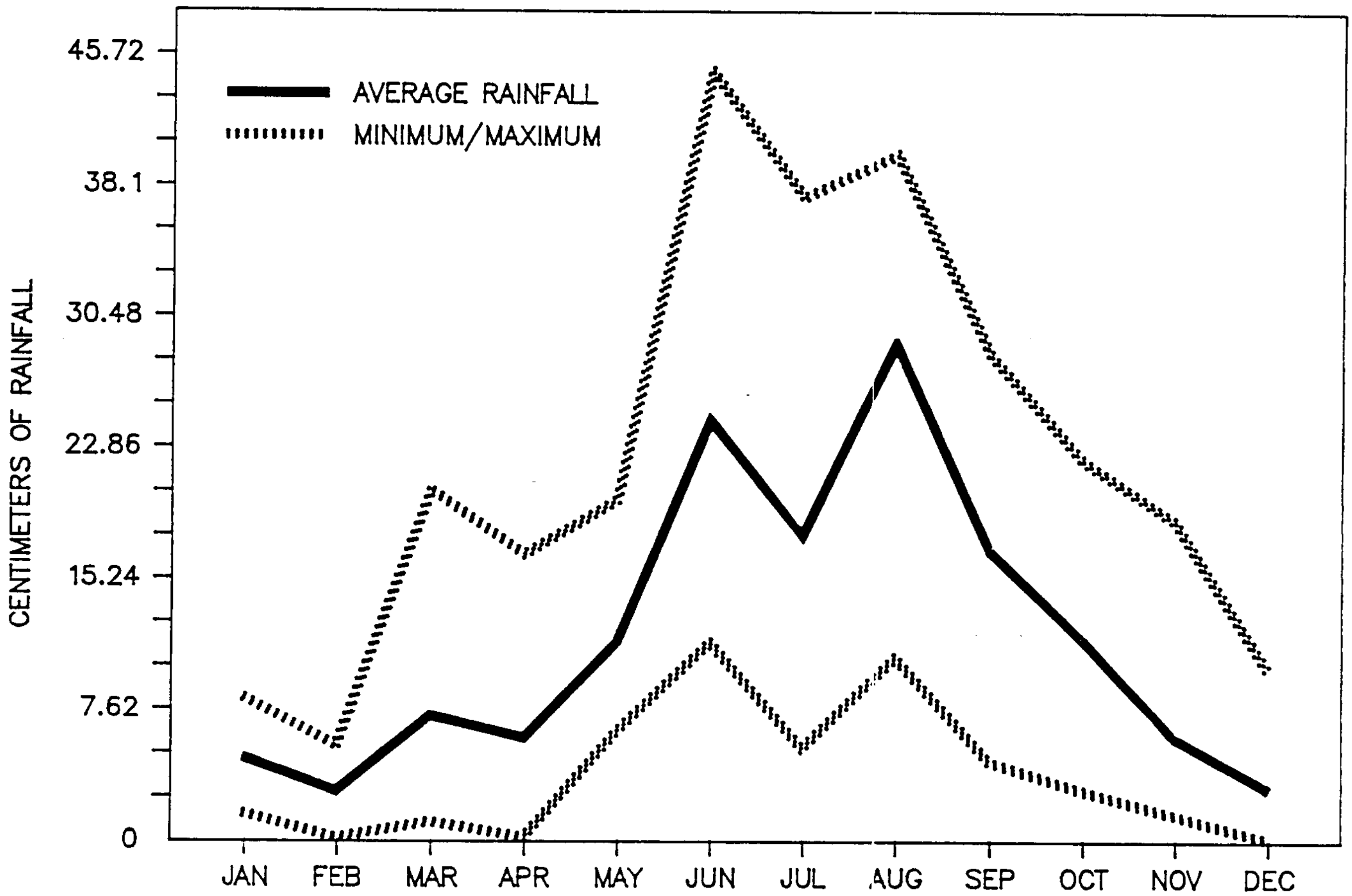

Fig. 6. Range and mean monthly rainfall (cm), Oasis Ranger Station, Big Cypress National Preserve, October 1984 - June 1991 (courtesy of the National Park Service).

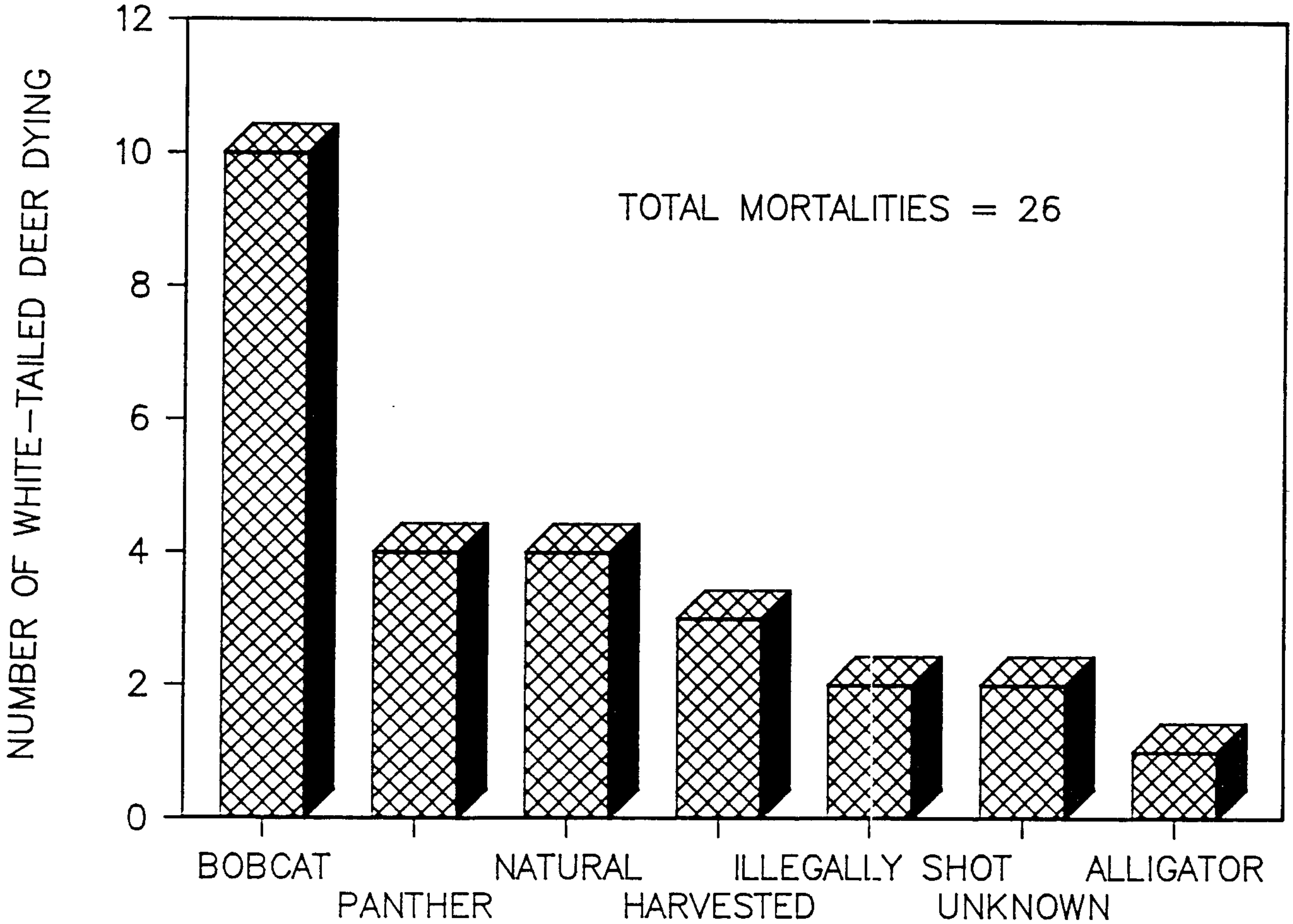

Fig. 7. Frequency distribution of mortality agents for white-tailed deer, Bear Island Unit, Big Cypress National Preserve.

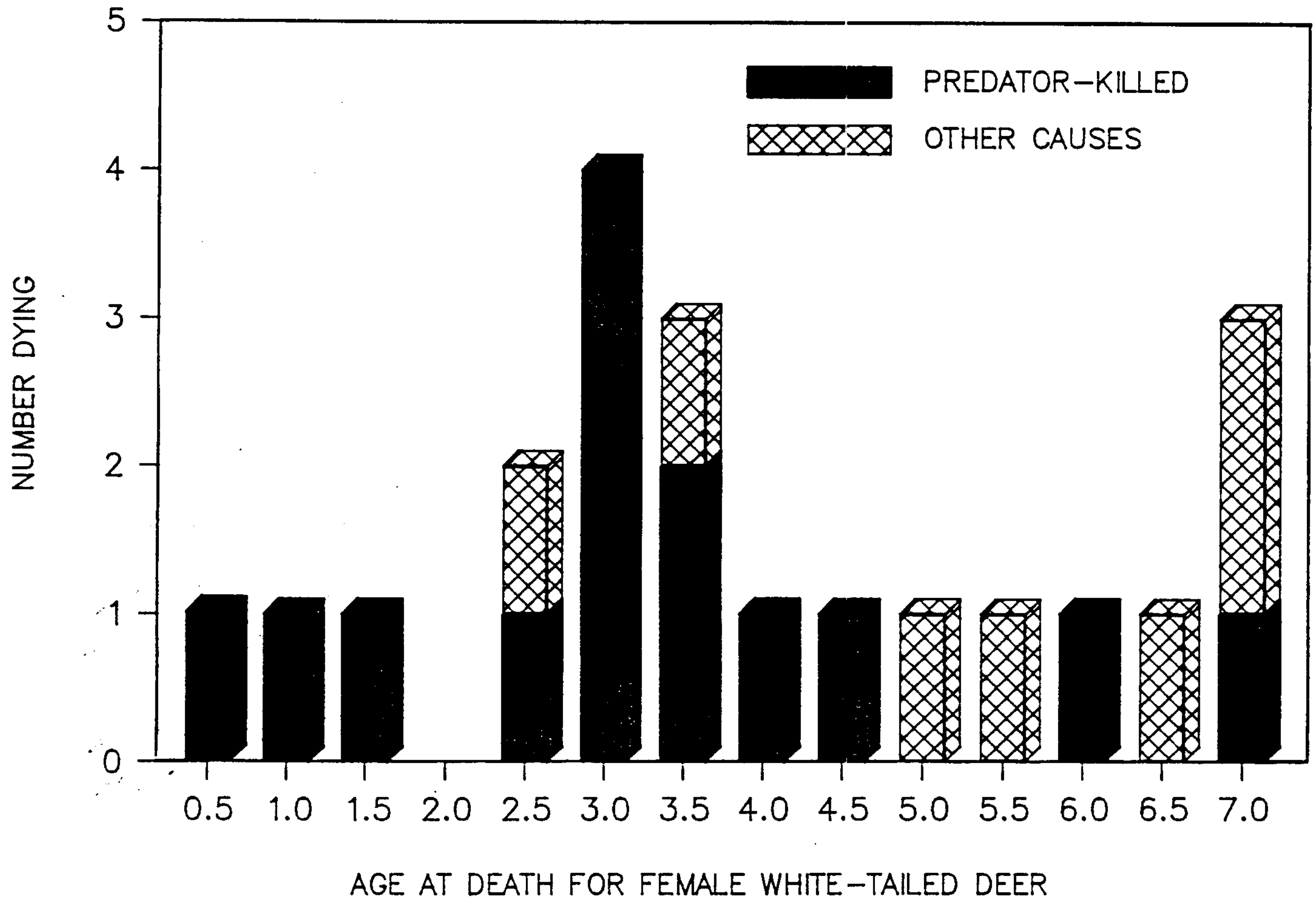

Fig. 8. Frequency distribution of ages-at-death for female white-tailed deer, Bear Island Unit, Big Cypress National Preserve.

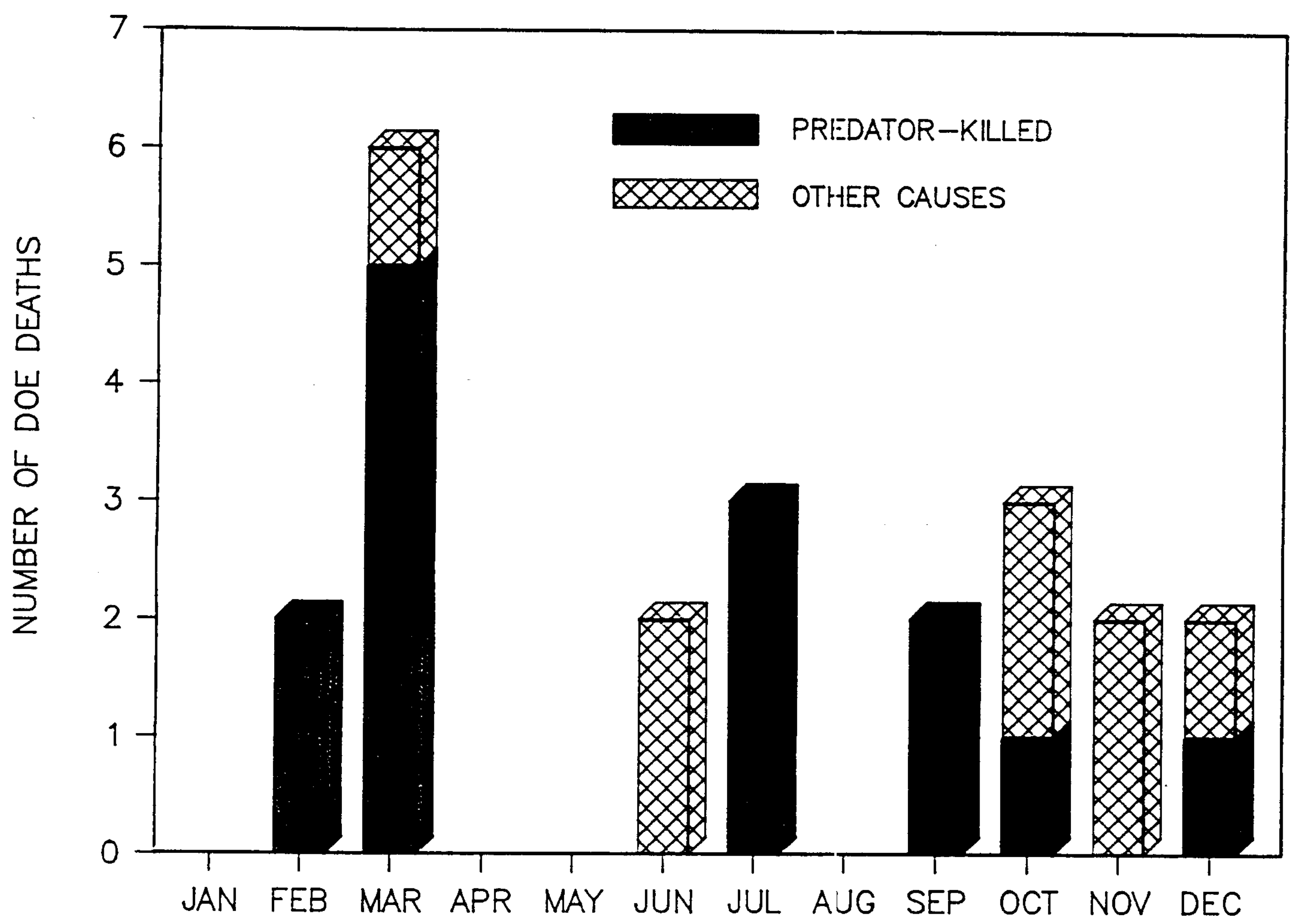

Fig. 9. Frequency distribution of mortalities of female white-tailed deer by month, Bear Island Unit, Big Cypress National Preserve.

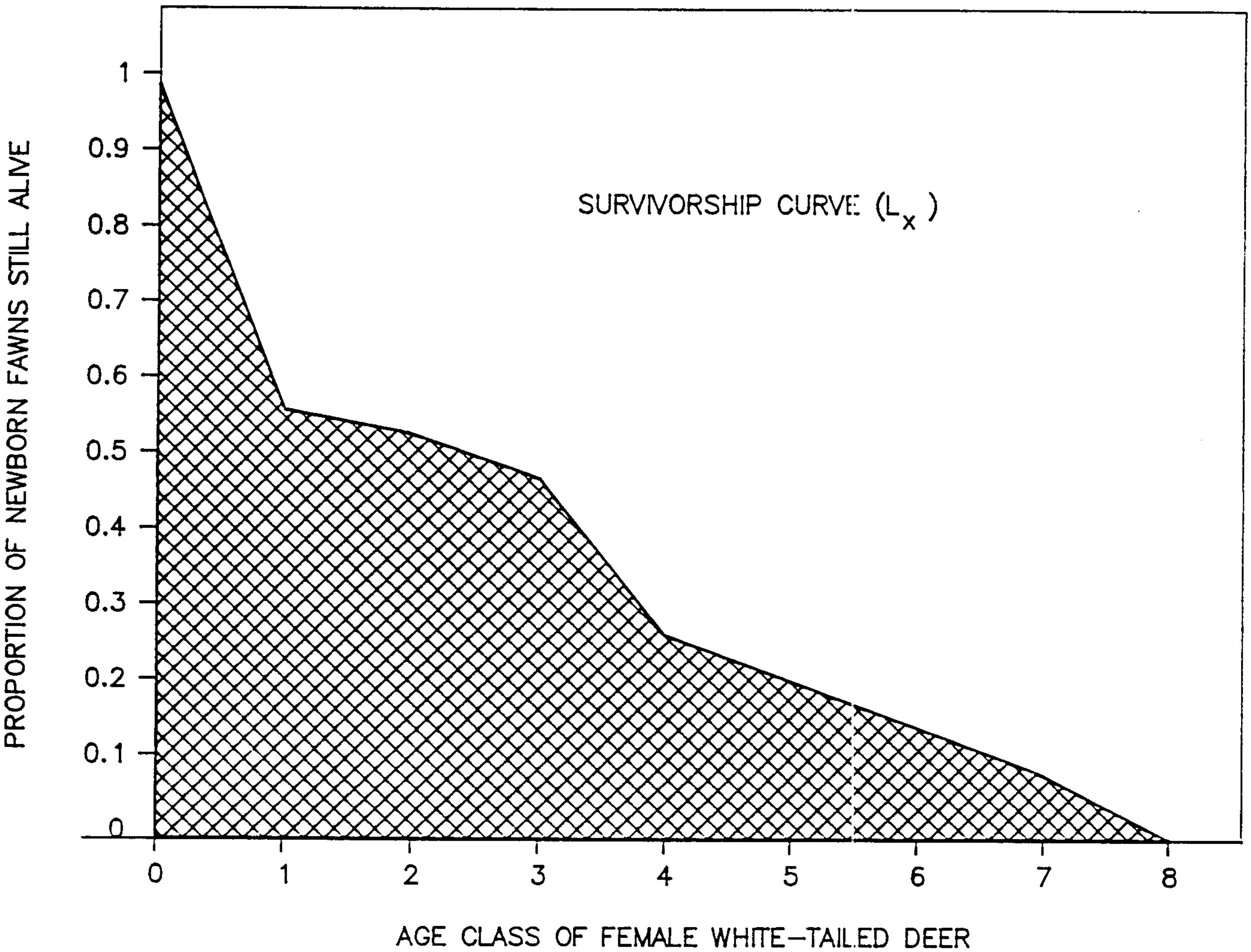

Fig. 10. Survivorship curve (L_x) for female white-tailed deer, Bear Island Unit, Big Cypress National Preserve.

Fig. 11. Mortality curve (Q_x) for female white-tailed deer, Bear Island Unit, Big Cypress National Preserve.

APPENDIX A. Habitat types of the Bear Island Unit, Big Cypress National Preserve, Florida.

I. Pine flatwoods or low pinelands (PP) - Slash pine (Pinus elliottii var. densa) growing as open forests on moderately well drained to poorly drained soils; usually associated with saw-palmetto (Serenoa repens) or wet prairies and contain many ponds and sloughs with marshes.

A. Pine and cabbage palm woods (PC) - Usually small areas where cabbage palm (Sabal palmetto) is scattered among the pines.

II. Hammock forests (HH) - Hardwood and palm forests usually dominated by broad-leaved evergreen trees and limited to small areas, growing on high upland to seasonally flooded soils and containing a great variety of south temperate to tropical species. Often a climax forest.

A. Cabbage palm hammocks (CA) - Dominated by cabbage palm and mostly low hammocks near swamps, in prairies, and pine flatwoods forests.

III. Inland swamps, cypress forests - Many types of forests on seasonally wet to continually flooded soils.

A. Mixed swamps (MS) - Forest of hardwoods with cypress (Taxodium distichum) present but not dominant. May include many low hammocks.

B. Cypress swamps (CS) - Usually seasonally flooded forests composed mainly of tall cypress trees with few to no hardwood trees. Includes cypress domes.

C. Open cypress forests (OC) - Low to medium tall, open forests of cypress often associated with pine forests and wet prairies, covering large areas in the Big Cypress region. Includes strands and scrub cypress.

D. Thicket swamps (TS) - Elderberry (Sambucus canadensis), willow (Salix caroliniana), and pop ash (Fraxinus caroliniana) thickets of low trees and tall herbs often occurring on areas that have been cleared then abandoned.

IV. Everglades and fresh water marshes (MA) - Treeless vegetation dominated by sedges, rushes, grasses, reeds, and other herbaceous plants, growing on soils that are seasonally wet or covered by water most of the year.

A. Saw grass marshes (SG) - Usually muck and peat soil areas dominated by saw grass (Cladium jamaicensis), covering the greater part of the Everglades and occurring in many pond and sloughs outside of the Everglades, particularly in some parts of the flatwoods region.

B. Flag marshes (FM) - Mixed marshes dominated by Sagittaria or Pontederia; common in shallow ponds and sloughs.

C. Mixed herb and shrub marshes (SM) - Marshes of many types with Myrica, Cephalanthus (buttonbush), and Baccaharis and other shrubs common. Occurring as transitional zones between marshes and bayheads, or between marshes and other swamps.

V. Wet prairies (WP) - Low dominantly grassy vegetation of seasonally wet soils. Usually distinguished from marshes by having less water and shorter herbage. Often marginal between marsh and forest areas in the flatlands regions.

VI. Dry prairies (DP) - Usually seldom flooded dry sand areas with grasses, saw palmetto, and other low shrubs. These treeless areas are often similar to the pine flatwoods but without pines.

A. Cabbage palm hammock prairies (CP) - Seldom flooded treeless grassy prairies in areas where cabbage palm hammocks are common.

VII. Agricultural/Disturbed (AD) - Includes areas formerly occupied by vegetation communities as described above, but now converted to agriculture, improved pasture, rock mines, urban areas, roadsides, etc. Scattered remnants of previous community may still exist.

Adapted from: Davis, J. H. 1943. The natural features of southern Florida. Florida Geol. Surv. Geol. Bull. 25. 311 pp.