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Abnormal Antler Cycles in Deer as a Result of Stress Inducing Factors **

[With 2 Tables & 8 Figs.]

The experiments were carried out on males: nine fallow deer, two roe deer, one red deer and one sika deer, some of the animals being used twice. These males were subjected to stress factors such as separation of the dominating male from the herd, fear caused by man, or aggregating of strange males with cut off antlers and therefore unable to manifest their social position. These stress factors delayed the shedding of antlers for a period ranging from a few days to one year. In fallow deer, the stressor caused changes in the cycle of one antler, while not affecting the other. The growth of a new antler in the stressed fallow deer occurred in spite of the persistence of the previous antler. These new antlers were always without brow tine, and had increased the basal surface (coronet). It was characteristic that when the stress was caused by the disturbance of the social hierarchy of the fallow deer, alterations in the antler cycle occurred only in bucks occupying extreme hierarchy positions. Control experiments demonstrated that cutting off the antler does not cause disturbances in the antlers cycle as long as it is not connected with changes in social hierarchy. The time of antlers shedding is probably conected with the adaptation of a male deer to the stressing factor.

I. INTRODUCTION

The papers concerning the regulatory mechanisms of the antler cycle have elucidated only partially the role of some factors involved. The effect of testosterone has been explained to a considerable extent (Wislocki, Aub & Waldo, 1947; Wislocki & Waldo, 1953; Tachezy, 1956; Jaczewski & Gałka, 1970; Lincoln, 1971a, b), and partially of oestrogens also (Goss, 1968). Some experiments have been made especially of gonadotrophic hormones of the function of the hypophisis (Freund, 1955; Stosic & Pantic, 1966; Hall, Ga-

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nong & Taft, 1966) especially of gonadotrophic hormones (Bruggemann, Adau & Karg, 1965; Jaczewski & Gałka, 1970; Jaczewski & Topiński, 1970; Jaczewski & Michalakowa, 1972). The role of the thyroid has also been studied (Lebedinsky, 1939; Bruhin, 1953; Freundova, 1955). The effect of photoperiodic factors has been investigated also (Jaczewski, 1952; Jaczewski, 1954; Goss, 1969a, b).

The role of adrenal cortical hormones and of *ACTH* is poorly understood. The inhibition of antlers growth during unfavourable circumstances was observed as early as 1839 by Darwin (1959). He described that during the transportation of a male deer from America to Europe, the antlers growth was restrained. Vogt (1947) and Reyel (1952, see Bubenik, 1966) reported negative effects of military operations on the antler cycles in natural habitats during the Second World War. Hucin (1957) found some changes in the adrenal cortex of red deer (*Cervus elaphus* L.) accompanying the antler cycle. The fact that the ratio of adrenal to body weight depends of the factors eliciting the state of stress was demonstrated by Hughes & Mall (1958) in *Odocoileus virginianus* Erxl., and then by Bubenik & Bubenik (1965) in *Capreolus capreolus* (L.). Bubenik (1962) described a case of antler growth inhibition in a roe deer buck due to the prolonged action of fear.

Bubenik (1966) reported the inhibition of antler growth in a roe deer buck after administration of cortisone. On the other hand, Goss (1963) did not found any inhibitory action of cortisone on antlers shadding caused by castration of male sika deer (*Cervus nippon* Temminck.). In his experimens cortisone also did not cause the velvet shedding in castrated sika deer. However, Doutt & Donaldson (1959), and Donaldson & Doutt (1965), pointed out the importance of corticosteroids in the mechanism of antler cycle. They described one case of the occurrence of antlers in a female Virginia deer probably caused by a tumour made up of adrenal cortical type cells. Bubenik (1972) suggested that in roe deer bucks corticosteroids participate in the final stage of antler growth.

Comparative studies play an important role in the understanding of the function of the adrenal glands (Wegner, 1971). It is also known that the number of animals in a group and the social hierarchy both exert considerable influence on adrenal function in laboratory animals (Gärtner & Bonath, 1971). However the adrenal function and the effect of stress on the biology of *Cervidae* are poorly investigated. These factors may be of practical importance in connection with the civilization changes in deer natural environment.

The aim of the present study was to explain the role of ecological, and especially ethological factors, in the mechanism of antlers cycle. Therefore male deer were subjected to stressing factors in the period preceding the shedding of antlers.

II. MATERIALS AND METHODS

In most cases the experiments depended on eliciting changes in the herd hierarchy by the introduction of strange males or by the separation of the dominating males from the herd. In fallow deer the state of stress was additionally complicated by antlers amputation. In two cases, fear of man was used as the stressor.

As a rule the casting off of antlers occurs earlier in older males, each individual cast his antlers from year to year a few days later (Skinner, 1921; Mohr, 1932). Therefore in the case when a male retained his antlers up to the day in which they were lost in previous year, the disturbance of the antler cycle was assumed. The delay in the shedding of antlers was expressed in the number of days in relation to the date that they were shed in the previous year (Raesfeld, 1971) and this time was employed as an approximate indicator of the stressor action.

The difference between the day of casting off of the right and left antler was used as a second indicator of stress. This was based on the observation that old male deer cast both antlers usually on the same day, while in young animals a small difference, not exceeding 1—2 days, may occur (Raesfeld, 1971), Any bigger difference was assumed as the effect of the stressor.

The observations were carried out on a deer farm in the Institute of Genetics and Animal Breeding, Polish Academy of Sciences at Popielno, and in the Zoological Gardens in Warsaw and Płock. The following number of animals were used in the experiments: two bucks of roe deer *Capreolus capreolus* (Linnaeus, 1758), one sika deer *Cervus nippon* Temminck, 1838, one red deer *Cervus elaphus* Linnaeus, 1758 and nine fallow deer *Cervus* (*Dama*) *dama* (Linnaeus, 1758). Some of the animals were used twice in the experiments, and in such cases, a one-year interval was left between experiments.

III. COURSE OF THE EXPERIMENTS

Three phases can be distinguished in the experiments. In the first phase different stressors were employed to ascertain whether cyclic changes of antlers are a good indication of the effect of stress on the organism. For this purpose different deer species were subjected to the following stressors: separation of an animal from the herd (Table 1, No. 1, 3); introduction of a male to the herd (Table 1, No. 4); or fear of man (Table 1, No. 2). As a result a delay in antler casting, ranging from 3 to 15 days, was observed. In one case (Table 1, No. 4) after the persistence of the antlers for 15 days longer than in the previous year, the roe deer buck was injected with a high dose of trankwilina (0.0093 g of chlorpromazinum per kg body wt.). Under the influence of this anti-

-stress drug, this buck shed his antlers within 36 hours after the injection.

In the second phase, only fallow deer were employed. They were subjected to a stressor consisting in the disturbance of the established

Table 1

First phase of experiments — influence of various stressors on male of *Cervidae*.

Item	*C. capreolus*	*D. dama*	*C. elaphus*	*C. capreolus*
Date of birth	1965	1967	1967	1967
Anticipated date of antlers casting	Dec. 23, 1968	May 22, 1968	April 17, 1970	Nov. 8, 1970
Date of stressor application	Dec. 23, 1968	May 22, 1968	April 14, 1970	Aug. 20, 1970
Casting of left antler	Sept. 5 1969	May 22, 1968	April 27, 1970	Nov. 29, 1970[2]
Casting of right antler	Dec. 23, 1968	May 25, 1968	April 27, 1970	Nov. 29, 1970
Effect in days	14	3	ca. 10[1]	ca. 20[1]
Type of stressor	Isolation from herd	Fear of men	Isolation from herd	Isolation from herd + fear of men

[1] Casting occurred in 36 h after injection of tranquiline, [2] Delay in casting occurred on both sides and was calculated from the moment of appearance of the roll of new growth in case 3, and from the date of casting in the previous year in case 4.

Table 2

Second phase of experiments — influence of hierarchie disturbances on males of Dama. In bold face are the bucks introduced to the herd.

No.	Date of birth	Male	Date of aggregation and of amputation	Position in the hierarchy	Casting Left	Casting Right	Effect in days
				1969			
1	1964	**A**	Jan. 3, 69	I	Sept. 7	May[1]	ca. 120
2	1965	B	Jan. 3, 69	II	May[1]	May[1]	
3	1968	**C**	Jan. 3, 69	III	May[1]	May[1]	
4	1968	**D**	Jan. 3, 69	IV	May 10, 70	May[1]	ca. 360
				1970			
5	1964	A	—	III	May 8	May 1	
6	1965	B	—	II	May 1	May 1	
7	1968	C	—	IV	May 14	May 15	
8[2]	1968	**D**	—	I	May 10	May 8	
				1971			
9	1964	A[3]	Oct. 23, 70				
10	1965	B[4]	Oct. 23, 70				
11	1968	C	Oct. 23, 70	II	May 8	May 8	
12	1968	D	Oct. 23, 70	I	May 7	June 10	34
13	1970	E	Oct. 23, 70	III	May 2	May 8	5

[1] Casting occurred between 3rd and 15th May, 1969. Wear 1970 — interval in experiments. [2] From Feb. 1970 to Oct. 1970 was isolated from the herd. [3] Died on Feb. 2, 1971. [4] Died on Jan 10, 1971.

social hierarchy by introducing of a strange male to the herd. The males were unable to manifest their social posistion, because their antlers were cutt off a little above the burr previously. In 1969 buck *B* was the »master« of the pen and then three other males were introduced to his enclosure (Table 2). The year 1970 was left as an interval in the experiments. It was assumed that following the derangement of the hierarchy and of the antlers cycle in 1969, these parameters would return to normal after one year. During this period, in order to repeat the experiment of 1969, the subordinated buck *D* was transferred to another pen 500 m away. In the year 1970/71, after the one year interval buck *D* was introduced to his herd again after the amputation off antlers in all males. Within a short time, this buck attained the dominating position in the pen. The effect of disturbances of the herd hierarchy in this group is shown in Table 2. Both in 1969 and 1971 the inhibition of the shedding of antlers occurred only in males occupying extreme positions in the herd hierarchy (Table 2). The picture of the

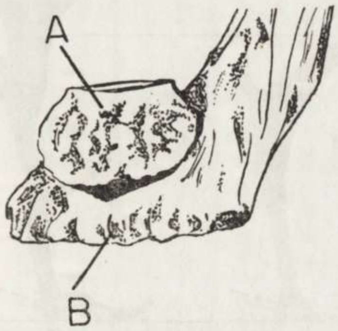

Fig. 1

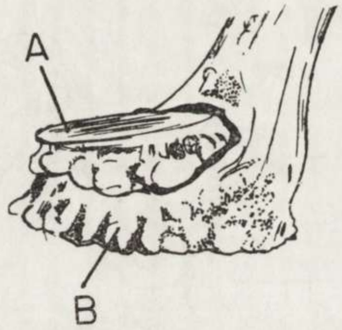

Fig. 2

Fig. 1. Right antler of fallow deer *A*.
A — stump of the antler from 1968 cast off on Sept. 7, 1969, in a few days after the shedding of the velvet from B. B — lower part o the antler which grew in spite of persistence of the previous antler A. Antler B was cast off at proper time in 1970.

Fig. 2. Right accreted antlers of the fallow deer *D* from 1968 and 1969.
A — stump of the antler from 1968, B — lower part of the antler from 1969. Both antler were cast together on May 10, 1970.

coronets of the persisting antlers differs from the normal ones by the more distinct decalcification (Fig. 6). The surface of the right coronet shown in Fig. 6 is slightly concave on the periphery and strongly concave and decalcified in the central part as compared with the coronet of the left antler shed at the proper time. The strong bleeding, observed after the delayed shedding of the small antler part indicates that this part could not be kept in place only by the growing velvet. The difference between the experiment in 1969 and 1971 consist in the earlier cutting off of the antlers and on the earlier introduction of strange males in the second experiment. Due to this in the latter case the period of adaptation of the animals to the stress situation was longer. It should be mentioned that in one case, after the abnormal antler cycle in fallow deer A in 1969, in the next year the brown tine of the left antler was branched (Fig. 8).

The third phase of the experiments was carried out to investigate whether the inhibition of antler casting was not caused by: a) development of an inflammatory state caused by the amputation of the antler in non-sterile conditions, with could induce the formation of connective tissue and hence mechanically retard the shedding of antler; b) by the stress evoced by the antlers amputation only; c) The similarity in the

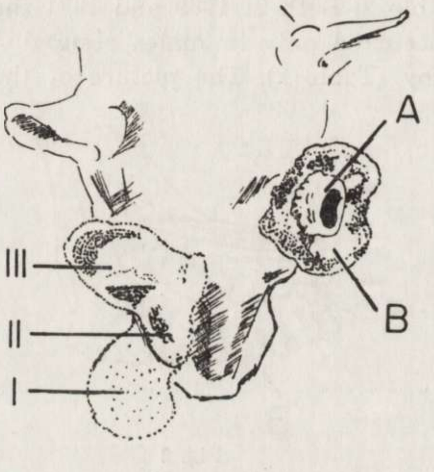

Fig. 3

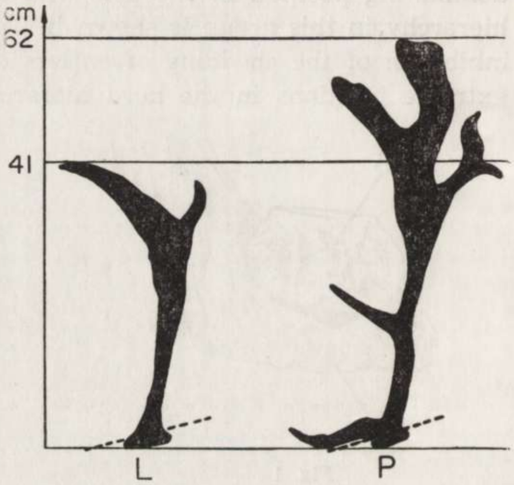

Fig. 4

Fig. 3. View from above of fallow deer *D* dominating in 1971.
A — remaining stump of the left antler from 1970. B — growing left antler in 1971. On the left side there is the right antler: I — brow tine, II — tray tine, III — growing top of the antler (drawing from a photograph taken on June 6, 1971).

Fig. 4. Antlers of fallow deer *D* in 1971.
P — the right antler which grew in spite of a 34-day delay in the shedding of the previous antler. L — the left antler which grew normally. After finishing the experiments the antlers were amputed. The broken line shows the place of cutting. On the left the lenght of the antlers is given in cm.

structure of steroids hormones and therefore the adrenal cortical-hormons may act similary as testosterone and oestrogens on the process of antler shedding. In the present work a non specific factor caused similar results as were reported by G o s s (1968) and J a c z e w s k i & G a ł k a (1970) after injecting oestrogens and testosterone.

Ad a). In two males of fallow deer, experimental inflammation was elicited by injecting in the region of the base of the left antler 0.5 mg of nitrogen mustard (Nitrogranulogen, Polfa, s. 30569) dissolved in 1 ml of NaCl. The injection was made a few days before the expected date of antler shedding. Both fallow deer cast their antlers on the expected day. However, in the next cycle small changes were observed in the growth of antlers, with consisted of softening and droping of the left brow tine (Fig. 7).

Ad b). One male of red deer and one of sika deer were kept on separate enclosures but together with the animals belonging to the other species. Each stag occupyied in this groups the dominanting position.

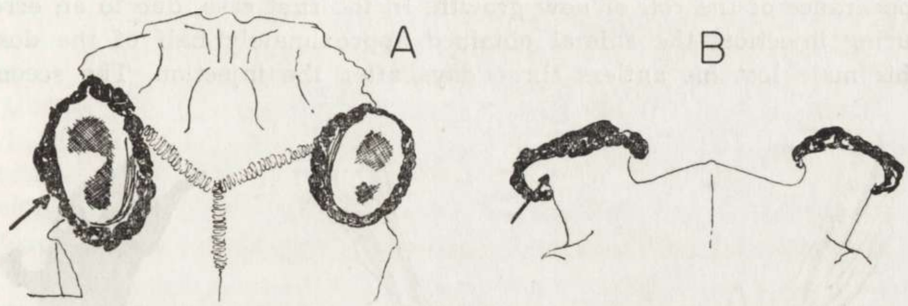

Fig. 5. Skull of the fallow deer buck *A* died on Febr. 2. 71.
A — The arrow indicate the stump of the right antler, on this side the casting off of the antler in 1969 was delayed. The increased burr is visible. B — The arrow indicate the increased circumference of the upper part of the pedicle.

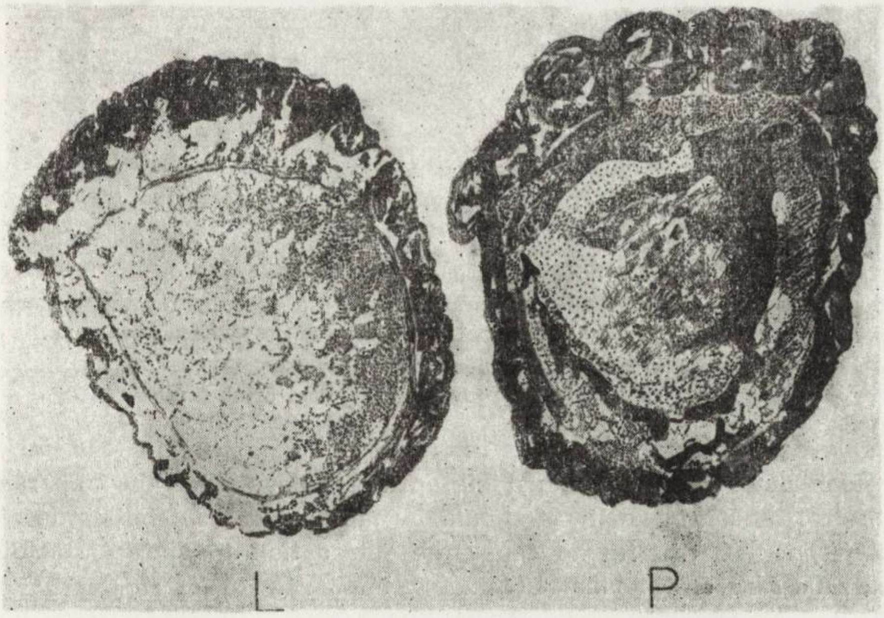

Fig. 6. The basal surfaces (coronet) of the antlers of fallow deer *A*.
L — coronet of the left antler cast on May 1969, convex. P — coronet of the right antler cast on Sept 7. 1969, the calcified surface is more concave in the central part than at the periphery.

Their antlers were cut off some 6 months before the expected date of antlers shedding. In these conditions the amputation did not alter the hierarchy in the group and the antler cycles remaind unchanged also. Similarly, a roe deer buck kept in a pen alone did not show changes in his antler cycle following antler amputation.

Ad c). Two fallow deer bucks were injected with 250 mg of cortisone (Cortison, Continental Pharma, s. 70H03-2) using cap-chur gun after the appearance of the roll of new growth. In the first case, due to an error during injection, the animal obtained approximately half of the dose. This male lost his antlers three days after the injection. The second

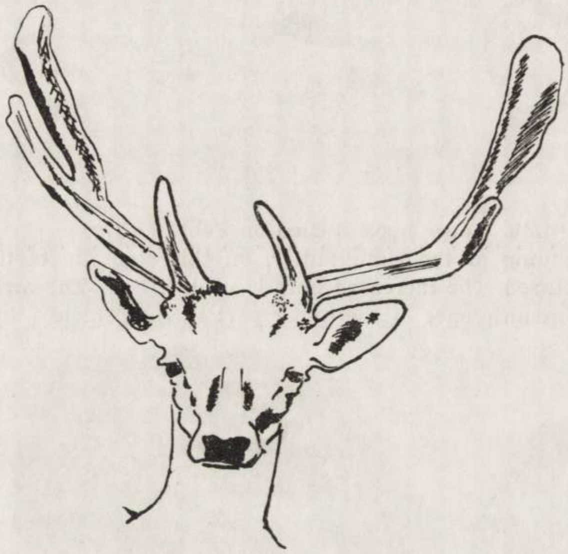

Fig. 7 Fig. 8

Fig. 7. The fallow deer C on August 1970.
Nitrogen mustard was injected unilateraly before the shedding of the antlers of the previous cycle. The left growing antler was the twisted brow tine.

Fig. 8. — Fallow deer buck *A* in Sept. 1970.
Left antler has an additional point on brow tine.

animals was given in two day intervals two injections of 250 mg of cortisone but nevertheless shed his antlers 3 days after the apperance of the roll of new growth. It should by mentioned that similar dose of testosterone is sufficient to cause the retardation in antlers shedding (J a c z e w s k i & G a ł k a, 1970).

IV. RESULTS AND DISCUSSION

Literature concerning the effect of stress on the antler cycle of *Cervidae* is limited to the few references mentioned in the Introduction.

In experimental conditions, only Bubenik (1962, 1966, 1971) observed inhibition of antler growth in a roe deer buck under the effect of fear or injections of cortisone. The experiments described above indicate that stress may also inhibit the process of antlers shedding, the effect being limited in some cases to one side only.

The observations carried out on 4 three-year-old roe deer bucks demonstrated that in conditions devoid of stress, the difference in time between the casting off of both antlers does not exceed 48 hours. This has been also noted by Raesfeld (1970). In an experiment described above the influence of a strong stress was responsible for the increase of the difference between the shedding of the right and the left antler to 14 days (Table 1, No. 1). The separation of a red deer male from the herd and the territory over which he dominated gave a similar result (Table 1, No. 3). The roles of new growth appear usually 1 to 3 days before the casting of antlers and may be regarded as a good indicator of this event. In this experiment the difference increased to 13 days, which indicated an inhibitory effect of stress on casting off of antlers (Table 1, No. 3). Also fear of man caused a delay in the shedding of the antlers (Table 1, Nos 2 and 4).

Some interesting results were obtained in the second phase of the experiments by disturbing the hierarchy in a herd of white fallow deer. This stress caused unilateral inhibition of antler shedding but the growth of the next antlers not was inhibited, although they were characterized by the lack of brow tine. The literature provides several examples of simultaneous occurrence of antlers from consecutive years persisting on the heads of male deer (Linke, 1967; Bubenik, 1966; Raesfeld, 1970). These cases concerned mainly the animals killed during hunting and hence they lack scientific explanation. In the experiments described here it was observed that the growth of an antler from the previous year stump was always slower in the initial phase. This can be explained by the necessity of surrounding the stump by a larger roll of new growth. Hence at the moment when the antler growing normally had already formed the brow tine, the second antler started growing in normal direction from the base. In such situations the brow tine was not formed in these experiments (Fig. 3, Table 2, No. 3). It should be mentioned here that the antler, growing from under the stump had a considerably larger basal surface (coronet) than the antler growing normally. This increased coronet persisted in subsequent years (Fig. 5), although the circumference of the beam was normal. A very similar result was obtained by Wislocki & Waldo (1951) after a delay in antler shedding in Virginia deer caused by injections of testosterone.

The experiments described in the present paper indicate that the abnormal antler cycle caused by stress is often asymetric and asynchronous. This effect is similary to the results of Jaczewski (1961) who observed similar, although smaller differences between the cycle of the right and left antler in deer subjected to operations. The asynchronous cycle of the right and left antler was also observed by Goss (1969) in sika deer kept in artificial rhythm: 12 hours of light and 12 hours of darkness. The causes of this asynchronism and asymmetry are difficult to explain.

The difference between the year 1969 and 1971 in the time of retardation of antlers shedding in a herd of fallow deer (Table 2) is associated with an earlier disturbance of hierarchy in 1971, on account of which the stressor acted 3 months longer. It can be assumed that the longer time of adaptation to the stressor caused a less pronounced changes in the antler cycles in 1971.

The third phase of the experiments indicate that the disturbances of the cycles were not caused by the mechanical process of cutting off of the antlers, but was caused by stress factors arising from the lack of antlers and the impossibility to manifest the social position of the animal. This concerns particulary the individuals occupying the first and last hierarchy positions.

The experiments depending on the action of one particular corticosteroid (11-dehydro-17-hydroxycorticosterone-21-acetic), and the application of the pilot dose only, do not justify the drawing of conclusion as to the effect of cortisone. The obtained negative result confirms the observations of Goss (1963), but these were also based on very limited material. The opposite results were obtained by Bubenik (1962, 1966, 1971). Moreover, the studies of Vogt (1947), Reyel (1952), Hucin (1957), Doutt & Donaldson (1959, 1965) and Bubenik (1972) suggest that corticosteroids play an important role in the regulation of antler cycle. The difference in the obtained results may be related to the fact that these authors employed different species of *Cervidae*. The interspecific differences within *Cervidae* with regard to antler cycle regulation were already stated by Goss (1963), Bubenik (1966) and Jaczewski (1967). Bubenik (1966) in his monograph put forward a hypothesis trying to explained the interspecific differences of hormonal regulation of the antler cycle by differences in phylogenesis. However, at present this hypothesis could not be regarded as proved.

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ZAKŁÓCENIA CYKLU POROŻA JELENIOWATYCH POD WPŁYWEM CZYNNIKÓW STRESSOWYCH

Streszczenie

Przeprowadzone eksperymenty miały na celu wyjaśnienie wpływu stressora na cykliczność poroża jeleniowatych. Do doświadczeń użyto 13 sztuk jeleniowatych, w tym 5 sztuk dwukrotnie. Doświadczenia przeprowadzono w warunkach hodowli zagrodowej. W doświadczeniu nr 1 wykazano, że stressory takie jak: oddzielenie samca od stada lub przeniesienie na inny wybieg spowodowały opóźnienie zrzucenia od 5 do 15 dni (Tabela 1). W doświadczeniu 2 łączono samca z grupą obcych osobników, po obcięciu wszystkim sztukom poroża. Stressorem w tym wypadku był brak możliwości manifestowania swej pozycji stadnej. Zahamowanie zrzucenia następowało u samca dominującgeo i ustępującego, pozostawiając bez zmian cykliczność poroża samców zajmujących wewnętrzne pozycje hierarchiczne (Tabela 2). Działając tym stressorem uzyskano zahamowanie zrzucenia narostków u 4 samców w dwóch powtórzeniach, od 5 dni do całego roku.

W doświadczeniach kontrolnych wykazano, że amputacja poroża, po której nie występowały żadne zmiany hierarchiczne, nie powodowała odchyleń od prawidłowej cykliczności poroża oraz że na odchylenia cykliczności nie miał wpływu mogący się ewentualnie wywiązać stan zapalny w nasadzie narostka.

Przeprowadzone doświadczenia, poza wykazaniem silnego oddziaływania stressora typu psychicznego na cykl poroża u jeleniowatych, wskazały również na zróżnicowanie siły działania stressora w zależności od zajmowanej przez samce pozycji hierarchicznej. Ważnym efektem przeprowadzonych eksperymentów jest również obserwacja wzrostu narostków. Wzrostu, który choć wolniejszy, jednak następował pomimo zahamowania zrzucenia narostka z poprzedniego cyklu, dając w efekcie znaczną niesymetryczność narostków. Niesymetryczność ta wynikała z różnicy w tempie wzrostu narostka normalnego i wyrastającego spod zeszłorocznego kikuta. Wzrost ten po stronie, gdzie nastąpiło zahamowanie zrzucenia był wolniejszy (Ryc. 3) i odbywał się ze zwiększonej podstawy (Ryc. 1. 2). Wzrost z podstawy o zwiększonej średnicy utrzymywał się w następnych latach (Ryc. 5). Widoczne zmiany osteoporotyczne i esteomalacyjne podstawy przetrzymanego narostka wskazują, iż zahamowanie zrzucenia narostka było procesem aktywnym (Ryc. 6).