Nat. Hist. Res., Vol. 10 No. 2: 107—113, March 2009

Method for Estimation of Winter Browse Availability for the Japanese Serow from Stem Diameter-Forage Weight Relationships

Keiji Ochiai

Natural History Museum and Institute, Chiba
955-2 Aoba-cho, Chuo-ku, Chiba 260-8682, Japan
E-mail: ochiai@chiba-muse.or.jp

Abstract A method for estimating the availability of winter browse for the Japanese serow, *Capricornis crispus*, was examined on the basis of the stem basal diameters of five deciduous broadleaved species and two evergreen coniferous species. Regression equations were developed to convert basal area to browse mass for each species.

Key words: browse availability, Japanese serow, mass estimate, stem diameter.

Estimation of forage availability is important in the ecology and management of wildlife populations, particularly in studies of animal-habitat relationships and diet choice. A direct approach for estimating forage availability for herbivores, the clip-and-weight method, yields highly accurate results, but is laborious (Shafer, 1963 ; Harlow, 1977). Indirect estimation methods using various types of regression analysis approaches that relate an easily measured attribute of a plant or plant part to its weight have therefore been developed (Rutherford, 1979). Independent variables commonly used in these regression equations have been twig diameter (e.g., Basile and Hutchings, 1966 ; Telfer, 1969 ; Lyon, 1970 ; Peek *et al*., 1971), canopy volume (Lyon, 1968 ; Peek, 1970), tree height-diameter index (Bobek and Bergstrom, 1978), and stem diameter (e.g., Brown, 1976 ; Alaback, 1986 ; MacCracken and Van Ballenberghe, 1993 ; Visscher *et al*., 2006). Although twig diameter-weight relationships are useful for estimation of forage availability, the method is time-consuming because a count of available twigs is needed for estimating forage mass per tree or unit area. Canopy volume and tree height-diameter indices are also useful, but their measurement is more laborious than that of stem diameter. The stem diameter-browse weight method, which is used for estimation of forage mass from stem diameter, seems to be a more practical method than the others in terms of labor saving if the relationships are sufficiently significant.

The Japanese serow, *Capricornis crispus*, is a solitary, monogamous ungulate indigenous to Japan. My colleagues and I have been examining serow-habitat relationships, including relationships among population density, territory size, reproduction, and habitat, in three study areas : Shimokita in Aomori Prefecture, Asahi in Yamagata Prefecture, and Kamikochi in Nagano Prefecture. For the purposes of this type of study, effective estimation of serow forage availability is indispensable, but all previous estimations of forage availability for this species have been made by the clip-and-weight method (Haneda *et al*., 1976 ; Furubayashi, 1979, 1980 ; Ito *et al*., 1984 ; Sone *et al*., 1999). Therefore, examination of the stem diameter-browse weight method would aid the estimation of forage availability for the Japanese serow, and help to clarify serow-habitat relationships.

Winter is an important period in investigations of animal-habitat relationships, because it is a critical season when food resources are at their lowest for herbivores in boreal habitats. Furthermore, both sexes of the Japanese serow hold intrasexual resource-defended territory (Ochiai, 1983 ; Kishimoto and Kawamichi, 1996 ; Ochiai and Susaki, 2002). Territory size and population density of this species are therefore likely to be affected by browsing conditions in winter, making it important to elucidate winter forage availability. Because the major winter diet of the serow in all three study areas consists of deciduous broadleaved species, together with evergreen coniferous species in Kamikochi (Kiuchi *et al*., 1979 ; Ochiai, 1999 ; T. Mochizuki, unpublished data), I chose several of these species as winter browse materials.

The aim of this study was to clarify the relationships between stem basal area and mass of winter browse for the Japanese serow among several species of

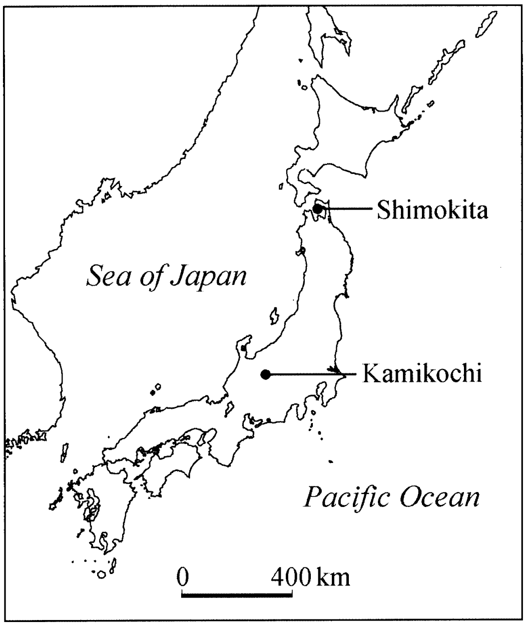

Fig. 1. Location map of the study areas.

deciduous broadleaved and evergreen coniferous species, and to develop regression equations for converting basal area to browse mass. In addition, because serows also consume dwarf bamboo in winter in Kamikochi (T. Mochizuki, unpublished data), I collected data to estimate the forage availability of dwarf bamboo.

Materials and Methods

1. Study areas

To devise a method for estimating the availability of winter browse for the Japanese serow, I conducted field surveys of deciduous broadleaved species in Wakinosawa (41°8′N, 140°49′E), a municipal district of Mutsu City, on the Shimokita Peninsula, Aomori Prefecture, northern Japan. I also surveyed evergreen coniferous species and dwarf bamboo in Kamikochi (36°15′N, 137°38′E), a municipal district of Matsumoto City, Nagano Prefecture, central Japan (Fig. 1).

The Shimokita study area ranges in elevation between 0 and 240 m, and lies in the cool temperate zone. The mean annual temperature is 9.8°C, mean monthly temperatures range from -0.8°C in January to 22.6 °C in August, mean annual precipitation is 1285 mm, and mean annual maximum depth of snow cover is 75 cm (range : 21–147 cm), based on data from 1984 to 2007 at the nearest meteorological station (15 m altitude), 4 km east of the study area (Japan Meteorological Agency, 2008). The vegetation consists principally of mature deciduous broadleaved forest (75% of the area) dominated by Mizunara oak, *Quercus crispula* Blume, and Japanese beech, *Fagus crenata* Blume. Conifer plantations (Japanese cedar *Cryptomeria japonica* D. Don, and Japanese red pine *Pinus densiflora* Sieb. et Zucc.) and natural coniferous forest of hiba arborvitae, *Thujopsis dolabrata* var. *hondae* Makino, cover 13% and 7% of the area, respectively.

The Kamikochi study area is at an elevation of 1500–2000 m, and situated in the upper montane and subalpine zones. The mean monthly temperature in January is -7.5°C and that in August is 17.6°C, mean annual precipitation is 2637 mm (data for 1935–1960), and annual maximum depth of snow cover ranges from 96 to 339 cm (data for 1966–1974) at the Taisho Pond, 1495 m altitude (Nagano Regional Forestry Office, 1977). The vegetation of the area can be categorized into four types: forests of willow, *Chosenia arbutifolia* (Pallas) Skvortsov, along the Azusa River; mixed forests of Japanese wingnut, *Pterocarya rhoifolia* Sieb. et Zucc., and Japanese elm, *Ulmus davidiana* Planch. var. *japonica* (Rehder) Nakai, in flat areas near the river; forests of Nikko fir, *Abies homolepis* Sieb. et Zucc., on the lower slopes of the mountains; and forests of northern Japanese hemlock, *Tsuga diversifolia* (Maxim.) Masters, on the upper slopes. Samples for measurement were collected around Abou, 7 km southwest of Kamikochi, because samplin g of branches and leaves is prohibited at Kamikochi, which is located in a Special Protection Zone of the national park.

2. Field survey of deciduous broadleaved species at Shimokita

I chose five deciduous broadleaved species as materials: spice bush, *Lindera umbellata* Thunb. var. *membranacea* (Maxim.) Momiyama; Japanese witch hazel, *Hamamelis japonica* Sieb. et Zucc. var. *obtusata* Matsumura; fullmoon maple, *Acer japonicum* Thunb.; Japanese linden, *Tilia japonica* (Miq.) Simonkai; and Japanese bush cranberry, *Viburnum wrightii* Miq.. These are common undergrowth and main browse species for serows inhabiting the study area and account for 68.7% to 75.5% of the winter diet (Ochiai, 1999).

I analyzed the relationships between availability of winter browse for the Japanese serow and stem basal area at the snow surface, according to points (1) to (3) below, in January and February 1997 and 1998.

(1) Moving along new serow trails in the snow, I used calipers to measure to the nearest 0.05 mm the diameter of twigs of the five species at points freshly

Table 1. Mean twig diameter at the point of browsing, and length and weight of bites browsed by Japanese serows in five under storey species. A single bite (bite unit) was estimated from the mean twig diameter at the point of browsing.

Species	Mean ± SD of twig diameter at point of browsing (mm), n=50	Mean ± SD of length of bite units (mm), n = 30	Mean ± SD of dry weight of bite units (g), n = 30
Lindera umbellata var. *membranacea*	2.7 ± 0.6	64.0 ± 21.1	0.157 ± 0.022
Hamamelis japonica var. *obtusata*	2.6 ± 0.5	64.2 ± 9.3	0.186 ± 0.008
Acer japonicum	2.5 ± 0.4	70.3 ± 19.6	0.180 ± 0.007
Tilia japonica	3.2 ± 0.9	70.8 ± 24.1	0.223 ± 0.008
Viburnum wrightii	2.2 ± 0.4	48.8 ± 11.5	0.119 ± 0.030

browsed by serows. The mean twig diameter at the point of browsing was calculated from 50 samples for each species.

(2) I sampled 30 twigs of each species that were not browsed and, using calipers, measured to the nearest 0.1 mm the length of the twig from the tip to the point corresponding to the mean twig diameter at the browsing point. Using an electronic weighing scale, I also measured to the nearest 0.0001 g the dry weight of the part of the twig that corresponded to a single bite (" bite unit ") of the Japanese serow.

(3) I measured both stem basal diameter at the snow surface and browse availability per stem for the same tree, and analyzed the relationships between the two. Using calipers accurate to the nearest 0.05 mm, I first measured the stem basal diameter at the snow surface. Next, to determine browse availability per stem, I determined the number of bite units per stem on each stem situated below a height of 1.8 m above the snow and thus accessible to serows (Furubayasi, 1980). If the stem was taller than 1.8 m, I measured the basal diameter of every branch situated below 1.8 m instead of the basal diameter of the stem at the snow surface. After the field survey, I then multiplied the number of bite units per stem by the mean dry weight of a bite unit estimated by the method mentioned above in (2). The relationship between stem basal diameter and browse availability per stem was analyzed from 80 samples for each species.

3. Field survey of evergreen coniferous species and dwarf bamboo at Kamikochi

I conducted a field survey of two species of evergreen conifer, *A. homolepis* and *T. diversifolia*, and a species of dwarf bamboo, *Sasa senanensis* (Fr. et Sav.) Rehder, in April 2006. Because the shape of the feeding signs of the Japanese serow was not obvious on the branches and leaves of the evergreen conifers, I estimated the size of the bite unit from my observations of feeding signs and feeding behavior without making an exact decision regarding the point of browsing on the branches and leaves, meaning that the bite unit for evergreen conifers was decided on a best-guess basis. I sampled 30 twigs that were considered to represent the bite unit for each species of evergreen conifer, measuring the dry weight of each unit with electronic scales to the nearest 0.0001 g. I then analyzed the relationship between winter browse availability and stem basal area at the snow surface around the evergreen conifers in accordance with the method described above in (3). I used fallen branches on the snow as samples for analysis as well as stems, because leaves on the fallen branches of evergreen conifers are an important winter forage source for serows living in Kamikochi.

In our study of serow-habitat relationships, we estimate the availability of dwarf bamboo per unit area by multiplying the mean dry weight of one leaf by the number of leaves available for serows. To obtain data for estimation of *S. senanensis* availability, I sampled 30 leaves of this species and measured their dry weights using electronic scales to the nearest 0.0001 g.

4. Nomenclature

The scientific names of plant species in this report are based on Satake *et al.* (1989a, b).

Results

1. Deciduous broadleaved species

The mean twig diameter at the point of browsing ranged from 2.2 to 3.2 mm; the mean length of the bite unit was 48.8 to 70.8 mm; and the mean dry weight of the bite unit was 0.119 to 0.223 g (Table 1). Winter browse availability was significantly correlated with stem basal area in all five species (Fig. 2).

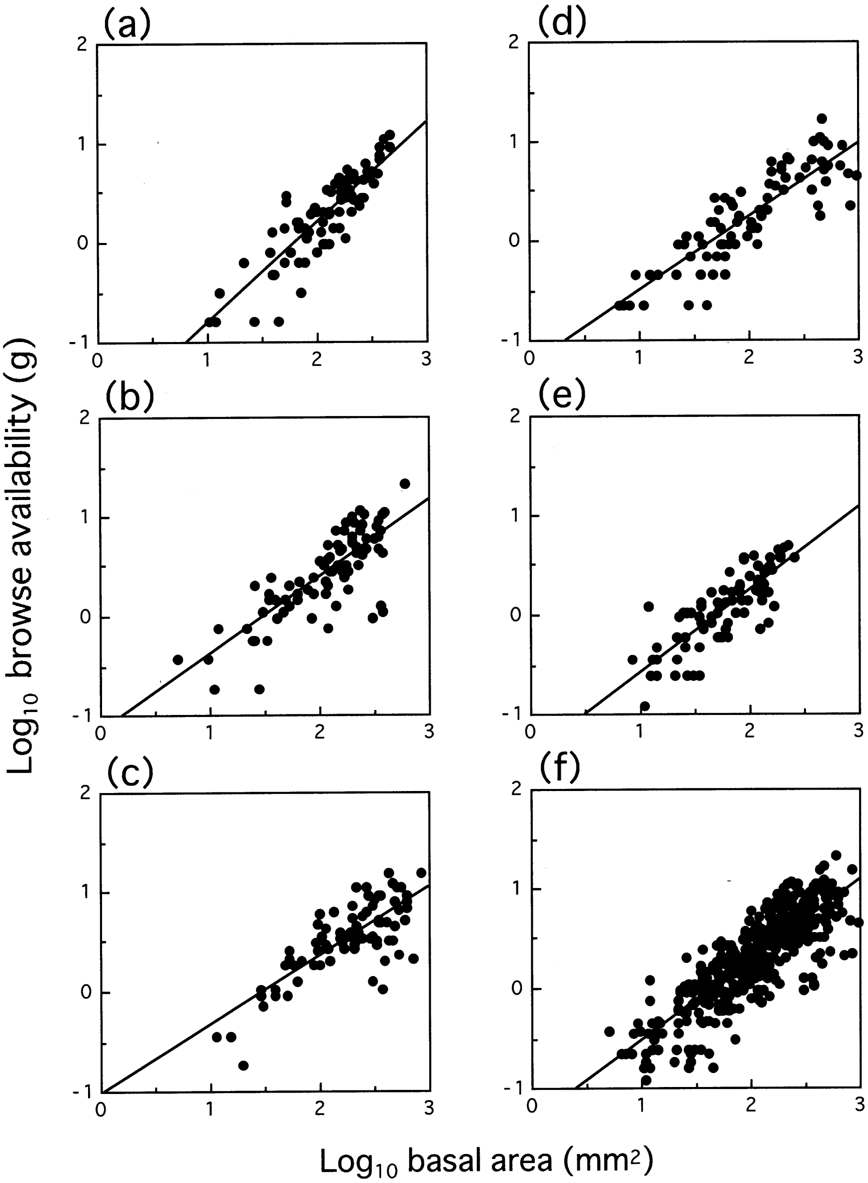

Fig. 2. Relationships between logarithms availability of winter browse for the Japanese serow and stem basal area at the snow surface in five deciduous broadleaved species. (a) *Lindera umbellata* var. *membranacea*; (b) *Hamamelis japonica* var. *obtusata*; (c) *Acer japonicum*; (d) *Tilia japonica*; (e) *Viburnum wrightii*; (f) all five species. Regression statistics were (a) $y = 1.01x - 1.83$ ($R^2 = 0.75$), (b) $y = 0.78x - 1.17$ ($R^2 = 0.63$), (c) $y = 0.68x - 1.01$, ($R^2 = 0.59$), (d) $y = 0.75x - 1.24$ ($R^2 = 0.75$), (e) $y = 0.83x - 1.41$ ($R^2 = 0.66$), and (f) $y = 0.81x - 1.33$ ($R^2 = 0.69$). $P < 0.001$ for (a)-(f), and $n = 80$ for (a)-(e) and 400 for (f).

2. Evergreen coniferous species

The mean ± SD dry weight of the bite unit for *A. homolepis* and *T. diversifolia* was 0.567 ± 0.122 g and 0.336 ± 0.119 g, respectively. Winter browse availability was significantly correlated with stem basal area in both species (Fig. 3).

3. Dwarf bamboo

The mean ± SD dry weight of one leaf of *S. senanensis* was 0.390 ± 0.089 g.

Discussion

Serow browse availability per stem, expressed as

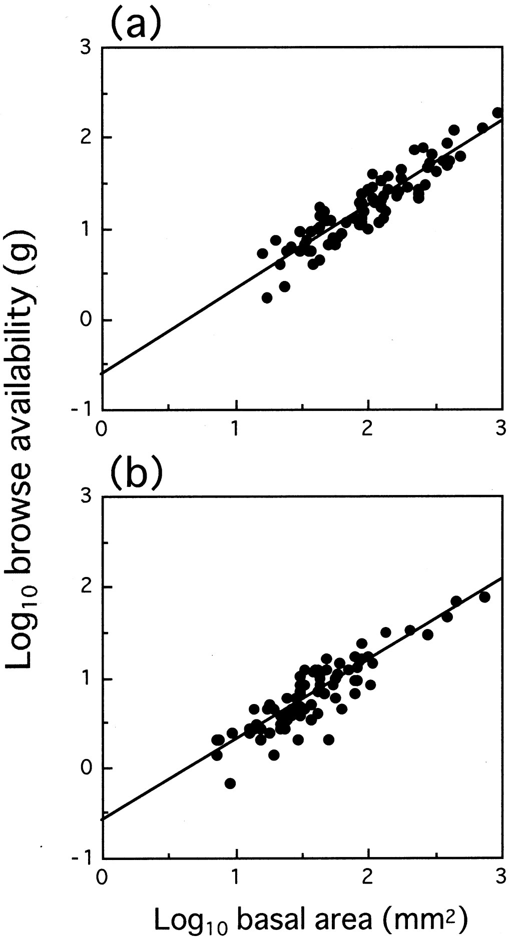

Fig. 3. Relationships between logarithms availability of winter browse for the Japanese serow and stem basal area at the snow surface in two evergreen coniferous species. (a) *Abies homolepis*; (b) *Tsuga diversifolia*. Regression statistics were (a) $y = 0.93x - 0.61$ ($R^2 = 0.84$), (b) $y = 0.88x - 0.59$ ($R^2 = 0.78$). $P < 0.001$ and $n = 80$ for (a) and (b).

total dry weight, was positively correlated with stem basal area for all of the five deciduous broadleaved species and two evergreen coniferous species examined. The allometric relationship between stem basal area and whole-tree leaf area was conceptualized as the pipe model (Shinozaki *et al.*, 1964a, b), which proposes that a plant may be considered as an assemblage of many unit pipe systems, each consisting of a leaf element and a connecting pipe. Although the tree form model describes the correlation between stem basal area and leaf volume, it also seems to be valid for the relationship between stem basal area and twig volume.

The present study represents a first step for estimation of serow browse availability, because many researchers have found that regression equations are specific to each browse species (Telfer, 1969; Peek, 1970; Alaback, 1986; MacCracken and Van Ballenberghe, 1993). In addition, equation coefficients may differ for any given species among sampling sites, as well as with the size of the plant, by vegetation type, and with twig location on a plant (MacCracken and Van Ballenberghe, 1993). Furthermore, because estimation of the bite unit on evergreen conifers may not have been sufficiently precise in the present study, further investigations are needed. However, the present results suggest that relationships between stem diameter and mass of winter browse for the Japanese serow are sufficiently significant. The stem diameter-browse weight method for the Japanese serow is therefore likely to be useful as a labor-saving strategy in field surveys and will be efficient for studies of serow-habitat relationships.

Acknowledgments

I thank K. Kumagawa, K. Susaki, and Y. Yamada for their help in the field surveys. I also thank T. Mochizuki who kindly permitted the use of his unpublished data. I am indebted to M. Hara and K. Ozaki for their comments on the manuscript. This study was supported by a Grant-in-Aid for Scientific Research from JSPS (Japan Society for the Promotion of Science).

References

Alaback, P. B. 1986. Biomass regression equations for understory plants in coastal Alaska: effects of species and sampling design on estimates. Northwest Sci. 60: 90-103.

Basile, J. V. and S. S. Hutchings. 1966. Twig diameter-length-weight relationships of bitterbrush. J. Range Manag. 19: 34-38.

Bobek, B. and R. Bergstrom. 1978. A rapid method of browse biomass estimation in a forest habitat. J. Range Manag. 31: 456-458.

Brown, J. K. 1976. Estimating shrub biomass from basal stem diameters. Can. J. For. Res. 6: 154-158.

Furubayasi, K. 1979. Relationships between vegetation and damage on planted trees by Japanese serows. *In* Report of Studies on the Japanese Serow, Natural Monuments, pp. 53-90. The Board of Education of Gunma Prefecture, Maebashi. (In Japanese)

Furubayasi, K. 1980. Food habits and food supply in each vegetation type for the Japanese serow in the Shimokita Peninsula. *In* Society of Japanese Serow Research in the Shimokita Peninsula (ed.), The Japanese Serow in the Shimokita Peninsula, pp. 99-

115. Society of Japanese Serow Research in the Shimokita Peninsula, Sendai. (In Japanese)

Haneda, K., A. Muya, M. Hamanaka and K. Hashido. 1976. Study on the amount of food supply available for Japanese serow (*Capricornis crispus*) in summer at Iwakura State Forest in central Japan. Bull. Inst. Nature Educ., Shiga Heights, Shinshu Univ. 15 : 43–46. (In Japanese with English summary)

Harlow, R. F. 1977. A technique for surveying deer forage in the southeast. Wildl. Soc. Bull. 5 : 185–191.

Ito, E., Y. Mori, S. Hayashi, H. Hibi, A. Terada and A. Matsumoto.1984. A study on habitat management for the Japanese serow–estimating amount of food supply for serows. 32th Trans. Chubu Br. Jpn. For. Soc. : 51–53. (In Japanese)

Japan Meteorological Agency. 2008. http : // www.data.jma.go.jp/obd/stats/etrn/index.php (In Japanese)

Kishimoto, R. and T. Kawamichi. 1996. Territoriality and monogamous pairs in a solitary ungulate, the Japanese serow, *Capricornis crispus*. Animal Behaviour 52 : 673–682.

Kiuchi, M., H. Kudo, M. Yoshida, M. Miyasaka, M. Hoshino, K. Yamazaki, S. Kato and C. Umezu. 1979. Social organization and habitat use of the Japanese serow in Asahi mountain ranges. *In* Nature Conservation Society of Japan (ed.), Conservation Reports of Japanese Serow, Special Natural Monuments II, pp. 19–72. Nature Conservation Society of Japan, Tokyo. (In Japanese)

Lyon, L. J. 1968. Estimating twig production of serviceberry from crown volumes. J. Wildl. Manage. 32 : 115–119.

Lyon, L. J. 1970. Length- and weight-diameter relations of serviceberry twigs. J. Wildl. Manage. 34 : 456–460.

MacCracken, J. G. and V. Van Ballenberghe. 1993. Mass-diameter regressions for moose browse on the Copper River Delta. Alaska. J. Range Manage. 46 : 302–308.

Nagano Regional Forestry Office. 1977. National Forest of Kamikochi. 11 pp. Nagano Regional Forestry Office, Nagano. (In Japanese)

Ochiai, K. 1983. Territorial behavior of the Japanese serow in Kusoudomari, Wakinosawa Village. J. Mammal. Soc. Jpn. 9 : 253–259. (In Japanese with English abstract)

Ochiai, K. 1999. Diet of the Japanese serow (*Capricornis crispus*) on the Shimokita Peninsula, northern Japan, in reference to variations with a 16-year interval. Mammal Study 24 : 91–102.

Ochiai, K. and K. Susaki. 2002. Effects of territoriality on population density in the Japanese serow (*Capricornis crispus*). J. Mammal. 83 : 964–972.

Peek, J. M. 1970. Relation of canopy area and volume to production of three woody species. Ecology 51: 1098–1101.

Peek, J. M., L. W. Krefting and J. C. Tappeiner. 1971. Variation in twig diameter-weight relationships in northern Minnesota. J. Wildl. Manage, 35 : 501–507.

Rutherford, M. C. 1979. Plant-based techniques for determining available browse and browse utilization: A review. The Botanical Review 45 : 203–228.

Satake, Y., H. Hara, S. Watari and T. Tominari (eds.). 1989a. Wild Flowers of Japan–Woody Plants I. 321 pp. Heibonsha, Tokyo. (In Japanese)

Satake, Y., H. Hara, S. Watari and T. Tominari (eds.). 1989b. Wild Flowers of Japan–Woody Plants II. 305 pp. Heibonsha, Tokyo. (In Japanese)

Shafer, E. L. 1963. The twig-count method for measuring hardwood deer browse. J. Wildl. Manage. 27 : 428–437.

Shinozaki, K., K. Yoda, L. Hozumi and T. Kira. 1964a. A quantitative analysis of plant form – the pipe model theory. I. Basic analysis. Jpn. J. Ecol. 14 : 97–105.

Shinozaki, K., K. Yoda, L. Hozumi and T. Kira. 1964b. A quantitative analysis of plant form – the pipe model theory. II. Further evidence of the theory and its application in forest ecology. Jpn. J. Ecol. 14 : 133–139.

Sone, K., H. Okumura, M. Abe and E. Kitahara. 1999. Biomass of food plants and density of Japanese serow, *Capricornis crispus.* Mem., Fac. Agr., Kagoshima Univ. 35 : 7–16.

Telfer, E. S. 1969. Twig weight-diameter relationships for browse species. J. Wildl. Manage. 33 : 917–921.

Visscher, D. R., E. H. Merrill, F. Daniel and J. L. Frair. 2006. Estimating woody browse availability for ungulates at increasing snow depths. For. Ecol. Manage. 222 : 348–354.

幹直径と食物重の関係によるニホンカモシカの冬期の利用可能食物量の推定法

落合啓二

千葉県立中央博物館
〒260-8682　千葉市中央区青葉町 955-2
E-mail : ochiai@chiba-muse.or.jp

5 種の落葉広葉樹と 2 種の常緑針葉樹について，幹直径に基づくニホンカモシカの冬期の利用可能食物量の推定法を検討した．各種について，幹直径を利用可能食物量に変換するための回帰式を求めた．