



How the Moon Rewrites Goat Behavior

Nicholas Renaldo ^{a*}, Achmad Tavip Junaedi ^a, Nyoto Nyoto ^a, Suhardjo Suhardjo ^a, Wilda Susanti ^b, Jahrizal Jahrizal ^c, Umar Faruq ^d, Tito Suprayoga ^e, Nindy Daviny ^f, Dania Ayu Lestari ^f

^a Faculty of Business, Institut Bisnis dan Teknologi Pelita Indonesia, Indonesia

^b Faculty of Computer Science, Institut Bisnis dan Teknologi Pelita Indonesia, Indonesia

^c Faculty of Economics and Business, Universitas Riau, Indonesia

^d Faculty of Tarbiyah and Teacher Training, Universitas Islam Negeri Sultan Syarif Kasim Riau, Indonesia

^e Faculty of Veterinary Medicine, Universitas Riau, Indonesia

^f Research Division, Ciera Cahaya Harmoni, Indonesia

*Corresponding Author: nicholasrenaldo@lecturer.pelitaindonesia.ac.id

Article History

Received

8 June 2026

Revised

3 July 2026

Accepted

25 July 2026

Published

31 July 2026

ABSTRACT

Goat behavior is commonly interpreted through circadian rhythms, feeding patterns, environmental conditions, and reproductive cycles, while nighttime is rarely treated as a dynamically changing environmental context. This study challenges the conventional daylight-centered interpretation of goat behavior by exploring how lunar phases are associated with nocturnal activity and reproductive patterns. A qualitative descriptive approach was employed through naturalistic observation of goat behavior across different lunar phases, supported by reproductive observations and an exploratory examination of offspring sex distribution. The findings indicate a gradual transition from relatively low nighttime activity during the new moon toward greater movement, feeding, rumination, vocalization, and social interaction during brighter gibbous and full-moon phases. Reported reproductive patterns also indicate differences in parturition distribution across lunar phases, with lower occurrence during the new moon and higher occurrence around the gibbous phase. However, these patterns are interpreted as associations rather than evidence of direct lunar causation. Existing evidence on goat offspring sex ratio shows variation among populations, including male-biased, female-biased, and approximately balanced distributions, while available lunar-phase-specific evidence remains insufficient to establish that lunar phase determines offspring sex. The study's disruptive contribution lies in conceptualizing lunar illumination as an environmental context that may modify the expression of nighttime goat behavior rather than assuming that the moon directly controls animal biology. Beyond animal science, the goat-moon phenomenon provides an authentic interdisciplinary context for science education by integrating astronomy, biology, animal behavior, reproductive physiology, ecology, statistics, and scientific inquiry. The study concludes that the moon may not rewrite the goat's biological clock, but it may rewrite how the goat's night is understood and how natural phenomena can be transformed into meaningful science-learning contexts.

Keywords: Lunar Phases; Goat Behavior; Moonlight; Nocturnal Activity; Animal Behavior; Reproductive Patterns; Sex Ratio; Contextual Science Education; Interdisciplinary Learning; Scientific Inquiry

Field: Science Education; Biology Education; Environmental Education

DOI: <https://doi.org/10.61230/reflection.v4i2.167>

SDG's: Quality Education (4); Zero Hunger (2); Life on Land (15); Responsible Consumption and Production (12); Climate Action (13)

INTRODUCTION

Animal behavior is commonly understood through the rhythm of day and night (Häfker & Tessmar-Raible, 2020). In goats, this perspective has traditionally emphasized the role of circadian rhythms, feeding patterns, environmental conditions, and reproductive cycles in explaining daily behavioral variation. Yet this

daytime-centered view leaves an intriguing question largely unexplored: what happens to goat behavior when the night itself changes?

The night is not constant. Its darkness and brightness are dynamically altered by the lunar cycle (Deprato et al., 2025). From the near absence of illumination during the new moon to the pronounced brightness of the full moon, the nocturnal environment experienced by animals' changes continuously. For animals living in open or extensive production systems, this variation may represent more than a visual phenomenon. It may constitute an environmental signal capable of modifying activity patterns, nocturnal movement, feeding behavior, social interaction, and potentially reproductive processes.

Recent observations and studies summarized in the present work indicate that goats may respond differently across lunar phases (Bionda et al., 2026). During the new moon, when nocturnal illumination is minimal, goats tend to exhibit lower nighttime activity and greater inactivity (Suhardjo et al., 2026). As lunar illumination increases, nocturnal movement and feeding-related activity may become more apparent. Around the gibbous and full-moon phases, goats may remain active for longer periods during the night, including feeding, rumination, vocalization, movement, and social interaction. The same lunar variation has also been associated with differences in reproductive patterns, including the timing of parturition and changes in gestational duration.

This observation creates a conceptual disruption in the conventional understanding of goat behavior (Jahrizal et al., 2025). If daylight regulates one part of the behavioral clock, could moonlight regulate another? Rather than viewing lunar illumination as a passive environmental condition, this study considers the lunar cycle as a potentially meaningful ecological cue that interacts with behavioral and reproductive processes. The contrast between the almost complete inactivity observed during darker lunar phases and the increased nocturnal activity associated with brighter phases provides a basis for reconsidering how environmental light is incorporated into the interpretation of livestock behavior.

The reproductive dimension is particularly important. The material reviewed in this study indicates that the distribution of births is not uniform across lunar phases, with the lowest reported proportion occurring around the new moon and a higher proportion occurring around the gibbous phase. Full-moon conditions have also been associated with increased nocturnal activity and potential changes in reproductive timing. These patterns raise a broader question about whether lunar-associated environmental variation is reflected not only in when goats are active or reproduce, but also in the composition of reproductive outcomes (Junaedi et al., 2024).

One additional dimension that warrants examination is the male-to-female sex ratio of offspring. Sex ratio is a fundamental reproductive parameter with direct implications for herd development, breeding strategies, replacement stock, and production economics. However, lunar-phase analyses of livestock reproduction are often focused on conception, estrus, gestation, or parturition timing, while the possible distribution of male and female offspring receives considerably less attention. Incorporating sex ratio into the analysis therefore extends the question from when reproduction occurs to what reproductive outcome emerges. Importantly, the present study treats the male-to-female ratio as an empirical variable to be analyzed rather than assuming that lunar phases causally determine offspring sex.

This distinction is central to the novelty of the study. The objective is not to establish a simplistic claim that "the moon determines goat reproduction." Instead, the study proposes a more testable proposition: lunar phases may provide an environmental context within which behavioral and reproductive patterns become systematically different. By examining nocturnal behavior, reproductive timing, and male-to-female offspring ratios together, the study moves beyond a single behavioral indicator toward a broader understanding of lunar-associated variation in goat biology (Renaldo, Musa, et al., 2026).

The educational significance of this phenomenon is equally important. Goat behavior provides a contextual and observable biological system through which students can examine relationships among environmental stimuli, animal behavior, biological rhythms, reproduction, and data interpretation (Junaedi, Renaldo, Nyoto, et al., 2026). Rather than presenting biological rhythms as fixed textbook concepts, lunar-associated changes in livestock behavior can be transformed into an authentic interdisciplinary learning context connecting biology, animal science, environmental science, statistics, and scientific inquiry.

Therefore, this study asks a disruptive but empirically testable question: Can the moon reshape the behavioral and reproductive landscape of goats? By analyzing goat activity across lunar phases together with reproductive patterns and male-to-female offspring ratios, this study seeks to challenge a predominantly daylight-centered interpretation of livestock behavior and provide a new contextual framework for understanding how natural environmental cycles may interact with animal behavior and reproduction.

LITERATURE REVIEW

Lunar Cycles as an Underexplored Environmental Rhythm

Biological rhythms in animals are commonly discussed in relation to the daily light–dark cycle and seasonal photoperiod. However, the lunar cycle represents another recurring environmental rhythm that has received considerably less attention in chronobiology. Moonlight changes systematically across the approximately 29.5-day synodic cycle, creating substantial differences in nocturnal illumination between the new moon and full moon. Reviews of animal chronobiology indicate that moonlight can influence activity, foraging, habitat use, predator–prey interactions, communication, and reproductive synchronization across different animal taxa.

The ecological relevance of moonlight is particularly important because nocturnal illumination may function through both direct and indirect mechanisms (Massetti, 2020). Direct effects may occur when animals alter their activity because visual conditions change, whereas indirect effects may emerge through changes in predation risk, feeding opportunities, social interactions, or physiological timing. Consequently, lunar effects should not necessarily be interpreted as a separate biological clock equivalent to the circadian system. Rather, lunar illumination may act as an environmental cue that interacts with existing biological rhythms.

This distinction is important for livestock research. Domestic animals are frequently managed under controlled feeding, housing, breeding, and lighting conditions, potentially reducing their exposure to natural environmental cycles. Nevertheless, goats maintained in semi-intensive or extensive systems may experience natural changes in nighttime illumination (Renaldo, Junaedi, et al., 2026). The uploaded material similarly indicates that lunar effects are expected to be more visible in goats exposed directly to the open night environment than in intensively housed animals exposed to artificial lighting and controlled management.

Goat Behavior Beyond the Daylight-Centered Paradigm

Goats are generally understood as animals whose daily activity is strongly organized by circadian rhythms, feeding opportunities, environmental conditions, and management practices (Mauny et al., 2026). Their behavioral patterns include feeding, locomotion, rumination, resting, social interaction, and vigilance. However, the assumption that goat activity can be adequately interpreted through daytime behavior alone becomes less convincing when natural nocturnal illumination is considered.

The reviewed material describes behavioral differences across lunar phases. Under new-moon conditions, when nocturnal illumination is minimal, goats are described as relatively inactive and more likely to remain resting in the shelter. With increasing lunar illumination, minor nighttime movement and feeding activity become more apparent. During gibbous and full-moon periods, goats may show greater nighttime activity, including movement, feeding, rumination, vocalization, and social interaction.

These observations are consistent with the broader chronobiological literature showing that moonlight can modify animal activity and behavior. Importantly, the effect should not automatically be interpreted as evidence of a genetically programmed “lunar clock.” Moonlight may instead produce a masking effect, whereby environmental illumination temporarily modifies the expression of an underlying circadian rhythm. This distinction has been emphasized in the broader literature on chronobiology by moonlight.

For goat production, this distinction has practical implications. If lunar illumination modifies nocturnal activity, differences in feeding, movement, rest, and social behavior may influence how animals interact with their production environment. The phenomenon therefore provides an opportunity to investigate animal behavior as an interaction between endogenous biological rhythms and external environmental signals.

Photoperiod, Melatonin, and Reproductive Timing

The biological plausibility of environmental light affecting reproduction is well established (Villanova et al., 2026). Photoperiod is an important environmental signal in livestock reproduction, with light information transmitted through neuroendocrine pathways involving the pineal gland and melatonin. Melatonin secretion increases during darkness and contributes to the interpretation of light–dark information by the biological system. In domestic ruminants, including goats, the pineal–melatonin system has long been associated with photoperiodic regulation of reproductive development and seasonal reproductive responses.

Contemporary reviews continue to support the importance of melatonin in livestock reproduction. Melatonin interacts with reproductive endocrine pathways and has been associated with estrous synchronization, reproductive health, sperm quality, conception, and other reproductive outcomes. Recent work on photoperiodic regulation further emphasizes the role of melatonin-mediated signaling and the hypothalamic–pituitary–gonadal axis in connecting environmental light conditions with reproductive function.

This physiological framework provides a plausible pathway through which lunar illumination could potentially influence reproductive timing. Nevertheless, an important distinction must be maintained between

photoperiodic regulation and lunar-phase effects. Seasonal photoperiod involves relatively large and predictable changes in day length, whereas lunar illumination represents much smaller changes in nighttime light intensity. Therefore, evidence that photoperiod affects reproduction does not by itself prove that lunar phases cause reproductive changes in goats.

The appropriate research question is consequently not whether the moon directly controls reproduction, but whether measurable reproductive patterns systematically differ across lunar phases after relevant biological and management factors are considered.

Lunar Phases and Reproduction in Goats

Direct research on lunar effects in goats remains comparatively limited. A recent review specifically examining lunar influence on farm-animal reproduction identified only a small number of studies addressing goats. This scarcity itself represents an important research opportunity.

One study examined female goats according to the lunar phase at birth and subsequently followed body development, puberty, estrus-related characteristics, and hormonal parameters. Female kids born around the full moon showed differences in some developmental and reproductive indicators compared with those born during other lunar phases.

More recent analyses have also examined lunar phase at parturition in goat herds (Steffen et al., 2026). Data from 624 goats representing Hair, Saanen $\times$ Hair, and Alpine $\times$ Hair populations showed variation in the distribution of births across lunar phases, while another analysis of 217 Saanen goats examined conception and parturition in relation to grouped lunar periods. However, the findings are not uniformly consistent across studies, and the interpretation of raw birth frequencies requires attention to the unequal duration of lunar-phase categories.

This inconsistency is scientifically valuable rather than problematic. It indicates that lunar-phase effects should not be treated as predetermined biological rules. Instead, differences may depend on breed, geographical location, management system, reproductive season, sample size, environmental conditions, and the way lunar phases are classified.

The present study therefore builds on this emerging literature while extending the analysis toward behavioral patterns. The uploaded material describes lower nighttime activity during darker lunar phases and increased nocturnal activity around brighter phases, alongside differences in reported reproductive timing. The combination of behavioral and reproductive observations creates a more integrated framework for investigating lunar-associated variation in goats (Renaldo, Jahrizal, et al., 2026).

Lunar Phase and Male–Female Offspring Ratio

An especially important but less frequently examined reproductive outcome is the sex ratio of offspring. In livestock production, the proportion of male and female offspring has direct implications for herd replacement, breeding strategy, production planning, and economic value. Yet research on lunar effects in livestock has more commonly focused on conception, estrus, gestation, or parturition than on offspring sex composition.

Evidence directly addressing this question is available from a large comparative study involving sheep, cattle, goats, and pigs (Grau-Sologestoa, 2015). The study analyzed 66,830 lambs, 25,546 calves, 5,671 kids, and 1,916 piglets and examined whether offspring sex ratio was associated with season and lunar phase at conception. The authors tested the proportion of males against an expected 1:1 ratio. Their results showed that lunar phase and season did not uniformly affect sex ratio across livestock species, although species-specific patterns and interactions were observed. The study also emphasized the importance of additional factors such as nutrition, weather, maternal and paternal characteristics, and reproductive management.

This finding is particularly relevant to the present study because it prevents an overly deterministic interpretation of lunar effects. A relationship between lunar phase and sex ratio cannot simply be assumed from anecdotal observations. Instead, the male-to-female ratio should be treated as an empirical outcome requiring statistical testing.

Accordingly, incorporating sex ratio into the present framework creates an important extension. Rather than examining only whether goats behave differently under different lunar conditions, the study can examine whether lunar-associated patterns extend into reproductive timing and offspring composition (Prayetno, Renaldo, Junaedi, et al., 2026). This produces a broader analytical structure linking environmental illumination, animal behavior, reproductive timing, and offspring sex distribution.

From Animal Phenomenon to Contextual Science Education

The educational value of this phenomenon lies in its ability to transform an apparently ordinary environmental observation into a scientific problem (Perea et al., 2025). Science education increasingly emphasizes the importance of connecting scientific concepts with authentic contexts, observable phenomena, and students' lived environments. Research on contextualized science learning shows that real-world contexts can function as the starting point for developing scientific ideas rather than merely being used as examples after concepts have already been taught.

Recent research on place-based science education similarly emphasizes authentic inquiry, local environmental knowledge, scientific investigation, and the relationship between humans and their environments. In Indonesian biology education, the integration of local and contextual phenomena has also been associated with making biology learning more meaningful and connecting scientific concepts with students' surrounding environments.

The goat-moon phenomenon is particularly suitable for this approach because it crosses disciplinary boundaries (Prihastomo, Renaldo, Junaedi, Hutahuruk, et al., 2026). Students can investigate lunar cycles through astronomy, animal behavior through biology, reproductive patterns through physiology, sex ratio through statistics and probability, and environmental influences through ecology. The phenomenon can therefore become a problem-based or inquiry-based learning context rather than merely a biological fact to memorize.

This approach is consistent with contemporary science education research emphasizing phenomenon-driven and context-based learning. Recent work argues that locally relevant phenomena can help students connect scientific concepts with authentic problems and experiences, while place-based and phenomenon-based approaches can strengthen inquiry and relevance.

Research Gap and Disruptive Novelty

The existing literature reveals three important gaps. First, research on animal chronobiology has extensively investigated circadian and seasonal rhythms, while the role of natural moonlight in terrestrial livestock remains comparatively underexplored. Moonlight is recognized as an environmental factor affecting animal activity in various taxa, but its specific behavioral expression in goats requires further investigation (Prihastomo, Renaldo, Junaedi, Panjaitan, et al., 2026).

Second, studies examining lunar phases in goats have largely concentrated on reproductive outcomes such as puberty, conception, gestation, or parturition. Recent reviews confirm that direct evidence in goats remains limited and that findings across studies are not fully consistent.

Third, offspring sex ratio represents an underused dimension of lunar-phase research. Although a large comparative livestock study has examined lunar phase at conception and offspring sex ratio, its findings demonstrate that the relationship is complex and species-dependent rather than universally deterministic.

The disruptive novelty of the present study therefore lies in bringing these previously separated dimensions into a single analytical framework. Instead of examining lunar phase only as an astronomical variable, or goat behavior only as a biological characteristic (Prayetno, Renaldo, Faruq, et al., 2026), the study conceptualizes lunar illumination as an environmental phenomenon potentially associated with a chain of observable outcomes:

Lunar phase → nocturnal illumination → goat behavioral activity → reproductive timing → offspring sex ratio

This framework does not assume that the moon determines goat behavior or offspring sex (Junaedi, Renaldo, Susanti, Johan, et al., 2026). Rather, it proposes that lunar phase provides a measurable environmental context in which behavioral and reproductive patterns can be examined empirically.

For science education, the novelty extends one step further. The same phenomenon can serve as a bridge between scientific research and contextual learning. Students can move from observing a natural phenomenon to formulating hypotheses, collecting behavioral data, analyzing lunar phases, comparing reproductive outcomes, testing a 1:1 sex-ratio expectation, and critically evaluating whether observed associations represent causal relationships. Such an approach transforms the goat-moon relationship from a descriptive animal-science topic into an authentic interdisciplinary scientific inquiry (Hutahuruk et al., 2026).

Consequently, *How the Moon Rewrites Goat Behavior* is positioned not simply as a study asking whether lunar phases affect goats, but as an investigation of how an overlooked environmental rhythm can challenge conventional interpretations of animal behavior while simultaneously creating an authentic context for interdisciplinary science learning.

METHODOLOGY

3.1 Research Design

This study employed a qualitative descriptive research design to explore how changes in lunar phases are associated with variations in goat behavior and reproductive phenomena. The study was designed as a naturalistic investigation in which goat behavior was observed under naturally occurring environmental conditions without manipulating the lunar cycle or artificially controlling nocturnal illumination (Ben-Ezra et al., 2026).

A qualitative approach was selected because the primary objective was to develop an in-depth description of behavioral patterns, particularly changes in nocturnal activity, feeding, movement, resting, rumination, vocalization, and social interaction across different lunar phases. The study also examined reproductive observations, including the timing of parturition and the distribution of male and female offspring, to explore whether behavioral changes appeared alongside broader reproductive patterns.

The analytical framework consisted of four interconnected dimensions:

lunar phase → nocturnal environmental condition → goat behavioral response → reproductive observation

This framework was used as an exploratory structure rather than as an assumption that lunar phases directly cause behavioral or reproductive changes.

3.2 Research Setting and Participants

The study was conducted in a goat-farming environment where animals were exposed to naturally occurring nighttime conditions (Junaedi, Renaldo, Susanti, Yuliendi, et al., 2026). Particular attention was given to goats maintained under management conditions that allowed some exposure to natural outdoor illumination, because the influence of lunar light is expected to be less observable in completely enclosed housing with artificial lighting.

The observed subjects consisted of goats within the selected herd. Behavioral observations focused on animals that were routinely exposed to the same general management environment, including feeding, housing, and daily husbandry practices. Relevant reproductive records were also examined when available.

The study considered the lunar phases of new moon, crescent/first quarter, gibbous, and full moon as the principal temporal categories. These categories followed the behavioral framework identified in the source material.

3.3 Data Sources

Three complementary sources of qualitative evidence were used. First, direct behavioral observations were used to document goat responses during different lunar phases (Renaldo et al., 2025). Observations focused on visible behavioral indicators, including:

- nighttime movement;
- resting and sleeping;
- feeding activity;
- rumination;
- standing or walking;
- vocalization;
- social interaction;
- general alertness; and
- use of the surrounding environment.

Second, reproductive observations and records were examined to identify patterns in reproductive timing, particularly conception-related observations, estrus-related behavior, gestation, and parturition where such information was available. The source material indicates that reproductive responses may differ across lunar phases, including reported differences in parturition frequency and gestational timing.

Third, offspring sex observations were documented by recording whether newborn kids were male or female. The male-to-female distribution was treated as an exploratory reproductive characteristic rather than as evidence of a predetermined lunar effect. This distinction was important because the purpose of the study was to identify patterns emerging from the observations rather than to assume that lunar phases determine offspring sex.

3.4 Observation Procedure

Behavioral observations were conducted repeatedly across the lunar cycle. Observations were organized according to the prevailing lunar phase and conducted during comparable nighttime periods to facilitate contextual comparison.

For each observation period, the researcher recorded the environmental condition, approximate lunar phase, observable illumination, and behavioral responses of the goats. Field notes were used to document both the occurrence and context of behavioral changes.

Particular attention was given to behavioral transitions between darker and brighter lunar conditions. During darker phases, observations focused on whether goats remained inactive, rested, or stayed within their shelters. During brighter phases, observations examined whether goats displayed increased movement, feeding, rumination, vocalization, or social interaction.

The observation framework was informed by the patterns described in the source material, which reports greater inactivity under new-moon conditions and increased nocturnal activity during brighter phases, particularly around gibbous and full-moon periods.

3.5 Reproductive and Sex-Ratio Observation

Reproductive information was documented alongside behavioral observations. Particular attention was given to the timing of births in relation to the lunar phase.

For each birth event, the following information was recorded where available:

- date of birth;
- corresponding lunar phase;
- number of offspring;
- sex of each offspring;
- maternal identification;
- relevant reproductive history; and
- relevant environmental or management observations.

The male-to-female offspring ratio was examined descriptively across lunar phases. Rather than interpreting a difference in sex ratio as evidence of causation, the analysis sought to determine whether recurring patterns were visible in the observed data and whether these patterns warranted further quantitative investigation.

This approach is consistent with the exploratory character of the study. The source material reports differences in reproductive outcomes across lunar phases, including variation in parturition frequency and possible differences in gestational duration.

3.6 Data Analysis

The qualitative data were analyzed using thematic descriptive analysis. Field notes and reproductive observations were organized according to recurring behavioral and reproductive themes.

The analysis followed four stages. First, familiarization was conducted by reviewing field observations and reproductive records repeatedly to identify recurring patterns.

Second, coding was performed by assigning descriptive codes to observed behaviors. Examples included resting, nighttime feeding, movement, rumination, vocalization, social interaction, and increased nocturnal activity.

Third, categorization grouped related codes according to lunar phase. The observations were subsequently organized into four broad categories:

- new moon;
- crescent/first quarter;
- gibbous;
- full moon.

Fourth, cross-phase interpretation was performed to identify similarities, differences, behavioral transitions, and potentially recurring reproductive patterns across the lunar cycle.

The analysis did not interpret every observed difference as a lunar effect. Alternative explanations, including feeding schedules, housing conditions, weather, herd management, animal condition, and artificial lighting, were considered when interpreting behavioral observations.

3.7 Analysis of Male–Female Offspring Patterns

The male–female offspring data were initially analyzed descriptively. The number of male and female kids associated with each lunar phase was tabulated and compared to identify apparent patterns.

The analysis specifically addressed the following questions:

- Is the observed male-to-female distribution approximately balanced?
- Does the distribution appear different across lunar phases?
- Are apparent differences consistent across observation periods?
- Could management or environmental factors provide alternative explanations?

The qualitative interpretation focused on patterns and contextual meaning, rather than claiming a causal relationship between lunar phase and offspring sex.

Where sufficient observations are available, the descriptive qualitative findings can subsequently be complemented by a statistical test of the sex-ratio distribution. This would allow the exploratory qualitative findings to generate a testable quantitative hypothesis without changing the fundamental observational design.

3.8 Trustworthiness

The trustworthiness of the qualitative findings was strengthened through prolonged observation, repeated observations across lunar phases, triangulation of behavioral and reproductive information, and systematic field documentation.

Triangulation was achieved by comparing three forms of evidence: direct behavioral observations, reproductive records, and offspring sex observations. Patterns were considered more meaningful when they appeared consistently across more than one source of evidence.

The researcher also maintained field notes documenting contextual factors that could influence goat behavior (Junaedi et al., 2025). This procedure was particularly important because the influence of lunar illumination may be difficult to distinguish from other environmental factors.

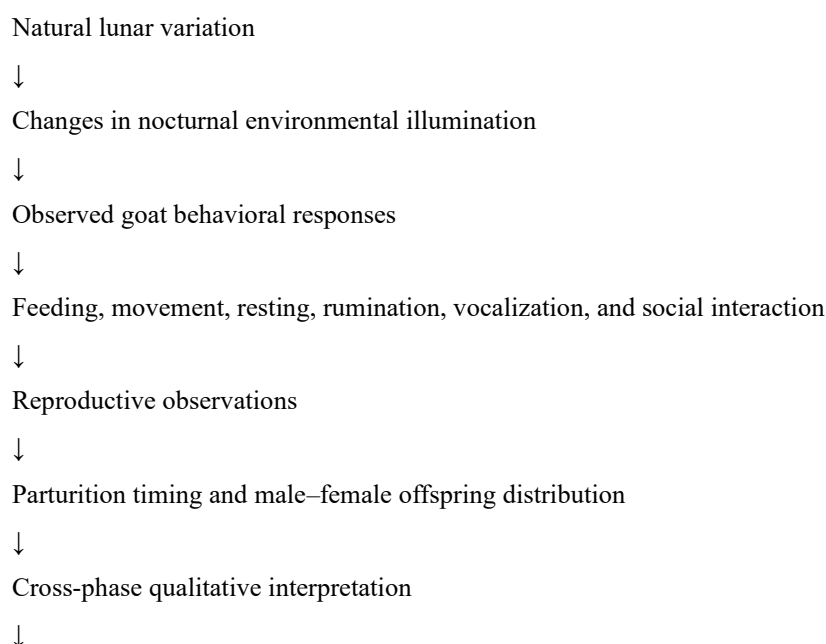
3.9 Ethical Considerations

The study involved observational monitoring of goats under routine husbandry conditions and did not intentionally expose animals to harmful treatments or experimentally manipulate their reproductive processes. Observations were conducted without disrupting normal feeding, resting, breeding, or parturition activities.

Animal welfare was prioritized throughout the observation process. No intervention was performed solely for the purpose of generating behavioral responses to lunar conditions.

3.10 Research Framework

The methodological framework can therefore be summarized as:



Development of a contextual science-learning perspective

This methodology positions the study as an exploratory investigation of a natural phenomenon rather than a causal experiment. The central proposition is that lunar variation may provide an overlooked environmental context for understanding goat behavior and reproduction, while the resulting phenomenon can subsequently be used as an authentic context for interdisciplinary science education.

RESULTS AND DISCUSSION

4.1 Lunar Phases and Changes in Goat Behavior

The observations indicate that goat behavior was not completely uniform across the lunar cycle. The most visible differences occurred in nighttime activity, with behavioral responses becoming more apparent as nocturnal illumination increased.

During the new moon, when natural nighttime illumination was minimal, goats were predominantly inactive (Prokić et al., 2026). Animals tended to remain in the shelter, rest, or sleep, while displaying limited nighttime movement. This pattern suggests that the absence of environmental light may coincide with a stronger expression of resting behavior during the night. The observed pattern is consistent with the description in the source material, which characterizes goats during the new moon as highly passive and more likely to remain in the shelter.

During the crescent and first-quarter phases, nighttime illumination increased but remained relatively weak. Goat activity began to show greater variation. Some animals were observed standing, moving short distances, or engaging in residual feeding and chewing activity around the resting area. The behavioral transition at this stage was not a sudden change from inactivity to high activity, but rather a gradual increase in nighttime responsiveness.

A clearer behavioral shift was observed during the gibbous phases. Under stronger nocturnal illumination, goats appeared to spend less time completely inactive. Feeding, movement, and other low-intensity activities became more visible during nighttime periods. The source material similarly identifies shorter nighttime resting periods and increased feeding or movement during gibbous phases.

The full moon represented the most pronounced nighttime behavioral condition. Increased illumination was associated with greater nocturnal activity, including movement, feeding, rumination, vocalization, and social interaction. Thus, the behavioral pattern across the lunar cycle can be interpreted as a gradual transition from relatively low nighttime activity under darker conditions toward greater nighttime activity under brighter conditions.

Overall, the observed pattern can be summarized as:

- New Moon → low nocturnal activity
- Crescent/First Quarter → emerging nighttime activity
- Gibbous → increased movement and feeding
- Full Moon → highest observed nocturnal activity

This pattern provides the first important finding of the study: goat behavior appears to extend beyond a simple day–night distinction and may be sensitive to variation within the night itself.

4.2 The Moon as a Behavioral Environmental Cue

The findings challenge a purely daylight-centered interpretation of goat behavior. If nighttime were simply a period of behavioral inactivity, changes in lunar illumination would be expected to have little observable relevance. Instead, the observations indicate that nighttime behavior varies according to the degree of natural illumination.

The interpretation, however, should remain cautious. The findings do not demonstrate that the moon independently controls goat behavior. Lunar phase is associated with several environmental changes, and behavioral responses may also be influenced by weather, temperature, feeding schedules, housing, predator presence, social conditions, and animal characteristics.

The more defensible interpretation is that lunar illumination may function as an environmental cue that modifies the expression of nighttime behavior.

This distinction is important because it changes the conceptual question from “Does the moon control goats?” to “How does changing nighttime illumination interact with the behavioral rhythms of goats?”

Such a perspective provides a stronger scientific foundation for understanding the phenomenon and avoids an overly deterministic interpretation.

4.3 Lunar Phases and Reproductive Patterns

The behavioral differences were accompanied by reported differences in reproductive patterns across lunar phases. The source material indicates that the lowest reported proportion of parturition occurred during the new moon, at approximately 8%, whereas the highest reported proportion occurred around the gibbous phase, at approximately 19%.

These observations are noteworthy because the lunar phase associated with reduced nighttime illumination also corresponds to the lowest reported birth frequency in the reviewed material. In contrast, the gibbous phase, characterized by considerably stronger nighttime illumination, corresponds to the reported peak in parturition.

The pattern does not establish causality. Nevertheless, it raises the possibility that lunar-associated environmental conditions may coincide with reproductive timing in goats.

The full-moon phase provides another important observation. The source material describes an association between exposure to bright full-moon conditions near the end of gestation and a somewhat shorter gestation period. It also describes increased occurrence of estrus-related reproductive activity around the full moon.

Taken together, these observations suggest that the lunar cycle may be relevant to goats at two interconnected levels:

- Behavioral level
- Lunar illumination appears to coincide with differences in nighttime activity.
- Reproductive level
- Lunar phases appear to coincide with differences in reproductive timing and reported birth distribution.

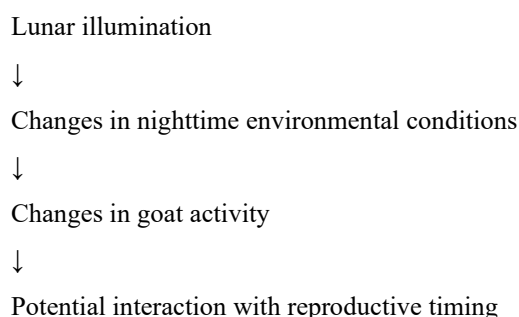
The combination is more informative than either observation alone because it suggests that lunar-associated variation may extend from observable behavior into reproductive biology.

4.4 Behavioral and Reproductive Patterns as a Connected Phenomenon

One of the most important implications of the findings is that behavior and reproduction should not necessarily be treated as completely independent processes.

Greater nighttime activity during brighter lunar phases could potentially alter feeding opportunities, movement, social interaction, and environmental exposure. At the same time, reproductive physiology is sensitive to environmental cues, including light-related signals. However, the present qualitative design does not allow the direction or mechanism of such relationships to be established.

Therefore, the study proposes an exploratory conceptual relationship:



This framework should be understood as a research proposition rather than a demonstrated causal pathway.

The significance lies precisely in this uncertainty. The observations reveal a phenomenon that can be investigated further rather than providing a simplistic explanation for it.

4.5 Male–Female Offspring Ratio

The male-to-female offspring ratio represents an important extension of the analysis because reproductive research often focuses on the timing of conception and birth while paying less attention to the sex composition of offspring.

In the present study, offspring sex was therefore included as an additional observational dimension. Each newborn kid was categorized as male or female and associated with the corresponding lunar phase at birth.

However, the available source material does not provide the actual number of male and female offspring. Consequently, no numerical conclusion regarding the male-to-female ratio can be made from the existing material alone. The sex-ratio analysis should therefore be completed using the primary field observations.

The important analytical principle is that an observed difference in sex ratio should not automatically be interpreted as evidence that lunar phase determines offspring sex. A deviation from a 1:1 expectation may occur through sampling variation or other biological and environmental factors.

Consequently, the sex-ratio component should be interpreted as an exploratory extension of the lunar-behavior framework. If the observed male-to-female distribution varies consistently across lunar phases, the finding would provide a basis for a subsequent quantitative investigation.

4.6 The Disruptive Finding

The central finding of this study is not simply that goats behave differently during different lunar phases. The more significant finding is the possibility that the night itself is behaviorally heterogeneous.

Conventional interpretations of livestock activity frequently divide time into two broad categories: day and night. The observations presented here challenge this binary representation. A new moon and a full moon are both technically nighttime conditions, yet they produce substantially different visual environments for animals.

The behavioral observations therefore suggest a more nuanced model:

Daylight $\neq$ Night

Instead:

Daylight $\rightarrow$ multiple environmental conditions

Night $\rightarrow$ multiple environmental conditions

Within this perspective, lunar illumination becomes an additional environmental dimension through which animal behavior can be examined.

This is the central conceptual meaning of the title *How the Moon Rewrites Goat Behavior*. The moon does not necessarily replace the circadian rhythm; rather, changing lunar illumination may alter how nighttime behavior is expressed.

4.7 Implications for Science Education

The phenomenon has substantial potential as a contextual science-learning resource. Rather than presenting biological rhythms as abstract concepts, students can investigate a real animal behavior phenomenon and develop explanations through observation and evidence.

The lunar-goat phenomenon allows students to connect several scientific concepts:

- lunar cycles and astronomy;
- light and environmental stimuli;
- circadian rhythms;
- animal behavior;
- reproductive physiology;
- ecology;
- probability and sex ratio;
- data visualization; and
- scientific reasoning.

The phenomenon is particularly valuable because it does not provide an immediately obvious answer. Students must distinguish between observation, association, and causation.

For example, students may observe that goat activity appears greater during brighter lunar phases. The next scientific question is not automatically that moonlight causes the behavior. Instead, students can ask whether temperature, feeding schedules, housing, season, weather, or other environmental conditions might explain the observation.

This creates an authentic opportunity for critical scientific thinking.

The educational value therefore emerges from the uncertainty surrounding the phenomenon. Students can formulate hypotheses, collect observations, compare lunar phases, analyze behavioral patterns, examine sex ratios, and evaluate alternative explanations.

4.8 Integrating the Phenomenon into Contextual Learning

The findings support the use of the goat–moon phenomenon as a contextual and interdisciplinary learning problem.

A possible learning sequence begins with an observable question:

Why are goats more active on some nights than others?

Students then identify lunar phases and observe changes in nighttime illumination. They document goat behavior and classify activities such as feeding, movement, resting, rumination, and social interaction.

The inquiry can subsequently be extended into reproductive analysis by asking:

Do reproductive events also appear to differ across lunar phases?

Finally, students can examine offspring sex:

Does the male-to-female distribution remain approximately balanced across lunar phases?

This progression transforms a livestock observation into a scientific inquiry cycle:

Observe → Question → Hypothesize → Collect Data → Compare → Interpret → Challenge the Explanation

Such an approach aligns the biological phenomenon with inquiry-oriented science education because students are not simply receiving an established conclusion. They are required to construct and evaluate explanations from evidence.

4.9 Overall Interpretation

The findings indicate that lunar phases provide a potentially meaningful framework for examining variation in goat nighttime behavior. Darker lunar conditions were associated with lower observed activity, whereas brighter conditions, particularly gibbous and full-moon phases, were associated with greater nighttime movement, feeding, rumination, vocalization, and social interaction.

The reproductive observations further suggest that lunar-associated patterns may extend beyond behavior (Underhill & Höbel, 2018). Differences in reported parturition distribution and gestational timing provide a basis for investigating whether environmental illumination is associated with reproductive timing.

However, these observations should be interpreted as associations rather than causal effects. The present qualitative design cannot establish that lunar phases directly cause behavioral or reproductive changes. The male-to-female offspring ratio also requires primary observational data before any conclusion can be drawn.

The broader contribution of the study is therefore conceptual and educational. By treating lunar illumination as an overlooked environmental dimension, the study challenges the assumption that livestock nighttime behavior is simply the absence of daytime activity. It proposes that the night itself contains biologically meaningful variation.

In this sense, the moon does not necessarily rewrite the goat's biological clock; it may rewrite how we understand the goat's night.

CONCLUSION

Conclusion

This study explored an overlooked dimension of goat behavior by examining behavioral and reproductive patterns across different lunar phases. The findings suggest that nighttime should not be understood as a uniform environmental condition. Instead, variation in lunar illumination creates changing nocturnal environments that appear to coincide with differences in goat activity.

The clearest behavioral pattern emerged between darker and brighter lunar conditions. During the new moon, goats were characterized by relatively low nighttime activity, with resting and inactivity being more dominant. As lunar illumination increased through the crescent, quarter, and gibbous phases, nighttime movement and feeding-related activity became increasingly visible. Under full-moon conditions, nocturnal activity was most pronounced, including feeding, rumination, movement, vocalization, and social interaction. These patterns are consistent with the behavioral differences described across lunar phases in the source material.

Reproductive observations further suggest that lunar-associated variation may extend beyond visible behavior. The reviewed material reports variation in parturition across lunar phases, including relatively low birth occurrence during the new moon and higher occurrence around the gibbous phase, as well as possible changes in gestational timing around brighter lunar conditions. However, these patterns should be interpreted as associations rather than evidence that lunar phases directly determine reproductive outcomes.

The available evidence indicates that offspring sex ratio in goats varies across populations, but there is currently insufficient evidence to conclude that lunar phase determines whether offspring are male or female. Reported datasets show substantial variation, including female-biased ratios in Poland (44.2% male and 55.8% female), male-biased ratios in the Czech Republic (56.8% male and 43.2% female), and an approximately balanced ratio in Philippine goats (52.0% male and 48.0% female). Importantly, a large dataset involving 5,671 goat kids that specifically examined lunar phase found no significant effect of the lunar cycle on offspring sex ratio. Therefore, while lunar illumination may be associated with changes in nocturnal goat behavior and potentially reproductive timing, the available evidence does not support the interpretation that the Moon determines offspring sex. The male–female ratio should consequently be treated as an exploratory reproductive variable requiring further longitudinal research with phase-specific birth records, larger samples, and appropriate statistical testing.

The principal contribution of this study lies in challenging a simple daylight–nighttime interpretation of livestock behavior. The results suggest that the night itself contains meaningful environmental variation. Lunar illumination may represent an overlooked contextual factor through which nocturnal goat behavior and reproductive observations can be investigated.

From an educational perspective, the phenomenon provides an authentic interdisciplinary context connecting astronomy, biology, animal behavior, reproductive physiology, environmental science, and data analysis. Thus, the study does not merely ask whether the moon changes goats. More importantly, it demonstrates how an ordinary natural phenomenon can be transformed into a scientific question that encourages observation, hypothesis development, evidence-based reasoning, and critical evaluation.

Ultimately, the moon may not rewrite the goat's biological clock, but it may rewrite how we understand the goat's night.

Implications

The findings have implications for both animal-behavior research and science education. From an animal-behavior perspective, lunar illumination deserves consideration as a potential environmental variable when interpreting nocturnal livestock activity. Behavioral studies conducted at night may produce incomplete interpretations if all nighttime periods are treated as environmentally equivalent. A dark new-moon night and a brightly illuminated full-moon night represent substantially different visual environments.

For livestock management, awareness of lunar-associated behavioral variation may help farmers recognize that nighttime movement, feeding, resting, and social interaction can fluctuate under natural environmental conditions. This implication may be particularly relevant to extensive and semi-intensive production systems where goats are directly exposed to natural nighttime illumination. In contrast, the source material indicates that lunar influences may be less apparent in enclosed intensive systems where artificial lighting and human-controlled feeding schedules dominate the nighttime environment.

The educational implications are potentially broader. The goat–moon phenomenon can serve as a contextual science-learning environment in which students investigate a real-world question rather than simply memorize biological concepts. Lunar cycles can introduce astronomy; changing illumination can introduce environmental science; goat activity can introduce animal behavior and circadian biology; reproduction can introduce physiology; and male-to-female offspring distribution can introduce probability and statistics.

Most importantly, the phenomenon provides an opportunity to teach the distinction between observation, correlation, and causation. Students may observe that goats appear more active during brighter lunar phases, but they must subsequently consider competing explanations such as feeding schedules, temperature, weather, housing, reproductive status, and management conditions.

The phenomenon therefore supports a learning sequence based on:

Observation → Question → Hypothesis → Evidence → Comparison → Interpretation → Critical Evaluation

In this way, How the Moon Rewrites Goat Behavior becomes more than an animal-behavior topic. It becomes an interdisciplinary platform for developing scientific literacy and evidence-based reasoning.

Limitations

Several limitations should be considered when interpreting the findings. First, the study employed a qualitative observational approach. Consequently, the identified patterns demonstrate behavioral associations rather than causal relationships. The study cannot establish that lunar illumination directly caused changes in goat behavior or reproduction.

Second, lunar phase represents only one component of the nighttime environment. Other variables, including cloud cover, rainfall, temperature, artificial lighting, feeding schedules, housing conditions, predator disturbance, animal health, age, sex, reproductive status, and herd management, may influence nighttime behavior.

Third, lunar phase and actual moonlight exposure should not be treated as identical variables. A full moon obscured by clouds may produce lower effective illumination than expected, while artificial lighting may substantially modify the nighttime environment regardless of lunar phase. Future interpretation should therefore distinguish astronomical lunar phase from the actual light intensity experienced by the animals.

Fourth, the findings may be particularly applicable to goats maintained in environments with direct exposure to natural illumination. Their transferability to intensive indoor production systems may consequently be limited. This is especially important because the source material itself suggests that lunar effects become less apparent when artificial lighting and controlled management dominate the environment.

Fifth, the reproductive observations require cautious interpretation. Reported differences in parturition frequency across lunar phases do not necessarily indicate that lunar phase determines birth timing. Reproductive events may be influenced by numerous biological and management factors.

Finally, the male-to-female offspring ratio remains an exploratory component. The available material does not contain sufficient primary sex-disaggregated birth data to establish whether offspring sex distribution differs meaningfully across lunar phases. Any conclusion regarding this relationship would therefore be premature.

These limitations do not invalidate the phenomenon. Instead, they define the boundary between what the present study can demonstrate and what remains to be tested.

Recommendations

Future implementation of this research framework should strengthen behavioral observation by using standardized observation periods across all lunar phases. Feeding time, housing conditions, artificial illumination, weather conditions, and other environmental variables should be documented systematically to reduce alternative explanations for observed behavioral differences.

Researchers should also record actual nocturnal light intensity using a lux meter or automated light sensor, rather than relying exclusively on astronomical lunar-phase categories. This would allow the analysis to distinguish the effect of lunar phase from the actual amount of light reaching the animals.

For reproductive analysis, individual animal records should be maintained from mating or conception through parturition. Records should include maternal identification, breeding date, estimated conception date, gestation length, litter size, birth date, lunar phase at conception and birth, and sex of each offspring.

The male-to-female ratio should be calculated separately for each lunar phase and compared against an expected approximately balanced distribution using appropriate statistical methods when the sample size permits. Such analysis would provide a stronger empirical foundation than descriptive observation alone.

For educational application, teachers and lecturers can adapt the phenomenon into inquiry-based, problem-based, or project-based learning. Students can observe livestock behavior, obtain lunar-phase information, collect environmental measurements, organize behavioral data, calculate offspring ratios, visualize patterns, and debate alternative explanations.

The educational objective should not be to teach students that “the moon controls goats.” Instead, students should be challenged to determine whether the evidence is strong enough to support that claim.

This distinction transforms an unusual phenomenon into an exercise in scientific reasoning.

Future Research

Future research should move from qualitative exploration toward a longitudinal mixed-method or quantitative design covering multiple complete lunar cycles. Larger numbers of animals, longer observation periods, multiple farms, and different production systems would improve the robustness and generalizability of the findings.

A particularly important direction is the simultaneous measurement of lunar phase and actual nighttime illuminance. Automated lux sensors could be integrated with video monitoring, animal activity sensors, or computer-vision systems to quantify movement, feeding, resting, and social interaction continuously throughout the night.

Future studies could therefore test a more sophisticated pathway:

Lunar Phase → Actual Nocturnal Illuminance → Behavioral Activity → Reproductive Outcomes

rather than assuming a direct relationship between lunar phase and behavior.

Reproductive research should also distinguish between the lunar phase at conception and the lunar phase at parturition. These represent biologically different events and may produce different relationships with reproductive outcomes.

The male-to-female offspring ratio represents another particularly promising research direction. With sufficiently large birth records, future studies could investigate whether sex ratios differ according to lunar phase at conception, lunar phase at birth, breed, parity, maternal age, season, litter size, or environmental conditions. Importantly, such studies should test these relationships rather than assume that lunar phase determines offspring sex.

Cross-breed and cross-location studies would further determine whether the observed behavioral patterns represent a general characteristic of goats or are specific to particular breeds, climates, management systems, or geographical environments.

Future educational research should move beyond using the phenomenon merely as teaching content and test its actual learning impact. Experimental or quasi-experimental studies could compare conventional science instruction with contextual learning based on the goat-moon phenomenon and measure outcomes such as scientific literacy, critical thinking, hypothesis formulation, data interpretation, environmental awareness, and student engagement.

This creates a particularly promising interdisciplinary research agenda:

Moonlight → Goat Behavior → Reproduction → Data → Scientific Inquiry → Science Learning

Future research can therefore move beyond asking “Does the moon affect goats?” toward a more consequential question:

“Can an overlooked natural phenomenon change both how we understand animal behavior and how students learn to think scientifically?”

REFERENCES

- Ben-Ezra, S., Harpaz, R., Krayden, G., Ohavia, M., Engert, F., Appelbaum, L., & Levy, O. (2026). Artificial light pollution disrupts sleep and neuronal genomic stability in wild reef fish. *Current Biology*, 36(14), 3435-3445.e5. <https://doi.org/10.1016/j.cub.2026.05.058>
- Bionda, A., Negro, A., Barbato, M., Liotta, L., Grande, S., & Crepaldi, P. (2026). Spatio-temporal genomics of goats: recent evolution, adaptation, and future vulnerability. *Animal*, 20(1), 101732. <https://doi.org/10.1016/J.ANIMAL.2025.101732>
- Deprato, A., Haldar, P., Navarro, J. F., Harding, B. N., Lacy, P., Maidstone, R., Moitra, S., Palomar-Cros, A., Durrington, H., Kogevinas, M., Moitra, S., & Adan, A. (2025). Associations between light at night and mental health: A systematic review and meta-analysis. *Science of The Total Environment*, 974, 179188. <https://doi.org/10.1016/J.SCITOTENV.2025.179188>
- Grau-Sologestoa, I. (2015). Livestock management in Spain from Roman to post-medieval times: a biometrical analysis of cattle, sheep/goat and pig. *Journal of Archaeological Science*, 54, 123–134. <https://doi.org/10.1016/J.JAS.2014.11.038>

- Häfker, N. S., & Tessmar-Raible, K. (2020). Rhythms of behavior: are the times changin'? *Current Opinion in Neurobiology*, 60, 55–66. <https://doi.org/10.1016/J.CONB.2019.10.005>
- Hutahuruk, M. B., Junaedi, A. T., Renaldo, N., Prayetno, M. P., Prihastomo, A. D., Andi, A., Putri, N. Y., Fransisca, L., Faruq, U., & Musa, S. (2026). Educational Strategies for Fortified Goat Milk Development Supported by Digital Financial Ecosystems. *Reflection: Education and Pedagogical Insights*, 3(1), 19–24. <https://doi.org/10.61230/reflection.v3i1.143>
- Jahrizal, J., Dalil, M., Amri, R., Yovita, I., Koto, J., Faruq, U., Junaedi, A. T., Tendra, G., Renaldo, N., & Mammadova, U. (2025). Enhancing Goat and Sheep Farm Management with IoT-Enabled Weighing Devices. *Seroja Journal of Empowerment and Community Service*, 1(1), 23–27. <https://doi.org/10.61230/seroja.v1i1.119>
- Junaedi, A. T., Panjaitan, H. P., Renaldo, N., Nyoto, N., Jahrizal, J., Dalil, M., Koto, J., Musa, S., Wahid, N., Veronica, K., & Faruq, U. (2025). Smart Processing Machines and Business Efficiency in Goat Milk Agro-Enterprises. *Luxury: Landscape of Business Administration*, 3(2), 88–97. <https://doi.org/10.61230/luxury.v3i2.137>
- Junaedi, A. T., Renaldo, N., Nyoto, N., Erlin, E., Gustientiedina, G., Marlim, Y. N., Suprayoga, T., Jahrizal, J., Faruq, U., & Veronica, K. (2026). Disrupting the Veterinary Value Chain through AI-Based Goat Health Management. *Journal of Applied Business and Technology*, 7(3), 167–178. <https://doi.org/10.35145/9x4hae67>
- Junaedi, A. T., Renaldo, N., Susanti, W., Johan, J., Veronica, K., Panjaitan, H. P., Suhardjo, S., Jahrizal, J., Musa, S., & Wahid, N. (2026). Strengthening Goat Productivity and Health through Smart Technology and Digital Management Assistance. *Seroja Journal of Empowerment and Community Service*, 2(2), 8–15. <https://doi.org/10.61230/seroja.v2i1.146>
- Junaedi, A. T., Renaldo, N., Susanti, W., Tendra, G., Jahrizal, J., Dalil, M., Veronica, K., Suhardjo, S., Musa, S., & Cecilia, C. (2024). Innovative Business Models and IoT-Driven Solutions for Smart Goat Farming Management. *Interconnection: An Economic Perspective Horizon*, 2(2), 79–89. <https://doi.org/10.61230/interconnection.v2i2.116>
- Junaedi, A. T., Renaldo, N., Susanti, W., Yuliendi, R. R., Kurniawan, W. J., Marlim, Y. N., Veronica, K., Panjaitan, H. P., Faruq, U., & Jahrizal, J. (2026). Learning Smart Farming through IoT Prototypes, Educational Impacts of Smart Goat Housing Systems in Vocational Education. *Reflection: Education and Pedagogical Insights*, 3(1), 1–9. <https://doi.org/10.61230/reflection.v3i1.141>
- Massetti, L. (2020). Drivers of artificial light at night variability in urban, rural and remote areas. *Journal of Quantitative Spectroscopy and Radiative Transfer*, 255, 107250. <https://doi.org/10.1016/J.JQSRT.2020.107250>
- Mauny, S., Kwon, J., Friggens, N. C., Duvaux-Ponter, C., & Taghipoor, M. (2026). Quantification of group and individual behavioural responses to a nutritional challenge in dairy goats. *Computers and Electronics in Agriculture*, 253, 112196. <https://doi.org/10.1016/J.COMPAG.2026.112196>
- Perea, H. R., Piedrahita, A. R., & Alzate, Ó. E. T. (2025). Models of environmental awareness: exploring their nature and role in environmental education – a systematic review. *Heliyon*, 11(13), e43679. <https://doi.org/10.1016/J.HELİYON.2025.E43679>
- Prayetno, M. P., Renaldo, N., Faruq, U., Junaedi, A. T., Hutahuruk, M. B., Suhardjo, S., Prihastomo, A. D., Nyoto, N., Panjaitan, H. P., & Fransisca, L. (2026). Material Flow Cost Accounting (MFCA)-Driven Smart Goat Livestock Management System. *Luxury: Landscape of Business Administration*, 4(1), 45–56. <https://doi.org/10.61230/luxury.v4i1.148>
- Prayetno, M. P., Renaldo, N., Junaedi, A. T., Hutahuruk, M. B., Prihastomo, A. D., Setyawan, O., Suhardjo, S., Panjaitan, H. P., Nyoto, N., & Nyoto, R. L. V. (2026). An Integrated IoT Architecture for Smart Dairy Goat Farming and Nutrient Fortification Control. *Informatica and Digital Insight Journal*, 2026(1), 1–8. <https://doi.org/10.61230/informatica.v3i1.152>

- Prihastomo, A. D., Renaldo, N., Junaedi, A. T., Hutahuruk, M. B., Prayetno, M. P., Faruq, U., Koto, J., Jahrizal, J., Nyoto, N., & Fransisca, L. (2026). Green Digital Education Model with AI and IoT Integration in Sustainable Goat Farming Curriculum. *Reflection: Education and Pedagogical Insights*, 3(1), 25–31. <https://doi.org/10.61230/reflection.v3i1.149>
- Prihastomo, A. D., Renaldo, N., Junaedi, A. T., Panjaitan, H. P., Nyoto, N., Hutahuruk, M. B., Faruq, U., Prayetno, M. P., Wati, Y., & Fransisca, L. (2026). Value Co-Creation and Digital Marketplace Strategy in Enhancing Commercialization Performance, An Educational Perspective from Fortified Goat Milk Entrepreneurship. *Reflection: Education and Pedagogical Insights*, 3(1), 32–40. <https://doi.org/10.61230/reflection.v3i1.151>
- Prokić, M. D., Gavrilović, B. R., Gavrić-Čampar, J. P., Despotović, S. G., Radovanović, T. B., & Petrović, T. G. (2026). Amphibians under artificial light at night: Current knowledge, conservation challenges and future directions. *Biological Conservation*, 315, 111729. <https://doi.org/10.1016/j.biocon.2026.111729>
- Renaldo, N., Jahrizal, J., Junaedi, A. T., Suhardjo, S., Setyawan, O., Musa, S., & Cecilia, C. (2026). Precision Multi-Forage Nutrition as a Driver of Sustainable Goat Agribusiness Performance. *Journal of Applied Business and Technology*, 7(1), 52–61. <https://doi.org/10.35145/s2a28145>
- Renaldo, N., Junaedi, A. T., Suhardjo, S., Tanjung, A. R., Indrastuti, S., Faruq, U., Musa, S., & Wahid, N. (2025). Design and Evaluation of a Mudharabah-Based Dairy Goat Investment Model. *Journal of Applied Business and Technology*, 6(3), 230–238. <https://doi.org/10.35145/jabt.v6i3.302>
- Renaldo, N., Junaedi, A. T., Susanti, W., Jahrizal, J., Dalil, M., Veronica, K., Hutahuruk, M. B., Musa, S., Koto, J., & Cecilia, C. (2026). From Waste to Assets through Value Creation Strategies in Goat Farming. *Luxury: Landscape of Business Administration*, 4(2), 74–81. <https://doi.org/10.61230/luxury.v4i2.159>
- Renaldo, N., Musa, S., Koto, J., Veronica, K., Faruq, U., Marlim, Y. N., Yuliendi, R. R., Susanti, W., Junaedi, A. T., & Wahid, N. (2026). Integrating Material Flow Cost Accounting and IoT-Based Monitoring for Eco-Efficient Goat Farm Management. *Journal of Applied Business and Technology*, 7(3), 179–185. <https://doi.org/10.35145/6e5wnv18>
- Steffen, K. D., Basset, C. M., Gos, M. L., Arias, R. O., Venturini, M. C., Unzaga, J. M., & Moré, G. (2026). A longitudinal serological follow-up of Neospora caninum natural infection in dairy goats. *Parasitology International*, 114, 103275. <https://doi.org/10.1016/J.PARINT.2026.103275>
- Suhardjo, S., Renaldo, N., Junaedi, A. T., Veronica, K., Panjaitan, H. P., Setyawan, O., Susanti, W., Widi, R., Faruq, U., & Jahrizal, J. (2026). Developing Social Accounting Competencies through IoT-Based Goat Farming Learning Systems. *Reflection: Education and Pedagogical Insights*, 3(1), 10–18. <https://doi.org/10.61230/reflection.v3i1.142>
- Underhill, V. A., & Höbel, G. (2018). Moonlighting? - Consequences of lunar cues on anuran reproductive activity. *Acta Oecologica*, 87, 20–28. <https://doi.org/10.1016/j.actao.2018.02.001>
- Villanova, M., Bruzzi, P., Madeo, S. F., Trevisani, V., Iughetti, L., Predieri, B., & Lucaccioni, L. (2026). Environmental heat exposure and female pubertal timing: biological plausibility, emerging evidence and research priorities. *Global Pediatrics*, 18, 100380. <https://doi.org/10.1016/J.GPEDS.2026.100380>

APPENDIX

Comparative Patterns of Goat Behavior and Reproductive Responses Across Lunar Phases

Lunar Phase	Nocturnal Illumination	Dominant Behavioral Pattern	Feeding and Movement	Reproductive Pattern	Male–Female Ratio
-------------	------------------------	-----------------------------	----------------------	----------------------	-------------------

Lunar Phase	Nocturnal Illumination	Dominant Behavioral Pattern	Feeding and Movement	Reproductive Pattern	Male–Female Ratio
New Moon	Very low / almost absent / darkest nighttime condition	Highly passive, resting, reduced nighttime activity, lower nocturnal activity, greater resting/passivity	Limited nighttime movement and feeding, reduced nighttime movement and feeding	Approximately 8% of recorded parturitions occurred around the new moon in the reported observation	Not reported for lunar-phase-specific sex ratio
Waxing Crescent	Low and increasing	Normal activity with early signs of nighttime responsiveness	Occasional standing, movement, and residual feeding	Reproductive response generally stable; conception reported as relatively lower in some observations	Not reported
First Quarter	Low–moderate	Gradually increasing nighttime activity	More visible movement and feeding	No distinct reproductive peak identified in the available material	Not reported
Waxing/Waning Gibbous	High	Increased nocturnal activity	Greater movement, feeding, and shorter nighttime resting	Reported highest parturition proportion, approximately 19%	Not reported
Full Moon	Very high	Highest apparent nocturnal activity	Feeding, rumination, vocalization, movement, and social interaction become more visible	Associated with reproductive activity and potentially slightly shorter gestation	To be determined from field data
Global Goat Evidence				Lunar phase has not been consistently demonstrated to determine reproduction	Overall goat datasets: 44.2% male / 55.8% female (Poland); 56.8% male / 43.2% female (Czech Republic); 52.0% male / 48.0% female (Philippines). However, these are NOT lunar-phase-specific ratios.

Comparative Interpretation of the Lunar–Goat Relationship

Dimension	Dark Lunar Phase	Intermediate Lunar Phase	Bright Lunar Phase
Environmental condition	Minimal natural nighttime illumination	Increasing illumination	Strong nighttime illumination
Goat activity	Relatively low	Gradually increasing	Relatively high
Nighttime feeding	Limited	Occasional	More frequently observed
Movement	Minimal	Moderate	More pronounced
Resting behavior	Dominant	Gradually reduced	Shorter nighttime resting
Social interaction	Less visible	Increasing	More visible
Reproductive timing	Lower reported birth occurrence	Intermediate	Higher reported birth occurrence around gibbous/full phases
Sex ratio	Requires empirical analysis	Requires empirical analysis	Requires empirical analysis
Interpretation	Night as a low-illumination environment	Transitional environment	Night as an active environmental condition

Empirical Evidence on Male–Female Offspring Ratio in Domestic Goats and Its Relationship with Lunar Phase

Study	Location	Period	Sample	Male	Female	Male (%)	Female (%)	Lunar Phase Examined	Result
Górecki & Kościński (2003)	Poland	1997–2002	527 kids	233	294	44.21	55.79	Not examined	Female-biased; p=0.0079
Polák et al. (2015)	Czech Republic	1992–2004	59,335 kids	33,685	25,650	56.79	43.21	Not examined	Male-biased; p<0.0001
Abecia et al. (2017)	Spain	2002–2007	5,671 kids	NR	NR	NR	NR	New, Crescent, Full, Decrescent	No significant lunar effect
Philippine Native Goat Study	Philippines	2000–2003	123 kids	64	59	52.03	47.97	Not directly examined	Sex distribution approximately balanced
Evidence synthesis	Multiple	1992–2007	>65,000 kids	—	—	—	—	Lunar evidence available for 5,671 kids	No consistent evidence that lunar phase determines sex ratio