Acta vet. scand. 1982, *23*, 107—117.

From the Department of Obstetrics and Gynecology, College of Veterinary Medicine, Hautjärvi, the Division of Reindeer Research, Finnish Game and Fisheries Research Institute, Rovaniemi, and the Department of Physiology, University of Oulu, Oulu, Finland.

# FOETAL GROWTH IN THE REINDEER

By

*K. Roine, M. Nieminen* and *J. Timisjärvi*

ROINE, K., M. NIEMINEN and J. TIMISJÄRVI: *Foetal growth in the reindeer.* Acta vet. scand. 1982, *23*, 107—117. — In connection with reindeer slaughter 348 foetuses were collected at different foetal developmental stages and studied together with 20 full-term newborn calves with respect to weight, crown-rump length, metacarpal bone length and appearance of ossification foci. On the basis of these measurements polynomial growth curves were constructed. Weight gain was most rapid during the last trimester of gestation, but total and metacarpal bone length gain showed only minor acceleration towards the end of pregnancy. Ossification was apparent at an age of about 6 weeks. Undernutrition during late winter was observed to retard the foetal growth.

b o d y w e i g h t; f o e t u s; c r o w n-r u m p l e n g t h; m e t a-
c a r p u s; o s s i f i c a t i o n; p r e g n a n c y; s e a s o n s.

In the scope of biological investigations the reindeer is regarded rather as a wild ruminant, but on the other hand it is also subject to economic activities. Hence, it is difficult to obtain an adequate series of samples for investigative purposes, especially if the foetal growth is being considered. The only possibility is to sample at commercial slaughter of the animals. Nevertheless, some descriptions of foetal weight and length gain have been published (*Gavrilova* 1973, *Dauphine & McClure* 1974, *Krog et al.* 1980). Ossification in the bovine foetus has been found to correlate well with foetal age (*Winters et al.* 1942, *Gjesdal* 1969) and has been studied also in the reindeer (*Gavrilova*). In the present paper, the foetal weight and length gain as well as the metacarpal growth of the reindeer foetus were investigated and on the basis of the actual measurements some growth curves were constructed by computer calculation. The onset of ossification was also noted.

## MATERIAL AND METHODS

Altogether 348 excised foetuses were collected from slaughtered reindeer hinds (Rangifer tarandus tarandus L.) during 3 winters within the Finnish reindeer rearing area (Fig. 1). The time of sampling, the estimated mean age of the foetuses studied and the depth of the snow cover are given in Table 1 and Fig. 1, respectively. The estimates of the foetal age are based on observations made on the mating season of the reindeer (*Roine* 1974). The material also included 20 full-term newborn reindeer calves.

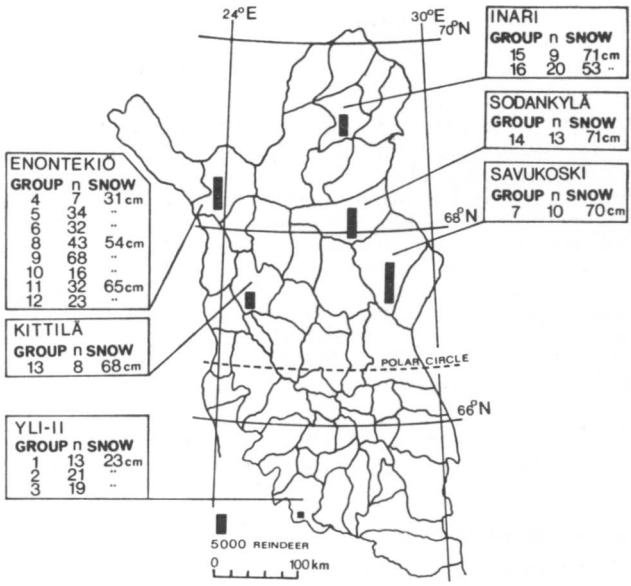


Figure 1. Map of the Finnish reindeer rearing area. Sites of sampling are indicated by the names of the parishes, under which are given the group numbers, numbers of the animals in the given group and also the depth of the snow at the time of sampling. The black bars indicate the estimated total number of reindeer in the given area.

In foetuses measuring less than 10 cm, the crown-rump length was recorded with a precision of 1 mm, and in the larger specimens in an identical manner with a precision of 1 cm, avoiding stretching of the foetuses. Thereafter weighing was performed on ordinary laboratory scales with a precision of 1 g. The full-term newborn calves were measured as the larger foetuses and weighed with a precision of 100 g.

After measurement of the length and weight, the foetuses were frozen and cut in the median plane into 2 symmetrical halves. X-ray filming was done with the section surface against the casette. The length of the metacarpal bone was measured to the nearest 1 mm. Measurements were taken from both halves of the foetuses and the results given as the mean of the two.

The appearance of ossification foci was studied by staining the foetuses (length less than 10 cm) with Alizarin Red S solution (*Hafez & Rajakoski* 1964). Before staining, the foetuses were fixed in 10 % formalin and cleared in 2 % KOH solution.

The function fittings used were obtained from least square solutions calculated from the actual group mean values with a computer (PDP 11). In this respect the foetal age was calculated as days and the estimate was based on October 10 as a conception time. This age estimate is used in the figures.

## RESULTS

Reliable measurements of the length of the foetus could be made at an age of about 1 month. The length increased rapidly from about 6 mm up to 613 mm (Table 1) in a curvilinear manner (Fig. 2). A downward deviation from the calculated growth

Table 1. Foetal growth in reindeer estimated from Finnish slaughterhouse samples.

| Group | Sampling date | Estimated age (weeks) | n | Foetal weight (g) ($\bar{x} \pm s$) | n | Foetal length (mm) ($\bar{x} \pm s$) | n | Metacarpus length (mm) ($\bar{x} \pm s$) |
|---|---|---|---|---|---|---|---|---|
| 1 | 6.11.1969 | 4 | | | 13 | 6.5 ± 1.6 | | |
| 2 | 12.11.1969 | 5 | | | 21 | 11.0 ± 3.7 | | |
| 3 | 24.11.1969 | 6 | | | 19 | 22.8 ± 5.8 | | |
| 4 | 3.12.1969 | 8 | 7 | 13.3 ± 7.7 | 7 | 68.3 ± 11.5 | 6 | 2.5 ± 1.1 |
| 5 | 11.12.1970 | 9 | 34 | 20.9 ± 8.5 | 34 | 78.7 ± 12.3 | 34 | 3.6 ± 1.2 |
| 6 | 16.12.1970 | 10 | 32 | 24.8 ± 9.6 | 32 | 82.3 ± 12.4 | 32 | 4.2 ± 1.3 |
| 7 | 31.12.1970 | 12 | 10 | 95.3 ± 34.6 | 10 | 133.7 ± 19.2 | 10 | 11.7 ± 2.5 |
| 8 | 11.1.1971 | 13 | 43 | 130.9 ± 40.9 | 43 | 150.0 ± 18.4 | 40 | 13.4 ± 2.8 |
| 9 | 16.1.1971 | 14 | 68 | 251.4 ± 94.7 | 68 | 181.8 ± 25.4 | 68 | 18.8 ± 4.6 |
| 10 | 31.1.1971 | 16 | 16 | 409.1 ± 113.9 | 16 | 213.1 ± 21.2 | 16 | 25.1 ± 4.0 |
| 11 | 12.2.1971 | 18 | 32 | 613.6 ± 210.6 | 32 | 242.5 ± 28.5 | 32 | 30.3 ± 5.4 |
| 12 | 27.2.1970 | 20 | 23 | 952.6 ± 242.4 | 23 | 287.0 ± 26.6 | 23 | 40.2 ± 6.2 |
| 13 | 3.3.1970 | 21 | 8 | 1117.5 ± 161.6 | 8 | 308.8 ± 11.3 | 8 | 43.4 ± 3.2 |
| 14 | 13.3.1970 | 22 | 13 | 1267.3 ± 175.9 | 13 | 326.9 ± 16.0 | 13 | 49.5 ± 4.5 |
| 15 | 2.4.1970 | 25 | 9 | 1517.8 ± 506.7 | 9 | 341.1 ± 48.1 | 9 | 58.4 ± 12.9 |
| 16 | 10.5.1977 | 31 | 20 | 5345.0 ± 880.5 | 2 | 613.5 ± 52.4 | 2 | 104.9 ± 20.4 |

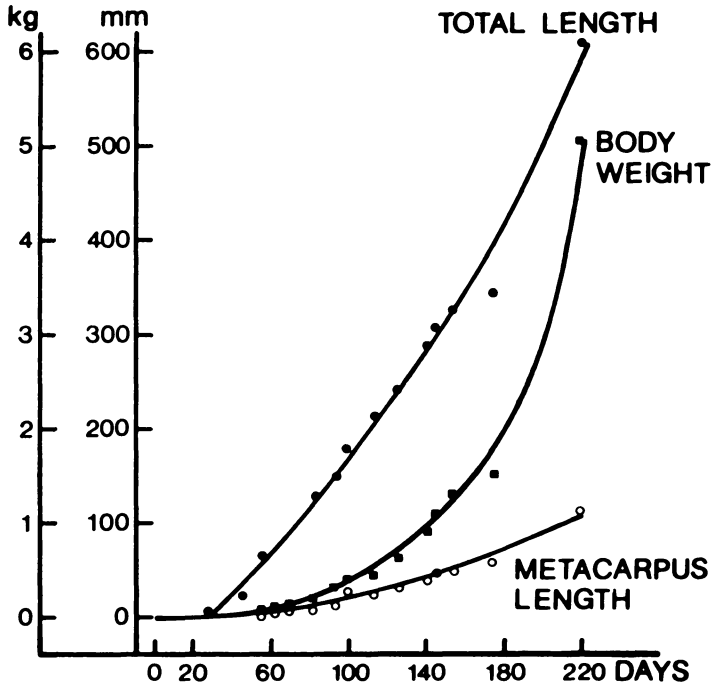


Figure 2. The total length, body weight and metacarpal bone length of the reindeer foetus as plotted against the age of the foetus. The age is estimated as days with October 10th as a zero point. Curves are least square solutions based on actual mean values of the given groups. 2 polynoms are fitted for body weight, namely between days 0 and 67 and between days 82 and 220. The equations are: Body weight (0 to 67) = $-0.00036x^3 + 0.053x^2 - 1.58x - 0.000096$; R = 0.9999, F = 2500; Body weight (82 to 220) = $0.000065x^4 - 0.035x^3 + 6.8x^2 - 567.6x + 17029.9$; R = 9986, F = 3387; Total length (27 to 220) = $0.00000178x^4 - 0.000797x^3 + 0.122x^2 - 4.83x + 64.7$; R = 0.9978, F = 2422; Metacarpus length (27 to 220) = $0.000000316x^4 - 0.000162x^3 + 0.031x^2 - 2.09x + 47.69$; R = 0.9992, F = 4823.

curve was noted at the point of 25 weeks (about 5½ months) (Fig. 2). The growth rate accelerated steadily during the whole gestation period when represented mathematically by the first order time derivative of the growth curve (Fig. 3). The second order time derivative of the growth curve was rather constant.

Reliable records of total body weight of the foetus could be made at an age of about 8 weeks. The total body weight increased from 13 g up to 1500 g during the subsequent 4 months (Table 1, Fig. 2) whereafter it tripled and was about 5300 g at birth. A

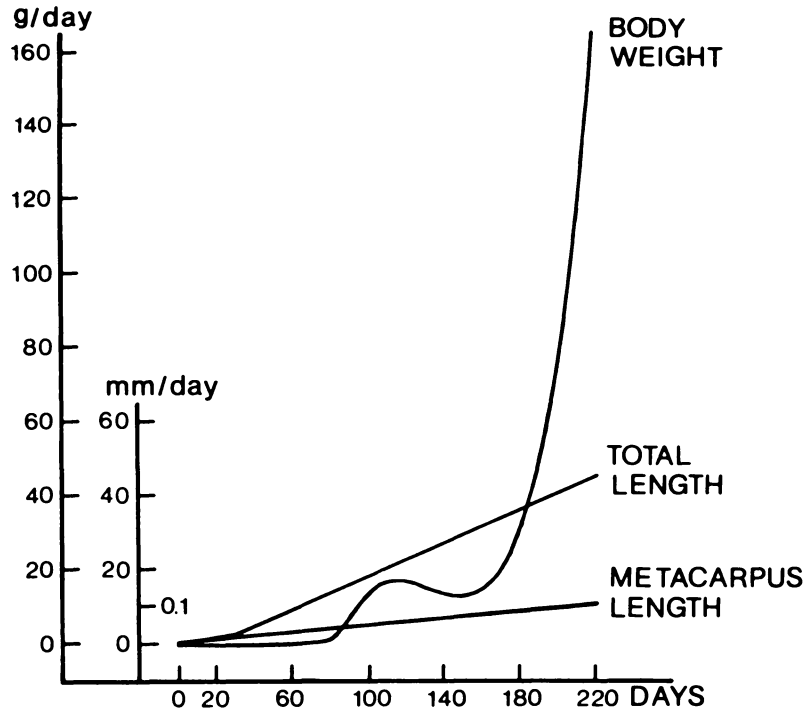


Figure 3. First order time derivates of the curves represented in Fig. 2. The curves indicate the daily weight and length gain. The equations are calculated for the same time domains as in Fig. 2. The equations are: body weight (0 to 67) = $-0.0011x^2 + 0.106x - 1.58$; body weight (82 to 220) = $0.00026x^3 - 0.105x^2 + 13.6x - 567.6$; total length (27 to 220) = $0.00000712x^3 - 0.00239x^2 + 0.244x - 4.83$; Metacarpus length (27 to 220) = $0.00000126x^3 - 0.000486x^2 + 0.062x - 2.09$.

downward deviation from the calculated growth curve was observed at an age of about 25 weeks. The first order time derivative of the growth curve showed an initial increase in the daily weight gain followed by a decrease. During the last 2 months of gestation the daily weight gain increased rapidly (Fig. 3). When plotted against the total body length the body weight showed a curvilinear increase (Fig. 4).

The metacarpal bone was discernible at an age of ca. 7 weeks. At an age of 8 weeks the length of the metacarpus was about 2.5 mm. At birth it was on average 104 mm (Table 1, Fig. 2). The growth was curvilinear (Fig. 2). The first order time derivative showed a steady increase in growth rate (Fig. 3) and the second one was constant. In actual measurements a slight devia-

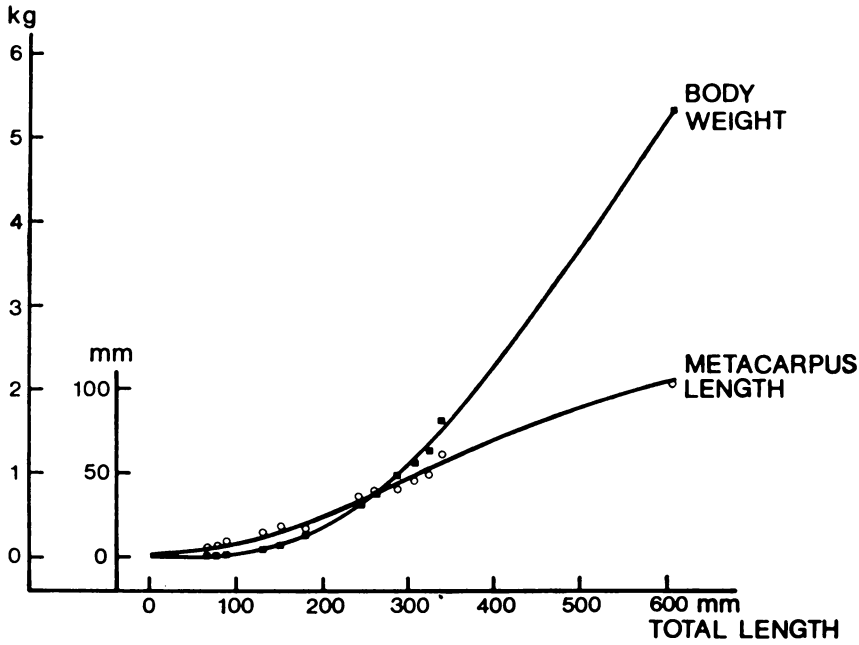


Figure 4. Body weight and metacarpal bone length as plotted against total length of the foetus. Equations are: Body weight (27 to 220 days) = $-0.000000037x^4 + 0.000035x^3 + 0.009x^2 - 1.54x + 69$; R = 0.9998, F = 31400; Metacarpus length (27 to 220 days) = $0.000014x^4 - 0.0019x^3 + 0.035x^2 + 6.63x + 53.9$; R = 0.9997, F = 12900.

tion downward from the calculated curve was observed at an age of 25 weeks (Fig. 2). If plotted against the total body length the length of the metacarpal bone showed a slightly sigmoid curve (Fig. 4).

Ossification began when the foetus had reached a crown-rump length of about 40 mm (age about 6 weeks). The first bones to ossify were those of the skull, thoracal and cervical vertebrae, scapulae and ribs. Ossification of humerus, radius and ulna began some days later, that of metacarpus at an age of 7 weeks and phalanges 2—3 weeks later. Carpus ossified at an age of 5 months (CRL 32—35 cm). Ossification of femur and tibia began at an age of 7 weeks, that of metacarpus appr. at the same time and phalanges 2—3 weeks later. Calcaneus ossified at an age of 3 months and tarsus 6—8 weeks later. As a whole, it seemed that the ossification processes of the fore limbs preceded the corresponding events of the hind limbs. Length growth was relatively uniform in the bones of the extremities. Figs. 5 and 6 give x-ray views of reindeer foetuses.

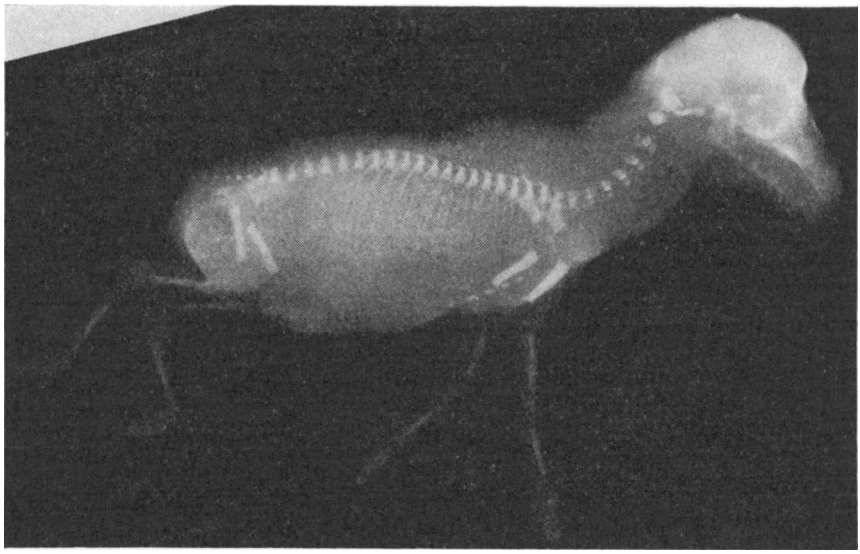

Figure 5. An X-ray view of a reindeer foetus, estimated age about 10 weeks.

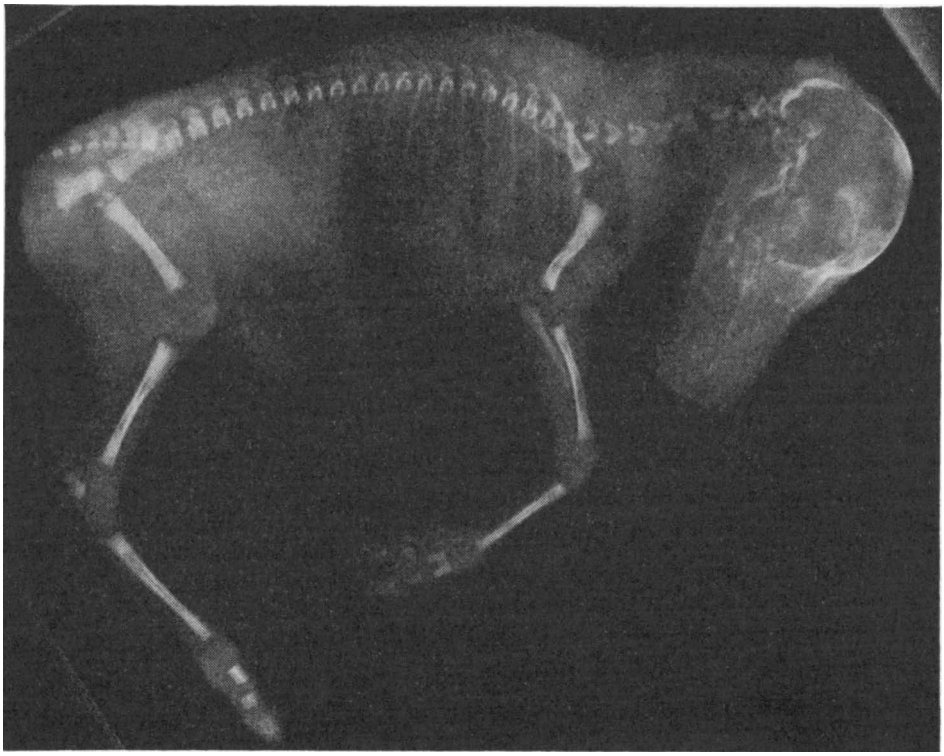

Figure 6. An X-ray view of a reindeer foetus, estimated age about 3½ months. Sternum has been sectioned away during the preparation process.

## DISCUSSION

The reindeer breeding season begins in September and October and by mid-October over 90 % of the hinds have ovulated (*Roine* 1974). Under favorable conditions the conception rate is 90—95 % (*Skjenneberg & Slagsvold* 1968). The gestation period lasts about 220 days (*Varo* 1964, *Dott & Utsi* 1973). Parturition commences in mid-May (*Espmark 1971, Nieminen et al.* 1978, 1980a) and hence, pregnancy in the reindeer occurs in winter.

The allantochorion reaches the ends of both uterine horns in about the 5th week of gestation and in the 6th week there exist clear signs of placental attachement (*Roine*). In the white-tailed deer (Odocoileus virginianus) placentation begins at a foetal length of 4—13 mm (*Sinha et al.* 1969) and in the moose (Alces alces) when foetal length is about 20 mm (*Markgren* 1969). Implantation is reported to be delayed in the roe deer (Capreolus capreolus) (*Bischoff* 1854). In this species the blastocyst is said to be in a state of diapause from August until the end of December (*Aitken* 1974, *Sempere* 1977).

In the present study, the mean foetal length was about 6—7 mm in the early November, and if the majority of hinds had conceived by October 10th, the average age of the foetus was about 1 month. The corresponding foetal length in the white-tailed deer (*Cheatum & Morton* 1946) and moose (*Markgren*) is slightly greater (8 and 7—9 mm, respectively). During the second month of gestation the foetal length of the reindeer increased tenfold. The weight of the reindeer foetus increased slowly in December and early January but thereafter (foetal age about 3 months) the weight gain was more marked and rather curvilinear up to early April, as observed also by *Krog et al.* (1980), and in the white-tailed deer by *Verme* (1963). The weight gain showed a rapid acceleration during the last months of gestation when the weight increased from about 1.5—2 kg to the birth weight of about 5 kg, but the length gain at the same time showed a linear increase (Fig. 3). This increase in the reindeer growth rate is observed also by *Gavrilova* (1973) and *Krog et al.*.

Ossification begins more or less simultaneously throughout the forthcoming large bones at an age of 6 weeks but 4—16 weeks later in the forthcoming smaller ones. Ossification is rather uniform in both fore- and hindlegs although it begins slightly earlier in the forelegs. In the white-tailed deer ossification begins at an age of 2 months and the skeleton will be complete within 4 months (*Short* 1970), while in cattle the ossification foci become

x-ray positive about a week earlier (*Gjesdal* 1969). The sequence of ossification is similar in these 3 species.

The nutritional requirements of the developing foetus are reflected in the hind's energy balance and result in an increased total food intake (*Moustgaard* 1959). At first, the demand for nutrients is rather small but increases progressively towards the end of the gestation (*Maynard & Loosli* 1962). In the reindeer, the growing foetus, when it triples its weight during the last 6 weeks of gestation, can increase the hind's energy demand by only 15 % (*McEwan* 1970, *McEwan & Whitehead* 1971, *Roine* 1974, *Nieminen* 1980). According to *Preobrazhenskii* (1961) the reindeer hind uses only 30 kg of additional lichen for the growth and development of her foetus.

Although the reports on the relation between nutritional conditions and duration of gestation are contradictory (*Thomson & Thomson* 1949, *Verme* 1965, *Forbes* 1967) it seems that undernutrition will retard the foetal growth and increase perinatal mortality (*Thomson & Thomson* 1949). If the reindeer is taken into consideration, the nutritionally critical time is the snow-covered period, especially the late winter since the availability of food is limited by the deep and encrusted snow. Although the reindeer has good adaptive mechanisms and metabolism is adjusted to a lower level (*Klein* 1970, *Nieminen et al.* 1977) the present results suggest a slightly retarted foetal growth at this time as judged from the first order time derivatives of the growth curve.

Calving commences usually in late April and reaches its peak in mid-May (*Espmark* 1971, *Nieminen et al.* 1978). The newborn calf is well developed, can walk and begins to suck about ½ h after birth. Its thermoregulation (*Nieminen et al.* 1980b) and cardiovascular system (*Hirvonen et al.* 1979) are well developed. The growth is rapid (*Nieminen et al.* 1980a), and under favorable conditions the calves may reach sexual maturity at an age of 6 months (*Roine* 1974).

## REFERENCES

*Aitken, R. J.:* Delayed implantation in the roe deer (Capreolus capreolus). J. Reprod. Fert. 1974, *39*, 225—233.

*Bischoff, T. L. M.:* Entwicklungsgeschichte des Rehes. (Development of the roe deer). J. Ricker's Buchhandlung. Giesen 1854.

*Cheatum, E. L. & G. H. Morton:* Breeding season of white-tailed deer in New York. J. Wildl. Manage. 1946, *10*, 249—263.

*Dauphine, T. C. & P. L. McClure:* Synchronous mating in Canadian barren-ground caribou. J. Wildl. Manage. 1974, *38*, 54—66.

*Dott, H. M. & M. N. P. Utsi:* Artificial insemination of reindeer (Rangifer tarandus). J. Zool. (Lond.) 1973, *170*, 505—508.

*Espmark, Y.:* Mother-young relationship and ontogeny of behavious in reindeer (Rangifer tarandus L.). Z. Tierpsychol. 1971, *29*, 42—81.

*Forbes, J. M.:* Factors affecting gestation length in sheep. J. agr. Sci. 1967, *68*, 191—194.

*Gavrilova, A. V.:* Rost i razvitie telosloženija severnogo olenja v plodnyj period. (Growth and development of the reindeer in foetal period). Sbornik naucnyh rabot. Vypusk 2. Murmanskoe Knižnoe Izdatelstvo 1973, 3—9.

*Gjesdal, F.:* Age determination of bovine foetuses. Acta vet. scand. 1969, *10*, 197—218.

*Hafez, E. S. E. & E. Rajakoski:* Placental and fetal development during multiple bovine pregnancy. Anatomical and physiological studies. Anat. Rec. 1964, *150*, 303—316.

*Hirvonen, L., J. Timisjärvi & T. Peltonen:* Observations on circulatory adjustment in newborn reindeer and elk. Med. Biol. 1979, *57*, 352—356.

*Klein, D. R.:* Tundra ranges north of the boreal forest. J. Range Manage. 1970, *23*, 8—14.

*Krog, J., M. Wika & P. Savalov:* The development of the foetus of the Norwegian reindeer. Proc. 2nd Int. Reindeer/Caribou Symp. Røros 1980, pp. 306—310.

*Markgren, G.:* Reproduction of moose in Sweden. Viltrevy — Swedish Wildlife 1969, *6*, 125—299.

*Maynard, L. A. & J. K. Loosli:* Animal Nutrition. McGraw-Hill Co., New York 1962, 533 pp.

*McEwan, E. H.:* Energy metabolism of barren ground caribou (Rangifer tarandus). Canad. J. Zool. 1970, *48*, 391—392.

*McEwan, E. H. & P. E. Whitehead:* Measurement of the milk intake of reindeer and caribou calves using tritiated water. Canad. J. Zool. 1971, *49*, 443—447.

*Moustgaard, J.:* Nutrition and reproduction in domestic animals. *In:* Eds. Cole, H. H. & P. T. Cupps: Reproduction in Domestic Animals. Vol. 2. Academic Press 1959.

*Nieminen, M.:* Nutritional and seasonal effects on the blood haematology and chemistry in reindeer (Rangifer tarandus tarandus L.) Comp. Biochem. Physiol. 1980, *66*, 399—414.

*Nieminen, M., P. Väyrynen & R. Väyrynen:* Poron ravitsemusfysiologiasta. (Nutritional physiology of reindeer). Suomen Luonto 1977, *36*, 98—101.

*Nieminen, M., J. Timisjärvi & E. Saari:* Poron vasonta ja vasakuolemat. IV. Vasonta Kaamasen koetokassa. (Calving and neonatal mortality in the reindeer. IV. Calving among the experimental herd in Kaamanen). Poromies 1978, *6*, 12—17.

*Nieminen, M., M. Koskela, M. Leinonen & J. Timisjärvi:* Electrophoretical studies on serum proteins in growing and fully-grown reindeer (Rangifer tarandus tarandus L.). Comp. Biochem. Physiol. 1980a, *65*B, 35—44.

*Nieminen, M., J. Timisjärvi, V. Ojutkangas & R. Hissa:* Annual blood catecholamine, thyroxine, lipid and glucose levels in growing and fully-grown reindeer. Proc. 28. Int. Congr. Physiol. 1980b, pp. 345—348.

*Preobrazhenskii, B. V.:* Management and breeding of reindeer. Ed. P. S. Zhigunov. Reindeer Husbandry. Moskva 1961, p. 78—128.

*Roine, K.:* Studies on Reproduction in Female Reindeer. Helsinki 1974, 55 pp.

*Sempere, A.:* Plasma progesterone levels in the roe deer, Capreolus capreolus. J. Reprod. Fert. 1977, *50*, 365—366.

*Short, C.:* Morphological development and aging of mule and white-tailed deer fetuses. J. Wildl. Manage. 1970, *34*, 383—388.

*Sinha, A. A., U. S. Seal, A. W. Erickson & H. W. Mossman:* Morphogenesis of the fetal membranes of the white-tailed deer. Amer. J. Anat. 1969, *126*, 201—242.

*Skjenneberg, S. & L. Slagsvold:* Reindriften och dens naturgrunnlag. (Reindeer Husbandry and Its Ecological Principles). Universitetsforlaget, Oslo 1968, 317 pp.

*Thomson, A. M. & W. Thomson:* Lambing in relation to the diet of the pregnant ewe. Brit. J. Nutr. 1949, *2*, 290—305.

*Varo, M.:* Tutkimuksia poron jalostusmahdollisuuksista. (Studies on possibilities to refine the reindeer). Ann. Agric. Fenn. 1964, *3*, 296—310.

*Verme, L. J.:* Effect of nutrition on growth of white-tailed deer fawns. Transactions of the 28th North American Wildlife and Natural Resources Conference, March 4—6, 1963.

*Verme, L. J.:* Reproductive studies in penned white-tailed deer. J. Wildl. Manage. 1965, *29*, 74—79.

*Winters, L. M., G. W. Green & R. E. Comstock:* Prenatal development of the bovine. Univ. Minn. Agric. exp. Sta. Techn. Bull. 1942, No. 151.

## SAMMANFATTNING

*Den fetale tillväxten hos ren.*

I samband med renslaktning tillvaratogs 348 foster från olika perioder och undersöktes samtidigt med 20 fullgångna nyfödda kalvar. Man mätte vikten, längden av bålen från stuss till krona samt förekomsten av ossifikationsfoci. På basen av dessa mätningar beräknades polynomväxtkurvor. Viktökningen var snabbast under den sista tredjedelen av dräktighetstiden. Däremot visade den totala och metakarpala tillväxten av längden av benstommens ben endast mindre ökning mot slutet av dräktighetstiden. Ossifikation kunde konstateras vid en ålder av 6 veckor. Undernäring i en sen period av vintern konstaterades verka retarderande på fostrets tillväxt.

*(Received January 11, 1982).*

Reprints may be requested from: J. Timisjärvi, the Dept. of Physiology, University of Oulu, Kajaanintie 52 A, SF-90220 Oulu 22, Finland.