Comparison of Survival Estimates Using Age-Specific Mortality and Radiotelemetry Data for Florida Key Deer

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Abstract - Obtaining reliable survival estimates is important in the management of wildlife populations, particularly for the construction of computer simulation models. Many methods for estimating survival (e.g., radiotelemetry) are cost-prohibitive or time consuming. Life tables can provide survival estimates using data routinely collected by some management agencies. We calculated annual survival for *Odocoileus virginianus clavium* (Key deer) using age-specific mortality data. We compared our life-table estimates to those calculated from radiotelemetry data. Key deer survival estimates derived from life tables were similar to rates calculated from radiocollared deer. The only exception was for yearling/adult females on north Big Pine Key, where the life-table estimate was only slightly outside of the 95% confidence interval for the radiotelemetry estimate. Our results suggest that life tables based on age-specific mortality data can be a useful tool in estimating survival for Key deer. Comparing survival estimates from both methods allowed us to evaluate potential biases due to violation of assumptions associated with life-table calculations. While wildlife managers should be aware of the potential biases, age-specific mortality data may provide an adequate and cost-effective alternative for estimating survival.

Introduction

Estimating wildlife population demographics is an important component in construction of simulation models (e.g., harvest models, population viability analyses [PVAs]) used to predict population trends. Annual survival is an important population parameter that influences population growth (Krebs 1999, Rabe et al. 2002, White and Bartmann 1998) and is a key component in the development of these models. For example, PVAs are commonly used in endangered species management (Akçakaya 2000, Boyce 1992) and require precise survival estimates. Many methods for estimating survival exist; however, each of these methods have their own benefits and problems (Krebs 1999). Estimating survival from radiotelemetry or mark-recapture data, for example, can provide precise estimates under mild assumptions, yet often at great expense (Krebs 1999). Limited or declining budgets of many wildlife management agencies may prohibit the use of radiotelemetry data in estimating survival (Rabe et al. 2002). Alternative approaches to estimating survival might include the use of age-composition data or life tables (Krebs 1999). However, these alternative approaches require more restrictive assumptions than telemetry or mark-recapture which, if violated, can bias estimates (Caughley 1977, Williams et al. 2002).

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Life tables can be used to estimate age-specific mortality or survival from an assumed cohort using various methods including age at death, age of remains, and age distribution of a population (Caughley 1977, Krebs 1999). Although data collection for life tables also can be expensive (Caughley 1977), some agencies such as the US Fish and Wildlife Service (USFWS) National Key Deer Refuge (NKDR) routinely collect deer mortality data that can be used in the construction of life tables. Use of already collected data could be a cost-effective way for agencies to estimate important population parameters for use in managing wildlife populations.

Caughley (1977) cautioned against the improper use of these methods and violations of assumptions in life-table construction. For example, to estimate survival from carcasses or skulls, collected data must represent a random sample of all population mortalities and the population must have a stable age distribution and a known rate of increase (Caughley 1977). Potential biases pertaining to data collection include the use of hunter-harvest mortalities, seasonal collection (i.e., winter or summer only), or mortalities resulting from rare events such as catastrophes. Each of these situations could produce biased survival estimates. Udevitz and Bellachey (1983) presented a method in which the assumption of either stable age distribution or known rate of increase may be removed by combining age-at-death data and independently sampled standing-age-structure data. Regardless of which method is used, care should be taken to evaluate the accuracy of survival estimates based on life-table data, and, whenever possible, these estimates should be validated with estimates derived by other means such as radiotelemetry data. Use of erroneous survival estimates in making management decisions could have potentially devastating effects on a population, especially in the management of an endangered species like *Odocoileus virginianus clavium* Barbour and G.M. Allen (Florida Key deer).

Key deer are a sub-species of white-tailed deer endemic to the Florida Keys (Hardin et al. 1984). Urban development and habitat fragmentation threaten the Key deer population, with 50% of Key deer mortality attributed to deer-vehicle collisions (Harveson et al. 2004, Lopez et al. 2003b). Since 1968, the USFWS NKDR has collected Key deer mortality data (Lopez et al. 2004) as part of a long-term monitoring program. Additionally, radiotelemetry data have been collected during two separate studies from December 1968 to June 1972, and January 1998 to December 2000 (Hardin 1974, Lopez 2001, Silvy 1975). Survival estimates for Key deer using radiotelemetry data were recently reported (Lopez et al. 2003b), which offers a unique opportunity to compare survival estimates from different sources (i.e., radiotelemetry versus mortality data). Our research objectives were to evaluate the use of USFWS Key deer mortality data as an alternative method for calculating survival by (1) estimating Key deer survival using USFWS Key deer mortality data, and (2) comparing these survival estimates to previously published survival estimates calculated from radiotelemetry data.

Study Area

The Florida Keys are a chain of small islands approximately 200-km long extending southwest from peninsular Florida. Big Pine Key (BPK; 2548 ha) is within the boundaries of the NKDR in Monroe County, and supports approximately 60% of the deer population (Lopez 2001). Soil types vary from marl deposits to bare rock of the oolitic limestone formation (Dickson 1955). Island vegetation varies by elevation with *Rhizophora mangle* L. (red mangrove), *Avicennia germinans* (L.) L. (black mangrove), and *Laguncularia racemosa* (L.) Gaertn. f. (white mangrove), and *Conocarpus erectus* L. (buttonwood) forests occurring near sea level (maritime zones). As elevation increases inland, maritime zones transition into hardwood (e.g., *Bursera simaruba* (L.) Sarg. [gumbo limbo], *Piscidia piscipula* (L.) Sarg. [Jamaican dogwood]) and pineland (e.g., *Pinus elliottii* Engelm. [slash pine], *Serenoa repens* (Bartr.) Small [saw palmetto]) upland forests with vegetation intolerant of salt water (Dickson 1955, Folk 1991).

Methods

Life-table data

Since 1968, USFWS NKDR staff have recorded deer mortality as part of recovery efforts. Dead animals were located primarily by direct sightings, citizen reports, and observation of *Cathartes aura* Linnaeus (Turkey Vultures). Animals collected were held frozen prior to necropsy examination or necropsied immediately. Carcass quality or ability to determine cause of death ranged from good to marginal (Nettles 1981, Nettles et al. 2002). Age, sex, body mass, and cause of death were recorded for each animal using procedures described by Nettles (1981), and all mortality locations were recorded. Attempts were made to collect all deer mortalities on BPK. The island's small size (2548 ha), high human population (4026; US Census Bureau 2000 population estimate), and lack of predators make it likely that most deer mortalities were located. While some carcasses may have been missed, it is reasonable to assume that those found represented an unbiased sample of deer mortalities.

Life tables were constructed for Key deer by sex and age using the USFWS mortality data collected from 1995–2000 on BPK. Lopez et al. (2003b) reported differences in survival between the northern and southern portions of the island, thus, we analyzed our data for two areas: north BPK (NBPK; carcasses located north of Watson Boulevard) and south BPK (SBPK; carcasses located south of Watson Boulevard). Age-specific survival was estimated for each area by sex and age-class assuming a stable age distribution and an instantaneous population growth rate of 0.00 (Caughley 1977, Krebs 1999, Lopez et al. 2004). We believe that the deer population on BPK has a stable age distribution because there is no evidence of major variation in mortality or recruitment rates. Lopez et al. (2004) analyzed Key deer survival using radiotelemetry data and found no difference in survival for data collected from 1968–1971 compared to data collected from 1998–2000 (Lopez et al. 2003a). Further, Key deer are not susceptible to hard-winter die-offs due to the tropical nature of the Keys, and as an unhunted population, there have been no changes in mortality risk due to increased or decreased hunting pressure. While the Florida Keys are susceptible to potentially catastrophic hurricanes, there have been no major impacts to the deer population from 1968–2000.

We estimated the Key deer population growth rate using the average number of deer seen per year during USFWS survey counts. Spotlight surveys were conducted monthly along an established survey route (same beginning and ending point) to provide NKDR biologists with an index of population size (Lopez et al. 2004). We calculated the mean (0.004) and standard error (0.066) of yearly growth rates from 1995–2000. There was no difference between life table calculations using $r = 0.000$ or $r = 0.004$, thus, we assumed that the population was stationary from 1995–2000. We also compared our estimated growth rate from 1995–2000 ($r = 0.004$) to the growth rate from 1970–2000 reported in Lopez et al. (2004; $R = 1.038$ or $r = 0.037$) and found that the latter rate fell within the 95% confidence interval of our estimate of the population growth rate, supporting our estimate of population growth and stable age distribution.

The estimated number of deer dying for each age interval was calculated using the equation

$$d'_x = d_x e^{rx}$$

where: d_x = actual number of carcasses in each age class, r = instantaneous population growth rate, x = age class, and e = base of natural logarithms (i.e., 2.71828). Survival (p_x) was calculated using the equation (Caughley 1977)

$$p_x = 1 - \left(\frac{d_x}{\sum_{y=x}^{x\max} d_y} \right)$$

Deer of unknown sex or age were not used in calculations. For comparison purposes, we calculate survival for fawns (< 1 year of age) and yearlings/adults using a weighted mean by grouping carcasses aged ≥ 1 year (Caughley 1977). Survival estimates, standard errors, and confidence intervals were computed using the program SURVIV (Udevitz and Ballachey 1998, White 1983).

Radiotelemetry data

Lopez et al. (2003b) recently reported Key deer survival estimates based on 314 radiocollared animals by sex, age, and area (north BPK, south BPK, and No Name Key [NNK]). Due to constraints from small sample sizes with our mortality data, we were not able to construct life tables for NNK. Deer were classified into three age groups, fawn (< 1 year old), yearling (1–2 years old), and adult (≥ 2 years old). However, yearling and adult age groups were combined as model selection found no differences in survival for these age groups (Lopez et al. 2003b). Annual Key deer survival was estimated using a known-fate model framework in program MARK (Lopez et al. 2003b, White and Burnham 1999).

We used survival estimates calculated from radiotelemetry data as a benchmark for comparison under the assumption that these estimates best reflected actual Key deer survival rates. Known-fate models estimate survival with high precision since the status of each animal is known at each sampling occasion (alive, dead, or censored; Lopez et al. 2003b, White and Burnham 1999). In addition, the assumptions of stable age distribution and known rate of increase are not required with known-fate models as they are with life-table estimates calculated from age-specific mortality data. Therefore, if our survival estimates based on mortality data are biased due to violation of life-table assumptions, then our estimates should differ from those calculated using radiotelemetry data. We compared life table survival estimates to radiotelemetry survival estimates for each area, sex, and age category (Lopez et al. 2003b) using 95%-confidence intervals (estimate ± 1.96SE). Survival estimates calculated from mortality data and radiotelemetry data were considered similar if 95%-confidence intervals overlapped (Johnson 1999).

Results

A total of 506 deer (177 females, 329 males) mortalities was recorded by USFWS biologists from 1995–2000. Key deer survival estimates derived from life tables were similar to rates calculated from radiocollared deer (Table 1). The only exception was for yearling/adult females on NBPK where the life-table estimate was only slightly outside of the 95%-confidence interval for the radiotelemetry estimate (Table 1). Overall, variability was smallest for our life-table survival estimates compared to those based on radiotelemetry data. Life table estimates differed by area (NBPK and SBPK) and age group (fawn and yearling/adult), but were similar by sex (Table 1).

Table 1. Annual Key deer survival estimates by data source (mortality, radiotelemetry), sex, and age group on north Big Pine Key (NBPK) and south Big Pine Key (SBPK), FL.

			Mortality[A]				Radiotelemetry[B]			
Sex	Age	Area	Survival	SE	95% LCI	95% UCI	Survival	SE	95% LCI	95% UCI
Female										
	Fawn	NBPK	0.667	0.058	0.553	0.780	0.726	0.109	0.512	0.940
	Fawn	SBPK	0.739	0.042	0.657	0.820	0.695	0.091	0.517	0.873
	Y/Adult	NBPK	0.707	0.037	0.634	0.780	0.848	0.033	0.783	0.913
	Y/Adult	SBPK	0.610	0.034	0.544	0.676	0.710	0.082	0.549	0.871
Male										
	Fawn	NBPK	0.683	0.051	0.582	0.784	0.668	0.091	0.490	0.846
	Fawn	SBPK	0.741	0.028	0.686	0.796	0.599	0.158	0.289	0.909
	Y/Adult	NBPK	0.678	0.035	0.609	0.748	0.583	0.060	0.465	0.701
	Y/Adult	SBPK	0.563	0.024	0.516	0.612	0.412	0.099	0.218	0.606

[A]Mortality data collected by US Fish and Wildlife Service from 1995–2000.
[B]Radiotelemetry data collected from 1968–1972 (Silvy 1975) and 1998–2000 (Lopez 2001).

Discussion

Construction of life tables with mortality data for white-tailed deer requires several assumptions that may introduce bias (Caughley 1977); thus, results should be viewed cautiously. For example, we found a small, although significant, difference in estimated survival of yearling/adult females between the two data sources (Table 1.) Accurate survival estimates for adult females are particularly important as these estimates tend to have a significant impact on large ungulate population trends (Rabe et al. 2002, White and Bartmann 1998). Overestimating adult female survival could have detrimental effects in both endangered species and game population management. Our life table survival estimates, however, underestimated yearling/adult female survival which would produce a lower, more conservative estimate of population growth. The reason for this difference is unknown. Possible explanations include biases with the life-table and/or radiotelemetry estimates. It is possible that one of the life-table assumptions (e.g., random sample, stable age distribution, or known-growth rate) may have been violated.

However, with one slight exception, survival estimates between the two methods were similar suggesting that estimating survival based on mortality data may be an adequate alternative to collecting radiotelemetry data. The purpose of this paper was to evaluate the utility of using mortality data for estimating survival for Key deer. In the absence of known-survival rates, we chose the best available estimates, those calculated using radiotelemetry data (Lopez et al. 2003b). Thus, for comparison purposes, we used the same age, sex, and area categories as reported in Lopez et al. (2003b). Better models for estimating survival using mortality data may exist and can be easily evaluated using the program SURVIV (White 1983) or MARK (White and Burnham 1999), which calculate AIC, likelihood ratios, and goodness-of-fit estimates for various user-defined models. For example, we set survival equal for ages ≥ 1 year. Other models can be specified such as equal survival across all ages, or equal survival for adults only and separate survival for fawns and yearlings. The statistics generated by the program SURVIV can be used to select the most appropriate model for estimating survival of Key deer based on mortality data (Udevitz and Ballachey 1998, White 1983).

Management Implications

We found life-table survival estimates to be similar to those derived from radiotelemetry data, suggesting an alternative for estimating survival of Key deer. The long-term monitoring of Key deer mortality by USFWS biologists offers managers such an opportunity. In our study, comparing results from both methods allowed us to evaluate potential biases due to violation of assumptions associated with life-table calculations. Furthermore, alternative methods exist which can eliminate some of the assumption associated with life-table calculations. For example, combining age-structure data with mortality data permits the elimination of either the assumption of stable age structure or known rate of increase (Udevitz and Bellachey 1998). While wildlife managers should be aware of the potential biases associated with life-table calculations, age-specific mortality data may provide an adequate and cost-effective alternative for estimating survival.

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