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Review article

# Effect of artificial light in the female domestic cat reproduction: What we know so far?

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A B S T R A C T

Domestic felids (*Felis catus*) have been traditionally categorized as seasonal polyestrous with induced ovulation. Thus, the ability to augment or distribute the number of litters born throughout the year would offer a desirable advantage. Artificial-light regimens have been used to overcome seasonal variations in this species. Understanding the mechanisms that underlie photoperiodicity might enable the development of improved and sustainable breeding schemes. The aim of this article was therefore to summarize the present knowledge on the effect of artificial light on female-cat reproduction. To that end a systematic review of the literature from 1940 to the present was performed. International original articles and scientific abstracts were also included, and at the conclusion we emphasized areas that require further research.

## 1. Introduction

In big cities, domestic cats *(Felis catus)* are displacing dogs as the most common pet. This may be because cats require less space and are more affordable (González-Ramírez and Landero-Hernández, 2021). Thus, enhancing the knowledge of their breeding physiology for reproductive management purposes is welcomed.

Domestic felids have been traditionally categorized as long day seasonal polyestrous with induced ovulation (Hurni, 1981; Scott and Lloyd-Jacob, 1959). In mammals, living under natural environmental conditions, the duration of the reproductive season is mainly determined by the geographical latitude (Hurni, 1981). At the equator and in the tropics, the longest and the shortest days of the year are scarcely different, thus being not enough to shorten the reproductive phase. Conversely, at higher latitudes, the decreasing hours of daylight induce a seasonal anestrus, thus confirming the cat to be sensitive to photoperiod (Leyva et al., 1989a; Hurni, 1981; Scott and Lloyd-Jacob, 1959; Dawson, 1941). Thus, from the equator to the tropics cats can produce up to three litters throughout the year. From that latitude, the reproductive season diminishes progressively towards polar circle, where it lasts about 6 months producing no more than one to two litters per year (Hurni, 1981). For that reason, the possibility to produce litters throughout the year, independently of the season, could be a species goal which might be also useful in the wild counterparts.

Specifically, in the domestic cats the onset of the period of anestrus is closely related to the decreasing length of the day after the longest day of the year. Conversely, the onset of the breeding period occurs after the shortest day of the year — that is, under the consequent increasing daily increment in light (Dawson, 1941).

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The mechanism by which light influences the hypothalamus-hypophyseal gonadal axis is through the secretion of the neurohormone melatonin (5-methoxy-N-acetyltryptamine) by the pineal gland (Leyva et al., 1984). Melatonin acts, via two receptors, MT1 and MT2, in the suprachiasmatic nucleus of the brain to endogenously control the circadian rhythms that are entrained by the light–dark cycle (von Gall et al., 2002). Thus, as the photoperiod shortens, the levels of serum melatonin increase causing a reduction of ovarian activity. Furthermore, no estrus was found to occur when exogenous melatonin (5 mg iv) was administered to queens under 24 h of light (Leyva et al., 1989b).

Although artificial light regimens have been used to overcome seasonal variations of this species in both breeding and laboratory settings, little detailed information is available on the cat reproductive performance bred under controlled light conditions.

Light as an environmental factor consists of three main aspects: intensity, wavelength and duration (i.e. photoperiod). The luminous intensity per unit area, known as illuminance, is measured in an international unit known as lux. Typical room illumination is 300–500 lux, whereas outdoor light varies from 1500 lux on a cloudy day to 100,000 lux on a sunny day (Bialek, 2012). Daylight has a distribution of wavelengths or light spectrum between 400 and 700 nm which may exert variable effects on animals (Wright and Lack, 2001). Different kinds of light sources, including incandescent, fluorescent, or light-emitting diodes (LED) produce varied light spectrums. In this respect, LED, emits more blue-appearing portion of the visible spectrum (400–485 nm) than other sources. These shorter wavelengths showed to cause the greatest melatonin suppression (Wright and Lack, 2001).

Understanding the mechanisms that underlie photoperiodicity might enable for the development of improved and sustainable breeding schemes. The aim of this review was to summarize the present knowledge of the effect of artificial light on female cat reproduction. Areas that require further research were highlighted.

## 2. Methods

A systematic review of the literature across three databases (CAB Direct, PubMed, and Scopus) was conducted using the following search terms "domestic cat', '*Felis catus*", 'felid", "reproduc*", "female", "estrous cycle", "estrus", "pregnan*", "gestat*", "light" "photoperiod" and their combinations along with the Boolean operator tools, AND, NOT or OR. The question that motivated our search was "what do we exactly know of the effects of artificial light on female cat reproduction?".

International peer reviewed publications were downloaded for the period from 1940 to 2022. First, based on the title and abstract,

**Table 1**
Published reports on the effects of artificial light on female domestic cat estrous cycle.

| Ref. & latitude | Number of animals | Light source & intensity | Light (L)/24 h schedules | Response | Mean lag to response |
|---|---|---|---|---|---|
| Dawson (1941) 42.3736° N | 6 | Natural light + 200-W clear bulbs | -7L/d for 39 d then addition of 1, 2, 3, 4, 5, 6 h for 7, 6, 6, 6, 6 d and then indefinitely along with natural light. | 100 % estrous response | 50–71 d from light increase |
| Scott and Lloyd-Jacob (1959). 51.5072° N | -10<br>-22 control | One 1.5-m long fluorescent lamp | 12L/d for 170 d | -9/10 estrous response<br>-21/22 estrous response | -54 d<br>-90 d |
| Robinson and Cox (1970) 51.5072° N | 35–45 | Daylight + fluorescent lighting | 14L/d for 10 years | Two peaks of litter production: summer and winter | |
| Hurni (1981) 47.5596° N | 50–350 | Windowless rooms with white fluorescent tubes. 90–250 lux | 15–30 m:<br>-12L/d<br>-1 m 9L/d + 1 m 14L/d<br>-1 m 10L/d + 2 m 14L/d<br>-2 m 10L/d + 1 m 14L/d<br>-1 m 9L/d + 1 m 12L/d + 1 m 15L/d | Peak mating rate/week: x<br>-4 %<br>-9.5 %xxx<br>-7.5 %<br>-10 %<br>-16.5 %xxx | From beginning of experiment:<br>XX<br>-60 d<br>-63 d<br>-77 d<br>-77 d |
| Leyva et al. (1984) 38.5449° N | 12 | 40-W fluorescent strip lights<br>323 lux | -8L/d for 140 d<br>-14L/d for 140 d<br>-24L/d for 140 d | -No cycling<br>-cycling<br>-cycling | |
| Leyva et al., (1989) 38.5449° N *Light manip* | 16<br>-<br>-n 6<br>-n4<br>- | Four 40-W fluorescent strip lights<br>323 lux. On 6–20 h. | 14L/d for 2 years<br>-14L/d 50 d then for 90 d:<br>-24L/d or<br>-8L/d<br>Then studied for 30 d and back to 14 L/d | -<br>-2 estruses/m<br>-0.8–1 estrus/m<br>-No cycling, E2 lower | -<br>-<br>-45 d, increased antral follicle development<br>-<br>-in 16 d estrus |
| Chantal (1993) 48.8566° N | 18 | Two neon tubes of 150 lux | -8L/d<br>-1 m 12L/d + 14L/d<br>-12 L:1D:1 L:10D/d<br>-12 L:4D:1 L:7D/d | -0 % estrus<br>-85 % estrus<br>-85 % estrus<br>-85 % estrus | From light increase:<br>-45 d<br>-15 d<br>-15 d |
| Caransa et al. (2010) 34.5200° S | 6 | Daylight + one 100-W incandescent bulb lamp | 14L/d for 1 year | Days in heat/m increased in long days + ascending photoperiod | |

Note: Light per day (L/d), dark (D), month/s (m), day/s (d), watt (W).

the publication was either excluded or advanced to full-text screening. Second, the full text was reviewed to confirm study eligibility or exclude it. The reference lists of these publications were also searched for any citations related to the topic and additional articles were included in the initial selection. Copies or pdfs of any articles or other reports which were not available in the local library were obtained from the University interlibrary loan services.

## 3. Findings

A total of 114 publications were retrieved and only articles in which artificial light, either alone or in combination with natural photoperiod, was the intervention were initially considered to meet the inclusion criteria and selected for the present review.

All the publications were original research articles including longitudinal, retrospective descriptive and/or prospective interventional studies. Although, all the studies included were peer-reviewed publications, none of them was randomized and only one had a control group. Finally, five international articles and two scientific abstracts were deemed eligible for this review.

The number of adult queens included in each article ranged from 6 to 350, where only two studies studied more than 18 females. All the reports were located in the temperate zone between latitudes 38.5449° and 51.5072°. The end points of these reports were: the behavioral and/or cytological estrous response, the days of estrus per month, the mating rate, the parturition rate, the litter production, the follicular development assessed visually or the serum-estrogen increase. The reproductive effects of artificial light on queen reproduction of these selected publications were summarized below (Table 1).

## 4. Published studies

The first two reports were published in 1939 and 1940 from Massachusetts (latitude 42.3736° N), USA. In the first study, estrus was induced in 4 out of 7 queens kept in a windowed room with two clear 200-W bulbs. Estrus occurred after 49–62 days after an increasing illumination program (1.5, 3.5, 4.45 and 5:45 h were added for 12, 6, 7 and 70 days, respectively) during seasonal anestrus. The lights were turned on in the afternoon when natural light diminished (Dawson, 1941).

In the second study, 6 out of 6 cats had estrus induced 50–71 days later and follicles and/or corpora lutea were present in the ovaries. The authors subjected the cats to 7-h light and 17-hours dark daily (7L:17D) daily by shuttering the windows, 5 days a week, for 39 days. Thereafter, the light increment was provided late in the afternoon for 1, 2, 3, 4, 5 and 6 h for 7, 6, 6, 6, 6 and 2 days, respectively. Finally, the additional illumination of 6 h per day was maintained along with natural light. In both studies by this author, there was a considerable variability in the lag to the estrous response, ranging from 13 to 21 days respectively (Dawson, 1941).

In 1959, in London (latitude 51.5072° N), UK ten 15–18 month old female cats were subjected to increased illumination during seasonal anestrus. A 1.5 m fluorescent lamp, suspended over the catś pen, provided 12L:12D for 170 days. Twenty-two cats were used as a control. Nine out of the 10 treated cats evidenced estrus after 54 days, with 8 becoming pregnant. Conversely, 21 control queens had their first cycle in 90 days (Scott and Lloyd-Jacob, 1959).

Again, in London (51.5072° N latitude), UK in 1970, 35–45 queens were exposed to daylight, supplemented by fluorescent tubes, which providing a 14L:10D lighting program, were studied for a period of 10 years. Litter production occurred in winter and summer with minor variations throughout the years. Interestingly, the peak litter production in winter was more clearly defined than the one in summer. The poorest month for parturitions occurred at an intermediate time point (May). In this respect, the authors suggested that an internal rhythm might exist in female cats and that this rhythm could not be easily altered. These queens produced a mean of 2.5 litters per year that were not regularly spaced. Furthermore, the summer-born litters were larger than those of the winter (Robinson and Cox, 1970).

In a first trial, Hurni (1981) in Basel (47.5596° N), Switzerland using a 14L:10D lighting program obtained a weekly mating rate of about 3 % (Hurni, 1981). The same author in 1981 compared four lighting programs to the natural lighting pattern of the equatorial zone (12L:12D) in 50–350 queens for 15–30 months depending on the different experimental groups. The four lighting programs were: i) one month 10L:14D + two months 14L:10D **vs.** ii) 1 month 9L:15D + 1 month 14L:10D **vs.** iii) two months 10L:14D + one month 14 L:10D **vs.** iv) one month 9L:15D + one month 12L:12D + one month 15L:9 D). The animals were kept in windowless rooms lit by white fluorescent tubes producing 90–250 lux (average 150 lux) at 1 m above floor-levels. Each group had a three-month break between changes. Under the control equatorial conditions there was a fairly constant weekly mating rate of about 4 % with a production of 2.2 litters per cat per year.

Two months 10L:14D + one month 14L:10D (iii) induced estruses as early as 10 days after the onset the third month. In four weeks more than 10 % of the cats were mated (an observation of 187–210 queens for 30 months). One month 10L:14D + two months 14L:10 D (i) produced similar results with a lower peak in the mating rate of approximately 7.5 % during the fifth week. This peak declined thereafter (Hurni, 1981).

A progressively increasing lighting program (9, 12 and finally 15 h per day; iv) had a prompt (21 days after the 15 h onset) and narrowly grouped estrus induction (approximately breeding rate 16.5 % with the production of 1.8 litters per year) in 50 cats during an 18-month observation period. Conversely, a reversion to short days promptly lowered the number of cats coming into heat. Furthermore, this author also demonstrated that the change from short-day to long-day periods could be successfully repeated six times in a year (Hurni, 1981).

In 1984, another group of researchers in Davis (latitude 38.5449° N) CA, USA carried out one of the more complete studies (Leyva et al., 1984). Twelve adult female cats were maintained under a 14L:10D photoperiod (lights on between 6 and 20 h) provided by four 40-W fluorescent strip lights, which illumination resulted in 323 lux at the floor level, for 2 years. Queens were placed in three different photoperiod regimens of four females each: i) 8L:16D vs. ii) 14L:10D vs. iii) 24L:0D for 140 days. Ovarian function was evidenced by determination of daily plasma estradiol concentrations and by the exhibition of estrous behavior upon exposure to vasectomized males. All the cats in groups ii and iii had cyclic ovarian activity, whereas the group-i cats did not exhibit estrus. In this study, blood melatonin concentrations were also measured, by a radioimmunoassay, at 2-h intervals for 24-h. Mean and peak melatonin levels varied significantly among the three photoperiod groups. High melatonin values obtained in the group-i cats while the lowest levels of this hormone occurred in the group-iii females (Leyva et al., 1984).

In 1989, the same group of researchers in the same city (latitude 38.5449° N) of USA studied 10 cats under a 14L:10D regimen for 50 days, then submitted the queens to either 24L:0D (n = 6) or 8 L:16D (n = 4) for 90 days (Leyva et al., 1989a). At approximately 45 days after the onset of 24L:0D light regimen, all the animals had increased 17-ß-estradiol concentrations above the previous values obtained under 14 L:10D. Of interest was that the incidence of estrous cycles decreased under 24L:0D program to 1 per month compared to 2 per month under 14L10D. Conversely, under the 8L:16D schedule, estrous cycle activity immediately ceased and the interestrus 17-ß-estradiol concentrations became significantly lower under the 8L:16D schedule than under 14L:0D regimen (Leyva et al., 1989a).

In 1993, Chantal in Paris (48.8566° N), France also studied the effect of artificial light in the domestic cat (Chantal, 1993). Twenty females were exposed to natural light along with artificial light (two neon tubes of 150 lux) whenever needed by the personnel. Then, a 8L:16D program was used in a windowless 8 by 2 m room with 18 cats, which were divided into 3 groups of six animals each: i) exposed to 12L:12D for one month, then 14L:10D until estrus was detected, ii) 12L:1D:1L:10D or iii) 12L:4D:lL:7D. In all instances, estrus was detected by behavioral observation and vaginal smears. Once estrus was confirmed, the queens were either inseminated or mated. They all became pregnant. None of 8L:16D animals evidenced estrus, while increasing the lighting in group i caused estrus in 5/6 females (85 %) with a mean lag in estrus of 44.6 ± 0.5 days (about 15 days after the lighting increase). In groups ii and iii, where the females were given one-hour flash (1 L) after nightfall, an estrus occurred in 85 % after 15.6 ± 0.5 days (Chantal, 1993).

Finally, a total of 47 estrous cycles were studied in 6 adult females during 12 months by our group in La Plata (latitude 34.5200° S), Argentina (Caransa et al., 2010). The females were kept free in a room of our Feline Experimental Colony of the School of Veterinary Sciences. The animals were exposed to daylight through a glass window and complemented by one 100 watts incandescent bulb lamp for 14 h a day. Estrous cycles were detected daily by observation of the typical behavior and by vaginal cytology. The number of days in heat per month (DHM) was calculated for each queen. The months of the year were arranged into 4 groups of 90 days each according to their length in days (short vs. long) and the photoperiod (increasing vs. decreasing; Caransa et al., 2010).

Although the queens cycled throughout the year, the mean DHM significantly differed among the groups, with the long days being accompanied by an ascending photoperiod (18.1 ± 1.6 days) greater than those of descending photoperiod either with long days (9.8 ± 2.3 days) or short days (8.0 ± 0.1 days). Furthermore, when DHM was compared between the two ascending vs. the two of descending groups, the DHM of the former groups resulted significantly larger (Caransa et al., 2010).

**Table 2**

Graphic summary of the best results of the main reports of Table 1. The length of the horizontal arrows proportionally represents the mean lag to estrous response of the different reports (Dawson, 1941; Scott and Lloyd-Jacob, 1959; Hurni, 1981; Chantal, 1993; Leyva et al., 1989a, 1989b).

| Reference | Number of animals | Light source | Light (L)/24 h schedules | Lag to response | Estrous response |
|---|---|---|---|---|---|
| Dawson (1941) | 6 | | 7L for 39 d and gradually increase to 13 L | 50-71 d | |
| Scott & Lloyd-Jacob (1959) | 10 | | 12L/d for 170 d | 54 d | |
| Hurni (1981) | 50 | | 1m 9L/d +1m 12L/d + 1m 15L/d | 77 d | |
| Leyva et al., (1989) | 6 | | 14L/d for 90 d then 24L/d | 45 d | 0.8 -1/m |
| Chantal (1993) | 18 | | -12L:1D:1L:10D/d<br>-12L:4D:1L:7D/d | -15 d<br>-15 d | |

Note: Light per day (L/d), dark (D), month/s (m), day/s (d). Solid parts of the cats represent the percentage of estrous response.

## 5. Discussion and conclusions

Light manipulation of reproduction represents a nonhormonal, natural, cost-effective method that has been extensively used in other seasonal domestic species such as small ruminants, equines and poultry (Kim et al., 2022; Patel et al., 2016; Thimonier, 1981). This review summarizes the current knowledge on the reproductive effect of artificial light on domestic female cats and also identifies areas of knowledge that need further research. A thorough understanding of the effect of light on reproductive physiology is essential for managing the breeding performance in cats.

The scarcity in the number of international peer-reviewed original reports available on this topic was noteworthy compared to the literature on other seasonal domestic species in which the effect of light on reproduction has been described in detail (Kim et al., 2022; Patel et al., 2016; Thimonier, 1981). For example, the effect of the quantitative and the qualitative characteristics of light on the estrous cycle in mares have been extensively described (Kim et al., 2022). It is widely accepted that a light treatment with 14.5–16.0 h white light (100 lux), starting at winter solstice and ending around summer solstice induces cyclicity after about 70 days of treatment (Guillaume et al., 2000). Furthermore, it is clear that 3–10 lux, low-intensity blue light to a single eye suppresses melatonin and advances the breeding season in mares kept indoors (Walsh et al., 2013).

Noteworthily, excluding Caransa et al. (2010), these cat articles are 82–29 years old. Therefore, some were written at a time when the IMRaD format for scientific writing was not yet established, making their reading complex as well as difficult to understand and follow. Some studies were carried out in domestic cats bred under laboratory conditions for human research and written by laboratory-animal specialists or physicians instead of veterinarians. Furthermore, the lack of randomization and control groups in these studies severely undermines the utility of their findings. In most of these cat reports, the intensity and spectral composition of the exogenous light were insufficiently described, or not at all. Even though all the trials were placed at latitudes at which natural light could have also had an effect, the latitudes were not provided in most of the reports that combined exogenous with natural light. Furthermore, this combination of insufficiently described lights makes interpretation of results difficult.

Within this framework circumscribing the abundant limitations of some of these previous trials, certain conclusions could still be drawn after analyzing their findings (Table 2). Thus, for example, concerning the number of hours of light per day, 8 h would appear to be insufficient to induce cycling in this species (Chantal, 1993; Leyva et al., 1984, 1989a). Conversely, the minimum number of hours per day reported to induce estruses was 12 h (Chantal, 1993; Hurni, 1981; Scott and Lloyd-Jacob, 1959; Dawson, 1941). Nevertheless, the effect of less than 8 h was not described in any study.

In three reports, 14 h of light per day maintained cyclicity throughout the years with one or two peaks of annual activity in those years (Caransa et al., 2010; Leyva et al., 1989a; Robinson and Cox, 1970). Moreover, an increase in the number of hours up to 14 h per day induced estruses in four studies (Chantal, 1993; Leyva et al., 1984; Hurni, 1981; Dawson, 1941). In contrast, reversion to shorter days promptly lowered the number of cats coming into heat (Leyva et al., 1989a). Of particular significance was that, in one study, when the photoperiod was further increased to 24 h per day, the number of estruses per months decreased (Leyva et al., 1989a).

As discussed above, the quality and quantity of the light provided was scarcely described in most of the published articles. The authors who mentioned the source of light indicated either fluorescent tubes or incandescent bulbs (Caransa et al., 2010; Leyva et al., 1984; Robinson and Cox, 1970; Scott and Lloyd-Jacob, 1959; Dawson, 1941). One study used a neon tube (Chantal, 1993). Comparisons and conclusions about the effect of light spectrum therefore, cannot be drawn. Furthermore, most of these light sources have now been replaced by LEDs which was not used in any of these old studies.

Even though certain reports mentioned the power of the source of light (40–200 W), only 4 reported the illuminance which ranged from 90 to 323 luxes (Chantal, 1993; Leyva et al., 1984, 1989a; Hurni, 1981). Nevertheless, in this respect, we could still infer that an illumination much lower than natural daylight could induce cyclicity in the domestic cat. Similar findings have been reported for other seasonal domestic species (Kim et al., 2022; Patel et al., 2016; Thimonier, 1981).

The success rate of the different artificial photoperiods is difficult to compare among the studies as a variety of outcome measurements—end points—were used by the different authors. The lag in response to an increase in light also ranged from 10 to 70 days in the different reports, thus emphasizing the concept of the latency of the effect. Of practical significance, however, was that the wide range in the lag to respond would exclude this natural method from synchronization protocols. Of relevance, though, was that in one study a 1–4-h flash of light during the dark period increased the rapidity of the subsequent response, thus suggesting the possible existence of a degree of photosensitivity during darkness (Chantal, 1993).

Thus, there is a limited amount of knowledge available on the effect of artificial light on queen-cat reproduction which was mainly focused on its duration i.e. photoperiod. Several aspects—including light intensity and spectral composition in external light proof-rooms — as well as the eventual existence of photorefractoriness, as a manifestation of an internal rhythm which was suggested in certain studies, still remain to be determined (Caransa et al., 2010; Robinson and Cox, 1970). An update of the light sources using the available ones should also be considered. Ultrasonographic follicular follow up would confirm cytological and behavioral findings of the experimental females. Additionally, serum melatonin should preferable be measured by modern, validated immunoassays so that a standardized assay-system and reference values could be widely available.

Finally, we conclude that further experimental evidence based on randomized control trials with well-defined and analyzed outcomes, including a complete light program history, will be necessary to fine-tune a detailed lighting program for reproductive management in the domestic felids.

## CRediT authorship contribution statement

**Daiana Eaton:** Investigation, Initial analysis, Writing – original draft. **Augusto Lantermino:** Conceptualization, Initial analysis.

**Camila Lapuente**: Investigation, Initial analysis, Writing – review & editing. **Paula G. Blanco:** Writing – review & editing. **Cristina Gobello:** Conceptualization, Formal analysis, Writing – review & editing.


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## Conflict of Interest

The authors do not have any financial nor personal relationships with other people or organizations that could inappropriately influence the study.


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## References


Bialek, W., 2012. Biophysics: Searching for Principles. Princeton University Press, New Jersey. p. 640.

Caransa, A., Abeya, M., Delasota, P., García, P., Risso, A., Corrada, Y., Gobello, C., 2010. Seasonal reproductive patters of the domestic cats in La Plata, Argentina: a preliminary report. Jorn. Int. Vet. Práct. Argentina. Abstract 23.

Chantal, M., 1993. Induction of oestrus in cats by photoperiodic manipulations and social stimuli. Lab. Anim. 27, 278–280. https://doi.org/10.1258/002367793780745381.

Dawson, A.B., 1941. Early estrus in the cat following increased illumination. Endocrinology 28, 907–910. https://doi.org/10.1210/ENDO-28-6-907.

González-Ramírez, M.T., Landero-Hernández, R., 2021. Pet-human relationships: dogs versus cats. Animals 11 (9), 2745. https://doi.org/10.3390/ani11092745.

Guillaume, D., Duchamp, G., Nagy, P., Palmer, E., 2000. Determination of minimum light treatment required for photostimulation of winter anoestrous mares. J. Reprod. Fertil. Suppl. 56, 205–216.

Hurni, H., 1981. Daylength and breeding in the domestic cat. Lab. Anim., vol. 15, pp. 229–33. ⟨https://doi.org/10.1258/002367781780893803⟩, ⟨https://doi.org/10.5187/jast.2021.e123⟩.

Kim, S., Jung, H., Murphy, B.A., Yoon, M., 2022. Efficiency of Equilume light mask on the resumption of early estrous cyclicity and ovulation in Thoroughbred mares. J. Anim. Sci. Technol. 64 (1), 1–9. https://doi.org/10.5187/jast.2021.e123.

Leyva, H., Addiego, L., Stabenfeldt, G., 1984. The effect of different photoperiods on plasma concentrations of melatonin, prolactin, and cortisol in the domestic cat. Endocrinology 115 (5), 1729–1736. https://doi.org/10.1210/endo-115-5-1729.

Leyva, H., Madley, T., Stabenfeldt, G.H., 1989a. Effect of light manipulation on ovarian activity and melatonin and prolactin secretion in the domestic cat. J. Reprod. Fertil. Suppl. 39, 125–133.

Leyva, H., Madley, T., Stabenfeldt, G.H., 1989b. Effect of melatonin on photoperiod responses, ovarian secretion of oestrogen, and coital responses in the domestic cat. J. Reprod. Fertil. Suppl. 39, 135–142.

Patel, S.J., Pate, M.D., Patel, J.H., Patel, A., 2016. Significance of light in poultry production: a review. Adv. Life Sci. 5 (4), 1154–1160. https://doi.org/10.1258/002367770781036616.

Robinson, R., Cox, H.W., 1970. Reproductive performance in a cat colony over a 10-year period. Lab. Anim. 4, 99–112.

Scott, P.P., Lloyd-Jacob, M.A., 1959. Reduction in the anoestrus period of laboratory cats by increased illumination. Nature 184 (Suppl. 26), S2022. https://doi.org/10.1038/1842022a0.

Thimonier, J., 1981. Control of seasonal reproduction in sheep and goats by light and hormones. J. Reprod. Fertil. Suppl. 30, 33–45.

von Gall, C., Stehle, J.H., Weaver, D.R., 2002. Mammalian melatonin receptors: molecular biology and signal transduction. Cell Tissue Res. 309 (1), 151–162. https://doi.org/10.1007/s00441-002-0581-4.

Walsh, C.M., Prendergast, R.L., Sheridan, J.T., Murphy, B.A., 2013. Blue light from light-emitting diodes directed at a single eye elicits a dose-dependent suppression of melatonin in horses. Vet. J. 196 (2), 231–235. https://doi.org/10.1016/j.tvjl.2012.09.003.

Wright, H.R., Lack, L.C., 2001. Effect of light wavelength on suppression and phase delay of the melatonin rhythm. Chronobiol. Int. 18 (5), 801–808. https://doi.org/10.1081/cbi-100107515.