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Retrospective study on mortality pattern in endangered Nilgiri sheep under farm conditions

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Abstract
A retrospective analysis of mortality records maintained at the Sheep Breeding Research Station (SBRS), Sandynallah, The Nilgiris, Tamil Nadu, was carried out to characterise the pattern of mortality in Nilgiri sheep over six consecutive years (2020-21 to 2025-26). Individual death records (n = 224) were classified by age category (lamb/adult), sex, season and cause of death, and year-wise mortality rate was computed against the standing flock strength. Overall mortality ranged from 3.65% in 2020-21 to a peak of 16.14% in 2025-26, averaging 10.04% across the six years, with an intervening peak of 15.32% in 2022-23. Lamb mortality (5.13-30.71%) exceeded adult mortality (2.83-14.84%) in every single year of the study, and the gap widened sharply in 2025-26. Spring (March-May, the principal lambing season) and South-West monsoon (June-September) together accounted for 79.5% of all recorded deaths. Toxaemia (21.4%), enteritis (17.9%) and cold shock (15.2%) were the major diagnosed causes of mortality. Statistically significant associations were established between age category and study year, season, sex, and cause of death (χ^2 tests, $p < 0.01$). The findings point to peri-parturient management in the March-May lambing window, monsoon-season disease and nutrition management, and clostridial-disease control as priority areas for reducing mortality and safeguarding this conservation-priority breed at the station.

Keywords: Nilgiri sheep, mortality pattern, lamb mortality, seasonal mortality, toxaemia

1. Introduction

The Nilgiri sheep is a dual-purpose breed native to the Nilgiri hills of Tamil Nadu. It is recognised for its adaptability to high-altitude, low-input rearing systems and is valued for both fine wool and meat production (Venkataramanan *et al.,* 2013) [1]. Currently, the breed is endangered, with the population reduced to fewer than 1,000 individuals (Report, 2008; personal survey) [2], emphasising the urgent need for conservation measures (Bhatia *et al.*, 2005) [3].

Given the difficulty of conserving such small populations under free-ranging conditions, institutional farms have become essential to ex-situ conservation, serving as the primary means of maintaining nucleus flocks and enabling controlled breeding. The Sheep Breeding Research Station (SBRS) at Sandynallah exemplifies this role, functioning as the principal refuge for the breed. For more than 75 years, it has maintained a closed nucleus flock of Nilgiri sheep under consistent production and health monitoring. This sustained institutional record offers a continuous account of flock dynamics, making SBRS Sandynallah a valuable resource for epidemiological research. Analysing multi-year datasets highlights emerging health patterns, age-specific risks, and temporal shifts obscured by short-term monitoring. This long-term perspective addresses a significant literature gap regarding Nilgiri sheep mortality dynamics.

The present study was therefore undertaken to systematically document and analyse the pattern of mortality in Nilgiri sheep maintained at the Sheep Breeding Research Station, Sandynallah, over a six-year period from 2020-21 to 2025-26. The primary objective is to determine overall and age-category-wise mortality rates, comparing losses between lambs and adults across the study period. Additionally, the study identifies and ranks the major causes of mortality based on clinical and post-mortem diagnoses. It further examines how demographic and environmental factors—specifically age category, sex, and season—influence cause-specific mortality. Finally, the study assesses year-wise mortality trends to identify periods of elevated loss that warrant targeted epidemiological or management interventions. These findings establish an empirical framework to strengthen health management protocols in Nilgiri sheep breeding programs.

2. Materials and Methods

The study was conducted using records of the Sheep Breeding Research Station, Sandynallah (The Nilgiris district, Tamil Nadu), a high-altitude hill station with a temperate climate for most of the year and a distinct monsoon period with heavy rain and wind. Individual animal mortality records for the period 1 April 2020 to

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31 March 2026 were used for the current study. For each animal, the animal number, date of birth, date of death, sex, age category, and cause of death were recorded. The animals were classified as Lamb (age at death < 365 days) or Adult (age at death ≥ 365 days). Season of death was assigned by calendar month as follows: Summer (March-May), South-West monsoon (June-September), North-East monsoon (October-November) and Winter (December-February).

The standing population of the flock for lamb and adult were recorded separately for each study year (1st April-31st March). Mortality rate for each study year was calculated using the following formula.

$$\text{Mortality rate (\%)} = \left(\frac{\textit{Deaths during the year}}{\textit{Average standing strength during the year}} \right) \times 100$$

where

$$\text{average standing strength} = \left(\text{opening strength} + \text{closing strength}\right)/2$$

Data were summarised as frequencies and percentages and presented as year-wise, category-wise, season-wise, sex-wise and cause-wise distributions. Descriptive statistics were computed for age at death within each category. Data analysis was carried out using SPSS version 26. Chi-square (χ^2) tests of independence were carried out using SPSS statistical software to test the association of age category with year, season of death, sex and cause of death; a *p*-value of less than 0.05 was considered statistically significant.

3. Results and Discussion

The standing population of the flock of Nilgiri sheep at SBRS, Sandynallah (2020-2026) on each year is given in Table 1. The annual mortality percentage of Nilgiri sheep for six years (2020-21 to 2025-26) is presented in Table 2. A total of 224 deaths were recorded during the study period, ranging from 14 in 2020-21 to a high of 59 in 2025-26 (Figure 1). The overall mortality rate ranged from 3.65% to 16.14%, averaging 10.04% across the six years (Figure 2), and exceeded 10% in three of the six years (2022-23, 2023-24 and 2025-26), whereas 2020-21 recorded the lowest mortality. This mortality pattern is comparable to the annual variation reported in Madras Red sheep, where mortality ranged from 3.64% to 30.56% over five years and was attributed to disease outbreak, seasonal variation, fodder availability and predator attacks (Chandrasekar *et al.,* 2023) [4].

The average mortality recorded in the present study (10.04%) falls within the range of field-level mortality reported for Indian sheep breeds lower than the 14.12% reported for Madras Red sheep (Chandrasekar *et al.,* 2023) [4]. Taneja *et al.* (1991) [5] reported an average mortality rate of 14.59% Magra sheep. In contrast, lower farm-level mortality rates have been reported for southern indigenous breeds, including 4.96% in Madras Red sheep (Soundararajan, 2014) [6] and 9.81% in Mecheri sheep (Thiruvenkadan *et al.,* 2003) [7].

During the six-year study period, mortality in lambs consistently exceeded the mortality in adults. The age-wise disparity was least pronounced in 2020-21 and most extreme in 2025-26, when lamb mortality reached 30.71% compared to an adult mortality rate of 8.98% representing an almost 3.5 fold difference. Of the 224 total recorded deaths, lambs accounted for 114 cases (50.9%) and adults for 108 cases (49.1%).

With respect to sex, 131 of the 224 deaths recorded (58.5%) were female and 93 (41.5%) were male which reflects the female-majority flock structure. Similarly, Prabhakar *et al.,* (2025) [8] reported that mortality was higher in females (60.7%) compared to males (39.3%) in Nilgiri sheep.

The mean age at death was recorded at was 95.6 ± 72.3 days for lambs and 4.19 ± 2.08 years for adults. This distribution demonstrates that lamb mortality was concentrated in the pre-weaning phase, whereas adult deaths predominantly involved animals in their prime breeding years rather than older stock. This pattern might be attributable to the systematic culling practices implemented at the farm.

The annual mortality percentage of different seasons of Nilgiri sheep were presented in Table 3. The season wise mortality was highest during summer (4.34%), followed by the south-west monsoon (3.71%), north-east monsoon (1.25%), and winter (0.83%). The summer season and South-West monsoon together represented the primary period of flock loss, accounting for 79.5% of overall mortality across the six-year study period. This observation was similar to the high seasonal mortality reported in Madras Red sheep during the same season (5.91%) (Chandrasekar *et al.,* 2023) [4]. The high mortality in Madras Red sheep during summer season on the plains was attributed to thermal stress, but in Nilgiri sheep is attributable to the overlapping of the primary lambing season and seasonal fodder shortages.

The causes of mortality in Nilgiri sheep are presented in Table 4. Toxaemia emerged as the single most common cause of death overall, accounting for 21.4% of all mortalities, and was even more pronounced among lambs, where it accounted for 28.1% of deaths. Enteritis was the second most frequent cause overall (17.9%) but was, in fact, the major cause of mortality among adults specifically, accounting for 24.1% of adult deaths. Cold shock (15.2%), weakness/debility (10.7%), and predation (6.7%) accounted for the remaining major causes of mortality.

Sivaraj *et al.* (2026) [9] reported that clostridial enterotoxaemia (*Clostridium perfringens*, principally type D) was a major cause of sudden death in young sheep and goats reared under extensive grazing systems in India, with lambs and young stock found to be more susceptible than adults. This finding was consistent with the higher proportion of toxaemia-related deaths observed among lambs in the present study. Likewise, the concentration of cold shock deaths during the summer lambing season reflects the demanding combination of a high-altitude temperate climate and the physiological vulnerability of newborn lambs, a pattern also reported in sheep reared in Kashmir (Makhdoomi *et al.*, 2010) [10].

The higher proportion of enteritis among adult mortality points toward gastrointestinal disease acquired on pasture, probably linked to parasitic burden during the monsoon season, and is broadly consistent with reports from other organised sheep farms in India, where digestive and respiratory disorders rank among the leading causes of mortality (Ekambaram *et al.,* 2015) [11]. The substantial combined contribution of the summer and south-west monsoon periods to overall mortality also matches earlier findings on Nilgiri and Sandyno lambs at the same station, where environmental and seasonal factors were identified as key determinants of pre-weaning growth and survival (Anilkumar *et al.,* 2011) [12].

To evaluate whether age category was independently associated with study year, season, sex, and cause of death, Chi-square (χ^2) tests of independence were carried out (Table 5). the test confirmed that age category was significantly associated with study year ($\chi^2 = 25.533$, df = 10, $p = 0.004$) and with season of death ($\chi^2 = 17.513$, df = 6, $p = 0.008$), consistent with the marked clustering of lamb deaths in summer ($n = 56$) and the south-west monsoon ($n = 43$) described above, while adult deaths were comparatively more evenly spread across seasons, with a relatively higher share occurring in winter. Sex was also significantly associated with age category ($\chi^2 = 17.965$, df = 2, $p < 0.001$), consistent with the disproportionate share of mortality in male noted earlier despite their smaller representation in the flock. The strongest association was between cause of death and age category ($\chi^2 = 259.884$, df = 36, $p < 0.001$), statistically confirming the distinct lamb- and adult-specific cause-of-death profiles reported above — toxaemia and cold shock predominating in lambs, and enteritis and predation predominating in adults.

The observed mortality pattern reflects the interaction between high-altitude microclimatic conditions, farm management protocols, and disease challenges at the farm. Mitigating high lamb mortality requires targeted management strategies during the lambing season. Priority should be given to dedicated care for vulnerable lambs, optimised plane of nutrition for pregnant and lactating ewes, and strict adherence to strategic deworming and prophylactic vaccination schedules. In adult stock, overall losses can be reduced through the systematic culling of aged or chronically diseased animals, combined with perimeter fence fortification and enhanced herding oversight to prevent predation.

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Table 1. Standing population strength of Nilgiri sheep at SBRS, Sandynallah (2020-2026)

Year	Lamb	Adult	Total
31.03.2020	109	236	345
31.03.2021	164	258	422
31.03.2022	142	279	421
31.03.2023	90	233	323
31.03.2024	134	203	337
31.03.2025	119	295	414
31.03.2026	122	195	317

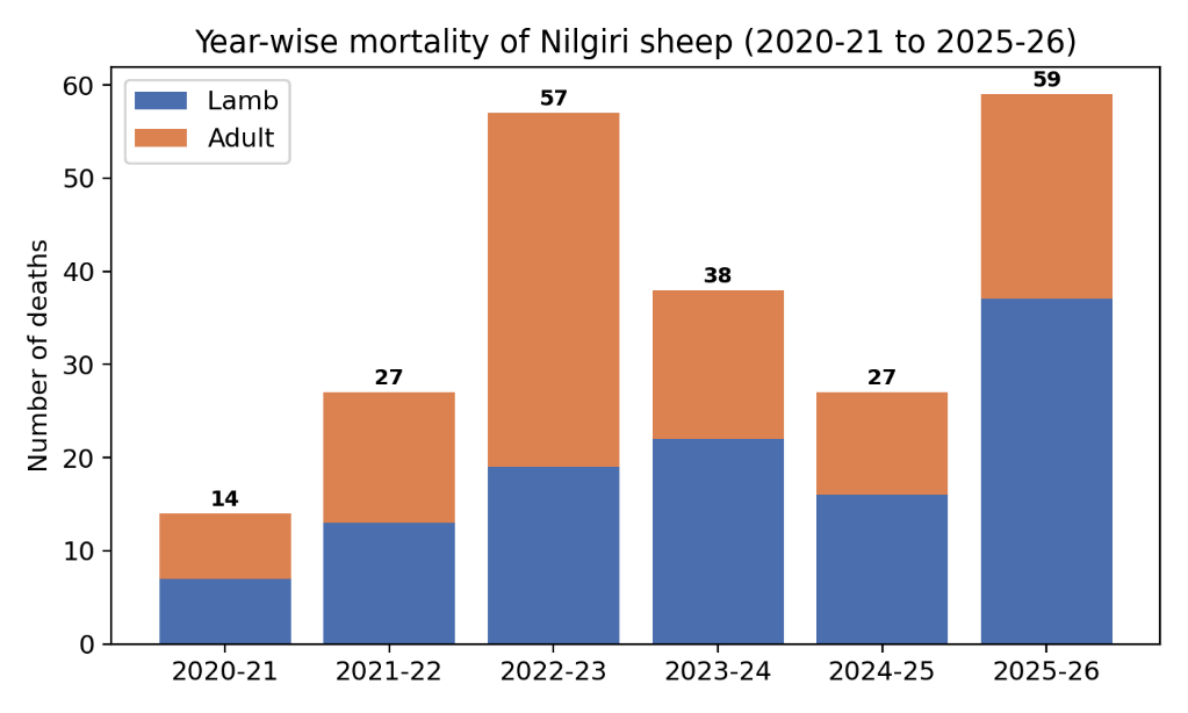


Figure 1. Year-wise mortality of Nilgiri sheep (2020-21 to 2025-26)

Table 2. Annual mortality percentage of Nilgiri sheep, by age category

Year	Total No. of Sheep at Risk	Lamb Mortality (%)	Adult Mortality (%)	Overall Mortality (%)
2020-21	384	5.13	2.83	3.65
2021-22	422	8.50	5.21	6.41
2022-23	372	16.38	14.84	15.32
2023-24	330	19.64	7.34	11.52
2024-25	376	12.65	4.42	7.19
2025-26	366	30.71	8.98	16.14
2020-21 to 2025-26	375	15.50	7.27	10.04

Table 3. Annual mortality percentage of different seasons of Nilgiri Sheep

Year	Total No. of Sheep at risk	Mortality percentage (%)			
		Winter	Spring	SW Monsoon	NE Monsoon
2020-21	384	0.00	1.56	1.83	0.26
2021-22	422	0.24	2.61	1.90	1.66
2022-23	372	1.08	4.84	8.06	1.34
2023-24	330	1.21	7.58	1.21	1.52
2024-25	376	0.53	3.73	2.40	1.07
2025-26	366	1.92	5.75	6.84	1.64
2020-21 to 2025-26	375	0.83	4.34	3.71	1.25

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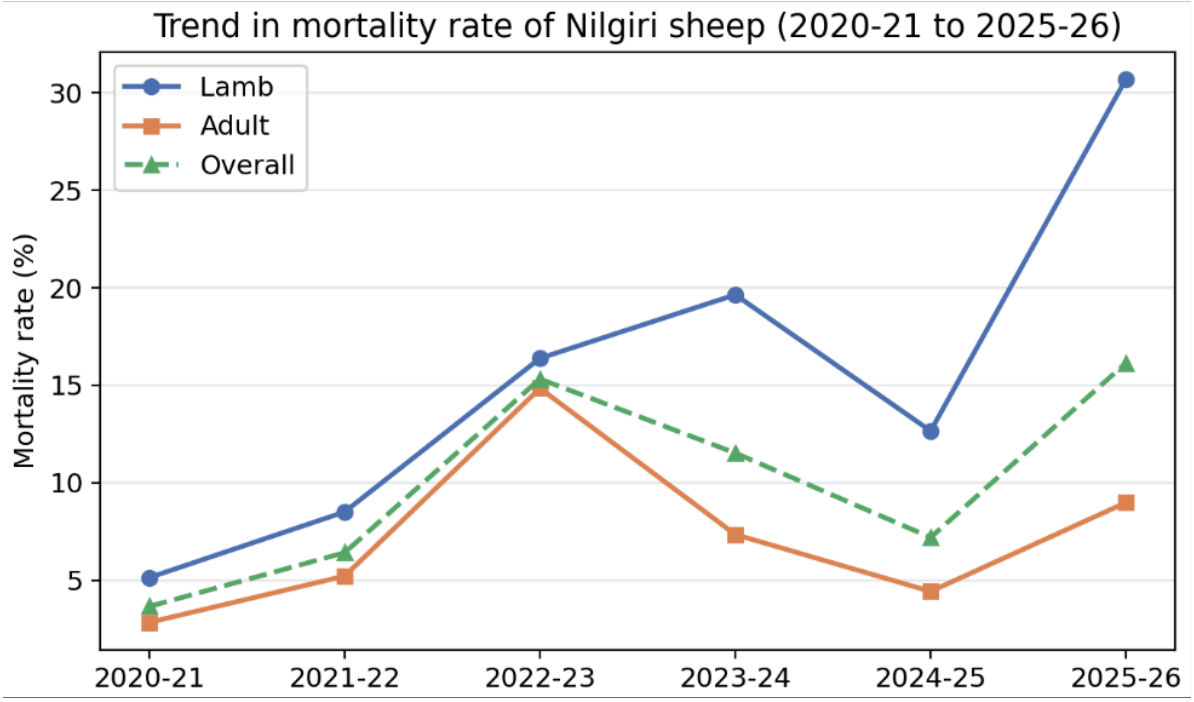


Figure 2. Trend in mortality rate (%) of Nilgiri sheep, 2020-21 to 2025-26

Table 4. Cause-wise mortality of Nilgiri sheep: overall, lamb and adult (2020-21 to 2025-26)

Cause of Mortality	Overall		Adult		Lamb	
	Number of deaths	Percentage	Number of deaths	Percentage	Number of deaths	Percentage
Toxaemia	48	21.4	16	14.8	32	28.1
Enteritis	40	17.9	26	24.1	14	12.3
Cold shock	34	15.2	18	16.7	16	14.0
Weakness / Debility	24	10.7	10	9.3	14	12.3
Predation	15	6.7	14	13.0	1	0.9
Septicaemia	11	4.9	5	4.6	6	5.3
Parasitic infestation	11	4.9	5	4.6	6	5.3
Bloat / Tympany	9	4.0	3	2.8	6	5.3
RespiratoryDiseases	6	2.7	2	1.9	4	3.5
Others	26	11.6	9	8.3	15	13.2
Total	224	100	108	100	114	100

Table 5. Chi-square (χ^2) test of independence for factors associated with mortality in Nilgiri sheep

Variable Comparison	N	Pearson χ^2	df	*p*-value	Significance
Year x Age Category	224	25.533	10	0.004	$p < 0.01$
Season of Death x Age Category	224	17.513	6	0.008	$p < 0.01$
Sex x Age Category	224	17.965	2	< 0.001	$p < 0.001$
Cause of Death x Age Category	224	259.884	36	< 0.001	$p < 0.001$

4. Conclusion

From this study it can be concluded that lambs showed markedly higher mortality than adults, and that mortality was concentrated in the summer season followed by south-west monsoon, with toxaemia, enteritis and cold shock as the leading causes of death. Proper care and management of ewes and lambs during the March-May lambing window, timely clostridial vaccination, and closer supervision of grazing during the monsoon can substantially reduce mortality in the Nilgiri sheep flock at Sandynallah and support the conservation of this breed.

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