THE EFFECT OF LATITUDE ON THE SEASONAL PATTERN OF REPRODUCTIVE HORMONES IN THE MALE WHITE-TAILED DEER

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Abstract—1. In order to investigate the effect of latitude on the seasonal variability of reproduction, plasma levels of LH, FSH, Prolactin (PRL) and testosterone (T) were determined in 6 adult male white-tailed deer of Southern Ontario (latitude 42°N) and 6 deer of Southern Texas (27°N).

2. LH peak (around 2 ng/ml) was found in Ontario deer in June; Texas values (almost 3 ng/ml) peaked in November.

3. FSH maxima (110 ng/ml in Ontario and 100 ng/ml in Texas deer) were detected in August (Texas) and September (Ontario).

4. PRL peak (around 90 ng/ml) was observed in Ontario in June. In Texas two peaks were observed; first (around 90 ng/ml) in May, the second one (around 50 ng/ml) in September–October.

5. Testosterone exhibited sharp peaks in both groups; in Ontario in November (13 ng/ml) and in Texas in December (12 ng/ml).

6. Significant differences between Ontario and Texas deer were found between timing of peaks of LH, PRL and T but not of FSH.

INTRODUCTION

Deer species of boreal and temperate regions exhibit a strictly seasonal pattern of reproduction which is accompanied by a corresponding fluctuation of reproductive hormones (Lincoln, 1971; Bubenik *et al.* 1975; Leader-Williams, 1979; Sempere and Boissin, 1981). In contrast, the reproductive pattern of tropical cervids is basically aseasonal (Branan and Marchington, 1987; Blouch, 1987). As the circannual levels of reproductive hormones of tropical species have been investigated only in populations transplanted to temperate zones (Van Mourik *et al.* 1986; Loudon and Curlewis, 1988), it is rather difficult to establish the true effect of latitude on the regulation of reproduction. In addition, comparing reproductive patterns of different cervid species may lead to wrong conclusions.

White-tailed deer (*Odocoileus virginianus*) have the widest geographical distribution of all cervids, reaching from boreal regions of northern Ontario to the tropical areas of southern Peru (Lincoln, 1985). In this species, populations of northern latitudes exhibit a precise synchronization of reproduction with the photoperiodicity. On the other hand, the further south the location of the deer, the more asynchronous is its reproductive pattern (Brokx, 1972; Stuwe, 1985).

In order to establish the role of seasonal fluctuation of male reproductive hormones on the breeding pattern of deer, plasma levels of LH, FSH, Prolactin (PRL) and testosterone (T) has been investigated in two populations of white-tailed deer; one from southern Ontario (Canada), and the other from southern Texas (USA).

MATERIALS AND METHODS

Animals and procedures

Six adult male white-tailed deer of each captive population (University of Guelph Deer Research Station near Cambridge, Ontario, latitude 42°N and Caesar Kleberg Wildlife Research Institute facility in Kingsville, Texas, latitude 27°N) (ranging in age from 3 to 7 yr) were kept year round in individual pens and fed *ad libitum* pelleted deer ration supplemented with hay and browse. Each buck was sampled bi-weekly from the jugular vein using a standard immobilization by Rompun and Ketamine (Bubenik and Smith, 1987). Blood was immediately centrifuged and plasma frozen for later determination of hormones by radioimmunoassays. The specificity, the sensitivity, intra- and interassays variances of all RIA are described in the article published previously (Bubenik *et al.*, 1986).

The length of the rut and the timing of parturition of captive populations of Ontario and Texas has been recorded in both locations.

Statistical analysis

The bi-weekly samples were pooled for monthly means of 12 values ($\pm$ standard error). The months and group (Ontario and Texas populations) factors were statistically evaluated by analysis of variance (ANOVA). The significance of months and group factors was then assessed by the two-tailed Student's *t*-test. Significance of $P < 0.05$ was accepted.

RESULTS

Luteinizing hormone

Significant seasonal variations ($P < 0.05$) were detected in both groups. In the Ontario group, the July peak was higher than any other month but September. In Texas deer the November maximum

Fig. 1. Seasonal levels of LH in 6 Ontario and 6 Texas adult, male white-tailed deer sampled bi-weekly. Each point on the graph is a monthly average of 10–12 samples; vertical bars indicate standard errors. An asterisk indicates significant difference ($P < 0.05$) between populations.

was higher than any other month but December. In addition distinct differences were detected between the populations (Fig. 1). Peak levels of Texas group (reached in November and December) were significantly higher ($P < 0.05$) than corresponding levels of the Ontario group.

Follicle stimulating hormone

Significant seasonal variation has been confirmed in both groups. In Ontario deer the peak FSH values in September are higher ($P < 0.05$) than all other months but August. The August levels are higher than all other months but September and October. In Texas deer the August and September values are higher than all other months but October. October levels are higher than all the rest except of August, September and November. Although the peak in Ontario deer appears to be more concise, there were no differences ($P > 0.05$) in magnitude or timing of peak levels between the two populations (Fig. 2).

Prolactin

Seasonal concentrations of prolactin exhibited surprisingly different patterns in the two groups (Fig. 3). There is a strong seasonal variation ($P < 0.005$) in Ontario deer. In the Ontario group, peak June levels are higher than any other month but May and July. In Texas deer, the peak levels observed in May and June are higher than any other month but July, September, October and November. There is no difference in the timing or magnitude of peak levels in both groups; except of October, significantly higher levels were detected in Texas deer from August to February.

Fig. 2. Seasonal levels of FSH in 6 Ontario and 6 Texas deer.

Testosterone

Of all reproductive hormones investigated in this study, testosterone exhibited the most distinct seasonal pattern ($P < 0.005$) (Fig. 4). Sharp peaks during the rut were detected in November (Texas group) and December (Ontario). In Ontario deer November levels are higher ($P < 0.05$) than any other month but November and December. There was no difference in magnitude of peaks between both groups. Because of large standard error, statistically

Fig. 3. Seasonal levels of prolactin in Ontario and Texas deer.

Fig. 4. Seasonal levels of testosterone in Ontario and Texas deer.

significant differences between monthly levels of both groups were detected only in the October and November.

Timing of the rut and the parturition period

Rutting season was fairly concise in the penned deer of southern Ontario, lasting usually from the middle of November to the middle of December. Parturition in Ontario occurs from the end of May to the middle of July, at the latest. The peak of the rut in Texas occurs usually in December, but rutting can stretch to the end of February. Parturition occurs in Texas mostly in June and July but some fawns were born as late as the beginning of October.

DISCUSSION

Photoperiodicity plays an important role in the regulation of reproduction in deer of temperate and boreal regions (Bubenik *et al.*, 1982; Bubenik, 1986). In most deer species of the tropical zones reproduction is either aseasonal (Stuwe, 1985; Redford, 1987), or if there is a predominant season of parturition, it is assumed to depend largely on climatic conditions (Blouch, 1987; Branen and Marchington, 1987) and not the photoperiodicity (Loudon and Curlew, 1988). In the tropical axis deer (*Axis axis*), bred and raised in southern England, individual testosterone

levels correlated well with the stage of antler development but there was not evidence of a seasonal synchrony within the deer herd (Loudon and Curlew, 1988). On the other hand, testosterone levels of axis deer kept in southern Texas not only correlated with the antler cycle but were also relatively well synchronized within the herd (Bubenik, Brown, Schams, unpublished). The difference between these two herds of axis deer could be due either to variance in the latitude or to the different origin of populations (such as from the north or the south of India) (Loudon and Curlew, 1988).

Another tropical deer, (*Cervus rusa timorensis*) investigated in southern Australia, exhibited a clear seasonality of reproduction (Van Mourik *et al.*, 1986). However, since the parturition period of this cervid is confined to the late fall, it appears that this deer is similar to the axis deer of southern Texas in that climatic selection for the most optimal forage conditions and not the photoperiodicity has been the determining factor of the reproductive synchronization (Branen and Marchington, 1987).

The role of seasonal variations of reproductive hormones in the timing of deer reproduction has been discussed in numerous papers (Bubenik *et al.*, 1982; Samper and Boissin, 1981; Lincoln, 1985). However it has not been conclusively established whether it is the readiness of the female or of the male reproductive system which is responsible for the initiation of the rut or to what extent the seasonal concentrations of male sexual hormones influence the level of fertility. In deer of temperate and boreal regions there appears to be a several months period of absolute infertility (Bubenik, 1971; Mirarchi *et al.*, 1977; Lincoln, 1985). However, in tropical species motile spermatozoa were collected from axis deer during all stages of the antler cycle (Loudon and Curlew, 1988), and the copulation of males with soft antlers (indicating only minimal T levels) resulted in the offspring (Goss, 1963; Chapman and Chapman, 1982).

At present, reports on seasonal levels of reproductive hormones of subtropical and tropical populations of deer are almost non-existent. Our present data could partly help to fill this gap.

FSH

The lack of difference between FSH levels of Ontario and Texas populations (Fig. 2) is not surprising as rising FSH concentrations may initiate spermatogenesis, but declining levels do not necessarily indicate an immediate decrease in fertilization capacity (Bubenik, 1971; Mirarchi *et al.*, 1977; Bubenik *et al.*, 1985a). Seasonal levels of FSH very similar to Ontario and Texas deer were also reported from Virginia (Mirarchi *et al.*, 1978).

LH and T

The statistically significant difference of November and December LH levels between both groups may be also highly significant physiologically. The difference in peak values of LH between both groups may be responsible for the differences in peak values of T and the timing of the rut. Because of a large variation of T levels between individuals of the Texas population, December and January concentrations were

not significantly different from Ontario deer. However, there still may be physiologically significant differences between both populations, as only bucks with high T levels can retain the antlers and keep their dominant social position which enables them to participate in breeding (Lincoln *et al.*, 1970). The individual bucks which maintain high T levels till January–February period may be responsible for the fertilization of those does which give birth in the early fall. In Ontario deer, T levels decline dramatically in December, and the variation between individuals was much smaller in the January–February period. This fact may contribute to the lack of out-of-season parturition in Ontario.

The pattern of seasonal variation of LH and T in Virginia deer appears to be intermediate between Ontario and Texas. LH concentrations peaked in October, and T reached maximum in November, but high T levels were still maintained in December (Mirarchi *et al.*, 1978).

Prolactin

Prolactin levels of both populations were significantly different in the fall and winter period (Fig. 3). This again was not surprising in view of the fact that this hormone is considered to be crucial in mediation of photoperiodically regulated seasonality (Bubenik, 1986; Bubenik *et al.*, 1986; Schams *et al.*, 1986). In cervids, PRL appears to modulate the sensitivity of testes to LH, presumably at the receptor level (Bubenik *et al.*, 1985b; Bubenik, 1986). Reduction of PRL levels by bromocriptine induced an immediate increase of T levels in white-tailed deer (a short day breeder) but a decrease of T in plasma of the roe-deer (a long day breeder) (Bubenik *et al.*, 1985; Schams *et al.*, 1986). These data indicate that the variation of PRL secretion may serve as a "secondary messenger of photoperiodically-dependent seasonality" (Bubenik *et al.*, 1986). Relatively high levels of PRL observed in Texas bucks during the fall months may have slowed down the rise of T and cause a delay in the peak of the rut.

Comparing seasonal levels of PRL in various cervids we have noticed an interesting phenomenon, an apparently negative correlation between latitude and the minimal seasonal concentrations. In white-tailed deer, average PRL levels reached a minimum of around 0.5 ng/ml in southern Ontario (latitude 42°), around 5 ng/ml in Virginia (latitude 37°) (Mirarchi *et al.*, 1978) and around 10 ng/ml in southern Texas (latitude 27°). Similarly, low winter concentrations (less than 1 ng/ml) were detected in roe deer in central Germany (latitude 49°N) (Schams *et al.*, 1986), but in southern France (latitude 46°N) the minimal PRL levels in roe deer were found to be around 4 ng/ml (Sempere *et al.*, 1983). Much higher winter levels of PRL (around 10 ng/ml) were observed in Rusa deer of southern Australia (latitude 38°S) (Van Mourik and Stelmasiak, 1985) and axis deer of southern Texas (around 20 ng/ml) (latitude 27°N) (Bubenik, Brown and Schams, unpublished). As the maximal PRL values, detected invariably during the longest days of May and June differ little (reaching 100–140 ng/ml in all deer species investigated, regardless of latitude) the difference in minimal levels can not be due

to the warmer climate found in lower latitudes. Higher ambient temperature is known to elevate PRL levels (Mills and Robertshaw, 1981) but higher levels of PRL found during the fall in the Texas population can not be attributed to the heat effect because the elevation coincides with the period of noticeable cooling.

Conclusion

Despite some significant differences in timing of seasonality of circannual levels of LH, T and PRL between Ontario and Texas deer, the similarities between peak levels and general trends of all reproductive hormones are quite surprising. In view of these facts it appears to us that the rather large difference in the length of parturition between the deer of Ontario and Texas may not be due as much to the difference in activation and deactivation of the male reproductive system (bucks of both population are fertile for several months) but rather due to the wide variation of the reproductive capability of the female (Bubenik *et al.*, 1985a).

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