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Nitrogen content in feces and the diet of Sika deer on the Boso Peninsula, central Japan

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Fecal and rumen nitrogen content of Sika deer (*Cervus nippon* Temminck 1838) on the Boso Peninsula, central Japan, were analyzed concerning their seasonal fluctuations and local differences at four areas on the Boso Peninsula. The mean fecal nitrogen was high in August and low in February in all the areas. The seasonal variation, however, was relatively small. This may be the result of the following reasons: the Boso deer feed on evergreen broad-leaves containing a high and stable nitrogen content in winter; little snow falls there; and the deer consume foods relatively low in nitrogen in summer. The fecal and rumen nitrogen content in both summer and winter depended on deer density.

Key words: *Cervus nippon*; density-dependent limitation; fecal nitrogen; rumen nitrogen; seasonal fluctuation.

INTRODUCTION

Protein is the most important nutrient for animals. In ungulates, the protein content in diets affects growth pattern (Wood *et al*. 1962; Kay 1985) and seasonal fluctuations in body weight (Gate & Hudson 1981; Leader-Williams 1988), and it varies among regions even within the same species (Johns *et al*. 1984; Mayer *et al*. 1984). The habitat of Sika deer (*Cervus nippon* Temminck 1838) ranges widely from the sub-cold coniferous forests of 50°N to the subtropical evergreen broad-leaved forests of 14°N (Ohtaishi 1986; Whitehead 1993). The dietary habits of the Sika deer in the evergreen broad-leaved forest zone of the Boso Peninsula differ from those in the northern deciduous broad-leaved forest zone: the Sika deer on Boso consume evergreen leaves in winter (Asada & Ochiai 1996), while in northern regions they consume mainly graminoids (Takatsuki 1991). Accordingly, it has been suggested that the seasonal fluctuation in food availability on the Boso Peninsula is less pronounced than that in the northern deciduous forests (Asada & Ochiai 1996). Here, we provide seasonally analytical data on the dietary protein content of deer in the evergreen broad-leaved forest zone of the Boso Peninsula.

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METHODS

Study area

The Boso Peninsula is located in Chiba Prefecture in central Japan (35°N, 140°E; Fig. 1). The elevation ranges from 0 m to about 300 m a.s.l., and the topography is very steep. The study area included the Tokyo University Forest in Chiba, which lies at the centre of the deer distribution. The annual precipitation is 2000–2400 mm, and the mean monthly temperature is about 4°C in mid-winter and 25°C in mid-summer (University of Tokyo 1988). The vegetation is characterised by the evergreen broad-leaved forests (*Machilus thunbergii*, *Castanopsis sieboldii* and the planted *Lithocarpus edulis*), natural coniferous forests (*Abies firma* and *Tsuga sieboldii*) and the plantations of conifers (*Cryptomeria japonica* and *Chamaecyparis obtusa*).

The study area was divided into four parts according to deer density: high density (21.9–26.5 deer/km^2; K. Ochiai & M. Asada, unpubl. data) in the Amatsukominato Area (AT): medium density in the Kamogawa area (KG) and the Katsuura area (KU; 14.1–17.7 deer/km^2 and 17.5 deer/km^2,

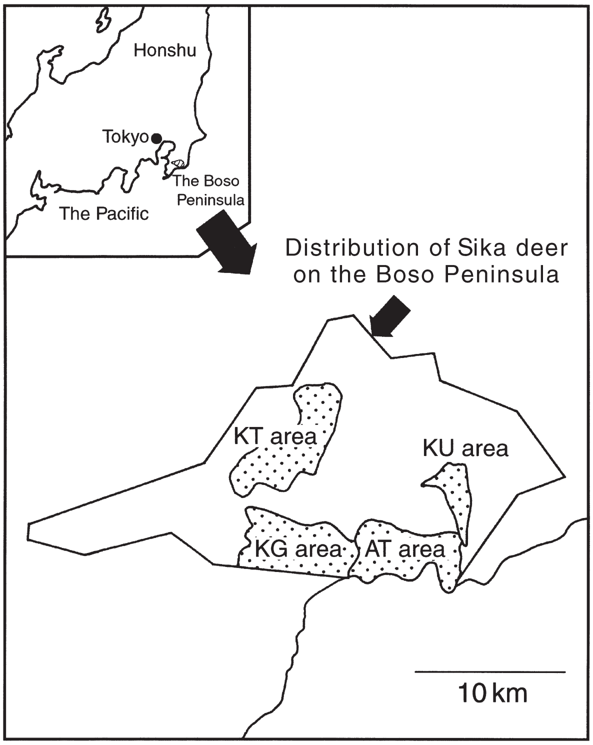

Fig. 1. Study area: KT, Kimitsu area; KU, Katsuura area; KG, Kamogawa area; AT, Amatsukominato area.

respectively): low density in the Kimitsu area (KT; 4.7–14.7 deer/km^2, Fig. 1).

Materials and methods

The nitrogen contents of a food have been generally used as an index of its protein contents because proteins contain 16% nitrogen (ranging from 15.7% to 18.9%, Robbins 1993). The nitrogen content multiplied by 6.25 (100/16) is termed the crude protein content. In order to estimate the dietary quality, besides rumen nitrogen content (RN; Klein & Schonheyder 1970; Staines & Crisp 1978), fecal nitrogen content (FN) has also been used (Lancaster 1949; Holechek *et al*. 1982; Leslie & Starkey 1985). The former can estimate the nutrient content of the diet directly, and analyze the quality of the whole rumen contents, and of each food item as well. Its disadvantage, however, lies in the difficulties associated with collecting sufficient samples. In contrast, the latter has the advantage of no need to kill animals, and has a lower sample variance than rumen sampling (Holechek *et al*. 1982). Both methods were used in this study.

Fecal samples, which consisted of more than 10 pellets per pellet group, were collected from more than 10 pellet groups in a 1 km-long line transect placed in each area in August 1994 and February 1995. Several fecal samples were included in the AT and the KT areas, which were collected in August 1993 and February 1994 as a preliminary investigation. Each fecal sample was dried at 70°C for 48 h and then ground with a mill.

We collected approximately 500 ml of rumen contents from each deer culled for pest control in the study area in August and October 1993, February 1995 and 1997, and March 1997. Each rumen sample was washed on a sieve with 5 mm openings and divided into two subsamples for nutritional analysis of the whole contents and each main food item. Each main food item was sorted out (evergreen broad-leaves, deciduous broad-leaves, graminoids and acorns). These samples were dried and ground in the same way as the fecal samples.

Nitrogen levels in the dry matter percentage of the fecal and rumen samples were estimated using the NC Analyzer (Sumitomo Chemical Co., Tokyo, Japan).

RESULTS

The FN was higher in August than in February in all areas (Table 1, $U = 2672.0$, $P < 0.001$). The FN differed among areas (Kruskal–Wallis test, $P < 0.001$): in summer, FN in the KU area was highest and FN in the AT area was lowest. In winter, that in the KT area was highest and that in the AT area was again lowest (the Kruskal–Wallis test, $P < 0.001$). There was an inverse correlation between deer density and fecal nitrogen contents in August (Fig. 2, $R^2 = 0.360$, $n = 41$, $P < 0.001$) and February ($R^2 = 0.505$, $n = 53$, $P < 0.001$).

The mean nitrogen level of the RN was 1.67% (SD = 0.21) in August, significantly higher than in October when it was 0.71% (SD = 0.08) ($U = 144.0$, $P < 0.001$, Fig. 3). In February, RN significantly increased to 1.34% ($U = 1155.5$, $P <$ 0.001). Between February and March, there was a significant increase ($U = 259.0$, $P < 0.01$). The

Table 1 Fecal nitrogen contents of Sika deer on Boso peninsula, central Japan

Year	Month	Area†	Deer density	n	Fecal nitrogen % Mean	SD
1993	August*	KT	8.4	4	3.19	0.23
1994	February*	AT	21.9	7	1.65	0.22
1994	February*	KT	14.7	5	2.34	0.25
1994	August	AT	21.9	14	2.46	0.25
1994	August	KG	17.7	13	2.49	0.30
1994	August	KU	ND‡	10	3.10	0.38
1994	August	KT	14.7	10	2.90	0.38
1995	February	AT	26.5	10	1.86	0.23
1995	February	KG	17.6	11	2.14	0.19
1995	February	KU	17.5	10	2.10	0.32
1995	February	KT	4.7	10	2.66	0.36

*Data from the preliminary sampling. †KT, Kimitsu area; AT, Amatsukominato area; KU, Katsuura area; KG, Kamogawa area. ‡No data.

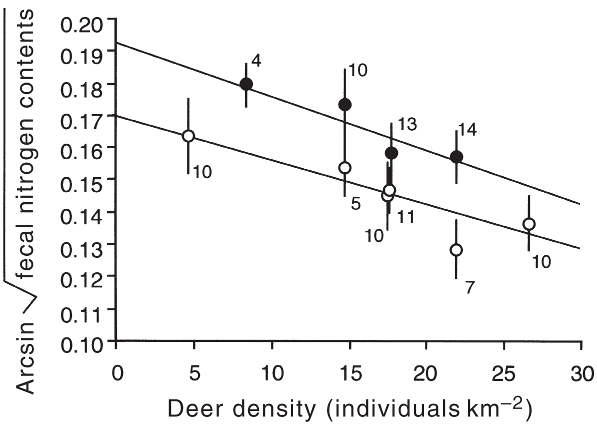

Fig. 2. Regression of fecal nitrogen contents in August (●, y = 0.19–0.0017x, $n = 41$, $R^2 = 0.360$, $P < 0.001$) and February (○, y = 0.17–0.0014x, $n = 53$, $R^2 = 0.505$, $P < 0.001$) on deer density on the Boso Peninsula, central Japan. The nitrogen content of each fecal sample is arcsine transformed. Mean values, SD, sample size and respective regression equations are shown.

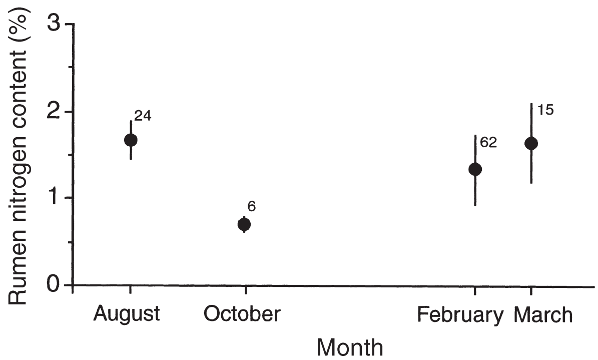

Fig. 3. Mean nitrogen content (%, ±SD) of total rumen contents of Sika deer on the Boso Peninsula, central Japan. Values shown in the figure refer to sample size.

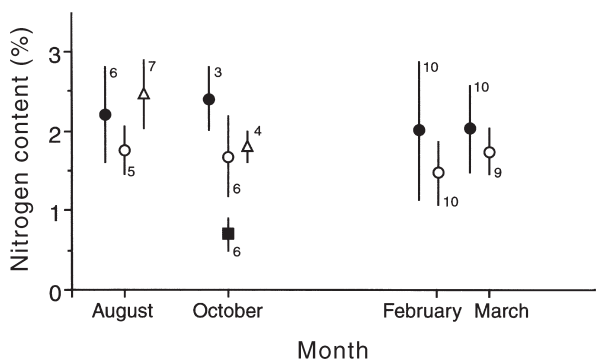

Fig. 4. Mean nitrogen content (%, ±SD) of each food item of Sika deer on the Boso Peninsula, central Japan: ●, evergreen broad-leaves; ○, graminoids; △, deciduous broad-leaves; ■, acorns. Values shown in the figure refer to sample size.

mean RN in March was 1.66%, which was not significantly different from that in August ($U = 185.5$, $P > 0.1$).

The mean nitrogen contents of the evergreen broad-leaves sampled from the rumen did not differ from month to month (Kruskal–Wallis test, $P > 0.1$, Fig. 4). The nitrogen content of the graminoids was significantly lower than that of the evergreen broad-leaves each month ($U = 7.5$, $P > 0.1$ in August, $U = 2.0$, $P > 0.05$ in October, $U =$

71.0, $P > 0.1$ in February and $U = 64.0$, $P > 0.1$ in March), and both did not show seasonal change (U-test, $P > 0.1$ between each month). The mean nitrogen content of the deciduous broad-leaves was 2.47% in August and 1.80% in October ($U = 25.0$, $P < 0.05$). Acorns were found from the rumen only in October, and the nitrogen content was 0.70% (SD = 0.2).

DISCUSSION

Quality of foods

Robbins (1993) reviewed the dietary protein requirements for maintenance of adult ruminants, giving a range of 5–9%. In Boso, the mean crude protein content of the diets was 10.4% in summer and 8.4% in winter. This indicates that dietary protein in Boso is above the maintenance level even in winter. Evergreen broad-leaves had relatively high crude protein contents through the year (Fig. 4). Its annual mean (SD) of the crude protein contents was 13.1% (4.13), having around the maximum growth level (13–20%, Robbins 1993). Graminoids, mainly sedges, had stable protein contents around 10%. In the Boso Peninsula, Sika deer has consumed these evergreen leaves as primary foods throughout the year (Asada & Ochiai 1996). Therefore, it is considered that Sika deer in Boso Peninsula have consumed foods of stable and high protein contents throughout the year.

Inter-population comparison

The FN levels have already been analyzed in Sika deer in the northern deciduous broad-leaved forest zone (39.1°N, 141.4°E); their mean FN was 3.34% (SD = 0.31) in summer and 1.77% (SD = 0.35) in winter (Watanabe & Takatsuki 1993). In summer, FN in the northern population was higher than any areas in Boso. In winter, however, the northern FN was lower than Boso. Thus, the magnitude of seasonal fluctuation was smaller in Boso than in northern population. This smaller fluctuation is a result of the main food (evergreen leaves) of the Boso deer having a stable and high nitrogen content throughout the year, when there is a relatively low snow fall which keeps the forest floor vegetation such as sedges available.

Density-dependent limitation of dietary nitrogen

Within the Boso Peninsula, the FN had a negative relation with the deer density both in summer and winter (Fig. 2). Since the FN has been considered as an index of dietary nitrogen (Raymond 1948; Holechek *et al*. 1982), this strongly suggested the density dependent decreasing of dietary nitrogen. In ungulates, it has been reported that the preference ranking of a food correlated with its nutrient contents (e.g. protein, energy, soluble carbohydrates; Westoby 1974). For density increases, deer have begun consuming less nutritious diets as a result of vanishing of high-quality forages. On the Boso Peninsula, Aucuba trees (*Aucuba japonica*), the leaves of which have a relatively high nitrogen content (more than 2% in winter; Yamamura & Kimura 1992), had decreased as the deer density increased (Asada *et al*. 1991). Therefore, it is likely that the density dependent decrease of the FN was due to a decrease by foraging of the plants having high nitrogen contents. In order to examine this hypothesis, a detailed study of the relationships among deer density, dietary nitrogen contents and forest plant communities is necessary.

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