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THE KEY DEER POPULATION IS DECLINING[1]

STEPHEN R. HUMPHREY, ***Florida State Museum and Department of Wildlife and Range Sciences, University of Florida, Gainesville, FL 32611***

BONNIE BELL,[2] ***U.S. Fish and Wildlife Service, National Key Deer Wildlife Refuge, P.O. Box 510, Big Pine Key, FL 33043***

Intense hunting pressure and changes in habitat reduced the once-abundant Florida Key deer (*Odocoileus virginianus clavium*) to historic lows of about 26 in 1945 (U.S. Fish and Wildl. Serv. 1985), 57 in 1952 (Allen 1952), and 25–80 in 1951–1952 (Dickson 1955). Responses to this problem were a ban on hunting (seldom enforced) by the State of Florida in 1939, establishment of the National Key Deer Wildlife Refuge (NKDWR) in 1957, desig-

[1] Contribution No. 7103 of the Journal Series, Florida Agricultural Experiment Station, Gainesville, FL 32611.

[2] Present address: U.S. Fish and Wildlife Service, White River National Wildlife Refuge, P.O. Box 308, DeWitt, AR 72042.

nation as an endangered species in 1967, and protection under the Endangered Species Act in 1973. With hunting eliminated and some habitat preserved, the population grew to an estimated 350–400 individuals by 1974 (Silvy 1975, Klimstra et al. 1978).

Subsequent qualitative judgment (Hardin et al. 1984) indicated a reduction to 250–300 animals by 1982, attributed to habitat loss and mortality associated with rapid urban and suburban development of the Lower Keys (U.S. Fish and Wildl. Serv. 1985). This possible decline raises the question of whether the existing conservation program is adequate. An immediate need is corroboration of the population trend. The purpose of this paper was to evaluate counts along transects by NKDWR staff to discern whether a decline has occurred.

METHODS

Spotlight counts were conducted once a month along road transects on Big Pine and No Name keys from July 1968 through 1984. The counts on Big Pine from 1968 to 1972 were made by Silvy (1975), beginning at 2230 hours, along 16 km of roads on and adjoining NKDWR. Both Hardin (1974) and Silvy (1975) made procedural suggestions based on their experience. No counts were made from 1973 to 1975. More extensive transect routes were established by NKDWR staff in 1976, covering representative roads throughout each island. In 1980 the routes were shortened. The 56-km Big Pine route was reduced to 32 km, and the 5-km No Name route was reduced to 3 km. After the routes were shortened, counts were begun at 2000 or 2100 hours and typically spanned 3 hours. Silvy (1975) concluded that all-island and NKDWR counts should not be compared, because the latter yielded higher counts. Therefore, trend analysis was appropriate only for data from 1976 to 1984.

Data on deer mortality were recorded continuously during the study in association with research, management, and law-enforcement activities. Dead animals were located by direct sightings, reports from citizens, or observation of turkey vultures (*Cathartes aura*). Deaths from miscellaneous causes (dogs, poaching, drowning, unknown) were not easily detected, but probably most animals killed on roads were detected, because their locations coincided with the travels of NKDWR staff and because flocks of vultures were highly visible.

Data on total annual rainfall were recorded by NKDWR staff on Big Pine Key. Rainfall is clinal in the Florida Keys, averaging 1,270 mm/year on Key Biscayne and 890 mm/year on Key West (Thomas 1974). Rainfall on Big Pine Key varies seasonally, averaging from 25 to 50 mm/month from December to March, 100 to 125 mm from May to June, and 150 to 175 mm in September.

Counts were expressed as average number of animals/1.61 km and averaged for each calendar year. Because the major procedural changes in 1976 set sample size at 9 years, all statistical tests were interpreted as significant at beta = 0.2. The purpose of this liberal criterion was to avoid making a Type II error under the null hypothesis of no population trend. We preferred to accept the alternate hypothesis that a trend existed rather than recommend no action when conservation would be appropriate.

Statistical analysis was done with the Statistical Analysis System (SAS Inst. Inc. 1982*a*,*b*) and facilities of the Northeast Regional Data Center on the University of Florida campus. Simple linear regression (PROC REG) was used to describe variation among counts and to test the hypothesis that rainfall affected counts. The hypothesis that population trends occurred was tested with multiple regression treating years and rainfall as covariables. Because our study was done on large islands with permanent water supplies, counts and number of animals killed along roads should covary with rainfall. During drought only the large islands retain lenses of fresh rainwater over the saline groundwater. In response, Key deer (1) swim from small, outlying islands to large, developed ones, (2) move from the periphery of a large island towards its center, and (3) enlarge their home ranges; deer disperse again when droughts cease (Allen 1952, Dickson 1955, Jacobson 1974, Silvy 1975).

We examined the multiple regressions for autocorrelation with the Durbin-Watson d-statistic because of the risk that successive values might be correlated. If autocorrelation is present, the test is biased toward the null hypothesis of no trend.

Regression results and limited applicability of the Durbin-Watson d-statistic led us to test the trend hypothesis with econometric methods, which avoid the autocorrelation problem. We used first-order time-series analysis (the random-walk model, PROC AUTOREG with NLAG = 1) and with exponential smoothing (PROC FORECAST, specifying a linear trend). A random-walk model assumes that the present is the best predictor of the future, and it predicts each count solely from the previous count, by randomly changing the sign and amount of change. Forecasting extrapolates into the future rather than testing hypotheses, so it makes no significance tests.

RESULTS AND DISCUSSION

Both Big Pine and No Name keys supply water year-round to Key deer (Dickson 1955). Deer counts on Big Pine (B) and No Name

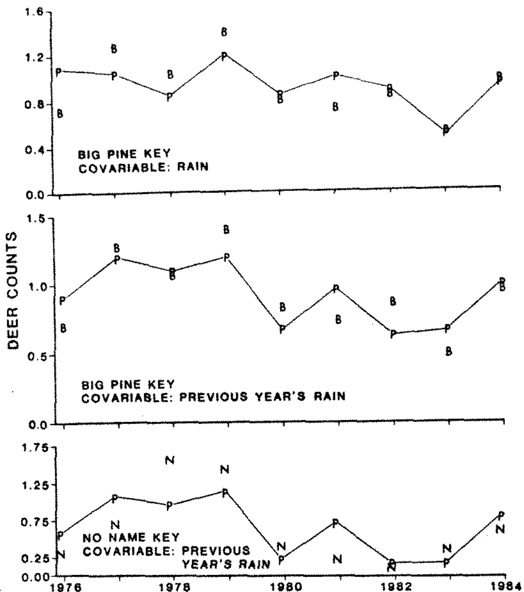

Fig. 1. Trend in counts (deer/1.61 km), accounting for the effect of rainfall. Actual counts are shown as B for Big Pine Key and N for No Name Key. Predicted values (P) were calculated by simple linear regression.

(N) keys were correlated (B = 0.69 + 0.38N, $r^2 = 0.52$, $F = 7.60$, $P = 0.028$). This result is consistent with the hypothesis that the hydroperiods of their freshwater lenses have similar effects on deer.

Deer counts on the 2 islands differed ($t = 2.37$, $P = 0.045$), with counts on No Name being lower and more variable (0.62 ± 0.54) ($\bar{x}$ ± SD) than on Big Pine (0.92 ± 0.28). Causes of this difference could include a longer average detectability distance of deer on Big Pine, a higher carrying capacity on Big Pine resulting from either (1) higher forage quality or (2) more area or access points supplying freshwater (as stated by Dickson [1955]), or a lower mortality rate on Big Pine. Only the last possibility is inconsistent with available data. No Name Key was extensively cleared by bulldozer in the early 1960s and now is dominated by dense, successional hardwood forest. Where undeveloped, Big Pine Key is a mosaic of pine (*Pinus elliottii*) savanna and tropical hardwood forest (mature and

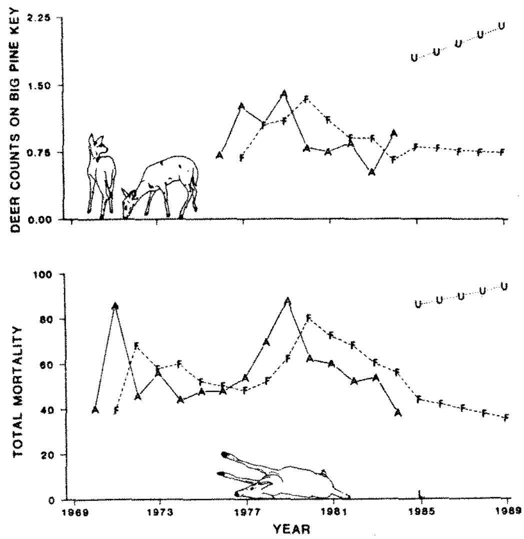

Fig. 2. Average annual counts (deer/1.61 km) on Big Pine Key and total deaths/year, showing actual values (A), forecasted values (F), and 95% confidence limits (U and L for 1985–1989 only).

successional). These differences in vegetation result in better visibility and more diverse forage on Big Pine Key.

Deer mortality was correlated with deer counts, considering data pooled from both islands (total mortality, $r^2 = 0.29$, $F = 4.16$, $P = 0.069$; road mortality, $r^2 = 0.20$ $F = 2.55$, $P = 0.141$). This result is consistent with the hypothesis that movement of deer causes concurrent changes in density and mortality.

The effect of rainfall on Big Pine Key for both the current year and the previous year was evaluated with 2 regression analyses. Deer counts declined slightly during 1976 to 1984 (Fig. 1). They were negatively affected by current-year rainfall (Big Pine counts, B = 98.26 − 0.0487Year − 0.0081Rain, $R^2 = 0.48$, $F = 2.74$, $P = 0.143$; No Name counts, $P > 0.2$). Deer counts were positively affected by previous-year rainfall (Big Pine counts, B = 141.19 − 0.0714Year + 0.0103Rain, $R^2 = 0.64$, $F = 5.36$, $P = 0.046$; No Name counts, N = 246.76 − 0.1253Year + 0.0176Rain, $R^2 = 0.53$, $F = 3.40$, $P = 0.103$). Partial correlation values and probability of a greater value of t for

Year for these 3 regressions are, respectively: $r^2 = 0.29$ and $P = 0.292$; $r^2 = 0.52$ and $P = 0.042$; $r^2 = 0.421$ and $P = 0.082$. These analyses indicate that deer densities on the large islands increased during dry years and decreased 1 year later; Jacobson (1974) made the same deduction from a different set of data. Coefficients of first-order autocorrelation (based on the d-statistic, $n = 9$) for the 3 significant regressions were, successively, 0.03, −0.46, and 0.04. Because published tables of significant d-values begin at $n = 15$, these coefficients cannot be interpreted, but caution directs re-evaluation of the apparent trend with econometric methods. No trend appeared in mortality variables.

Random-walk predictions of deer counts provided a fair fit to actual changes in counts (Big Pine counts, B = 100.76 − 0.0504Year, $r^2 = 0.30$, t-ratio = 0.81, approximate $P = 0.159$ compared with B = 79.46 − 0.0397Year calculated by ordinary least squares; No Name counts, $P > 0.2$). These results confirmed the negative trend of the counts. That the current count is more important than previous ones in predicting the future is consistent with the iterative nature of demographic processes.

Validation of the random-walk model led us to use an exponential discount rate of 30% in the forecasting algorithm to project trends >1 year into the future. Forecasts (Fig. 2) showed that both deer counts on Big Pine Key and total mortality should decrease ($m = -0.0120$ and -2.1787, respectively)—similar rates relative to their respective scales. The slope of forecasted counts was similar to but slightly less negative than results of the other analytical methods, suggesting an even higher discount rate as realistic. The combination of rates for counts and deaths leads to a prediction of population decline.

MANAGEMENT IMPLICATIONS

Based on 1969–1973 rates of land-clearing for development on Big Pine Key, Silvy (1975) predicted loss by 1992 of all remaining habitat not already dedicated to conservation. He concluded that the Key deer population inevitably would decrease. Although the rate of development has slowed somewhat since Silvy's study (Hardin et al. 1984), every test of the data on Key deer counts confirms the judgment that the population has declined recently. This fact mandates rapid implementation of the newly revised recovery plan. Additionally, optimal refuge design should be studied, because the NKDWR is fragmented by developing suburbs and may be ineffective as presently configured.

Significance levels used for these tests were lower than desirable, because of low resolution of the count data. An emergency exists when an endangered species is declining, so a better monitoring method should be devised, tested, and implemented. The method should (1) reduce variance by restricting counts to seasons when deer behavior stabilizes the conditions of observation, (2) provide estimates of variance by subdividing the travel route into sections, (3) determine how many repeated runs along transects are needed to produce the desired level of precision, and (4) use the line transect method of Burnham et al. (1980) to calculate density from count data. However, the original counting procedure should overlap the new one for a few years to assure continuity in monitoring the population.

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