Title	Indices for nutritional condition and thresholds for winter survival in sika deer in Hokkaido, Japan
Author(s)	YOKOYAMA, Mayumi; UNO, Hiroyuki; SUZUKI, Masatsugu; KAJI, Koichi; OHTAISHI, Noriyuki
Citation	Japanese Journal of Veterinary Research, 48(2-3), 119-127
Issue Date	2000-11-30
DOI	10.14943/jjvr.48.2-3.119
Doc URL	http://hdl.handle.net/2115/2852
Type	bulletin (article)
File Information	KJ00002400303.pdf

Jpn. J. Vet. Res. 48(2-3): 119-127(2000)

FULL PAPER

Indices for nutritional condition and thresholds for winter survival in sika deer in Hokkaido, Japan

Mayumi Yokoyama[1), Hiroyuki Uno[2), Masatsugu Suzuki[1), Koichi Kaji[3), and Noriyuki Ohtaishi[1).

(Accepted for publication : Aug. 24, 2000)

Abstract

We derived fat indices for sika deer (*Cervus nippon yesoensis*) in eastern Hokkaido, Japan, and estimated the probability of over-winter survival with a logistic regression model using fat indices. Kidney fat mass (KFM) appears to be an adequate index of wide range of physical conditions before the onset of severe nutritional stress. When KFM values fell below 20 g, femur (FMF) and mandible cavity fat (MCF) indices declined sharply. FMF and MCF were useful indices for detecting malnourished deer. A logistic regression model describes survival thresholds in two bone fat indices for calves (45%) and three fat indices for adult females (FMF=25%, MCF=30%, KFM=20g). These models are useful for estimating the probability of winter survival in Hokkaido sika deer.

Key words : *Cervus nippon*, fat index, logistic regression model, probability of survival, winter-killed deer

Introduction

The effects of nutritional condition on reproductive potential and over-winter survival are now recognized in many ungulate population[2,12,14]. For northern cervid populations, body fat has been considered a direct measure of energy reserves, affecting reproductive con-

[1) Mayumi Yokoyama, Masatsugu Suzuki, and Noriyuki Ohtaishi,
Laboratory of Wildlife Biology, Department of Environmental Veterinary Sciences, Graduate School of Veterinary Medicine, Hokkaido University, N18 W 9, Kita-ku,Sapporo 060-0818, Japan.

[2) Hiroyuki Uno, Eastern Hokkaido Wildlife Research Station, Nature Conservation Department, Hokkaido Institute of Environmental Sciences, Kushiro 085-0835, Japan

[3) Koichi Kaji, Nature Conservation Department, Hokkaido Institute of Environmental Sciences, Sapporo 060-0819, Japan

Corresponding author : Mayumi Yokoyama
Laboratory of Wildlife Biology, Department of Environmental Veterinary Sciences, Graduate School of Veterinary Medicine, Hokkaido University, N18W9, Kita-ku, Sapporo060-0818, Japan.
TEL : +81-11-706-5210
FAX : +81-11-706-5569
E-mail : mayuy@vetmed.hokudai.ac.jp

dition[2,11,35], fetal growth[32] and body size[35]. Kidney fat and marrow fat are often used as indicators of the nutritional condition of ungulates[6,7,10,21,28,30]. Condition assessment based on data from live deer is often biased towards healthy animals[5]. In spite of the need to recognize the symptoms of malnutrition[29] and to assess the condition of animals that have died[5], few studies have been conducted with winter-killed cervid populations[9,16]. A better understanding of the physical thresholds for winter survival would contribute to better nutritional ecology of deer populations.

On the island of Hokkaido, Japan, sika deer (*Cervus nippon yesoensis*) increased in number, and their range expanded from east to west during the 1980s[18]. The sika deer population in eastern Hokkaido was found to be good condition in 1991[38], and a 96.7% pregnancy rate was reported[33]. In the 1990s, on the other hand, over-grazing, heavy understory browsing, and bark peeling have been observed in Akan National Park indicating that food resources are becoming more limited[20,36]. The Akan district is an important wintering area, and it is thought to be one of the core areas from which deer have dispersed in eastern Hokkaido[17,25]. Reflecting limited food conditions, many winter-killed sika deer were found in Akan National Park in the winter of 1996 and 1997[37]. Although population density, stochastic climate variation and food quality may have affected the survival of sika deer in this population, little was known about the physical condition of wintering sika deer.

In this study we collected quantitative baseline data for condition characteristics of female and calf sika deer, using samples from both controlled-killed deer and natural mortalities. We also derived a logistic regression model of the relationship between fat indices and the probability of survival to judge the range of physical response to over-winter.

Materials and Methods

Study area

The main study area, used mostly by females in winter, is around Lake Akan, 328～440 m in altitude. Akan National Park (144°E, 43°N) encompasses 905 km^2 of mixed hardwood and evergreen forest in the eastern part of Hokkaido. The area is bordered by Mt. Oakan (1,371 m), Mt. Meakan (1,499 m), and Mt. Kikin (995 m). Mean annual temperature is 5 ℃, with the lowest monthly average of -10℃ in February[1]. Snow accumulates from late November to late April, and maximum snow depth is approximately 110 cm in March.

The main forested area is dominated by *Picea yezoensis, Abies sachalinensis, Acer mono, Tilia japonica,* and *Quercus mongolica*[15]. Broad-leaved forests are dominated by *Ulmus davidiana* var. *japonica* and *Fraxinus mandshurica* var. *japonica*, with *Alnus hirsuta* in riparian areas. In most forests, dwarf bamboo *Sasa senanensis* is the dominant understory plant, with summer growth of *Dryopteris crassirhizoma* and *Senecio cannabifolius.* Dwarf bamboo and broad-leaved trees provide important sika deer foods, especially in winter[20,39]. Private pastureland extends around the park, and the broad-leaved forests and mixed forests are similar to those in Akan National Park. Hunting is prohibited within the national park, but hunting pressure is high in surrounding areas, and more than 5,000 deer are removed each year in damage control harvests.

Sampling and methods

We collected 187 winter-killed carcasses and 20 road-killed sika deer carcasses from around Lake Akan during the late winter and early spring (March to April) of 1996 and 1997. We also collected 46 controlled-killed deer from the region adjacent to the park in April 1997 and 1998. We assessed physical condition by measuring kidney fat mass (KFM), femur marrow fat (FMF) and mandible cavity fat (MCF). Carcasses were collected within a hour (controlled-killed and road-killed) or a few days (winter-killed) following death. Both kidneys together with associated fat, femur, and mandible were removed and frozen at-20℃. Each end of kidney fat perpendicular to the longitudinal axis was removed[30] and only both perirenal fats were weighted[21]. We used a simple methods devised by Neiland (1970) for bone fat indices. To extract the marrow, the femur bone was half-defrosted, the midsection removed with a saw, and about 3 g sample of marrow collected from the central portion of the bone. The mandible cavity fat with nerve also extracted as the same procedure with femur. Subsequently, the bone fats were oven-dried at 80℃ until there was no further mass loss (72hours). The fat index was calculated as the mass of the dried marrow as percentage of its original fresh mass[26]. When the internal organs had been removed by scavengers, we used only bone still covered with skin and some flesh. Ages were estimated by the tooth replacement and the first incisor cementum annuli methods[19,27]. We categorized calf < 1 year and adult female ≤ 2 years old. We did not use yearling (1 ≤year < 2) samples for analysis because of small sample size. To determine the sex of calves with no apparent genitalia, we used the polymerase chain reaction (PCR) to amplify the Sry[34]. Analysis of variance was used to test for statistically significant differences among age or cause of death, and when appropriate the Tukey's HSD test was applied.

Variations in survival in relation to fat indices were analyzed using a linear logistic model[22]. If p is the probability of survival, then

$$p=[\exp \Sigma\alpha+(i\ \beta i\ X i)]/\{1+[\exp \Sigma\alpha+(i\beta i\ Xi)]\},$$

where X_i denotes the covariate i, α the intercept, and β_i the slope parameter. We assumed the probability of survival of controlled-and road-killed deer was 1 (living) and winter-killed deer was 0 (dying). The fit of the model was assessed by the use of a −2log likelihood statistic and a goodness-of-fit statistic, computed by statistica (StatSoft, Inc., 2300 East 14th Street, Tulsa OK 74104). The models were tested by calculating the estimated probability of sika deer survival and then comparing the result with the actual persistence or death of the controlled-killed or winter-killed deer. For this comparison, sika deer were considered likely to survive if the calculated survival probability was ≥0.5.

Results

Relationships of fat indices

We pooled the data from controlled-, road- and winter-killed deer for the liner regression analysis to reveal fat depletion patterns for each fat index. Although there are significant curvlinear relationships of KFM to both FMF (Fig. 1A) and MCF (Fig. 1B), when the value of KFM dropped to less than 20g, FMF declined more rapidly. The relationship between FMF and MCF indicated significant linear correlation ($P<0.001$) (Fig. 2). The FMF ranged widely (2.1-94.8%), but MCF showed a narrower range (10.9-80.6%) (Fig. 2).

Three fat indices of winter-killed deer were significantly lower than those of controlled-killed, respectively (Table 1). The average value of FMF approached 7-13% in winter-killed adult females and calves. The MCF of winter-killed deer was higher than that of FMF in calves and adult females. Values for females were significantly lower than those of calves in 1996. The average KFM level of winter-killed deer was approximately 7 g in adult females and 5 g in calves (Table 1).

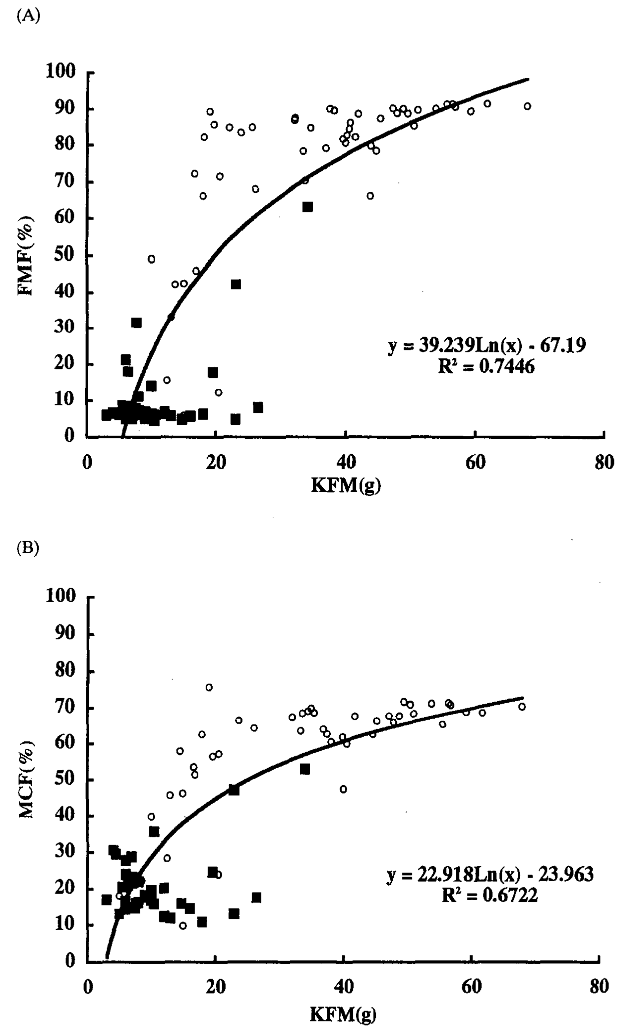

Fig. 1. Relationships of FMF (A) and MCF (B) to KFM in winter-killed and controlled-, road-killed sika deer in eastern Hokkaido, Japan during March and April, 1996-1998. Open circles = Controlled- and road-killed. Filled squares = Winter-killed.

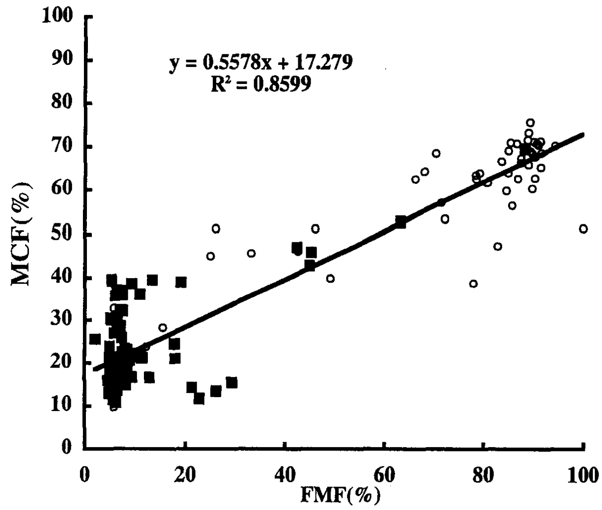

Fig. 2. Relationships between FMF and MCF in winter-killed and controlled-killed sika deer in Akan district, Hokkaido, Japan, during March and April, 1996-1998. Open circles = Controlled-, road-killed. Filled squares = Winter-killed.

Table 1. The mean and standard deviation of fat indices of winter−killed and controlled−killed sika deer in Akan district,Hokkaido during March to April, 1996−1998. Values accompanied by the same letter in the same indices are not different ($P < 0.05$) conducted by Tukey's test HSD.

		Winter-killed						Controlled-killed		
		1996			1997			1998		
Index	Age	n	mean	SD	n	mean	SD	n	mean	SD
FMF (%)	Calf	39	12.9[a]	4.8	46	7.9[a]	3.4	7	53.9[b]	20.0
	Adult female	14	7.5[a]	5.5	−	−	−	29	83.2[c]	10.7
MCF (%)	Calf	39	26.0[d]	10.8	46	22.4[de]	14.0	6	61.3[f]	4.7
	Adult female	15	15.2[e]	3.8	−	−	−	23	67.7[g]	4.4
KFM (g)	Calf	14	4.7[h]	3.8	14	3.6[h]	1.0	7	17.3[h]	6.7
	Adult female	10	6.9[h]	2.5	−	−	−	29	41.0[i]	13.5

Estimation of survival

Logistic regressions of winter-killed and controlled-, road-killed deer showed that the probability of survival increased with increasing fat indices in calves (FMF : $\chi^2=33.23, P<0.001, df=1$; MCF : $\chi^2=32.76, P<0.001, df=1$) (Fig. 3) and adult females (FMF : $\chi^2=48.19, P<0.001, df=1$; MCF : $\chi^2=61.70, P<0.001, df=1$; KFM : $\chi^2=30.65, P<0.001, df=1$) (Fig. 4). These relationships indicated that the probability of survival decreased as FMF and MCF were<45%, in calves (Fig. 3A, B). In adult females, a FMF <25%in dicated a decreased probability of survival (Fig. 4A) and MCF<30%, KFM< 20g were associated with a large decrease in the probability of survival (Fig. 4B, C). When we tested the predictive ability of the models using FMF for calves (FMFC) and adult females (FMFAF), the models correctly predicted survival for 70% of the calves and 97.7% of the adult females (Table 2). Similarly, the models correctly predicted mortality for 90% of the calves and 81% of the adult females. The pooled accuracy was 89% for calves and 93.2% for adult females. The MCF and KFM models both calves (MCFC, KFMC) and adult females (MCFA, KFMAF) also correctly predicted survival and mortality more than 80% of the time (Table 2).

Discussion

Utility of the fat indices as measures of overwinter survival probability

Since fat reserves are metabolized in response to climatic and nutritional stress[13,30,31], variation of our indices suggested the effect of these stress on sika deer individuals. The KFM of controlled-and road-killed deer in this study varied widely, with high levels of bone marrow fat, while winter-killed deer had no kidney fat and lower marrow fat levels (Fig. 1). This supports earlier findings that visceral fat, like kidney fat, is generally metabolized before bone marrow fat[28,29,30]. Therefore, the KFM of sika deer in Hokkaido can be a useful indicator for a wide range of conditions before the onset of malnutrition, just as it is with other northern cervids populations[3,7].

Bone fat is used as an indicator of physical status after all other fat deposits are completely depleted in ungulates[23,28,30]. In this study all ages of winter-killed deer mobilized bone fats. When KFM levels fall below 20g, sika deer seem to utilize bone marrow fat (Fig. 1), and then almost all FMF was metabolized until death. The MCF of sika deer was also metabolized when KFM fell below 20 g, but MCF levels were higher than levels of FMF in winter-killed deer. The mandibular cavity has more non-fat residue than do the

Table 2. Percent of correctly classified survival of sika deer in eastern Hokkaido, Japan during March to April based on the logistic regression models using each fat index.

Modeles	Age	Correctly predicted (%)		Correctness (%)
		Living	Dying	
FMFC	Calf	70.00	90.00	89.00
MCFC	Calf	88.89	91.67	90.24
FMFAF	Adult female	97.67	81.25	93.22
MCFAF	Adult female	100.00	100.00	100.00
KFMAF	Adult female	94.59	80	91.89

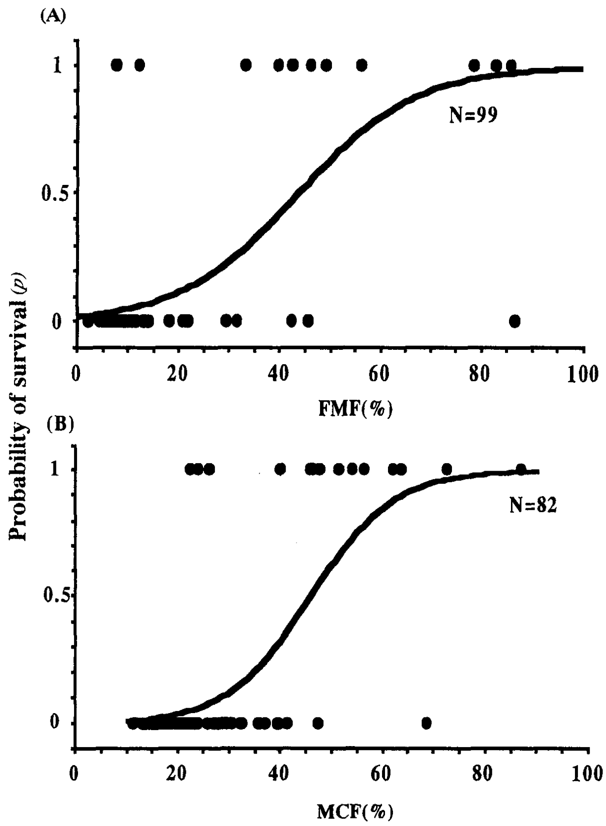

Fig. 3. Survival probabilities of winter-killed and controlled-killed calf sika deer in eastern Hokkaido during March and April in relation to fat indices. The equations for the significant logistic regression of the probability of survival p in relation to fat indices are : (A) logit $p=-3.70+0.09$FMF, (B) logit $p=-5.65+0.12$MCF.

other long bones[26]. MCF, however, was linearly related to FMF (Fig. 2), so it is effective as an index in assessing sika deer for malnutrition[6].

The average bone fat value for winter-killed calves was higher than that of adult females. This indicates that calves have less available marrow fat in winter and may be more sensitive to environmental stress[4,6,31]. In fact, during severe winters increased mortality is first apparent among calves[37]. These trends were similar to those reported for other winter-killed deer[4,8,9].

Threshold fat levels for winter survival

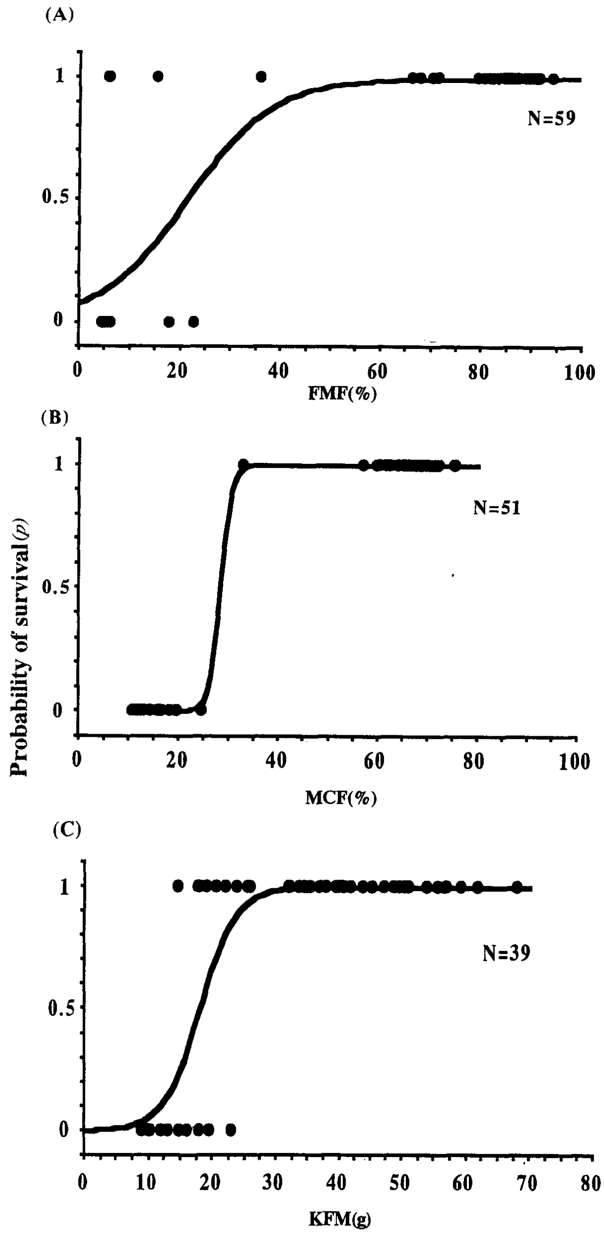

Fig. 4. Survival probabilities of winter-killed and controlled-killed adult female sika deer in eastern Hokkaido during March and April in relation to fat indices. The equations for the significant logistic regression of the probability of survival p in relation to fat indices are : (A) logit $p=-2.50+0.11$FMF, (B) logit $p=-26.41+0.94$MCF, (C) logit $p=-6.42+0.36$KFM.

Our study found that sika deer survival in Hokkaido was highly related to fat reserves in late winter (Fig. 3, 4), and that survival thresholds were different for calves and adult females. Cheatum (1949) reported that in Odocoileus poor physical condition corresponds to less than 50% of FMF and that less than 10% directly results in death. Similarly, Franzmann and Arneson (1976) proposed that average values of 10% FMF in winter-killed deer represented a "point of no return". Ratcliffe (1980) suggested that roe deer with FMF in excess of 75% were "healthy", while an FMF below 50% indicated a "poor" condition. In these studies, fat indices were traditionally used only to describe general physical condition, without estimating winter survival. Survival probabilities in our models were associated with intermediate fat levels between the "point of no return"[9] and "poor" conditions noted above[8,29]. Further, Moen (1994) suggested that weather-related mortality factors such as hypothermia, starvation and exhaustion are interrelated, not simple cause and effect relationships. Most winter-killed sika deer died in late March to early April, during snow-melt after harsh winter[37]. Given these consideration, our thresholds may give some suggestion about limitation of physical condition of deer. Although weather conditions and food availability have improved, once deer have reached a critical fat level, nutritional condition may not recover because of combined effects similar to those proposed by Moen (1994).

We believe the models and threshold levels presented here are useful in predicting the probability of sika deer over-winter survival in Hokkaido. Further, our thresholds give standard value for physical assessment of extremely poor condition in winter.

Acknowledgments

We are grateful to the members of the Hokkaido Hunting Association for providing many specimens. We also thank J. P. Moll assisted in English translation and gave many comments. We thank the Akan Royal Hotel, the Maeda Ippoen Foundation, Hoshino Resort Company, the Nature Preservation Sections of the subprefectural offices in Kushiro of Hokkaido Government for supporting our research. Hokkaido University students, members of Akan Ezo Deer Research Group and the staff of Eastern Hokkaido Wildlife Research Station assisted in carcass collection.

References

1) Akitaya, E., Naruse, K. and Shiroiwa, K. 1994. Climate and snow accumulation. In : Nature of Akan National Park, pp. 219-262, The Maeda Ippoen Foundation. (in Japanese)

2) Albon, S. D., Mitchell, B., Huby, B. J. and Brown, D. 1986. Fertility in female red deer (*Cervus elaphus*) : the effects of body composition, age and reproductive status. J. Zool. Lond. (A), 209 : 447-460.

3) Anderson, A. E., Bowden, D. C. and Medin, D. E. 1990. Indexing the annual fat cycle in a mule deer population. J. Wildl. Manage., 54 (4) : 550-556.

4) Ballard, W. B. and Whitman, J. S. 1987. Marrow fat dynamics in moose calves. J. Wildl. Manage., 51 (1) : 66-69.

5) Caughley, G. and Sinclair, A. R. E. 1994. Food and feeding. In : Wildlife ecology and management, pp. 82-109, Blackwell Science. Oxford.

6) Cederlund, G. N., Bergstrom, R. J, Stalfelt, F. V. and Danell, K. 1986. Variability in mandible marrow fat in 3 moose populations in Sweden. J. Wildl. Manage., 50 (4) : 719-726.

7) Chan-McLeod, A. C. A., White, R. G. and Russell, D. E. 1995. Body mass and composition indices for female barren-ground caribou. J. Wildl.

Manage., 59 (2) : 278-291.
8) Cheatum, E. L. 1949. Bone marrow as an index of malnutrition in deer. N. Y. State Conservationist, 3 : 19-22.
9) Franzmann, A. W. and Arneson, P. D. 1976. Marrow fat in Alaskan moose femurs in relation to mortality factors. J. Wildl. Manage., 40 (2) : 336-339.
10) Franzmann, A. W. and Ballard, W. B. 1993. Use of physical and physiological indices for monitoring moose population status- a review. Alces, 29 : 125-133.
11) Gerhart, K. L., White, R. G., Cameron, R. D. and Russell, D. E. 1996. Body composition and nutrient reserves of arctic caribou. Can. J. Zool., 74 (1) : 136-146.
12) Hanks, J. 1981. Characterization of population condition. In : Dynamics of large mammal populations, pp. 47-73, Fowler, C. W. and Smith, T. D. eds., John Wiley & Sons, New York.
13) Hewison, A. J. M., Angibault, J. M., Boutin, J., Bideau, E., Vincent, J. P. and Semp'er'e, A. 1996. Annual variation in body composition of roe deer (*Capreolus capreolus*) in moderate environmental conditions. Can. J. Zool., 74 (2) : 245-253.
14) Hobbs, N. T. 1989. Linking energy balance to survival in mule deer : development and test of a simulation model. Wildl. Monogr., 101 : 1-39.
15) Igarashi, T. 1986. Forest vegetation in Akan National Park, Hokkaido, Japan. Research Bulletins of the college Experiment Forest, Faculty of Agriculture, Hokkaido University., 43 : 335-494. (in Japanese with English summary)
16) Kaji, K., Koizumi, T. and Ohtaishi, N. 1988. Effects of resource limitation on the physical and reproductive condition of sika deer on Nakanoshima island, Hokkaido. Acta Theriol., 33 : 187-208.
17) Kaji, K., and Mano, T. 1995. Reports on the status of brown bear and sika deer in Hokkaido I, pp. 49-65. Hokkaido Institute of Environmental Sciences. Sapporo. (in Japanese)
18) Kaji K., Miyaki M., Saitoh T., Ono S. and Kaneko, M. 2000. Spatial distribution of an expanding sika deer population on Hokkaido Island, Japan. Wildl. Soci. Bull., 28 (3) : 699-707.
19) Koike, H., and Ohtaishi, N. 1985. Prehistoric hunting pressure estimated by the age composition of excavated sika deer (*Cervus nippon*) using the annual layer of tooth cement. J. Archaeol. Sci., 12 : 443-456.
20) Kondo, N., Uno, H. and Abe. H. 1994. Mammals of Akan. In : Nature of Akan National Park., pp, 841-908, The Maeda Ippoen Foundation. (in Japanese)
21) Leader-Williams, N. and Ricketts, C. 1982. Seasonal and sexual patterns of growth and condition of reindeer introduced into South Georgia. Oikos, 38 (1) : 27-39.
22) McCullgh, P. and Nelder, J. A. 1989. Generalized linear models. pp. 511. Chapman and Hall, London.
23) Mech, L. D. and DelGiudice, G. D. 1985. Limitations of the marrow-a technique as an indicator of body condition. Wildl. Soc. Bull., 13 (2) : 204-206.
24) Moen, A. N. 1994. Whitetail population dynamics. In : Deer, pp. 208-217. Gerlach, D. Atwater, S. and Schnell, J.

eds. Stackpole Books, Pennsylvania.

25) Nagata, J., Masuda, R., Kaji, K., Kaneko, M. and Yoshida, M. C. 1998. Genetic vatiation and population structure of the Japanese sika deer (*Cervus nippon*) in Hokkaido Island, based on mitochondrial d-loop sequences. Mole. Ecol., 7 : 871-877.

26) Neiland, K. A. 1970. Weight of dried marrow as indicator of fat in caribou femurs. J. Wildl. Manage., 34 (4) : 904-907.

27) Ohtaishi, N. 1980. Determination of sex, age and death-season of recoverd remains of sika deer (*Cervus nippon*) by jaw and tooth-cement. Archeol. Nat. Sci., 13 : 51-74. (in Japanese with English summary).

28) Ransom, A. B. 1965. Kidney and marrow fat as indicators of white-tailed deer condition. J. Wildl. Manage., 29 (2) : 397-398.

29) Ratcliffe, P. R. 1980. Bone marrow fat as an indicator of condition in roe deer. Acta Theriol., 25 : 333-340.

30) Riney, T. 1955. Evaluating condition of free ranging red deer (*Cervus elaphus*), with special reference to New Zealand. N. Z. J. Sci, Tech., 36 (Sect. B) 5 : 429-463.

31) Sæther, B. E. and Gravem, A, J. 1988. Annual variation in winter body condition of Norwegian moose calves. J. Wildl. Manage., 52 (2) : 333-336.

32) Skogland, T. 1984. The effects of food and maternal conditions on fetal growth and size in wild reindeer. Rangifer, 4 (2) : 39-46.

33) Suzuki, M and Ohtaishi, N. 1993. Reproduction of female sika deer (*Cervus nippon yesoensis* Heude, 1884) in Ashoro district, Hokkaido Japan. J. Vet. Med. Sci., 55 (5) : 833-836.

34) Takahashi, M., Masuda, R., Uno, H., Yokoyama, M., Suzuki, M., Yoshida, M. and Ohtaishi, N. 1998. Sexing of carcass remains of the sika deer (*Cervus nippon*) using PCR amplification of the Sry Gene. J. Vet. Med. Sci., 60 (6) : 713-716.

35) Thomas, D. C. 1982. The relationship between fertility and fat reserves of Peary caribou. Can. J. Zool., 60 (5) : 597-602.

36) Uno, H., Takashima, Y. and Tomizawa, H. 1995. Sika deer damaged the forest. Forest Protection, 249 : 36-38. (in Japanese)

37) Uno, H., Yokoyama, M. and Takahashi, M. 1998. Winter mortality pattern of sika deer (*Cervus nippon yesoensis*) in Akan National Park, Hokkaido. Mammalian Sci., 38 (2) : 233-246. (in Japanese with English summary)

38) Yokoyama, M., Maruyama, N., Kaji, K. and Suzuki, M. 1996. Seasonal changes of body fat reserves in sika deer of east Hokkaido, Japan. J. Wildl. Res., 1 (1) : 57-61.

39) Yokoyama, M., Kaji, K, and Suzuki, M. 2000. Food habits of sika deer and nutritional value of sika deer diets in eastern Hokkaido, Japan. Ecol. Res., 15 (3) : 345-356.