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Summer Dietary Compositions of Sika Deer on Yakushima Island, Southern Japan

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Abstract

Summer food habits of Sika deer (*Cervus nippon yakushimae*) on Yakushima Island, southern Japan, were studied focusing in particular on *Pseudosasa owatarii*, a dwarf bamboo native to the island. Fecal analyses showed that the food habit of the Sika deer on Yakushima island was plastic: the dietary composition was dominated by graminoids (ca. 90%), particularly *P. owatarii* (50%–60%) in the bamboo grassland of the *P. owatarii* zone above the timber line, whereas leaves and non-leafy parts of woody plants were important in the crytomeria forest and evergreen broad-leaved forest below the timber line. The maximum culm age of *P. owatarii* was 8.5 yr, but the majority of leaves (97.8%) were younger than 2.5 yr. Since the weight contribution of the leaves is great (27.7%) and the turnover rate is high, the *P. owatarii* grassland affords a good foraging place for the Sika deer on Yakushima Island.

Key words: Browser; *Cervus nippon yakushimae*; Food habits; *Pseudosasa owatarii*; Yakushima Island.

Introduction

Based on quantitative analyses of the food habits of Sika deer (*Cervus nippon*) populations in northern Japan (Takatsuki, 1980a, 1983, 1986), it is considered that the Sika deer there subsist on graminoids, particularly dwarf bamboos, that is, they are "grazers" in the sense of the Jarman-Bell principle (Bell, 1971; Jarman, 1974). Studies on the food habits of Sika deer in southwestern Japan, on the other hand, have shown that leaves of woody plants or fruits are important, that is, the deer there are "browsers" (Takatsuki et al., 1984; Takatsuki, 1988). These observations suggest that Sika deer, which inhabit various types of habitat show plasticity in their food habits. However, these areas including both evergreen and deciduous broad-leaved forests, which are inhabited by Sika deer are quite limited in Japan. Yakushima Island is a precious example of a habitat populated by a subspecies of Sika deer (*C. nippon yakushimae*), and which is also covered by various types of vegetation, ranging from sub-tropical to alpine (Miyawaki, 1980). The area above the timber line is covered by *Pseudosasa owatarii*, an endemic dwarf bamboo. I expected that this plant would be an important forage for the deer, because it is evergreen and abundant. The objectives of this study were to examine the summer dietary composition of the Sika deer on Yakushima Island focusing in particular on altitudinal variation, and to obtain basic information on the ecology of *P. owatarii*.

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Area Studied

Yakushima Island is situated 70 km south of Kyushu (30°20′N, 130°40′E). The island is fairly large (503 km^2), with very high peaks (around 1900 m), and rugged topography. The climate is warm and rainy, the mean annual temperature being 19.5°C in lower lying areas, and the mean annual precipitation as high as 3820 mm. In accord with these environmental characteristics, the vegetation of Yakushima Island shows clear altitudinal zonation (Miyawaki, 1980). Subtropical vegetation is present in areas lower than 200 m, and the next zone (200–800 m) consists of evergreen broad-leaved forest dominated by *Cyclobalanopsis* (*Quercus*) *salicina*, *C.* (*Q.*) *acuta*, and *Distylium racemosum*. Above the latter zone and up to 1800 m, cryptomeria (*Cryptomeria japonica*) forest predominates. This is in fact mixed forest composed of coniferous (*C. japonica*, *Tsuga sieboldii*, and *Abies firma*) and evergreen broad-leaved trees (*Trochodendron aralioides*, etc.). Above the timber line at 1800 m, there is an open bamboo grassland (*P. owatarii*) with patches of shrubs (*Rhododendron metternichii* var. *yakusimanum*, *Juniperus sargentii*, etc.).

Yakushima Island is inhabited by a subspecies of Sika deer (*Cervus nippon yakushimae*), known as Yaku Sika. This subspecies is smaller (body weights of adult males are ca. 40 kg, Takatsuki et al., 1987) than the Honshu Sika (*C. n. centralis*) (male body weight is 70–80 kg), and the antlers of the males have a maximum of three points whereas the Honshu Sika usually have four points (Imaizumi, 1960). They inhabit the whole island but are more often found above the timber line.

Methods

Between 15 and 26 July 1984, a search was made for fresh fecal pellets of Sika deer at 14 sites containing different vegetation types at different altitudes, among which samples were found and collected at eight sites (Fig. 1, Table 1). Two pellets were sampled from different fecal groups at each sampling site. The numbers of pellet groups differed from 1 to 24 (Table 2). They were gently crushed in water and then washed over a mesh (0.5 mm aperture), and the retained fragments were examined microscopically by the method of Stewart (1967). The

Table 1. Altitude and vegetation types of sites where fecal pellets of Sika deer were sampled on Yakushima Island. See Fig. 1 for locations.

Site no.	Alt. (m)	Vegetation type
1	1760	*Pseudosasa owatarii* type
2	1680	*Rhododendron metternichii* var. *yakushimanum-Juniperus chinensis* var. *sargentii* type
3	1640	*Rhododendron metternichii* var. *yakushimanum-Juniperus chinensis* var. *sargentii* type
4	1500	*Abies firma-Rhododendron metternichii* var. *yakushimanum* type
5	1450	*Tsuga sieboldii-Symplocos myrtacea* type
6	1230	*Cryptomeria japonica-Symplocos myrtacea* type
7	1190	*Abies firma-Symplocos myrtacea* type
8	1070	*Cryptomeria japonica-Symplocos myrtacea* type
9	960	*Cryptomeria japonica-Symplocos myrtacea* type
10	790	*Cyclobalanopsis acuta-Polystichopsis aristata* type
11	480	*Castanopsis cuspidata-Polystichopsis aristata* type
12	350	*Neolitsea aciculata-Eurya japonica* type
13	170	*Pasania edulis-Polystichopsis aristata* type
14	170	*Castanopsis cuspidata·Distylium racemosum-Polystichopsis cuspidata* type

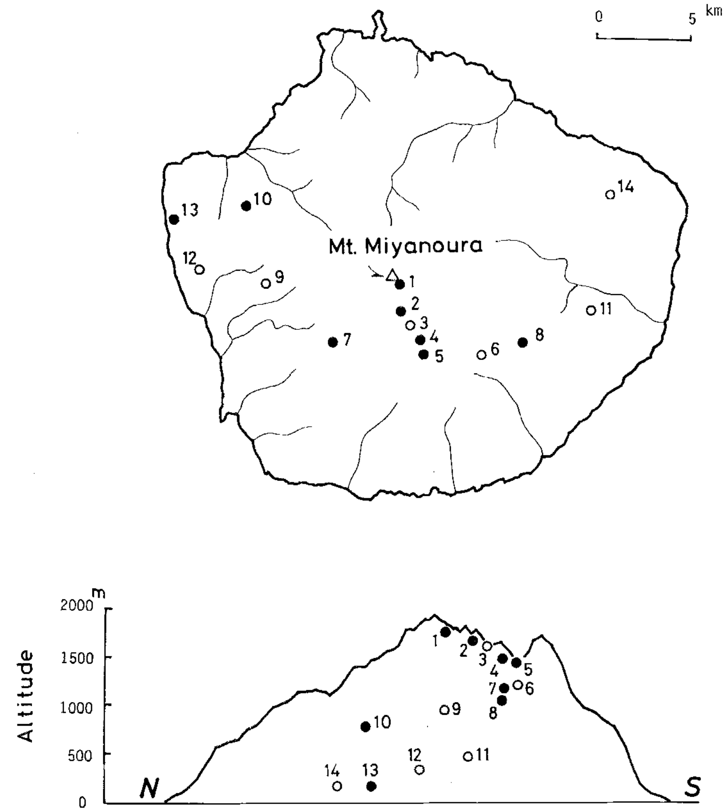

Fig. 1. Map and topographic section of Yakushima Island showing the sites of sampling of fecal pellets of Sika deer (*Cervus nippon yakushimae*). ●: pellets available; ○: pellets unavaialble.

fragments were spread over a slide graduated with 1×1 mm squares, identified, and counted up to a maximum of 400 points for each sample.

Above-ground parts of *P. owatarii* in a 0.5×0.5 m^2 quadrat were collected on a ridge (1760 m) between Onna Peak (1826 m) and Anbo Peak on 24 July 1984. Culm ages were estimated on the basis of the branching pattern (Suzuki, 1978). The youngest leaves and branches which appeared in the summer of 1984 were termed first-order (1') ones or 0.5 yr old, and plants bearing 1' branches which had appeared in the preceding year (1983) were termed 2' or 1.5 yr old, and so on. Bamboos were grouped into each order (age), and then leaves and branches were separated and sorted into each order. They were then oven-dried (48 hr at 80°C) to determine the dry weight.

Results

Fecal composition

P. owatarii occupied 50%–60% of the fecal composition at site 1 (1769 m) and site 2 (1680 m) in the *P. owatarii* zone around the peaks (Table 2). Other monocotyledons were also important at these sites, and the proportion of total graminoids reached about 90%.

The fecal composition at sites 4–8 (1070–1500 m) in the cryptomeria zone was quite dif-

Table 2. Fecal compositions (%) of Sika deer on Yakushima Island, July 1984. Figures in parentheses indicate the number of sampled fecal piles.

	Site 1 (6)		Site 2 (7)		Site 4 (6)		Site 5 (7)		Site 7 (7)		Site 8 (24)		Site 10 (5)		Site 13 (1)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Graminoids (total)	*90.5*	*2.3*	*89.3*	*3.8*	*7.3*	*3.2*	*2.3*	*1.1*	*2.3*	*2.8*	*1.8*	*1.3*	*8.5*	*3.2*	*56.8*	*7.5*
bamboo	47.8	6.2	57.8	5.6			0.8	0.8							26.5	2.9
grasses	20.0	3.1	6.3	1.5	1.0	0.7	0.3	0.4			0.5	0.9	4.0	1.9	17.8	3.6
sedges	6.0	1.6	6.3	2.3	1.8	1.3	0.8	0.4	0.3	0.4			0.8	0.8	2.5	0.5
other graminoids	2.0	1.4			1.0	0.0	0.7	0.5	1.0	1.2	0.5	0.5	3.3	0.4	1.0	1.2
sheath+culms	14.8	7.9	19.0	6.0	3.5	2.6			1.0	1.2	0.8	0.8	0.5	0.9	9.0	3.7
Woody plants (total)	*4.3*	*0.4*	*3.3*	*1.1*	*63.3*	*5.0*	*75.0*	*4.1*	*77.8*	*4.0*	*91.5*	*2.7*	*86.8*	*4.8*	*29.5*	*6.2*
leaves of woody plants (a+b)	*3.0*	*0.7*	*2.8*	*0.8*	*34.3*	*4.3*	*24.0*	*3.5*	*18.0*	*2.0*	*18.5*	*3.9*	*55.8*	*8.2*	*12.8*	*2.5*
broad-leaves (a)	3.0	0.7	2.8	0.8	29.3	4.9	18.0	2.5	12.5	2.6	18.0	3.9	54.3	7.8	12.5	2.7
coniferous leaves (b)					5.0	1.2	6.0	1.6	5.5	3.0	0.5	0.5	1.5	1.1	0.3	0.4
non-leafy parts*	1.3	0.5	0.5	0.2	29.0	0.6	51.0	3.3	59.8	5.4	73.0	0.4	31.0	1.2	16.8	1.5
Others (total)	*5.3*	*2.3*	*7.5*	*3.0*	*29.5*	*7.6*	*22.8*	*4.0*	*20.0*	*4.9*	*6.8*	*2.9*	*4.8*	*4.9*	*13.8*	*2.5*
fruits	0.3	0.4	1.8	0.8	19.8	3.7	13.5	2.1	13.8	4.7	1.0	0.7	0.5	0.5	7.3	3.3
seeds									0.3	0.4					0.8	0.4
unidentified	5.0	2.0	5.8	3.7	9.8	5.4	9.3	4.1	6.0	2.6	5.8	3.1	4.3	4.8	5.8	4.9

*Non-leafy parts: twigs, woody fibers and bark.

ferent. Graminoids accounted for only 2%–7%, whereas leaves of dicotyledons and non-leafy parts of woody plants (twigs and bark) occupied 80%–90% of the total. Leaves of dicotyledons were fewer in the lower areas, whereas non-leafy parts were increased. Although the epidermis of dicotyledonous leaves was not identifiable, it showed the characteristic patterns of evergreen broad-leaved plants. Epidermis of coniferous leaves was found in the feces collected in this zone, but the contribution to the total was small (ca. 5% at most).

Fecal composition at site 10 (790 m) was similar to those in the cryptomeria zone: woody plants were dominant (dicotyledonous leaves: 55.8%, twigs and bark: 31.0%) and graminoids accounted for only 8.5%. At site 13 (170 m), however, graminoids occupied as much

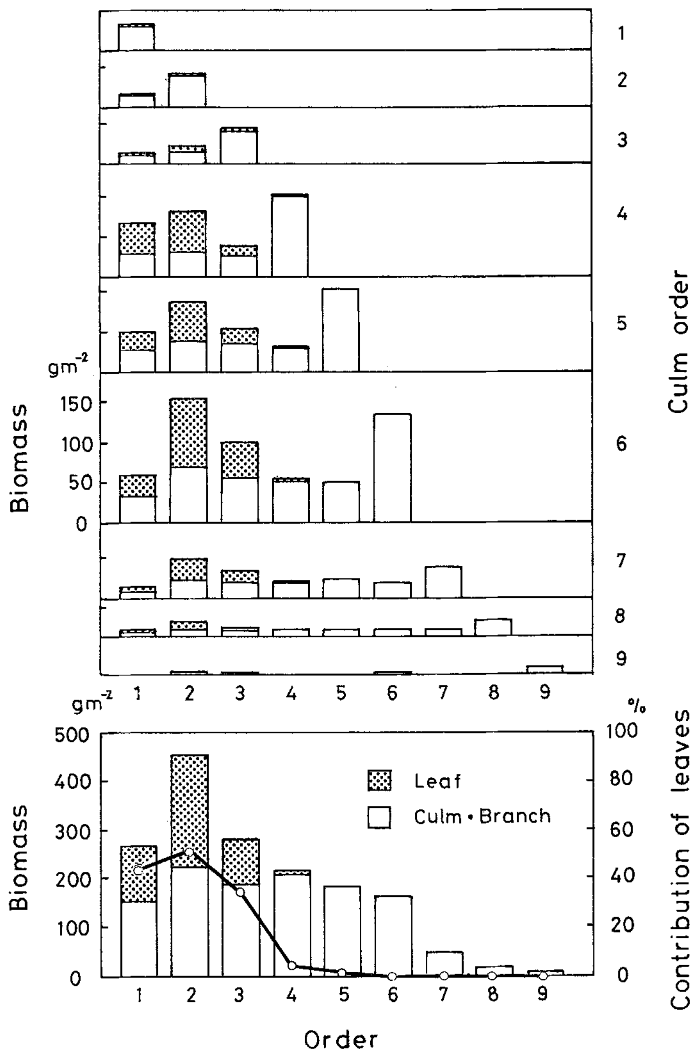

Fig. 2. Dry weights of leaves and non-leafy parts (culms and branches) of each order on culms of various orders (upper), and of the total "population" (lower) of *Pseudosasa owatarii*. —○—: contributions of leaves to the total above-ground biomass.

as 56.8%, and dicotyledons were not important. Most of the former (26.5% of the total composition) were identified as bamboo leaves, although the species was unknown. However, they were most likely *Pleiobalstus linearis*, because no other bamboos grow in the lower part of the island.

Pseudosasa owatarii

It was possible to estimate culm age by tracing the patterns of branching. By this method, the age of the oldest culm in the sample was found to be 8.5 yr.

Branches of 1' (0.5 yr old) and 2' (1.5 yr old) bore about two leaves, but 3' (2.5 yr old) branches bore only 0.8 leaves. Fewer of leaves were present on branches older than 4' (3.5 yr). The oldest leaves were 5.5 yr old, being younger than the oldest branch (8.5 yr).

Culms connected by rhizomes form parts of an individual bamboo, but each culm was tentatively regarded as an individual plant here. The culm density of the sample was as high as 676 m^{-2} and the above-ground standing crop was 1639.6 g m^{-2}. Figure 2 shows the standing crop distribution of leaves and non-leafy parts at each age. The weights of non-leafy parts did not vary significantly among plants less than 6' (5.5 yr old), and decreased rapidly thereafter.

Leaves occupied 27.7% of the above-ground standing crop, and the weight was biased to young leaves ($\leq$2.5 yr old), which occupied 97.8%. Current (0.5 yr) leaves occupied 25.6% of the total, but since the sample was collected in early July when the leaves were developing, their final contribution would have been greater. The respective contributions were estimated to be about 40%, 45%, and 15% for 1' (0.5 yr old), 2' (1.5 yr old) and 3' (2.5 yr old) leaves, based on the number of leaves. This indicates that the leaf turnover rate is high, and that the leaves eaten by Sika deer are young, and therefore probably more nutritious.

Discussion

Fecal analysis showed that the summer dietary compositions of the Sika deer on Yakushima Island differed greatly between the higher and lower areas. The deer living on open land around the peaks above the timber line subsisted on *P. owatarii*, indicating that they were a "grazer" type, whereas those in the forest zone in the lower area ate leaves of dicotyledonous plants, indicating that they were a "browser" type. The Sika deer on Yakushima Island exemplify the food habit plasticity of this species.

Besides the summer feces, we also analyzed 13 winter rumen contents collected in the lower area from December 1985 to January 1986 (Takatsuki and Suzuki, 1987). Analysis showed that woody plant leaves, especially those of evergreen trees and shrubs, were important constituents. Seeds including acorns, and those of *Ficus*, *Rhus*, etc. were also important.

P. owatarii grows widely and abundantly above the timber line on Yakushima Island and affords an abundant food supply for the deer. The weight contribution of leaves (27.7%) to the total above-ground biomass was considerable in comparison with other bamboo species: ca. 6% for *Sasa kurilensis*, ca. 17% for *Sasa nikkoensis*, and 17.8% for *Sasa oseana* (Oshima; 1961), and 24.7% for *Sasamorpha borealis* (Nishida and Kayama, 1972). Exceptions are *Sasa nipponica* (34.3%, Oshima, 1961) and *Pleioblastus chino* var. *viridis* (37.5%, Nishida and Kayama, 1982). Furthermore, the majority were composed of young leaves (Fig. 2). These data indicate that the *Pseudosasa owatarii* zone is a good foraging area for the Sika deer on Yakushima Island.

Sasa nipponica, an important forage for Sika deer in northern Japan (Takatsuki, 1983, 1986), is adaptive to grazing because of its high turnover rate of above-ground parts (Agata and Kamata, 1979; Takatsuki, 1986). In contrast, *Pleioblastus chino* compensates for the biomass reduction caused by grazing by increasing its culm density from 64 to 490 m^{-2} (Takatsuki, 1980b). The anti-herbivory adaptation of *Pseudosasa owaraerii* is more similar to that of *Pleioblastus chino* than to *Sasa nipponica*, because, 1) each culm often lives for 5–6 yr, 2) branching is frequent, and 3) culm density is quite high.

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