The Economics of Sheep Predation in Southwestern Utah

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Abstract

Ten sheep ranches in southwestern Utah were chosen for a verification study of sheep losses during 1972-1975. Using the ratio of verified predator kills to total lamb carcasses discovered, total lamb loss to predators was estimated. Predation accounted for 5.8% of total lambs docked or 62% of the total lamb loss. Coyotes made 94% of all predator kills. For the 10 herds (1972-1974) direct income loss due to lamb predation averaged $2,800 per herd; for a three-herd subsample (1972-1975) direct income loss averaged $3,500 per herd. Applying our study rate of predation to the entire Southwest region of Utah gave an estimate of 14,900 lambs killed by predators and a direct income loss of $419,000. In addition, the region suffered indirect or multiplier losses of $1,166,000 to $1,816,000 during the 4 years studied. Further data needs in predation economics could be achieved by integrating predation loss, predator population, and predator control data into a standard production function model.

Recent profit reductions have resulted in 10% annual decreases in Utah's sheep numbers (Statistical Reporting Service 1976) and have increased the sheepman's incentive to prevent livestock predation losses. Simultaneously, predator control has become increasingly complex. Early predator control research was aimed primarily at discovering methods of eradicating coyotes, the most troublesome predator (Bailey 1904, 1908). More recently, financial relief through economically efficient predator control has come into increased conflict with interests promoting esthetic, recreational, and ecological values associated with a viable predator population.

To define the magnitude of the predation problem and to provide a data base for an economic analysis, a verification study of sheep loss was initiated in March 1972 in the Cedar City area of Utah (Bowns et al. 1973a, 1973b; Davenport et al. 1973). A study requiring examination of each sheep carcass was chosen over a rancher survey questionnaire to eliminate possible reporting bias. In cooperation with the Cedar City Livestock Association and the Southern Utah State College (SUSC) Experimental Farm, 10 sheep ranches were selected as sample operations to form the data base for the initial 3-year phase. In the fourth year, 1975, the sample was reduced to three herds. All sample herds were migratory range sheep operations, typical of commercial sheep ranches throughout the Intermountain states. Most herds winter on desert ranges near the Nevada border west of Cedar City and after shed lambing in the spring are trucked or trailed to high elevation summer ranges east of Cedar City.

Methods

Cooperating ranchers and herders were asked to promptly report all dead and injured sheep so researchers could make an immediate examination to ascertain cause of death or injury. As the study proceeded, researchers increasingly relied on periodic checks of each pasture to locate lamb carcasses. Ranchers continued to report sheep losses and provide necessary lamb counts.

Total lamb loss was determined from the ranchers' inventory of lambs at docking, during trucking or trailing between the spring and summer range, and at weaning or marketing. The difference between docking and trucking or trailing counts gave the total spring lamb loss and the difference between trucking or trailing counts and weaning count gave the total summer lamb loss. Predation losses of age classes other than lambs were minor so inventory efforts were concentrated on lambs. Predator kills were verified according to strict criteria by experienced study personnel (Bowns 1976) and photographically documented.

If predation was not evident in the necropsy a lamb was classified as dying from natural causes. This statistic does not include natural pre-docking losses that occurred up to approximately 12 days after birth. All lamb carcasses were classified as (1) predator kills, (2) natural death, or (3) unknown cause of death. As the study progressed, researchers became more proficient in distinguishing between predatory and natural deaths. In 1973 the cause of death in 16% of lamb carcasses could not be diagnosed. In subsequent years 1% or less were listed as dying from unknown causes.

Despite the coordinated efforts of ranchers and researchers, only 36% of the total lamb losses in the initial study year were discovered

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Table 1. Percentage of examined lamb carcasses verified as predator losses in herds 1, 3 and 5, southwestern Utah, 1972-75.

Herd	1975 Spring	1975 Summer	1972-74 Mean Spring	1972-74 Mean Summer
1	0	85.7	0.6	86.9
3	20.0	62.5	43.7	69.9
5	58.7	92.7	47.0	89.4
Mean[1]	26.2	80.3	30.4	82.1

[1] Paired *t* test between spring 1975 vs. spring 1972-1974 and summer 1975 vs. summer 1972-1974 were insignificant at .05 level.

and examined by the researchers. The remaining carcasses were obscured by dense vegetation and scattered over such a vast area that intensive searches were impractical. In subsequent years, researchers became increasingly successful at finding lamb carcasses by searching bedgrounds, dry washes, ravines, specific drainages and particular pastures more frequently. Lamb carcasses discovered increased to 41% in 1973 and 57% in 1974. In 1975 the sample herds were reduced from 10 to 3 so search efforts could be concentrated. With the intensive sample of 3 herds, 89% of the total missing lambs were discovered and examined.

The percent of verified predator kills represents only the minimum predation loss (Table 1). To accurately assess the full magnitude and resulting economic impact of predator losses the number of undiscovered predator kills had to be estimated. The carcasses found by researchers were assumed to be a random sample of total lamb losses. Thus the proportion of predator kills among those carcasses examined was assumed to be the same as among the undiscovered missing lambs. Calculation of the ratio of *verified* predator losses to total examined lamb losses and expansion of that proportion to the unaccounted for lamb losses (total missing lambs minus examined carcasses) gave the *estimated* predator lamb losses. Estimated predator loss was then added to verified predator loss, yielding a total predator lamb loss (Table 2).

Table 2. Total predator lamb losses as a percentage of total lamb losses, southwestern Utah, 1972-75.

Year	Herds 1-10	Herds 1, 3 and 5
1972	72.8	72.1
1973	53.2	50.5
1974	59.2	63.4
1975	No Data	49.2

Separate ratios were calculated for each year, season, and herd. Average ratios were then calculated for each herd for each season. This approach gave an unbiased estimated predator loss, whereas a verified predator loss ratio obtained by simply summing verified predator losses for all herds in the aggregate would have weighted the ratio in favor of the years in which high predator losses occurred.

The validity of this statistical inference is confirmed by comparing the predator loss ratios for herds 1, 3, and 5 during the final study year (1975) with those of the first 3 years of the study (Table 1). If the underlying premise was incorrect, the ratios would have reflected a declining or increasing proportion of predator kills as the proportion of observed carcasses increased. Instead, the ratio of verified predator kills to total loss remained essentially constant throughout the study even though the percentage of lamb losses examined was 54% higher during 1975 than during the first year.

The difference between *total* predator lamb losses and *verified* predator kills is substantial. Table 3 reveals the relative disparity between verified and total predator kills. All conclusions in this study are based upon *total* predator lamb losses.

Results and Discussion

Coyotes were responsible for all verified predation losses in 1972, 89% of the verified loss in 1973, 94% in 1974, and 92% in 1975. Bears, cougars, domestic dogs, and pigs inflicted the remaining predation losses. Invariably, coyotes selected lambs over other age classes of sheep. Only 17 ewes were verified as predator kills during the spring and summer seasons in 4 years of study. Therefore, spring and summer sheep depredation in southwestern Utah is predominantly coyote predation on lambs.

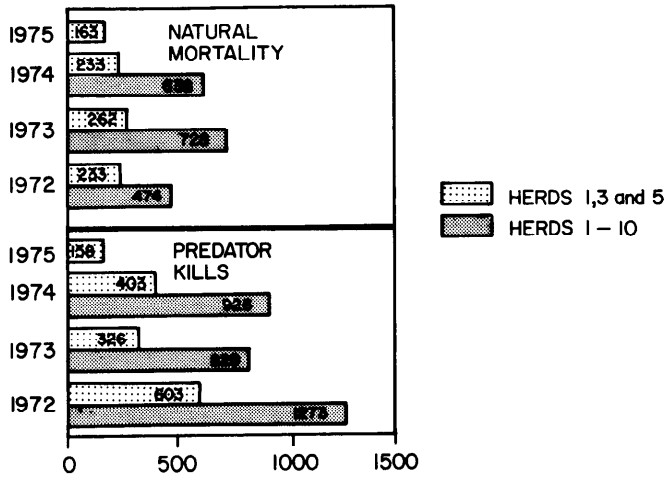

Fig. 1. *Natural mortality and total predator kills incurred by herds 1,3, and 5, 1972-75, and herds 1-10, 1972-74.*

During 3 years of study, predator lamb losses in herds 1-10 averaged 1,009 or 62% of the 1,623 mean total lamb loss. In herds 1, 3, and 5, which were studied for 4 years, total lamb loss averaged 584 with an average of 373 lambs (63%) destroyed by predators. Apparent from the annual losses shown in Figure 1 and corroborated by annual percentages of predation in Table 2, coyotes inflicted a majority (61%) of the total lamb loss. Also evident from comparison of Figure 1 and Table 2, greater total

Table 3. Total predator losses and verified predator losses as a percentage of lambs docked, southwestern Utah, 1972-75.

Year	Season	Herds 1-10 Total predator loss	Herds 1-10 Verified predator loss	Herds 1, 3 and 5 Total predator loss	Herds 1, 3 and 5 Verified predator loss
1972	Spring	0.75	0.48	0.87	0.68
	Summer	6.21	1.25	7.54	0.32
1973	Spring	0.56	0.51	0.77	0.78
	Summer	4.14	0.97	3.77	1.96
1974	Spring	0.86	0.69	0.91	0.69
	Summer	4.96	1.87	4.34	1.35
1975	Spring	No Data	No Data	0.95	0.65
	Summer	No Data	No Data	1.94	1.35
Mean	Spring	0.72	0.56	0.88	0.70
	Summer	5.19	1.36	4.40	1.25

losses corresponded to higher predation losses and vice-versa. Figure 1 clearly shows that annual natural mortality is much more static than losses inflicted by predators. Therefore, not only did predators inflict a majority of the total lamb loss, but most of the escalation in total lamb losses can be attributed to predators.

During the spring, lamb depredation remained almost constant, while mortality from natural causes (which constituted the majority of the total spring lamb loss) fluctuated widely. However, during the summer almost the entire lamb loss was due to predation, while natural causes were minimal and quite static (Fig. 1). Seasonal disparity in natural mortality was anticipated. Several studies (Safford and Haversland 1960; Venkatachalam et al. 1949), including research with the SUSC experimental herd (Matthews and Ogden 1957), have described susceptibility of preweaning lambs to high incidence of pneumonia, malnutrition, infection, etc., during the first 5 to 7 weeks after birth. By the time the summer trucking or trailing count was taken, most natural mortality had already occurred.

The reason for the difference between the spring and summer predation loss was not as apparent. Predator losses in the spring were consistently lower than during the summer. In herds 1, 3, and 5 for example, spring predator loss differed by only five lambs from an average predation loss of 55 lambs during 4 years of study. Summer predator losses for these same herds varied from 2 to 10 times as much (Fig. 2). The smaller predator losses on spring ranges suggest that coyote deterrents such as shed lambing and nightly impoundment with the presence of a herder (infeasible on summer ranges) have successfully reduced predation to the minimum feasible level, despite apparently greater resident coyote density on the spring range.

The relative magnitude of predator losses was computed on the basis of lambs docked, since the docking count was the first taken. During the entire study, 5.8% of the lambs docked were killed by predators. Individual herd predator losses varied from 0.2 to 11.3% in the summer and from 0 to 3.5% in the spring. The rate of predation in southwest Utah is remarkably similar to rancher surveys of predation losses taken throughout the West, including (1) Nielsen and Curle (1970), who reported 61 lambs and ewes lost per 1,000 head of sheep in Utah; (2) Early et al. (1974), who reported 38-40 lambs lost per 1,000 head of lambs and 26-28 ewes lost per 1,000 head of ewes in Idaho; and (3) Reynolds and Gustad (1971), who reported an average predation rate in four Western states of 5.3%. Percentages of verified predation in Table 3 vary from 0.48 to 1.87%, considerably less than the 4% rate of verified predation compiled in Nevada (Klebenow and McAdoo 1976). However, we believe that an intensive sample with constant surveillance as in the Nevada study would have caused our verified predator loss to approach the total predator loss.

The herds selected in the sample were assumed to provide a representative sample of predation rates throughout much of the state of Utah. Yet differences in the level of predation losses were evident between seasonal ranges and between herds sampled, indicating a complex aggregation of management and environmental interactions unique to each herd on each seasonal range (Taylor 1977). Therefore, any geographical delineation of a homogeneous population of sheep herds is arbitrary—a compromise between limiting study results strictly to the study area or a statewide expansion, which would not be entirely warranted due to the small number and regional concentration of the sample herds. The population represented by the study was defined as southwestern Utah, including seven counties (Beaver, Garfield, Iron, Kane, Piute, Washington, and Wayne) which adjoined or were included in the study area. The ten representative ranches comprise 4.5% of the sheep ranches in that region (U.S. Department of Commerce 1977).

To estimate regional lamb losses (Table 4), the sample herd predation rate was expanded to the number of lambs docked region-wide (Statistical Reporting Service 1976). Since county data were unavailable, the number of lambs docked in the seven-county area was calculated by prorating the state sheep inventory (U.S. Department of Commerce 1977). In the seven-county region, an estimated 14,855 lambs were killed by

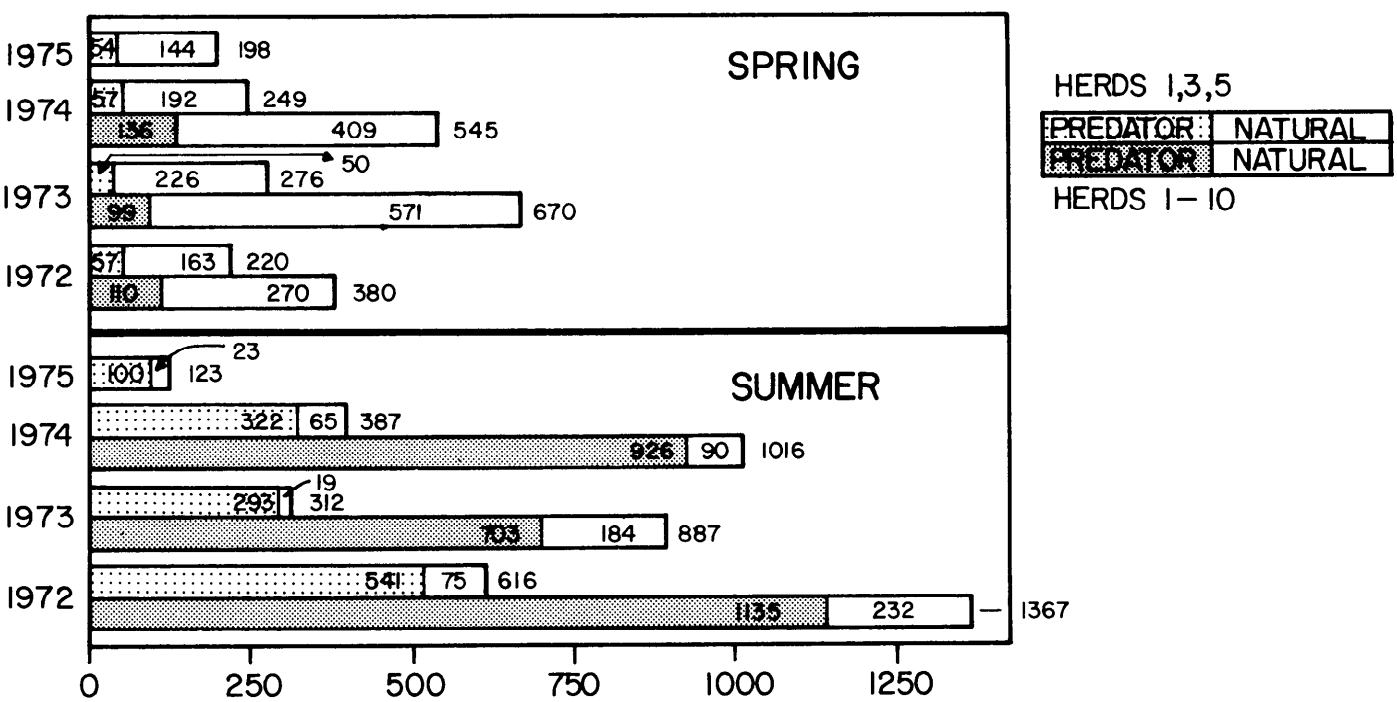

Fig. 2. *Total predator kills and natural mortality during spring and summer in herds 1,3,5, 1972-75, and in herds 1-10, 1972-74.*

Table 4. Computation of predator lamb losses in southwestern Utah, 1972-75.

Year	Lambs saved statewide[1] (1,000 lambs)		Rate of predation[2]		Regional proration[3]		Predator lamb loss in Southwestern Utah
1972	713	×	6.955	×	.1165	=	5,777
1973	635	×	4,699	×	.1165	=	3,476
1974	578	×	5.814	×	.1165	=	3,916
1975	502	×	2.886	×	.1165	=	1,688
Total							14,357

[1] Statistical Reporting Service (1976) data comparable to lambs docked.
[2] Number of lambs killed per 100 lambs docked.
[3] U.S. Department of Commerce 1977.

predators during the period 1972-1975, an average annual loss of 3,774 lambs (Table 4). Expansion of sample data to the entire state of Utah yielded a statewide predation loss of 127,521 lambs during the period studied.

Direct income loss due to lamb predation was calculated by multiplying the number of lambs destroyed times the average lamb value. Ideally, determination of the exact value of each lamb would require that any additional variable costs that would have been incurred after death of the lamb be subtracted from the market price. But since virtually all significant expenditures for lamb production are fixed in a lamb at birth, the average value of a predator kill would approximate the full fall market price. Thus average value was estimated by multiplying the price per hundredweight of Utah lambs (Statistical Reporting Service 1976) by 88 pounds, the average fall market weight of Utah range lambs (Goodsell and Belfield 1973). Study observations of coyote kills indicate that the average market weight may be conservative since coyotes appear to select larger than average lambs.

The direct income loss suffered by ranches 1-10 was estimated at $82,741 during the period 1972-1974 (Table 5). During the same period ranches 1,3, and 5 lost $41,913. This is an average annual loss per ranch of $2,758 and $3,493 for herds 1-10 and herds 1,3, and 5, respectively. Regional direct income losses were estimated at $419,323 for the 4 study years, an average annual loss of $1,897 for each of the 221 sheep ranches in southwestern Utah with sales greater than $2,500 (U.S. Department of Commerce 1977). Statewide predator losses were estimated at 3.6 million dollars for the same 4 years. As an indication of the severity of the impact of this loss on Utah's sheep industry, gross income for lamb and sheep sales in 1975 totaled 17.6 million dollars (Statistical Reporting Service 1976).

An expansion or contraction of one economic sector brings secondary changes in expenditures for inputs resulting in a decreased level of economic activity in other sectors of the economy. Hence, income losses resulting from predatory lamb losses reduce expenditures in the livestock sector and these "multiplier" effects reduce income of all other sectors of southwestern Utah's economy. Two such multipliers—a type I multiplier, which includes direct and indirect payments, and more comprehensive type II multiplier, which includes induced payments as well as direct and indirect payments—have been calculated for Utah's economy (Bradley 1967). The type I livestock multiplier of 2.781 and the type II livestock multiplier of 4.33 both ranked second compared to multipliers for 39 defined sectors in the state's economy. Applying these multipliers to estimates of annual direct income loss, the detrimental impact of predation lamb losses on the economy of southwestern Utah is shown in Table 5. During the 4 years studied, type I indirect income losses were $1,166,000 and type II indirect losses totaled $1,816,000.

It should be noted that total costs of coyote predation are composed of two parts: (1) the value of sheep that are destroyed by coyotes and (2) the costs incurred in attempting to control or deter coyote predation. Therefore, estimates in Table 5 of direct and indirect foregone income understate the total costs of predation by the amount ranchers spent on coyote control.

A final recommendation made by the historic Leopold Committee (1964) was that predator control programs be subjected to benefit-costs analysis. Cain et al. (1972) reiterated:

> Although the need for such economic studies was given high priority in the Leopold study, today, nearly eight years later, very little progress has been made in this direction. . .A review of costs and damage data available in 1971 reveals that the same state of affairs existed in 1964.

Studies in predation economics have traditionally been limited to estimates of depredation magnitude and assessment of damage. Focus should now shift to estimating the optimum rates of control and the coyote population density which is socially, economically, and ecologically acceptable. In economic studies of pesticide usage, production function models have provided a conceptual framework from which public policy has been examined (Headley and Lewis 1967; Economic Research Service 1971). Applied to predator control, a production function is the physical relationship between maximum obtainable lamb crop and successive increments of coyote control employed (Fig. 3). The level of coyote control and deterrent utilized throughout the current production cycle, plus residual control from previous years, are correlated with the resulting fall lamb crop. As the function approaches zero control, sample points

Table 5. Direct and indirect income loss of herds 1-10, herds 1,3, and 5, and for southwestern Utah, 1972-75.

Year	Lamb value per head (dollars)	Direct income loss: Herds 1-10	Direct income loss: Herds 1,3, and 5	Direct income loss: S.W. Utah	Indirect income loss S.W. Utah: Type I Multiplier	Indirect income loss S.W. Utah: Type II Multiplier
1972	24.38	31	15	141	392	609
1973	28.07	23	9	98	271	422
1974	30.71	28	12	120	334	520
1975	35.99	No Data	6	61	169	263
Total[1]		83	42	419	1,166	1,816

[1] Discrepency in column totals due to rounding.

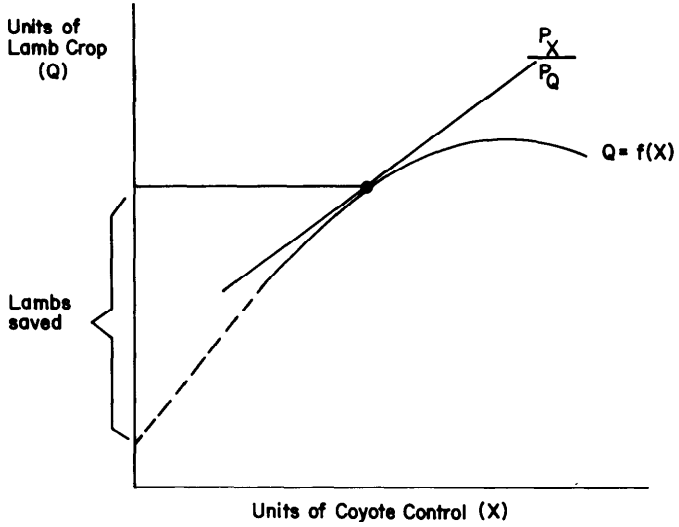

Fig. 3. *Hypothetical production function, f(X), with coyote control, X, the single input and lamb crop, Q, the output.*

will be absent because invariably some government or private control is practiced in any sheep producing area. Extrapolation of the function to the ordinate intercept (dashed line in Fig. 3) estimates the lamb crop in the absence of predator control—a figure which researchers have previously tried to calculate by studying comparable areas with and without coyote control (Munoz 1976; DeLorenzo and Howard 1975). Present value of the lambs saved from predators (total lamb crop minus estimated lamb crop without control) divided by the corresponding present value of predator control expenditures is the benefit-cost ratio measuring efficiency of the control program. The optimum control level is where the production function is tangent to the price line P_x/P_q in Figure 3, where P_x is the price (cost) of a unit of coyote control and P_q is the price (return of a unit of lamb production. At the optimum level, the last dollar spent on coyote control or deterent would return a dollar in additional lamb revenue. Knowledge of the optimum level would allow control expenditures in excess of optimum to be reduced and inadequate programs to be bolstered. Any deviations in coyote control or lamb crop from the optimum for social or environmental reasons could then be assessed in terms of trade-offs between lamb production and coyote populations.

Summary and Conclusions

This study was undertaken to assess lamb losses to predators and resulting economic losses in southwestern Utah. All field data collected from 10 sample herds pertain to lamb losses that occurred on spring and summer ranges between docking and marketing. Field work resulted in estimates of (1) total lamb loss, (2) verified predator kills, and (3) natural mortality. Since the verified predation kills represent only the minimum predation loss, the percentage predation of discovered carcasses were expanded to undiscovered lambs. The most serious predation occurred on summer ranges where intensive coyote deterrent isn't feasible. Fluctuations in total annual lamb losses were due primarily to declines or increases in predation.

The economic analysis was based on estimates of total predation loss. Even with current predator control programs, an average sheep ranch in the region suffered an estimated annual lamb loss of $1,856. Migratory range herds typical of those sampled averaged from $2,758 to $3,493 annually in predator losses. In addition, indirect regional losses could average as high as $454,000 annually—a severe detrimental impact on both the individual sheepman and the rural community.

Sound public policy concerning predator control must be based on continued investigation of the complex relationships between predator population, predator control activities, and livestock losses to predation. Hopefully, the data and analysis presented will be helpful in resolving some of the many issues in predator management.

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