Body Mass Condition in *Trimeresurus flavoviridis* (Viperidae) from the Okinawa Islands
—Regional Differences with the Examination of the Sampling Methods—

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沖縄諸島産ハブの肥満度
—採集方法別にみた地域差—

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Abstract. The length-mass regression lines were compared in habu, *Trimeresurus flavoviridis*, among samples collected by different methods and among samples from several regions of the Okinawa Islands. The body mass was smaller in snakes collected by trap than in those collected by hand in the middle and south of Okinawa Island. The body masses of snakes from the north of Okinawa Island, Tokashiki Island and Minna Island were smaller than those from the middle and south of Okinawa Island.

Key words: Body mass condition, Regional difference, Sampling method, *Trimeresurus flavoviridis*, Okinawa Islands

I Introduction

The body length composition of a snake species sometimes differs among populations, e.g. in *Notechis ater* (Schwaner, 1985), *Notechis* spp. (Shine, 1987), *Elaphe quadrivirgata*, *E. climacophora* (Hasegawa and Morigichi, 1989), *Thamnophis sirtalis* and *Nerodia sipedon* (King, 1989). However, no works have reported the difference of body mass condition among snake populations.

Habu, *Trimeresurus flavoviridis* (Viperidae), inhabits in the subtropical Ryukyu Archiperago, and grows up to be more than 200 cm in total length. Females larger than ca. 90 cm in snout-vent length lay eggs in July (Shiroma and Kamura, 1987; Nishimura and Kamura, 1993). Hundreds of individuals of habu, collected by several methods, were gathered in our institute. It was desirable to analyze the measurement data of each local population separately, but we could only ascertain the major areas of collection for most individuals.

The differences in the length composition were observed among the samples collected by different methods in habu (Minakami et al., 1980; Nishimura and Kamura, 1994). We must examine whether there are any sampling biases on the body mass condition in habu. The present study reported the differences in body mass condition among samples collected by different methods and among several regions in the Okinawa Islands.

II Methods

The materials were 3398 habu, collected by hand or by mouse baited trap in the Okinawa Islands between 1981 and 1993 (Table 1). Most individuals were collected by hand of habu-hunters (H") and kept by them without a supply of water. We measured body mass (BM, g) and snout-vent length (SVL, cm) within a month after capture. Most individuals, including all ones measured 11-30 days after collection, were supplied water for more than a day before the measurements. With a supply of water, BM of habu does not change much during a month (coefficient of variance $< 3\%$, Nishimura, 1986). The mean error range in BM of the whole sample was 10.2%, i.e. 6.0% through water balance and feces excretion (Nishimura and Kamura, 1992) plus 4.2% through water evaporation for 10 days (Nishimura, 1986), but that of most individuals was 6.0%.

The materials did not include individuals with trunk distended at stomach, nor very small individuals (SVL $<$ 45 cm), in order to exclude

those with preys in stomach and hatchlings with residual yolk (mean and SD of hatchling SVL, 32.8 cm, 2.1, Nishimura and Kamura, 1993), respectively.

Females with distended abdomen, collected before or during the egg laying season (July), were supposed to be gravid, and reared separately. Most of them were classified as gravid females (GF), with oviposition or oviductal eggs or large follicles (longer than 12 mm, Nishimura and Kamura, unpubl. data).

Most comparisons were made on individuals ≧ 70 cm in SVL, dominating in samples collected by H" and trap (Nishimura and Kamura, 1994), termed LF (large females except GF) and LM (large males). Smaller sized individuals (45-70 cm in SVL), termed SF (small females) and SM (small males), were few in most samples, except in those collected by hand and trap in the middle and south of Okinawa Island and compared among these samples (Table 1).

In Okinawa Island, the regional comparisons were made among samples from the south (south to Ginowan and Nakagusuku), middle and north (north to Onna and Ginoza) of the island (SOI, MOI and NOI, respectively), and from their sub-regions with a large sample size (Table 1).

The SVL-BM (both in logarithm) regression line (LMR) of each sex-size group ($N > 4$) was compared among samples using ANCOVA, with the significance level of $P = 0.05$. In order to express BM differences between two samples, the proportion (%) of the smaller BM estimated from the LMR in one sample / the larger BM of the other sample at the mean SVL is shown as "PBM at SVL".

Ⅲ Results

1. Intra-regional differences in LMR

(1) In the south of Okinawa Island (SOI)

The positions of LMR in LF (large non-gravid females) and LM (large males) were different between in the sample collected by hand of other than habu-hunter (H') and that collected by trap in Naha and Urasoe, dominated by the urban areas ($P < 0.05$, Table 1), with PBM of the latter, 90.8% at 102.6 cm (LF) and 92.7% at 107.6 cm (LM). In the sample collected by H', LMR was not significantly different between that from Naha and Urasoe and that from the areas south to Naha, dominated by the suburbs and farming areas (all $P > 0.05$, Table 1).

In the sample collected in the areas south to Naha, the position of LMR in LM collected by H' was different from that by H" ($P < 0.01$, Table 1), with PBM of the former, 92.4% at 112.2 cm. LMR of LF was not significantly different between these two samples, but P was 0.092 in the comparison of the position, with PBM of the former, 94.7% at 106.9 cm.

In the whole sample collected by H' in SOI, the position (in LF) and slope (in LM) of LMR were significantly different from that by H" ($P < 0.05$), with PBM of the former, 95.5% at 105.2 cm (LF) and 97.4% at 111.2 cm (LM), while those in SF (small females), SM (small males), and GF (gravid females) were not significantly different between these samples (all $P > 0.05$) (Table 1).

(2) In Gushikawa, an area in the middle of Okinawa Island (MOI)

In the sample collected in Gushikawa, the slope of LMR in LF collected by trap in the farming areas was significantly different from that collected in the suburbs ($P < 0.05$), while LMR in LM were not significantly different between these two habitats (both $P > 0.05$, Table 1). LMR in the sample collected by trap was not significantly different from that collected by H' (all $P > 0.05$).

(3) In the north of Okinawa Island (NOI)

The position of LMR in LM in the sample trapped in the mountains was different from that trapped near the villages in NOI ($P < 0.001$) with PBM of the latter, 93.3% at 108.6 cm, while LMR of trapped LF was not different between these habitats (both $P > 0.05$) (Table 1, Fig. 1). LMR in the sample trapped near the villages was not significantly different from that collected by H' (all $P > 0.05$).

(4) In the middle and south of Okinawa Island (MSOI)

Table 1. Comparison of the regression lines of body mass (g, in logarithm) on snout-vent length (SVL, cm, in logarithm) by ANCOVA. Locality -- SOI, MOI, NOI and MSOI are the south, middle, north and middle & south of Okinawa Island; Toka.: Tokashiki; I.: Island; N&H: Naha and Urasoe; S-N: areas south to Naha; GU: Gushikawa; G&G: Ginoza and Gushikawa; K&O: Kunigami and Ogimi. Method-- T: mouse-baited trap; H: hand; H': hand of other than habu-hunter; H": hand of habu-hunter. Habitat -- M: mountains; F: farming fields, woods and houses; S: suburbs; U: urban areas. Compared vs -- the sample to be compared. Sex-size group -- LF: large (SVL ≧ 70 cm) non-gravid female; LM: large male; SF: small (45 ≦ SVL < 70) female; SM: small male; GF: gravid female (with eggs or follicles > 12 mm). ANCOVA -- Comparing the slope (SL) and position (PO) of two regression lines. NS, (*), *, ** and ***: P > 0.05, P ≒ 0.05, P < 0.05, P < 0.01 and P < 0.001, respectively.

No	Collection				Compared vs	Sex-size group						
	Locality	Method	Habitat			LF			LM			Other (n)
					No	N	SL	PO	N	SL	PO	NS / P < 0.05
1	SOI	N&H	T	S,C	2	24	NS	*	28	NS	*	SF(5),GF(5) /
2		N&H	H'	S,C	3	66	NS	NS	62	NS	NS	SF(6) / SM(12)SL*
3		S-N	H'	S,F	4	24	NS	NS	26	NS	**	/ SM(7)SL*
4		S-N	H"	F,S		724	NS	NS	1184	NS	NS	SM(32) /
5		All	H'	S,F,U	6	103	NS	*	119	*	−	SF(16),SM(22),GF(10) /
6		All	H"	F,S		724			1184			SF(55),SM(32),GF(106) /
7		All	H	F,S,U	16	827	NS	NS	1303	NS	NS	SM(54),GF(116)/ SF(71)PO*
8		All	T	S,F		63			88			
9		All	T,H	F,S,U								GF(119) /
10	MOI	GU	T	F	11	52	*	−	91	NS	NS	
11		GU	T	S		37	NS	NS	65	NS	NS	
12		GU	T	F,S	14	97	NS	(*)	166	NS	NS	GF(9) /
13		GU	T	F,S	8	97	NS	*	166	NS	NS	
14		GU	H'	F,S		9	NS	NS	9	NS	NS	
15		G&G	H'	F,S	5	34	NS	NS	37	(*)	NS	SF(8),SM(11),GF(6) /
16		All	H	F,S		63	NS	NS	82	NS	NS	SF(10),SM(16),GF(11) /
17		All	T,H	F,S	9							GF(22) /
18	NOI	K&O	T	M	29	30	NS	NS	52	*	−	
19		K&O	T	M	20	30	NS	NS	52	(*)	***	
20		K&O	T	F	13	49	NS	NS	83	NS	NS	
21		K&O	T	F	8	49	NS	NS	83	NS	NS	
22		K&O	T	F	29	49	NS	NS	83	NS	NS	
23		K&O	T	M,F	29	79	NS	NS	136	NS	*	
24		All	H'	F	23	20	NS	NS	28	NS	NS	
25		All	H'	F	20	20	NS	NS	28	NS	NS	
26		All	H'	F	15	20	**	−	28	NS	NS	
27		All	H'	F	5	20	*	−	28	NS	NS	
28		All	H'	F	30	20	*	−	28	NS	*	
29	MSOI	All	T	F,S,U	30	180	NS	***	276	NS	***	SF(11),SM(8) / GF(13)PO*
30		All	H	F,S,U		892			1386			SF(81),SM(71),GF(128) /
31	Toka.	I.	H	M,F	30	13	NS	***	13	NS	***	
32	Kume	I.	H'	F	30	17	NS	(*)	26	NS	NS	
33	Minna	I.	T	F	29	5	NS	*	5	*	−	

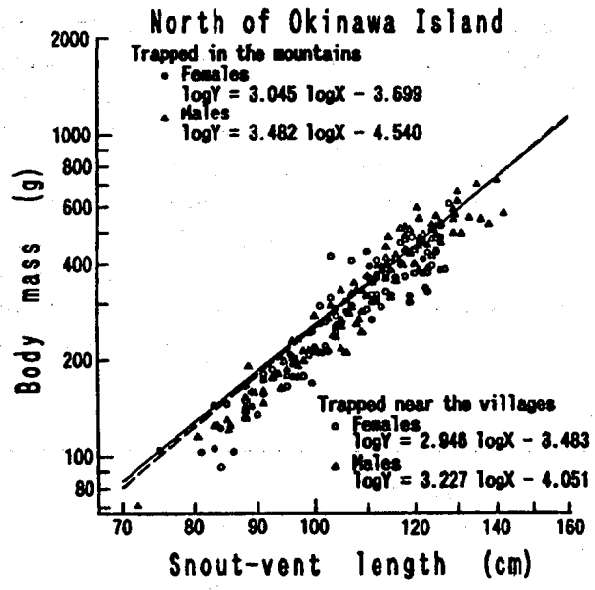

Fig. 1. Snout-vent length and body mass in large (snout-vent length ≧ 70 cm) habu, *Trimeresurus flavoviridis*, trapped in the north of Okinawa Island (dots). The position of the regression line was different between males trapped in the mountains and those near the villages ($P < 0.001$). The lines are regression lines of the sample trapped in the middle and south of Okinawa Island (continued: female; broken: male).

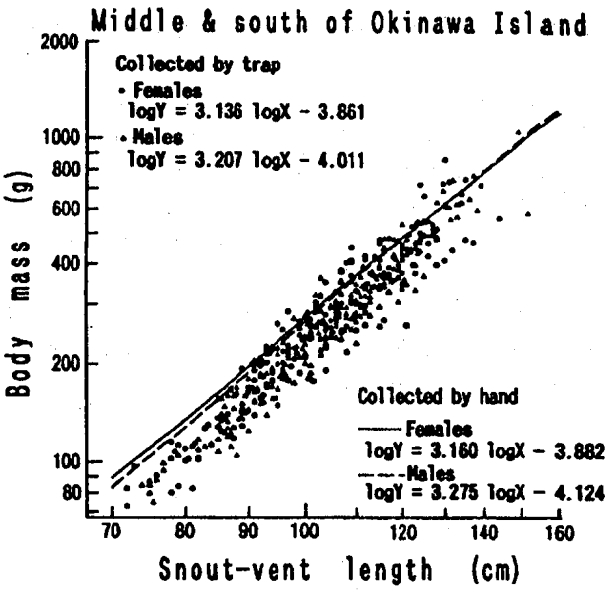

Fig. 2. Snout-vent length and body mass in large (snout-vent length ≧ 70 cm) *T. flavoviridis* from the middle and south of Okinawa Island. The positions of the regression lines were different both in females and males between those collected by hand (lines) and those by trap ($P < 0.001$).

The positions of LMR in both LF, LM and GF were different between the samples collected by hand and that by trap in MSOI ($P < 0.05$ or 0.001, Table 1, Fig. 2), with PBM of the latters, 93.9% at 103.5 cm (LF), 94.4% at 106.9 cm (LM) and 92.6% at 111.7 cm (GF).

In LM collected by hand, the position of LMR in individuals just after ecdysis (with clear body color, n = 318) was nearly significantly different from in those before ecdysis (with dark body color, n = 159) ($P = 0.071$), with PBM of the former, 97.5% at 111.7 cm.

In the sample collected by hand and by trap the position of LMR was different between SF (n = 93) and SM (n = 79) ($P < 0.05$, Fig. 3), with PBM of the latter, 95.6% at 57.4 cm.

2. Regional differences in LMR

(1) Among the samples collected by H'

The slope of LMR of LF collected in NOI was different from that in Ginoza and Gushikawa in MOI ($P < 0.01$) and from that in SOI ($P < 0.05$), while LMR of LM was not significantly different between these pairs of samples (all $P > 0.05$) (Table 1). There were no significant differences in LMR (all $P > 0.05$), between the sample from SOI and that from Ginoza and Gushikawa.

(2) Among the samples collected by hand

The position of LMR in SF was significantly different between in the sample collected in MOI and that in SOI ($P < 0.05$), with PBM of the former, 90.6% at 56.6 cm, while other LMR was not significantly different between these areas (all $P > 0.05$) (Table 1).

The slope (LF) and position (LM) of LMR in the sample collected by hand in MSOI was different from those in NOI (both $P < 0.05$) with PBM of the latter, 93.4% at 103.0 cm (LF) and 95.0% at 108.6 cm (LM) (Table 1, Fig. 4). The position of LMR in LF collected by hand in MSOI was nearly significantly different ($P = 0.071$) from that collected in Kume Island with PBM of the latter, 92.7% at 105.4 cm, while LMR in LM was not significantly different between these two regions (both $P > 0.05$) (Table 1, Fig. 4). The position of LMR in the sample collected by hand in MSOI was

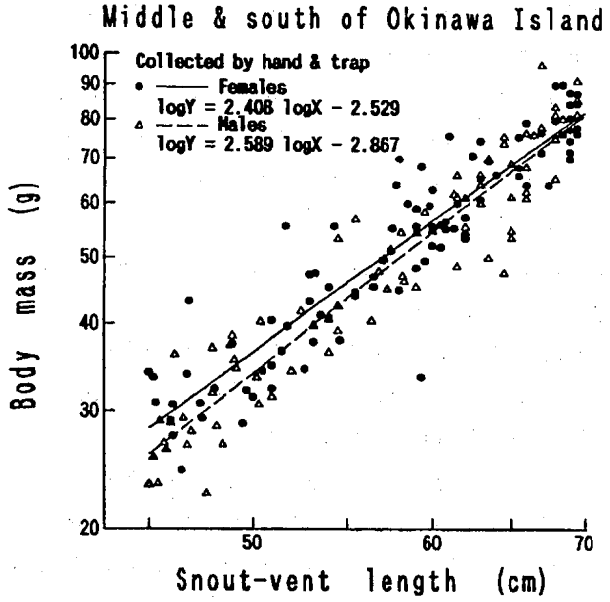

Fig. 3. Snout-vent length and body mass in small (45 ≦ snout-vent length < 70 cm) *T. flavoviridis* collected by hand in the middle and south of Okinawa Island. The position of the regression line was different between females and males ($P < 0.05$).

different from that in Tokashiki Island in LF and LM (both $P < 0.001$) (Table 1, Fig. 4) with PBM of the latter, 83.8% at 108.6 cm (LF) and 84.9% at 111.7 cm (LM).

(3) Among the samples collected by trap

The position of LMR in LF was different between the sample trapped in Gushikawa and that in SOI ($P < 0.05$), whereas there were no significant differences in LMR (all $P > 0.05$), among the samples trapped in the areas near the villages in NOI, in Gushikawa and in SOI (Table 1).

The slope of LMR in LM collected by trap in the mountain areas of NOI was different from that in MSOI ($P < 0.05$), with PBM of the latter, 93.9% at 105.4 cm, while LMR in LF from the mountain areas of NOI and LMR in LF and LM trapped near the villages in NOI was not different from respective LF and LM in MSOI (all $P > 0.05$) (Table 1).

The position (LF) and slope (LM) of LMR in the sample trapped in Minna Island was different from those in SOI (both $P < 0.05$) (Table 1, Fig. 5) with PBM of the former, 84.9% at 101.6 cm (LF) and 91.8% at 105.2 cm (LM).

(4) GF collected by hand and by trap

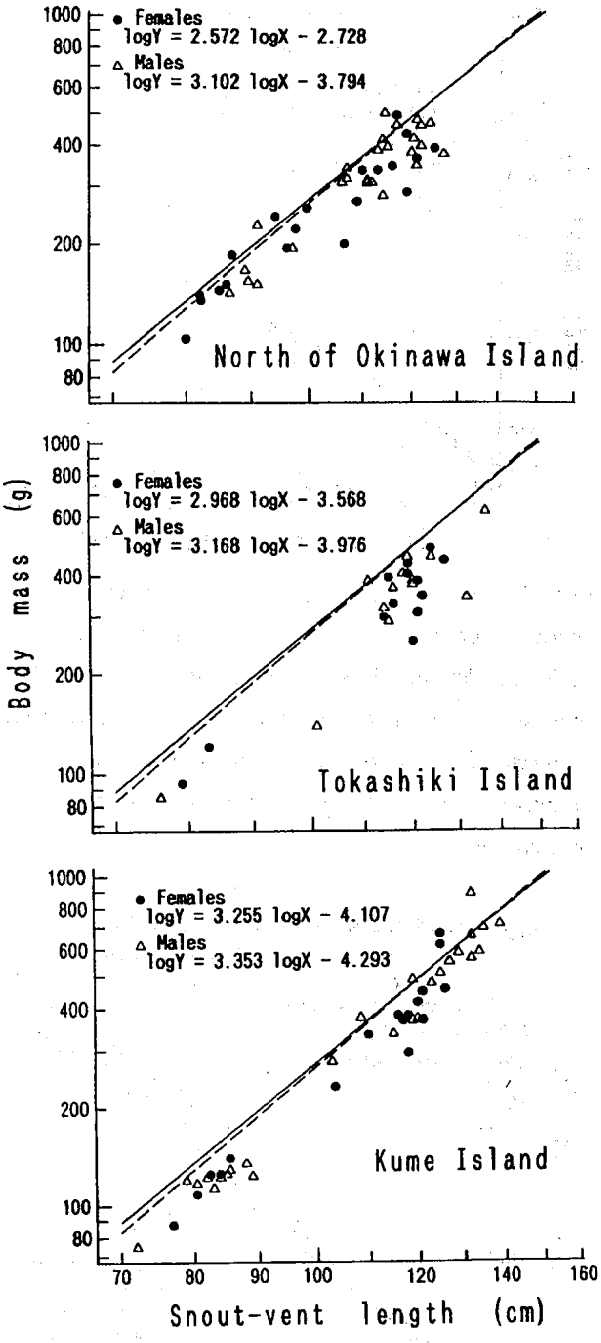

Fig. 4. Snout-vent length and body mass in large (snout-vent length ≧ 70 cm) *T. flavoviridis* collected by hand in other regions of the Okinawa Islands. See Table 1 for the comparison of the regression lines between in each sample and in that collected by hand in the middle and south of Okinawa Island (female: continued lines; male: broken line).

The LMR of GF was not significantly different between the sample from SOI and that from MOI (Table 1), nor between the sample in MSOI ($n = 141$) and in other regions ($n = 9$) (all $P < 0.05$) (Fig. 6). LMR of all GF was:

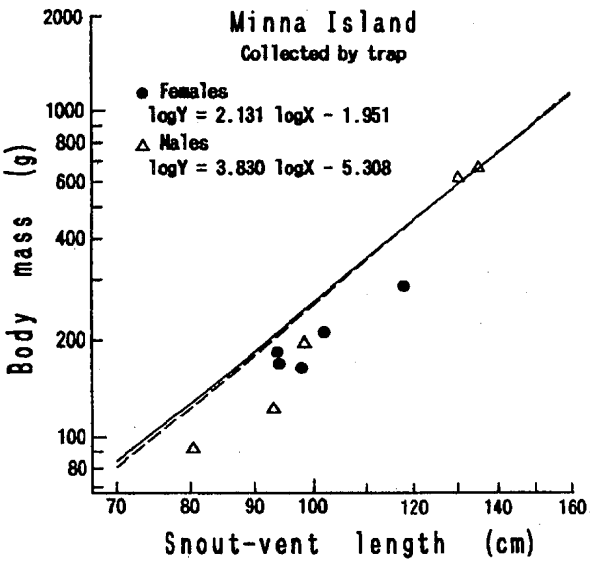

Fig. 5. Snout-vent length and body mass in large (snout-vent length ≧ 70 cm) *T. flavoviridis* trapped in Minna Island (dots). The position (in females) and slope (in males) of the regression lines were different from those in the middle and south of Okinawa Island (female: continued lines; male: broken line).

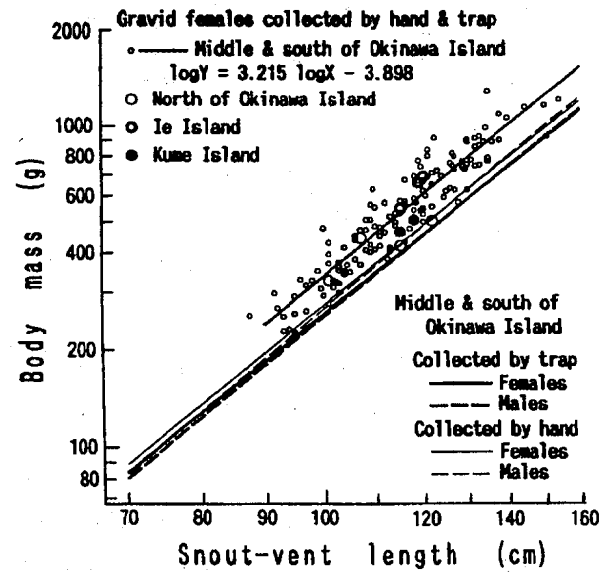

Fig. 6. Snout-vent length and body mass in gravid *T. flavoviridis* (dots and the dotted line). Other lines were regression lines of large individuals in the middle and south of Okinawa Island.

$$\log BM = 3.255 \log SVL - 3.985$$
$$(n = 151,\ r^2 = 0.883)$$

Ⅳ Discussion

It may not be proper to regard all significant ($P < 0.05$) differences in LMR observed in the present study as real differences among the samples, on account of the errors in measuring BM in small samples and the statistical effect of large samples. In the following discussion, we examine the differences with significant level $P < 0.01$, and those between samples with more than one sex-size groups of differences ($P < 0.05$).

One of the reasons that BM of trapped individuals was smaller than those collected by hand (mainly by H") in MSOI and that BM of those collected by H' was smaller than those collected by H" in SOI may be that in the sample collected by H" there were not a few individuals collected in early spring, when BM is large, (Nishimura and Kamura, in press), which was not in other samples.

It might be possible that fewer individuals collected by baited trap contain preys in their digestive tract than those collected by hand. However, the proportion of individuals with preys in digestive tract was low in those collected by hand and the mean decrease in BM at feces defecation was only 3.7% (Nishimura and Kamura, 1992). Therefore, the differences in the amount of preys in digestive tract may not be the major reason of the BM differences between the samples collected by hand and that by trap.

In the regional comparisons, the BM was smaller in the samples from NOI, Tokashiki Island and Minna Island than that from MSOI. The growth rate of SVL was estimated to be lower in habu from Minna Island and from NOI than that from MSOI (Nishimura, 1993; no-data for Tokashiki Island). The amount and composition of preys were supposed to be the main source of regional size differences in *Notechis ater* (Schwaner, 1985), *Notechis* spp. (Shine, 1987), *Elaphe quadrivirgata* and *E. climacophora* (Hasegawa and Morigichi, 1989). The present results may indicate that the body mass condition is good in the population with high growth rate of SVL.

The SVL growth rate was reported to be correlated with the ecdysis frequency in habu (Kamura and Shimamura, 1981). In the present study, the BM of individuals before ecdysis was larger than that after

ecdysis (not significantly).

LMR of small ($45 \leqq SVL < 70$ cm) female and male individuals from MSOI was:

$$\log BM = 2.508 \log SVL - 2.714$$

($n = 172$, $r^2 = 0.872$)

The BM at the mean hatchlings SVL, 32.8 cm (Nishimura and Kamura, 1993) is estimated to be 12.2 g through this equation. By adding the mean yolk weight (12.9% of the hatchling BM, Nishimura and Kamura, 1993) on this, the weight is 14.1 g, which is smaller than the hatchling BM, about 18 g. Therefore, the body mass condition of the hatchlings is better than that of the juveniles in habu.

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