Biomass of Food Plants and Density of Japanese Serow, Capricornis crispus.

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Biomass of Food Plants and Density of Japanese Serow, *Capricornis crispus.*

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Introduction

Japanese serow, *Capricornis crispus*, causes severe damages to young plantations of Japanese cedar, *Cryptomeria japonica*, and Japanese cypress, *Chamaecyparis obtusa*, and the control of local populations of serows is needed in some localities in Japan. Past studies have revealed the social structure (Akasaka and Maruyama 1977, Sakurai 1981, Ochiai 1983, Kishimoto 1987, Ochiai *et al.* 1993) and food habits of serows (Mikuriya and Obara 1970, Chiba and Yamaguchi 1975, Miyao 1976, Suzuki *et al.* 1978, Mori *et al.* 1981, Sakurai 1981). Although food supply is an important determinant factor of the density of serows, a few studies have been done only for local populations in a small area within a mountain (Ochiai *et al.* 1993). And there was no study on the relationship between these two variables on a larger scale, e.g., mountain mass or mountain system, which is necessary for establishing the means to control the populations of serows in a certain region in Japan.

In this study, we estimated the density of serows and the biomass of their available food plants in five mountain areas in Gunma Prefecture, about 150 km northwest of Tokyo, and examined the relationship between the density of serows and the biomass of food plants both within a mountain area and among the five mountain areas.

Methods

1. Serow population

We conducted aero driving census in five mountain areas in Gunma Prefecture; The Nakanojo National Forest (1649 ha) and the Kusatsu National Forest (648 ha), Oze (1100 ha), Okukinu (550 ha), and Nikura (925 ha) (Figure 1). The ground was covered with snow during winter. The depths of snow-coverings were 3-4 m in Oze, 1-2 m in Okukinu and Nikura, and < 1m in Nakanojo and Kusatsu.

We censused serow populations in Nakanojo and Kusatsu every March during the period from 1982 to 1986 and in November 1982 and 1983, and in Oze, Okukinu, and Nikura in January 1984. A crew for direct visual observation consisted of one pilot, one recorder, and two observers. The pilot operated a helicopter 20-30 m above the ground at the speed of 20-30 km/h. In steep valleys, a helicopter flew along the stream. In wide valleys, it flew up above one side of

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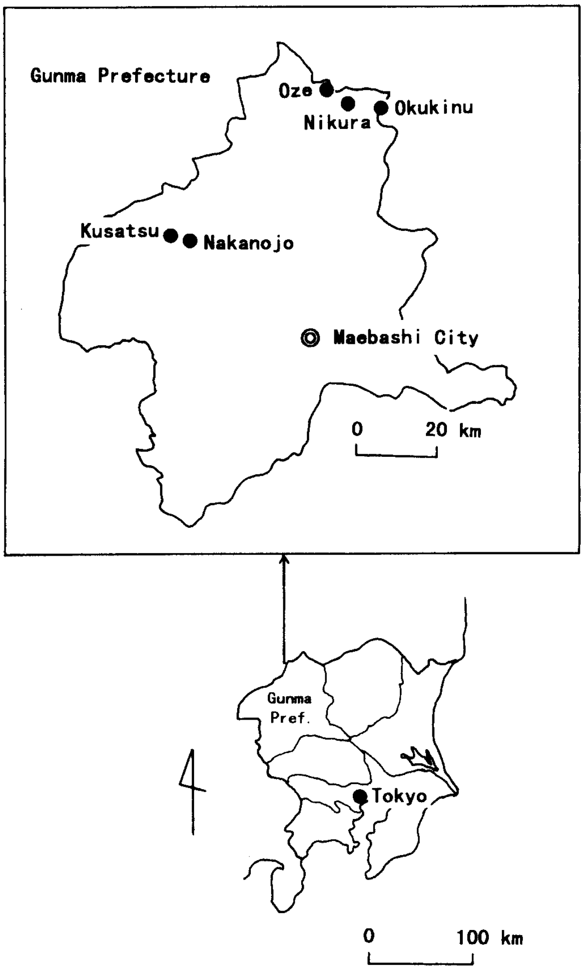

Fig. 1. Maps of study sites.

the slope and flew back down above the other. Observers looked around the entire slopes during the flight. When they found serows, they passed the information about the position and the number of serows to the recorder, who recorded them on a map of 1:10,000 scale (Abe and Kitahara 1989).

In order to estimate the discovery rate of this method, we caught three serows in a census area in Nakanojo in October 1985. After marking with paints, we released them at the places where they were caught. On 22 and 23 November 1985, we flew five times to find a total of 13 marked serows by the same method as in the ordinary census.

2. Biomass of food plants

In the five mountain areas, we divided forests into four types; (A) clear cut areas, (B) conifer plantations, (C) mixed forests, and (D) mature deciduous broad-leaved forests. According to the years after planting, we further subdivided conifer plantations into five groups; B1 (1-5 years after planting), B2 (6-10 years), B3 (11-15 years), B4 (16-30 years), and B5 (>30 years). Table 1 shows the proportions of the eight types of forests in each area obtained from the records in the forest register. We selected a representative stand for each of the eight types of forests in Nakanojo. The characteristic features of the eight selected

Table 1. Compositions of forests (% in area) in the five areas

Forest types	Areas				
	Nakanojo	Kusatsu	Oze*	Okukinu*	Nikura*
Clear cut area (A)	1~2	0~5			
Conifer plantations (B)					
1-5 years (B1)	6~14	9~12			1
6-10 years (B2)	13~15	0~4			
11-15 years (B3)	11~15	0~4			12
16-30 years (B4)	10~17	22~30		13	3
>30 years (B5)	5~6	10	27	73	17
Mixed forests (C)					
Young (≦ 40 years old)	1				
Old (>40 years old)	10~13			8	
Broad-leaved forest (D)					
Young (≦ 40 years old)	6			1	
Old (>40 years old)	24~25	40~49	73	5	67

* Forest composition in March 1984.

Table 2. Brief aspects of the eight types of forests

Forest types	Age (years)	Aspect	Slope (°)	Overstory			Understory
				Species	Height (m)	DBH (cm)	
Clear cut area (A)	0	S	20				*Celastrus orbiculatus*, *Flaxinus Sieboldiana*, *Sasa nipponica*
Conifer plantation (B1)	1~5	S	25				*Q. serrata*, *Aralia elata*, *Rubus crataegifolius*, *S. nipponica*, *Cr. japonica*
Conifer plantation (B2)	6~10	SE	35	*Cryptomeria japonica*	2~4	2~4	*Rhododendron semibarbatum*, *R. crataegifolius*, *Clethra barbinervis*
Conifer plantation (B3)	11~15	SE	<5	*Cr. japonica*	5~7	6~8	*Callicarpa japonica*, *Car. japonica*, *Hydrangea hirta*
Conifer plantation (B4)	21~25	SE	35	*Larix leptolepis*	10~22	10~15	*Q. serrata*, *Car. japonica*, *H. hirta*, *R. obtusum*, *Cacalia delphiniifolia*
Conifer plantation (B5)	>50	SW	26	*Chamaecyparis obtusa*	25	20~30	*H. hirta*, *Stephanandra incisa*, *Lindera umbellata*, *Styrax Shirasawana*, *S. nipponica*
Mixed forest (C)	21~25	SE	15	*Pinus densiflora*, *Cr. japonica*, *Quercus mongolica*	5~7	10~15	*Q. mongolica*, *Car. laxiflora*, *A. elata*, *Ilex macropoda*, *S. nipponica*
Deciduous broad-leaved forest (D)	>50	SE	35	*Q. mongolica*, *Carpinus japonica*, *Alnus hirsuta*, *Aesculus turbinata*	20	20~45	*Castanea crenata*, *H. hirta*, *H. paniculata*, *Prunus Grayana*, *S. incisa*, *Impatiens Toxtori*, *Polygonum Thunbergiana*, *Rabdosia umbrosa*, *Elatostema umbellatum*

stands are given in Table 2.

In Nakanojo, we observed browsing signs of serows on the shoots of < 5 mm in diameter and the leaves of almost all species of shrubs, the leaves of dwarf bamboo, *Sasa nipponica*, forbs, ferns, and the green parts of cedar of < 5 mm in diameter, in a horizontal zone up to 1.5 m above the ground (later we call this zone a browsing zone). Therefore, we regarded all the leaves and all the parts of shoots or twigs of < 5 mm in diameter in the browsing zone as available food plants.

In the three stands (B4, B5, and D), we divided the browsing zone vertically into two layers; the upper (> 0.5 m above the ground, dominated by shrubs) and the lower (≦ 0.5 m above the ground, dominated by forbs and dwarf bamboo). We settled randomly five 5 × 5 m plots along a slope and two 1 × 1 m quadrates on each 5 × 5 m plot for estimating the biomass of food plants in the upper and the lower layers, respectively. In the other five forests, dwarf bamboos were taller than 1 m or there was no shrubs taller than 0.5 m. Therefore, not dividing the browsing zone, we settled randomly five 1 × 1 m plots. In the four stands (A, B1, B5, D), we conducted the survey in November 1984 and August 1985, and in the other four stands (B2, B3, B4, C), in August 1985.

On each survey, we collected all the food plants on each plot and grouped them into five items; (1) dwarf bamboo leaves, (2) shrub shoots or twigs, (3) shrub leaves, (4) cedar needles (green parts), and (5) forbs including ferns. After drying at 75-80°C in a benchcircular oven for about five days, we weighed them. We estimated the green parts of each cedar sapling in B1 by the relationship between the sapling height and the weight of needles presented by Tanimoto (1982).

In B2, B3, B4, and C, we could not study the biomass of food plants in November. By November, all herbs were withered and all leaves of shrubs had fallen. In three out of the four stands (A, B5, D), the total biomass of shrub shoots and dwarf bamboo leaves did not differ significantly between August and November (A:F=0.49, B5:F=2.19, D:F=1.02, in all cases, $P>0.05$). In B1, although the total biomass of food plants in November was lower than that in August due to weeding in fall, shrubs might recover their shoot biomass by November and the biomass of shrub shoots did not differ significantly between August and November (F=0.27, $P>0.05$). Therefore, in the cases of B2, B3, B4, and C, we deemed it valid to use the sum of the biomass of shrub shoots and dwarf bamboo leaves in August for the values of the biomass of food plants in November. The biomass of food plants in some area was obtained by summing up the weighted food plant biomass of each type of the forest by its relative abundance.

The data were analyzed by F-test and a Mann-Whitney U-test.

Results

1. Serow population

In the five flights made in November 1985, we found nine out of a total of 13 marked serows, concluding that the discovery rate of this method was 70.2% (the 95% confidence range: 60.0-79.5%). We counted 72-117 and 10-17 serows every March in Nakanojo and Kusatsu, respectively, and estimated the density of serows as 6.3-10.1/km^2 in Nakanojo and 2.2-3.7/km^2 in Kusatsu (Table 3). The estimated densities of serows in Oze, Nikura, and Okukinu in January 1984 were 2.0 (the 95% confidence range: 1.7-2.4), 2.3(2.0-2.9), and 3.3(2.7-4.0)/km^2, respectively.

Table 3. The number of serows counted by aero driving census and their estimated density in March in Nakanojo and Kusatsu

Areas	Area	Number of serows					Density of serows (/km^2)				
	(ha)	1982	1983	1984	1985	1986	1982	1983	1984	1985	1986
Nakanojo	1649	95	117	102	90	72	8.2	10.1	8.8	7.9	6.3
Kusatsu	648	10	17	17	10	14	2.2	3.7	3.7	2.2	3.1

2. Food plants

Table 4 shows the biomass of food plants in August and November in the eight types of forests. In both cases, the biomass was highest in the young conifer plantations (B1-B3) and the young mixed forest (C), and lowest in the mature conifer plantation (B5). B1 was provided with fewer food plants than B2 and B3 in November due to weeding in fall, and the difference in the biomass of food plants was marginally significant between B1 and B3 ($U=6$, $P=0.11$).

In summer, the composition of food plants differed among the forests (Table 5). In B2

Table 4. Variations in the biomass of food plants (d.w. g/m^2) among the eight types of forests

Forest types	November 1984			August 1985		
	Mean*	S.D.	N	Mean*	S.D.	N
A	108.9^{b}	37.0	5	99.2^{b}	36.4	5
B1	112.6^{b}	59.5	5	292.3^{a}	51.6	5
B2	251.0^{a}	183.2	5	379.2^{a}	173.7	5
B3	200.4^{a}	96.1	5	310.4^{a}	93.8	5
B4	75.5^{c}	17.0	10	94.6^{b}	21.0	10
B5	23.5^{d}	14.6	10	35.6^{c}	13.7	10
C	268.6^{a}		1	345.2^{a}		1
D	70.8^{c}	20.7	10	92.7^{b}	34.8	10

* Means with different alphabet letters differ significantly.

Table 5. Compositions of food plants (% in dry weight) in the eight types of forests in August 1984

Food items	Forest types							
	A	B1	B2	B3	B4	B5	C	D
Dwarf bamboo leaves	86.8	78.7		2.3	59.0	80.8	61.4	80.7
Shrub shoots	4.7	3.0	15.8	20.7	20.7	12.6	16.4	6.9
Shrub leaves	8.1	9.0	14.9	27.6	18.7	5.8	22.2	3.8
Forbs	0.4	6.5	15.3	6.7	1.6	0.8		10.2
Cedar needles		2.8	54.0	42.7				

and B3, the green parts of cedar, herbs and shrub leaves, and shrub shoots occupied about 50%, 30%, and 20%, respectively. While, dwarf bamboo leaves occupied 60-90% and forbs and shrub leaves occupied only 4-20% of the total food plants in the other forests.

3. Relationship between serow density and food biomass

Table 6 shows the number of serows counted in the five forest compartments of Nakanojo and Kusatsu National Forests in November 1983 and in March 1984. More serows were counted in the compartments 38, 39, and 44 than in those of 40 and 42 in both census occasions, and the total number of serows did not differ between the two census occasions. These results suggest that the local distribution and the density of serows in a mountain area did not change drastically during the winter. Figure 2 shows the relationships of the density of serows in March with the biomass of food plants in August and November of the previous year in the respective compartments of Nakanojo and Kusatsu National Forests. In both cases, the rela-

Table 6. The number of serows counted in November 1983 and March 1984 in Nakanojo

Date	Compartment in Nakanojo National Forest					
	38	39	40	42	44	Total
20-21 Nov. 1983	23	18	10	10	16	77
12 Mar. 1984	17	26	8	12	15	78

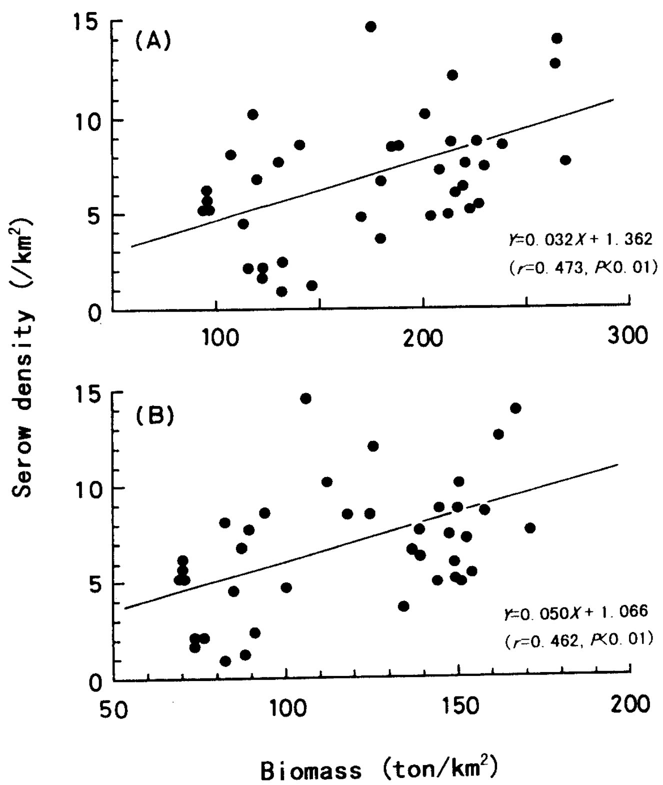

Fig. 2. Relationships between the density of serows in March and the biomass of food plants in August (A) and that in November (B) of the previous year in Nakanojo and Kusatsu.

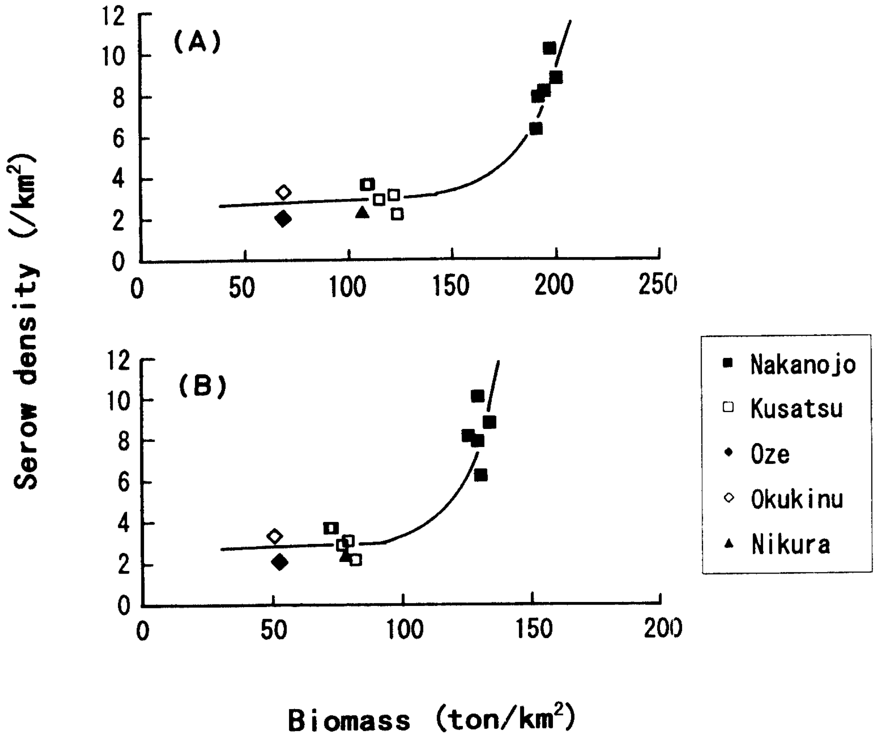

Fig. 3. Relationships between the density of serows in March and the biomass of food plants in August (A) and that in November of the previous year (B) for five mountain areas.

tionships were linear and the density of serows increased with the increasing of food biomass.

Figure 3 shows the relationships between the biomass of food plants and the density of serows in the five mountain areas. Because the biomass estimated in Nakanojo did not differ significantly from those obtained in other localities (Haneda *et al.* 1976, Haneda *et al.* 1979, Ito *et al.* 1984), we considered it possible to estimate roughly the biomass of food plants in Kusatsu, Oze, Nikura, and Okukinu from the values obtained in Nakanojo. The density of serows was also correlated positively with the biomass of food plants, but the relationship was non-linear. When the biomass was less than 150 ton/km^2 in August and less than 100 ton /km^2 in November, the density of serows did not increase significantly with the biomass of food plants. However, when food plants were more abundant than these threshold values, the density increased apparently with the biomass of food plants.

Discussion

In this study, the biomass of food plants was larger in the young conifer plantations than in the other types of forests as reported in other localities (Haneda *et al.* 1976, Shimokita Peninsula Serow Research Group 1980, Ito *et al.* 1984, Ochiai *et al.* 1993). This result shows that young conifer plantations provide serows with far more foods than the other types of forests and that the increase in food abundance in an area can primarily be caused by the increase in young conifer plantations. Because shrub shoots and cedar needles, which were dominant food items in 6-15 years old plantations, have lower nitrogen concentration than forbs, shrub leaves, and dwarf bamboo leaves (Soné *et al.* unpublished data), the food condition in ≦ 5 years old plantations may be better than that of 6-15 years old.

The density of serows showed positive relationships with the biomass of food plants in summer and winter. This result suggests that the food biomass was one of the important determinant factors in the serow density in winter. Because the density of serows showed a similar relationship with the biomass of food plants both in summer and winter, we could not determine which was more important to the level of serow population the food condition in summer or that in winter.

The relationship between the serow density and the food biomass in each forest compartment in Nakanojo was linear; the serow density was higher in the compartments with more abundant foods, as Ochiai *et al.* (1993) suggested for three local populations of serows in Aomori Prefecture. Serows usually live in their home ranges containing various types of forests, and the position of each home range does not change greatly in the successive years (Akasaka and Maruyama 1977, Haneda *et al.* 1980, Ochiai 1983, Kishimoto 1987, Okumura 1989). Serow density in some area is determined, to some extent, by the number of residents with their own home ranges. Since the size and permanency of a home range depends on the food availability (Sakurai 1981), serows can establish more home ranges in areas with abundant food supply than in those with poor food supply.

However, the relationship was non-linear in the five mountain areas and there was a threshold biomass for drastic increase in serow density. This suggests that some additional mechanisms might affect the relationship between food biomass and serow density between these mountain areas. However, we could not reveal these mechanisms.

Deep snow cover can greatly decline the availability of foods in winter. Therefore, although the biomass of food plants did not differ significantly among Oze, Nikura, Okukinu, and Kusatsu, the availability of food plants was expected to be lower in Oze, Nikura, and Okukinu than in Kusatsu because of deeper snow cover. However, the density of serows did not differ significantly among the four areas. Therefore, snow-covering depth might not have significant effects on the density of serows.

The overdispersion of serows may also be effective to explain a slight increase in the density of serows in comparison with the biomass of food plants in the areas with poor food supply. To reveal this mechanism, we need some more intensive studies on the serow populations in much larger areas than those in which these have been conducted; for example, studies of the populations in some mountain areas.

The threshold values were about 150 ton/km^2 in summer and about 100 ton/km^2 in winter. These values may be obtained in the case when young conifer plantations (≦ 15 years after plantation) occupy 20-30% of the area. These figures may be important for forestry, because, in the case when clear cut areas and young conifer plantations should occupy over 30% of the areas, serow may increase its density drastically, causing the damage to conifer saplings. The composition and spatial arrangement of various types of forests in some mountain area may also be important to control the local population of serows.

Summary

We examined the relationships between the density of Japanese serow, *Capricornis crispus*, and the biomass of food plants in five mountain areas in Gunma Prefecture, central

Japan, during the period from 1982 to 1986. We counted the number of serows by the aero driving method. The density of serows was estimated as 6.3–10.1/km^2 in Nakanojo and 2.0–3.7 /km^2 in the other areas. We measured the total biomass of available food plants in the eight types of forests in Nakanojo; clear cuts, conifer plantations of five different age-classes, young mixed forests of Japanese cedar and deciduous broad-leaved trees, and mature deciduous broad-leaved forests. The biomass was highest in the young conifer plantations (6–15 years after planting) and in a young mixed forest, and lowest in a mature conifer plantation. The serow densities both in each forest compartment of 210–350 ha in Nakanojo and Kusatsu and in the five mountain areas were positively related with the biomass of food plants. These results suggest that the food availability is an important determinant factor in the serow density. However, the relationship was non-linear in the five mountain areas, with a threshold biomass, 150 ton/km^2 in summer and 100 ton/km^2 in winter, for drastic increase in serow density.

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* in Japanese.

** in Japanese with an English summary.