Technical Notes:

Survival Analysis of Single and Twin Lambs

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Abstract

We illustrate the use of life tables and survival analysis for evaluating data on livestock losses. The techniques are used to compare the rate of coyote *(Canis latrans)* predation on single and twin lambs. Based on the number of lambs known to have been killed by predators, the survivorship of single and twin lambs was not significantly different $(P>0.05)$ for any year of the study. Survival functions which can be generated and used to evaluate data on livestock losses include the cumulative proportion of livestock surviving at the end of an interval, probability density, and hazard rate.

Key Words: *Canis latrans,* coyote, predation, sheep, life table

The use of life tables and survivorship curves was introduced to ecologists by Pearl in 1921 (Krebs 1972). Since that time, many researchers have used life tables to analyze survivorship of plant and animal species (e.g., Deevey 1947, Barkalow et al. 1970,

Fowler and Antonovics 1981). Use of life tables and survival analysis however, appear to have been overlooked by those studying livestock losses to predators. Most studies of predation evaluate livestock losses using statistical techniques such as analysis of variance and nonparametric statistics.

In this paper we illustrate the advantages of using life tables and survival analysis when evaluating data on livestock losses. The techniques involved are used to compare the rate of coyote *(Canis latrans)* predation on single and twin lambs at the University of California Hopland Field Station.

Relatively little is known about coyote selection for single and twin lambs. Munoz (1976) reported that twin lambs were attacked more often than single lambs and that coyotes probably found it easier to isolate from its mother one lamb of a set of twins than a single. In contrast, Gluesing et al. (1980), found that proportionately, coyotes killed almost twice as many singletons $(P<0.05)$ as they did twins and suggested that this may have resulted from single lambs being more active than twins.

Study Area and Methods

The Hopland Field Station is comprised of 2,168 ha ranging in elevation from about 150 to 915 m. The Field Station typically has mild, rainy winters and hot, dry summers. Annual rainfall averages about 90 cm per year. Temperatures average approximately 21° C

Table 1. Life table for 73 single lambs placed on pasture in 1981 on the University of California Hopland Field Station.

| Interval start time (days)	Interval end time (days)	No. sheep entering	No. sheep withdrawn	No. sheep exposed	No. sheep killed	Cumulative proportion surviving (%)	Probability density (%)	Hazard rate (%)
0.0	6.9	73.0	0.0	73.0	0.0	100.0	0.00	0.00
7.0	13.9	73.0	0.0	73.0	2.0	97.3	0.39	0.40
14.0	20.9	71.0	0.0	71.0	0.0	97.3	0.00	0.00
21.0	27.9	71.0	0.0	71.0	3.0	93.1	0.59	0.62
28.0	34.9	68.0	0.0	68.0	0.0	93.1	0.00	0.00
35.0	41.9	68.0	0.0	68.0	1.0	91.8	0.20	0.21
42.0	48.9	67.0	0.0	67.0	0.0	91.8	0.00	0.00
49.0	55.9	67.0	0.0	67.0	1.0	90.4	0.20	0.21
56.0	62.9	66.0	0.0	66.0	0.0	90.4	0.00	0.00
63.0	69.9	66.0	0.0	66.0	1.0	89.0	0.20	0.22
70.0	76.9	65.0	0.0	65.0	0.0	89.0	0.00	0.00
77.0	83.9	65.0	0.0	65.0	1.0	87.7	0.20	0.22
84.0	90.9	64.0	1.0	63.5	0.0	87.7	0.00	0.00
91.0	97.9	63.0	0.0	63.0	0.0	87.7	0.00	0.00
98.0	104.9	63.0	0.0	63.0	0.0	87.7	0.00	0.00
105.0	111.9	63.0	0.0	63.0	0.0	87.7	0.00	0.00
112.0	118.9	63.0	0.0	63.0	1.0	86.3	0.20	0.23
119.0	125.9	62.0	2.0	61.0	0.0	86.3	0.00	0.00
126.0	132.9	60.0	0.0	60.0	0.0	86.3	0.00	0.00
133.0	139.9	60.0	0.0	60.0	1.0	84.5	0.21	0.24
140.0	146.9	59.0	0.0	59.0	0.0	84.5	0.00	0.00
147.0	153.9	59.0	1.0	58.5	0.0	84.5	0.00	0.00
154.0	160.9	58.0	13.0	51.5	0.0	84.5	0.00	0.00
161.0	167.9	45.0	34.0	28.0	0.0	84.5	0.00	0.00
168.0	174.9	11.0	8.0	7.0	0.0	84.5	0.00	0.00
175.0	181.9	3.0	2.0	2.0	0.0	84.5	0.00	0.00
182.0	188.9	1.0	1.0	0.5	0.0	84.5	0.00	0.00
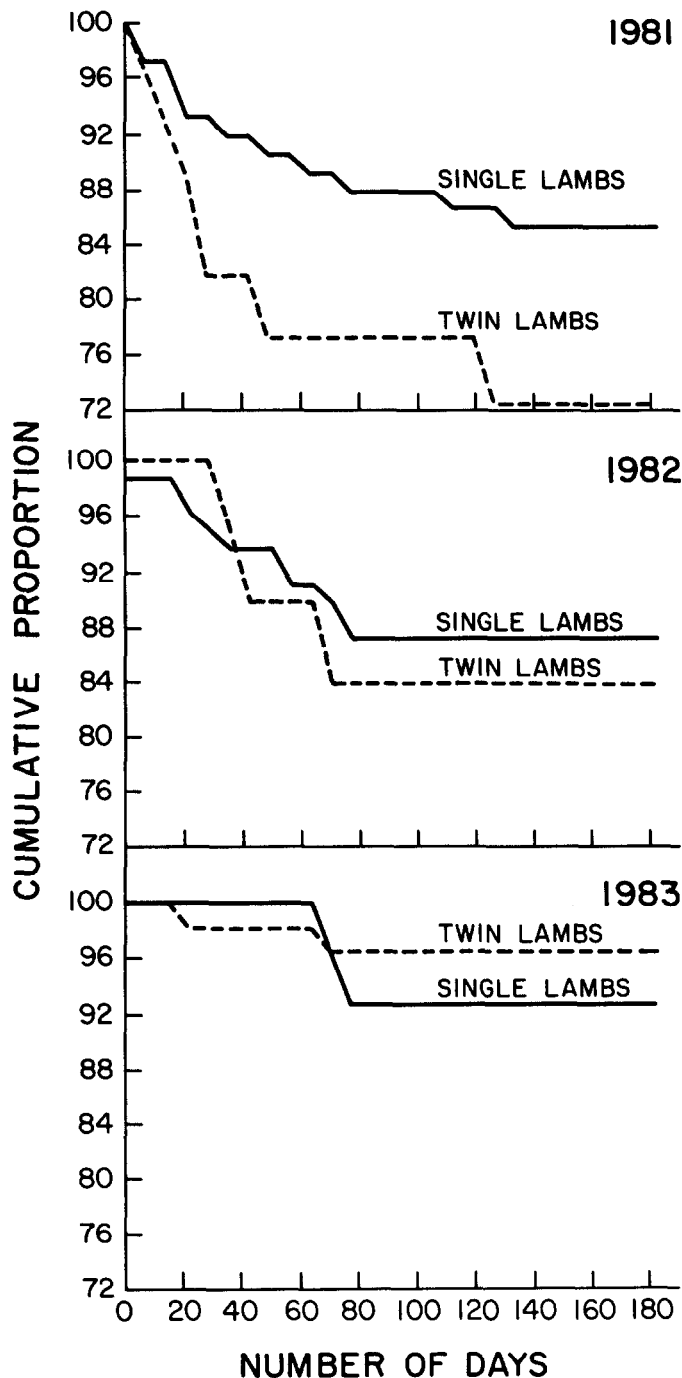
Fig. 1. *The cumulative proportion (%) of single and twin lambs surviving predation to time* t *during 1981, 1982, and 1983 on the University of California Hopland Field Station. Survivorship of single and twin lambs was not statistically different (P>0.05) for any of the 3 years.*

in the summer and 8° C in the winter. The vegetation is almost equally divided into 4 cover types: grass, woodland grass, dense woodland, and chaparral.

Data were gathered during 1981–83. During each year, ewes and 2-day-old lambs were placed on a 115-ha pasture. The number of single and twin lambs placed on pasture each year averaged 69 (55 to 79) and 30 (28 to 36), respectively. Animals were placed on pasture in January in 1981 and 1982 and in February in 1983. The number of days lambs were observed averaged 168 (132 to 188). Pastures were usually checked 6 days per week. Missing animals were identified at docking (about midway through the experiment)

or at the end of the study and were assumed to have been alive during one-half of the period exposed.

Lambs found dead were examined to ascertain cause of death. Deaths by predation were established from tooth-puncture wounds, wounds on skin and bones, hemorrhage around tooth marks, and tracks at kill sites. During all years, a professional government trapper was employed in an attempt to minimize predation losses.

Life tables for single and twin lambs were formulated and incremented in 7-day intervals. Survivorship curves were generated based on the proportion of animals surviving predation in each 7-day interval. Life tables of single and twin lambs were generated using the SURVIVAL program in ⸬ SPSS (1986) and were statistically compared using the algorithm of Lee and Desu (1972).

Results and Discussion

Life tables were developed for single and twin lambs of 1981, 1982, and 1983 (see Table 1 for example of 1981 single lambs). Survivorship of single and twin lambs based on the number of lambs known killed by predators was not statistically different (P>0.05) for any year of the study. The sample size of sheep known to have been killed by coyotes was too small to conclude anything about predation on singletons and twins.

Useful survival functions which can be calculated from life table data include the cumulative proportion of livestock surviving at the end of an interval, probability density, and hazard rate (Berkson and Gage 1950, Gross and Clark 1975). The cumulative proportion surviving at the end of an interval is an estimate of the probability of survival up to and including the current interval (Fig. 1).

The probability density function for a given 7-day interval is the chance per day that a predator kill will occur in that interval. Thus, for the single lambs on pasture in 1981, there was a 0.39% chance per day that a predator kill would occur from day 7 to day 13.9 (Table 1). The hazard rate is an estimate of the probability per day that a lamb entering a given interval will be killed in the interval. For the 7-day interval mentioned above, there was a 0.40% chance per day that a given lamb would be killed (Table 1).

For all years combined, the weekly probablility density and hazard rate during the first 12 weeks averaged 0.13% (SD = 0.13) and 0.14 (SD = 0.14), respectively, for singletons. During the last 15 weeks, the weekly probability density and hazard rate both averaged 0.01 (SD = 0.03). Thus, single lambs were most likely to be killed early in the study. A similar trend was observed for twin lambs.

There was a 15-fold difference in recovery rates (the ratio of missing/recovered lambs which died from all causes) for single and twin lambs. Overall, 87% of the animals which became missing were twin lambs. The reason for this wide differential is unknown. Clearly one way to minimize lamb losses, whether or not the cause of death of most missing animals was predation, is to manage ewes with twin lambs more intensively than ewes with single lambs, especially during the first 12 weeks of age.

Analyzing data on livestock losses with traditional statistical techniques provides little or no information as to how predation varies through time. Such insights, however, can be gained by evaluating survival functions such as the cumulative proportion surviving at the end of an interval, probability density, and hazard rate.

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