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EFFECT OF SHORTER OR LONGER EXPOSURE TO ARTIFICIAL LIGHTING OF PREGNANT MINK (*NEOVISON VISON*) ON THEIR REPRODUCTIVE PERFORMANCE

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Abstract. The aim of this study was to analyze the influence of the length of the period of artificial lighting of mink on their reproductive performance. The experiment was carried out on a mink farm in West Pomerania, Poland. Reproduction data of 1068 one-year-old female mink of the silverblue strain were analyzed. All females were in selection classes 7 and 8 and were mated four times, first between the 1st and 10th of March. Females were illuminated during pregnancy with artificial light such that the light day was 17 hours per day. Females were divided into two groups – one group was illuminated from March 20 to April 17, and the other from March 20 to May 15. The following reproductive indices were analyzed in relation to the length of illumination: length of diapause and gestation, litter size, number of live-born and weaned young per litter, percentage of barren females, percentage of females dead during gestation and lactation, and average length of lactation in which females died. Artificially illuminated females were characterized by longer diapause, longer gestation, larger litters, but they had higher mortality of young during maternal nursing. It was also found that females with shorter lactation reared slightly more young, and were characterized by a lower percentage of barren females and females dying during pregnancy and lactation. The analysis conducted in this study confirmed the period of illumination of pregnant mink until April 17 is sufficient in terms of reproductive performance of the females.

Key words: breeding mink, artificial illumination, reproductive parameters.

INTRODUCTION

Mink breeding is one of the largest branches of animal production not only in Poland, but also worldwide. In Poland the American mink ranks first among farmed fur-bearing animals in terms of the quantity and quality of pelts produced. Developing progress in breeding of American mink has led to initiation of research aimed at improving the quality of mink coats while simultaneously improving reproduction indices. To this end, a number of scientific studies have analysed the influence on reproduction parameters of factors such as length of daylight, date of first mating, mating frequency, age of females and their color variety, body condition. Special attention was paid to shortening the diapause period and consequently the length of pregnancy in mink. Other

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very important reproductive parameters are litter size, the number of live born kits per litter and the number of weaned per litter. In order to improve these parameters, experimental changes in the length of the light day were introduced. According to the analyses performed, it was found that the American mink responds positively to artificial lighting during pregnancy – the diapause period and thus the gestation period are shortened in the mink, and litter size increases (Felska-Błaszczyk and Sulik 2008; Felska-Błaszczyk et al. 2013). Since many scientific studies have confirmed the positive effect of light exposure of pregnant mink females on reproductive performance, this paper will attempt to analyze how long the light exposure of pregnant females should last.

Female mink are characterized by a monoestrous sexual cycle and induction of ovulation, occurring 36–72 hours after first mating (Tauson et al. 2000). The oestrus period lasts approximately 3 weeks, usually from March 3 to March 23, and the mating season continues on farms during this period. Mink are mated several times (usually four), and the first mating should be done between the 1st and 10th of March. The second mating is repeated the next day, the third mating after 7–8 days, and usually it is also repeated the next day. Therefore, the four-fold mating scheme is as follows: 1 + 2 + 8 + 9. The number of matings has been found to influence the length of diapause and thus pregnancy in American mink females, and the most optimal mating scheme is the quadruple one, as it optimizes the reproductive results achieved (Seremak et al. 2020).

With prolonged diapause, a decreasing number of mink born can be observed due to embryo death (Seremak et al. 2016a, 2016b). Diapause is a phenomenon of delayed embryo implantation in the uterine wall and has been developed as adaptation to increase female's reproductive success and optimize the timing of birth. During diapause, the mitotic divisions of the embryo are inhibited and the embryo remains in the blastocyst form without implanting in the uterine wall. Reactivation of embryonic growth occurs only after implantation of the embryo in the uterine wall, which is initiated by a prolonged light day (Felska-Błaszczyk et al. 2013; Fenelon et al. 2014, 2017). This occurs when the light day reaches the appropriate length, approximately 13 hours. Photoperiod and estrogen stimulate the pituitary gland to secrete prolactin, which affects the activation of the *corpus luteum* and the secretion of progesterone, leading to the implantation of the embryo in the uterine wall. The lengthening of the light day thus shortens the diapause period. In mink, the diapause period lasts from a few days to as many as several tens of days – on average it is 18 to 25 days, which makes pregnancy last on average from 45 to 55 days. The length of diapause depends on many factors, such as: the date of mating, the number of mating and also the length of lightening of the mink during pregnancy. Mink mated earlier have longer pregnancies than those mated later (Gulevich et al. 1995; Felska-Błaszczyk et al. 2008; Felska-Błaszczyk 2012). Gestation length affects prolificacy and litter viability; it has been found that the best litters are obtained from dams whose gestation lasted less than 45 days, while weaker and less numerous litters are obtained from those whose gestation lasted more than 55 days (Felska-Błaszczyk et al. 2012; Szczypułkowska and Felska-Błaszczyk 2016).

In order to accelerate the implantation of embryos in the uterine wall and thus shorten the diapause period, artificial illumination of females after mating was introduced on mink farms during our study. A sixteen-hour or seventeen-hour light day was introduced from the next day after mating season was completed. In contrast, the period for ending artificial illumination varied from 6 or 15 April (Felska-Błaszczyk et al. 2013). The 17-h light day was better – 2 to 3 shorter diapause days, larger litters and better survival of young during the rearing period were observed compared to control groups (Felska-Błaszczyk 2012).

Studies on increasing prolificacy by shortening diapause and thus shortening gestation as a result of experimentally extending the light day in the period just after mating in mink were conducted as early as the 1940s and 1950s by Hansson (1947) and Hammond (1951) and yielded positive results. In a later study by Allais and Martinet (1978), serum progesterone concentrations in mink housed under extended light day conditions increased several days earlier than in mink kept under natural conditions, which consequently led to earlier embryo implantation in the uterine wall and earlier births. Martinet et al. (1985) extended the light day to 15 hours per day for 2–4 weeks before the mating period and observed the stimulating effect of a long light day on progesterone and prolactin secretion. Duby and Travis (1972) also noted that gradually increasing the length of the light day after the cessation of winter fur growth accelerated the onset of the breeding season. According to Rebreanu et al. (1981) the gestation period of mink whose light day was lengthened shortened by an average of 12 days.

These studies have led to the fact that the illumination of female mink during the gestation period has entered the practice on many Polish farms. However, reproductive results were not analyzed in terms of the end of the light period, hence the present study. Will prolonged lightening of mink change their reproductive parameters, e.g. will it shorten diapause and increase litters? We will seek answers to these and other questions in this study. We assume that the period of illumination of pregnant mink need not be longer than until about mid-April, since it is in the first half of April that embryo implantation in the uterine wall most often occurs. Murphy et al. (1990) report that the average date of embryo implantation in American mink is April 3.

To test this hypothesis, we compare the lengths of application of two periods of illumination.

MATERIAL AND METHODS

Mink farm – animal welfare conditions

The experiment was conducted on a mink farm in West Pomerania, Poland, in 2019. The animals were kept in double-row universal sheds, which used for both females and males of the core herd, as well as for juveniles rearing. The animals were kept in accordance with the European Convention for the Protection of Vertebrate Animals and met the conditions of the Act on the Organization of Farm Animal Breeding and Reproduction of 10 December 2020 being in force in Poland. Individual sheds were placed at a distance of 3 meters from each other. The animals were kept in openwork cages of the Danish type measuring 90 cm × 45 cm × 45 cm (length × width × height); the cages were placed 70 cm above the ground. These cage sizes exceed the minimum requirements according to the above law and this size of cages according to Díez-León et al. (2017) provides adequate welfare conditions for the animals. The distance between adjacent cages was 6 cm to prevent biting and fur damage. The cages were combined into sets of 6. In each cage, on the front side, there was a nest box with a mesh insert, insulated with a mixture of barley straw and meadow hay.

Light intensity in the sheds has not been measured, however, according to Travis and Pilbeam (1980), light intensity in mink cages should be between 129 and 183 lux. In order to allow a proper level of light in the cages on the analyzed farm, care was taken to keep the skylights in the roof of the pavilions clean, thus allowing natural light to reach the cages, and artificial lighting provided light even on cloudy days.

The animals and fed a standard diet – semi-liquid feed produced on the basis of fish and chicken, the composition of which had been developed basing on the standards for feeding fur animals (Gugołek 2011). The feed was offered three times a day, and the daily ration for each individual was about 180 grams. Animals were provided with constant access to clean and fresh water by means of automatic nipple drinkers.

According to Henriksen et al. (2022) such maintenance conditions meet the requirements of the standardized WelFur-Mink protocol.

Experiment

Reproduction results of 1068 one-year-old female mink of the silverblue strain were analyzed during the experiment. Females of this strain were selected for the experiment because it is one of the most prolific breeding strains of mink. All females characterized by very good body condition, similar body weight, and very good coat traits. In this way, the influence of the above factors, i.e. body condition and excellent coat quality, on the reproductive performance of the females was eliminated. All females were mated four times according to the 1 + 2 + 8 + 9 system (figures represent individual days from the start of the mating season), and were first mated between March 1 and 10.

In order to illuminate the females during pregnancy, 11-Watt energy-saving bulbs (equivalent to 60 Watt conventional bulbs) were placed above the cages with females. The bulbs were installed at a height of 220 cm, at intervals of 270 cm in the middle of the feed corridor, i.e., over each group of animals (5 groups of females with 8 individuals each and 1 group of eight males).

During the analysis, females were divided into two groups according to the length of the light day for pregnant females. The length of the light day in both groups was the same, approximately 17 hours per day (in the beginning of the experiment, the females were artificially illuminated from 5 am to 6:30 am and from 5 pm to 10 pm). Light schedules were changed weekly to correspond to the changing day length, so that at the end of the experiment in one of the groups, the lamps were on about two hours a day (one hour in the morning and one in the evening). This length of light exposure was chosen based on the results of our own studies (Felska-Błaszczyk 2012; Felska-Błaszczyk et al. 2013), in which it was found to be the most optimal. Illumination of females began on 20 March, i.e., the day after the end of the mating season. The differences between the groups of animals that were analyzed for reproductive performance consisted in the length of the period during which females were artificially illuminated:

- females artificially illuminated longer time, from March 20 to May 15: 602 females,
- females artificially illuminated shorter time, from March 20 to April 17: 466 females.

Animals from the two experimental groups were housed in two separate pavilions, which were spaced apart so that they would not interfere with each other's light programs.

The following reproductive indices were analyzed in relation to the length of illumination:

- length of diapause and gestation – gestation length was determined in two ways: (1) defined as the period from the date of first mating to the date of delivery or (2) defined as the period from the date of last mating to the date of delivery; the length of diapause was calculated as follows: 36 days were subtracted from gestation length, since before diapause the embryo develops for 6 days, and the period from implantation until delivery is 30 days,
- litter size,
- number of live born young per litter,
- number of reared young per litter,
- percentage of barren females,
- percentage of females dying during pregnancy and lactation,
- average length of lactation in which females died.

Gestation length was calculated as the period between the date of first mating and the date of delivery. This is a different way of calculating gestation length compared to that proposed by, for example, Møller (2000) or Karimi et al. (2018), who counted gestation length as the period between the last mating and the delivery date. In our experiment, females were mated 4 times, with the first mating occurring between March 1 and March 10, e.g. a female mated the first time on March 5, mated the second time on March 6, mated the third time on March 13 and mated the fourth time on March 14. The difference between the first and last mating is 9 days and this should be included in the length of gestation; using males of different coat colors for mating on different dates, Felska-Błaszczyk et al. (2019) and Seremak et al. (2020) found young from each mating in the resulting litters.

In order to register the birth date, mink nests were from mid-April carefully checked by farm employees, 3 times a day – in the morning (between 8 am and noon), midday (between 12 and 4 pm) and evening (between 4 pm and 8 pm). The period and time frames of the inspection was based on Schou and Malmkvist (2017). The birth was check without opening the nest box, by means of a PVC pipe; a worker applied the pipe to the wall of the nest facing the feed corridor and listened for the noise that pups make in the nest. Once the sound of the young was detected, the nest was marked with a card, and the offspring count itself was conducted within 24 hours after parturition, following the methodology of Karimi et al. (2018). The fact that the first nest check is carried out 24 hours after parturition reduces the stress to the female. In both experimental pavilions, counting was carried out by the same farm employee, assisted by the author of the publication.

Statistical analysis

Statistica 13.3 PL (StatSoft Inc. 2019) software was used for mathematical and statistical data processing. General characterization was performed using selected mathematical and statistical parameters: arithmetic mean (M), standard deviation (SD) and standard error of mean (SEM). One-way analysis of variance for main effects (ANOVA), with Tukey's test for different group sizes, was used to determine the significance of differences between means in individual reproductive indices.

RESULTS AND DISCUSSION

Table 1 shows the statistical analysis of the effect of light duration on diapause and gestation length in illuminated female mink. Table 1 shows two ways of calculating gestation length in mink. In the world literature, researchers primarily use the latter method, that is, calculating gestation length as the period from the date of last mating to the date of parturition (Møller 2000; Hensen et al. 2010; Karimi et al. 2018). In the present study, a different method was used – pregnancy length was calculated as the period between the date of the first mating and the date of birth. The reason for choosing such a method was that pregnancies of 35 days were found when pregnancy length was calculated as the period between the last mating and the date of delivery (after subtracting the diapause period). Such a length of pregnancy seems too short. Another reason for choosing such a method was that, as a result of mating males in the first mating, offspring sired by these males are observed in the litter (Felska-Błaszczyk et al. 2019; Seremak et al. 2020). There are far fewer of them than those conceived after mating at the second mating date (in the second subcycle of oocyte maturation), about 15%, however they must not be disregarded.

No statistically significant differences were found, however, answering the question in the Introduction, it can be observed that females exposed for a shorter period of time had a shorter diapause and gestation length compared to females exposed for a longer period. Other results were obtained in our previous study – the females illuminated one week longer had shorter pregnancies and shorter diapauses than the females illuminated for a shorter period (Felska-Błaszczyk 2012). The results of this article were also confirmed in studies conducted in 2012 and 2013 (Felska-Błaszczyk 2012; Felska-Błaszczyk et al. 2013). The mink were illuminated for the period from 20 March to 6 April (Felska-Błaszczyk 2012) and from 20 March to 15 April (Felska-Błaszczyk et al. 2013), a period similar to the dates used in this study; in both works, artificial illumination had a positive effect on shortening the diapause period.

Timing of embryo implantation is mediated by a lengthening light day, which activates the pituitary gland to produce prolactin, which in turn activates the corpus luteum to produce progesterone, whose increasing levels lead to embryo implantation in the uterine wall (Martinet et al. 1981; Berria et al. 1989; Kaplan et al. 1991; Amistislavsky and Ternovskaya 2000). Consequently, when the length of the light day starts increasing earlier due to artificial illumination, the activation of hormones responsible for embryo implantation also occurs earlier, resulting in a shorter period of diapause and gestation.

Table 1. Statistical characteristics of diapause length and gestation length in relation to the period of illumination of females

Illumination duration	Diapause length, days				Gestation length, days			
	M	SD	SEM	P	M	SD	SEM	P
Length of pregnancy calculated from first mating to date of delivery								
Longer	17.39	3.32	0.14	0.10	53.39	3.32	0.14	0.10
Shorter	17.06	2.88	0.13	0.10	53.06	2.88	0.13	0.10
Total	17.25	3.14	0.10	–	53.25	3.14	0.10	–
Length of pregnancy calculated from last mating to date of delivery								
Longer	9.15	3.34	0.14	0.10	45.13	3.36	0.14	0.12
Shorter	8.82	2.93	0.14	0.10	44.82	2.93	0.14	0.12
Total	9.09	4.28	0.13	–	45.01	3.63	0.11	–

On the analyzed farm, the use of artificial lighting extended the light day to 17 hours immediately after the mating. This period was chosen as a result of the previous study that examined the effect of a 17-, 16-, and 14-hour light-phase of day on mink reproductive performance, and found that a 17-hour light period for pregnant females gave the best results (Felska-Błaszczyk 2012; Felska-Błaszczyk et al. 2013). In contrast, Allais and Martinet (1978) applied a 14-hour light day immediately after mating was completed. In both cases, illuminating the females resulted in accelerated embryo implantation and thus shortened the diapause and the entire gestation.

Analysis of the effect of length of artificial lighting on litter size and number of live born young per litter revealed statistical differences, at the $P \le 0.01$ level, in litter size (Table 2). Because nest inspection occurred 24 hours after parturition, the females may have eaten the dead mink, so the number of live-born mink appears to be a more authoritative indicator. More numerous litters were recorded in females that were illuminated, longer until 15 May. However, there was no effect of illumination length on the number of live-born young per litter, and their number was only slightly higher in females illuminated longer, which may indicate higher perinatal mortality of young in this group of females.

Table 2. Statistical characteristics of litter size, number and percentage of live-born young per litter as a function of the lactation period of females

Illumination duration	Litter size				Live-born per litter				Percentage of live-born
	M	SD	SEM	P	M	SD	SEM	P	
Longer	7.34^{A}	2.12	0.09	< 0.001	6.95	2.18	0.09	0.11	94.55
Shorter	6.88^{A}	1.92	0.09	< 0.001	6.74	1.96	0.09	0.11	97.48
Total	7.14	2.04	0.06	–	6.86	2.09	0.06	–	95.84

A – significant differences in column at $P \le 0.01$

In our previous study, we found that a period of lightning pregnant mink similar to “shorter one” in the present study increased the fertility of mink and also increased the percentage of live born young in a litter (Felska-Błaszczyk 2012). Comparing these data with the analysis performed in this study, some differences can be observed – litter size and the number of live born young per litter were higher with longer light exposure of females, which in the case of litter size was statistically confirmed at $P \leq 0.01$. On the other hand, the percentage of live born young was similar, that is, it was higher with shorter light exposure of females, which means better survival of mink during pregnancy with shorter light exposure.

Females of the same color variety, aged 1 year, had been selected for the analysis and all were mated four times – the first time between March 1 and 10. In this way, the influence of such factors as color variety, age, number of mating sessions and mating dates, which are otherwise important for the reproduction performance in mink, was eliminated. It has been found, for example, that two-year-old females mated more than once, the first time by March 10, are the most fertile (Lagerkvist et al. 1993; Amistislavsky and Ternovskaya 2000; Socha and Markiewicz 2002).

One factor that can affect litter size is the fecundity of the males used for subsequent matings (Sundqvist et al. 1985). Since male fecundity was not studied in this study, the results regarding litter size should be treated with some precaution.

However, there was no statistical effect of the length of the light period of the females during pregnancy on the number of young reared (Table 3). However, it can be observed that more young were reared by females that were illuminated for a shorter period. Shorter illumination of females causes that the young are born in better condition, which is also proven by the mortality rate of young mink during the maternal nursing period – it is more than twice lower in mink from mothers with shorter illumination compared to mink from mothers with longer illumination, which was statistically confirmed at $P \leq 0.01$ (Table 3). It is difficult to say why mortality of the young increased when longer illumination of pregnant mink was used. Apart from the length of illumination, the two groups did not differ in other factors. It is likely that the offspring of the females that were illuminated longer were born in poorer condition, which resulted in their higher mortality during the maternal nursing period. Schou and Malmkvist (2017) found that juvenile nest mortality is primarily influenced by prenatal and/or postnatal litter size. These authors noted that the focus should be on litter size and maternal welfare during gestation and parturition so as to increase vole survival.

Table 3. Statistical characteristics of the number of reared young per litter and mortality of young during rearing as a function of the females' light period

Illumination duration	Weaned per litter				Mortality in nursing [%]
	M	SD	SEM	P	
Longer	5.91	2.80	0.12	0.061	5.45^{A}
Shorter	6.22	2.32	0.11	0.061	2.52^{A}
Total	6.05	2.60	0.08	–	4.16

A – significant differences in column at $P \leq 0.01$

Similar results were obtained in our earlier study (Felska-Błaszczyk 2012) – young from females illuminated for a shorter period were characterized by lower mortality during rearing at mothers.

The percentage of barren females, as well as the percentage of females dead during gestation and the percentage of females was higher in the group of females artificially illuminated for longer (Table 4). Felska-Błaszczyk et al. (2010) noticed that the lowest percentage of barren females was in the group of females lactating for the first time from 1 to 5 March (19.88%), and the highest in the group of females lactating from 16 to 20 March (26.99%). The days of lactation on which females died ranged from 35 to 45 days after parturition, indicating that the demise may have been due to nursing sickness, otherwise known as lactation anemia or lactation emaciation syndrome in mink. Rouvinen-Watt (2003) reports that this disease can occur in mink around the 6th week of lactation, which is around day 42 postpartum, while mortality occurs around day 46 of lactation. Strychalski and Gugołek (2013), on the other hand, report that my symptoms appear sooner, between 3 and 6 weeks of lactation, that is, between 21 and 42 days of lactation, which corresponds to the days of lactation in which females died in this study. Clausen et al. (1992) state that this disease manifests itself in females in the latter part of the lactation period or in the first week after weaning, especially in females rearing large litters. Although the epidemiology of this disease is not fully understood, it has been found to occur more frequently in females rearing larger litters.

Table 4. Percentage of barren females that died during pregnancy and during the nursing period of young mink (lactation) in relation to female illumination and date of first mating

Illumination duration	Barren females [%]	Dying at pregnancy [%]	Lactation period		
			dead females [%]	day the female died, on average	mean litter size of a dead female
Longer	5.15	0.50	2.66	39.07	6.33
Shorter	3.22	0.43	1.29	39.25	7.75
Total	4.31	0.47	1.78	39.10	6.63

This syndrome most often affects high-yielding females, as evidenced by the results obtained in this study, as the average litter size was 6.63, and for females that died and were lit for a shorter time, the litter size was much larger at 7.75 individuals.

CONCLUSIONS

Although no statistical effect was observed females artificially illuminated longer, from 14 March to 15 May: were characterized by a longer diapause and thus a longer gestation. Females illuminated longer were characterized by more numerous litters, however, they had higher mortality of young during rearing at their mothers', which resulted in the fact that the number of live born young was not statistically different compared to females illuminated at shorter time (until 17 April). In addition, it was also found that females lit for a shorter time reared slightly more young and had a lower percentage of barren females and females that died during pregnancy and lactation. The analysis conducted in this study confirmed that the period of illumination of pregnant mink until April 17 is sufficient in terms of reproductive performance.

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WPŁYW KRÓTSZEJ LUB DŁUŻSZEJ EKSPOZYCJI CIĘŻARNYCH NOREK NA SZTUCZNE DOŚWIETLANIE (*NEOVISON VISON*) NA ICH WSKAŹNIKI ROZRODU

Streszczenie. Celem pracy była analiza wpływu długości okresu sztucznego doświetlania norek na osiągane przez nie wyniki rozrodu. Doświadczenie prowadzone było na fermie norek w zachodniopomorskiej Polsce. W trakcie doświadczenia analizowano wyniki rozrodu 1068 jednorocznych samic norki hodowlanej odmiany silverblue. Wszystkie samice były w klasie selekcyjnej 7 i 8 i były kryte czterokrotnie, a pierwszy raz zostały pokryte w terminie od 1 do 10 marca. Samice doświetlano w trakcie ciąży sztucznym światłem w taki sposób, że dzień świetlny wynosił 17 godzin na dobę. Samice podzielono na dwie grupy – jedna grupa doświetlana była od 20 marca do 17 kwietnia, a druga od 20 marca do 15 maja. Analizowano następujące wskaźniki rozrodu w zależności od czasu doświetlania: długość diapauzy i ciąży, wielkość miotu, liczbę żywo urodzonych i odchowanych młodych z jednego miotu, procent samic jałowych, procent samic padłych w okresie ciąży i w okresie laktacji, średnią długość laktacji, w której samice padły. Samice doświetlane sztucznie dłużej charakteryzowały się dłuższą diapauzą i dłuższą ciążą, bardziej licznymi miotami, jednakże stwierdzono u nich wyższą śmiertelność młodych w trakcie odchowu przy matkach. Stwierdzono, że samice doświetlane krócej odchowywały nieznacznie więcej młodych, ponadto w grupie tej mniejszy był procent samic jałowych i samic padłych w okresie ciąży i laktacji. Analiza przeprowadzona w niniejszej pracy potwierdziła, że doświetlanie samic w okresie ciąży pozytywnie wpływa na wyniki rozrodu, jednak nie jest konieczne, aby okres doświetlania trwał dłużej niż do 17 kwietnia.

Słowa kluczowe: rozród norek hodowlanych, doświetlanie, parametry rozrodu.