Morphological Variation and Sexual Dimorphism in *Gekko japonicus* from Fukuoka, Northern Kyushu, Japan

Shoji Tokunaga

ABSTRACT: The external morphology of 121 geckos collected on buildings in Fukuoka City was examined. All of them were identified as *Gekko japonicus* by the following characteristics. They had enlarged tubercles on the back, the neck, the forearm, and the crus. They had 2–5 (average, 2.9) cloacal spurs on each side of a tail. Adult males had 3–8 preanal pores. Forty-five percent of the specimens had caudal tubercles. More females had caudal tubercles than males. Males, with one exception, and females with SVL < 53 mm lacked swollen endolymphatic sacs. Of females with SVL ≥ 53 mm, 58.5% had swollen endolymphatic sacs. SVL of adult females older than one year old was larger than that of adult males older than one year. Sexual dimorphism in head length relative to SVL was small (male/female ratio = 1.013).

INTRODUCTION

Recently, important reports have been made regarding the classification and distribution of Japanese *Gekko*. Shibata (1981, 1983) reported the presence of great morphological variation among local populations of genus *Gekko* previously called *Gekko japonicus*. He suggested that the taxonomic status of *G. japonicus* type A, *G. japonicus* type B (*G. japonicus* and *G. hokouensis*, respectively, see below), and *G. yakouensis* should be reexamined. Zhou et al. (1982) showed that *G. japonicus hokouensis* differed significantly from other subspecies of *G. japonicus*. They treated *G. japonicus hokouensis*, which was formerly regarded as a synonym of *G. japonicus*, as an independent species, *G. hokouensis*. They examined the external morphology of 1018 individuals from China, and found no types intermediate between *G. japonicus* and *G. hokouensis*. They inspected specimens of the genus *Gekko* previously called *G. japonicus* from Japan also. They concluded that the specimens from the Okinawa islands were *G. hokouensis* and those from Honshu and Tsushima were *G. japonicus*.

These studies show the problems of previous taxonomic studies which failed to discriminate two species in populations previously called *G. japonicus* collectively (Okada, 1936; Nakamura and Uéno, 1963). In these studies intra- and inter-populational variations of morphology were incompletely noticed. Okada (1936) reported that *G. japonicus* had one cloacal spur on each side of the tail. He recorded
no variation in the number of cloacal spurs. Nakamura and Uéno (1963) reported that *G. japonicus* usually had one pair of cloacal spurs, but some individuals had 2 or 3 pairs. They also reported that some individuals had enlarged tubercles on the back of the limbs. However, they did not discuss these variation in morphologies in relation to the localities where the specimens were collected. For future study on taxonomy, the variation in one local population should be clarified and compared with that in other populations.

The recent studies on the distribution of other species of Japanese *Gekko* should also be noted. Kawata (1982) showed that *Gekko* inhabits northern Kyushu, and suggested its occurrence all over the island of Kyushu. Zhou et al. (1982) examined published records of specimens from Yamagawa, Kagoshima Prefecture, Japan and a specimen from Fukuoka (Fig. 1 of Okada, 1936). They identified those geckos from Kyushu island as *G. hokouensis*. The distribution of the species, however, should be reexamined (Shibata, 1983).

The present study has three objectives: first, to report the intrapopulational variations in the external morphology of a population of *G. japonicus* in Fukuoka; second, to provide information on the distribution of Japanese geckos; and third, to report morphological information on *G. japonicus*.

**MATERIALS AND METHODS**

A total of 121 specimens were collected on buildings in and around the campus of Kyushu University (33°37′N, 130°26′E) in Fukuoka in September 1977 and in August-September 1982. All specimens were fixed in 10% formalin and subsequently immersed in 80% ethanol.

The external morphology was observed under a stereo dissecting microscope (×7.5–20). Detailed methods of observation are described in each section. Snout-vent length (SVL), head width (HW), head length (HL) and tail length (TL) were measured after the specimens were fixed. SVL of each animal was taken from the tip of the snout to the anterior edge of the cloaca. HW was measured as maximum width of the head. HL was taken from the anterior tip of the snout to the posterior edge of the skull. TL was measured from the posterior edge of the cloaca to the tip of the tail. The measurements were made with vernier calipers.

The specimens were sexed by external morphology, by the morphology of the reproductive organs and by the presence or absence of Mullerian ducts. Males with SVL ≥ 44mm have hemipenal swellings and thick cloacal spurs. Because young males can not be differentiated from young females by external morphology, specimens with SVL from 40 to 55mm were dissected and sexed by the morphology of the repro-
ductive organs. Specimens smaller than 34mm were dissected and examined for the presence or absence of Mullerian ducts. When the ducts were fully developed, the specimen was determined as female.

In this study area, capture and recapture data showed that the age of this species could be estimated by SVL (Tokunaga, 1978). The specimens used in the present study were divided into three age groups; hatchlings, yearlings and adults older than one year old. In late August and early September, the SVL of each age group is as follows: less than 35mm for hatchlings, from 44 to 55mm for yearlings and larger than or equal to 55mm for adults older than one year old (Tokunaga, unpublished). This estimation is incomplete because the SVL of large yearlings and small adults overlap at an SVL of 55mm. In this study, specimens with SVL less than 54.0 mm were classified as yearlings and specimens with SVL larger than 56.0mm were classified as adults older than one year old. The age of specimens with an SVL of 54.0mm ≤ 56.0mm was not determined.

RESULTS

(1) Distribution of enlarged tubercles on the back and limbs

The dorsal surface of the body and limbs was divided into the neck, the back, the upper arm, the forearm, the thigh, and the crus. The presence of enlarged tubercles on each part was checked.

All specimens had enlarged tubercles on the neck, the back, the forearm, and the crus. No specimens had them on the upper arm. The difference in size between the enlarged tubercles on the forearm and the scales around them was small except in 2 specimens. Twenty-seven specimens (22.3%) had enlarged tubercles on the thigh. Some enlarged tubercles were scattered on the thighs of 20 out of the 27 specimens. The thighs of 2 specimens had the enlarged tubercles as dense as those on the crus.

(2) Number of cloacal spurs

Large tubercular scales, similar to the cloacal spurs, were occasionally found around the cloacal spurs. In some cases, the tubercular scales were difficult to discriminate from the cloacal spurs. In these cases, the number closest to the mode of the number of cloacal spurs (3) was adopted. The number of cloacal spurs is shown in Table 1. The average number of spurs was 2.9, varying from 2 to 5. When two cloacal spurs were present, the separation between the two spurs was always distinct.

(3) Number of preanal pores

All specimens with hemipenal swellings had preanal pores. Table 2 shows the
Table 1. The number of cloacal spurs. The figures show number of individuals.

<table>
<thead>
<tr>
<th>No. of left cloacal spurs</th>
<th>No. of right cloacal spurs</th>
<th>Sum</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>21 6 1 0</td>
<td>28</td>
<td>23.1</td>
</tr>
<tr>
<td>3</td>
<td>3 72 4 0</td>
<td>79</td>
<td>65.3</td>
</tr>
<tr>
<td>4</td>
<td>1 7 5 1</td>
<td>14</td>
<td>11.6</td>
</tr>
<tr>
<td>Sum</td>
<td>25 85 10 1</td>
<td>121</td>
<td>100.0</td>
</tr>
<tr>
<td>%</td>
<td>20.7 70.2 8.3 0.8</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. The number of preanal pores (adult males).

<table>
<thead>
<tr>
<th>No. of pores</th>
<th>3 4 5 6 7 8 Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of individuals</td>
<td>1 1 6 27 9 4 48</td>
</tr>
<tr>
<td>%</td>
<td>2.1 2.1 12.5 56.2 18.8 8.3 100</td>
</tr>
</tbody>
</table>

variation in the number of preanal pores. The number was 3–8, average 6.1. In some cases (5 out of 59), females had rudimentary preanal pores.

(4) Presence of caudal tubercles

The caudal tubercles were defined as scales which were at least 1.5 times larger than the scales around them. The presence or absence of caudal tubercles is shown in Table 3. In total, 45 percent of the specimens had caudal tubercles. More females had caudal tubercles than males ($\chi^2$-test, $P<0.025$).

Table 3. Occurrence of caudal tubercles. Figures show number of individuals. Figures in parenthesis show percentages. Presence/absence of caudal tubercles

<table>
<thead>
<tr>
<th>sex</th>
<th>present</th>
<th>absent</th>
</tr>
</thead>
<tbody>
<tr>
<td>males</td>
<td>16(14.7)</td>
<td>35(32.1)</td>
</tr>
<tr>
<td>females</td>
<td>33(30.3)</td>
<td>25(22.9)</td>
</tr>
<tr>
<td>Sum</td>
<td>49(45.0)</td>
<td>60(55.0)</td>
</tr>
</tbody>
</table>

Table 4. The number of caudal tubercles on intact tails. The number of caudal tubercles is shown as the number of lines of caudal tubercles.

<table>
<thead>
<tr>
<th>No. of tubercles</th>
<th>0 1 2 3 4 5 6 7 15</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of individuals</td>
<td>37 5 10 5 4 4 1 2 1</td>
</tr>
<tr>
<td>%</td>
<td>53.6 7.2 14.5 7.2 5.8 5.8 1.5 2.9 1.5</td>
</tr>
</tbody>
</table>
Table 4 shows the number of caudal tubercles on the intact tail. The number of caudal tubercles was expressed as the number of lines formed by them. Each line consisted of 1–4, usually 2, tubercles. In most cases, the number was less than 6, but as many as 15 were present on a tail of a female.

(5) Swelling of the endolymphatic sacs

Juveniles and males with one exception lacked swollen endolymphatic sacs. The single male with swollen endolymphatic sacs was 61mm in SVL, and showed no other tangible difference from other adult males.

Females with SVL<53mm lacked swollen endolymphatic sacs. Of females with

Figure 1. Frequency distribution of SVL of *G. japonicus*. Dotted, slashed, and hatched areas show hatchlings, yearlings, and adults older than one year old, respectively. Age of individuals with an SVL of 54.0mm ≤ ≤56.0mm was not one determined (open area). Females older than year have a larger SVL than males older than one year.
an SVL of $\geq53$mm, 58.5% had swollen endolymphatic sacs.

(6) Body measurements

The frequency distribution of SVL of males and females is shown in Figure 1. The maximum SVL of males was 64.4mm and that of females was 70.0mm. Although the mean SVL of females (54.3mm) was also greater than that of males (52.6mm), the difference was not significant ($P=0.052$, Mann-Whitney U-test). The sexual differences in SVL of hatchlings and yearlings were not significant ($P>0.5$ and $P>0.27$ respectively, U-test). The SVL of females older than one year was significantly larger than that of males older than one year ($P<0.006$, U-test).

The allometric relationships of HW to SVL, HL to SVL, and TL to SVL were calculated with their logarithmic values. Linear regression was not applied, because scattergrams showed that the variance in the value of the abscissa increased as the value of the ordinate increased (Campbell, 1967: 206-7).

The allometric relationships of HW to SVL, HL to SVL, and TL to SVL were calculated with their logarithmic values. Linear regression was not applied, because scattergrams showed that the variance in the value of the abscissa increased as the value of the ordinate increased (Campbell, 1967: 206-7).

The sexual differences in slopes and intercepts of the allometric equations were tested for each age group and for all age groups combined by means of the analysis of covariance. No sexual differences were found in slopes and intercepts of allometric equations of HW to SVL or TL to SVL ($P$ was greater than at least 0.10). The allometric equations for all individuals were as follows: $(HW) = 0.338 \cdot (SVL)^{0.887} \quad (r^2=0.967)$, $(TL) = 0.731 \cdot (SVL)^{1.076} \quad (r^2=0.974)$. In the same age groups, the sexual difference in relative HL was not significant, but the relative HL of all males combined was greater than that of all females combined ($P<0.05$). The allometric equations were $(HL) = 0.662 \cdot (SVL)^{0.739} \quad (r^2=0.948)$ for males and $(HL) = 0.704 \cdot (SVL)^{0.761} \quad (r^2=0.954)$ for females. The adjusted mean of HL of males (14.55mm) was greater than that of females (14.36mm) by 1.3%.

**DISCUSSION**

(1) Identification of the species

The results of previous studies (Kawata, 1982; Zhou et al., 1982) suggested the possible occurrence of three species of *Gekko* in Fukuoka city, where the present study was undertaken. All my specimens were *G. japonicus*, and not *G. hokouensis* (GH) or *G. tawaensis* (GT), for the following reasons. [1] My specimens had two or more cloacal spurs (GH and GT have one). [2] Enlarged tubercles were present on the dorsal surface of the body (GT lacks them). They were present also on the neck, the forearm and the crus (GH lacks them on these parts). [3] Adult males had preanal pores (GT lacks them).

This observation does not necessarily show the absence of the latter two species in Fukuoka. These two species have a tendency to avoid human habitations (Zhou...
et al., 1982; Kawata, 1980, 1981, 1982), whereas my specimens were collected on buildings. Further collection of geckos in the field is necessary to clarify the presence or absence of *G. tawaensis* and *G. hokouensis* in Fukuoka.

(2) The variation in external morphology

Zhou et al. (1982) reported that the number of cloacal spurs of *G. japonicus* from China is 3. Shibata (1983) reported that the number is usually 3 and sometimes 4 among the Japanese populations of Honshu, Shikoku, Oki, Goto, and Tsushima. Toriba et al. (1983) reported that *G. japonicus* from Tochigi usually had 3 cloacal spurs, but 6.9% (2/29) had 2 on the left and 3 on the right. My results show that the specimens from Fukuoka had 2–5 cloacal spurs. These reports indicate that the frequency distribution of cloacal spur number varies among populations.

Shibata (1981) reported that about 40% of *G. japonicus* from Oki and Tsushima have caudal tubercles on the back of the tail. My results show that caudal tubercles were present on the tails of 45% of the specimens. The frequency of their occurrence was different between males and females. The number of caudal tubercles varied from 0 to 15. This indicates that the number of caudal tubercles even within one population varies greatly.

The distribution of enlarged tubercles in this study was the same as that in the Chinese population reported by Zhou et al. (1982).

In the present study, the minimum SVL of females with swollen endolymphatic sacs was 53mm. It is known that calcium is secreted in the sac, but its function is unknown (Kluge, 1967). Ruth (1918) found some evidences in *Gekko* spp. to suggest that the sporadic occurrence of the calcareous material in the endolymphatic sac is correlated with the time of eggshell formation. The minimum SVL of *G. japonicus* containing oviducal eggs or enlarged follicles was 52mm (Tokunaga, unpublished). This value is close to the minimum SVL of females with swollen endolymphatic sacs. The sac swellings might be related to the formation of egg shells.

(3) Sexual dimorphism

Body size of lizards influences many ecological characteristics such as fecundity of females and competitive ability within a sex. The relationship between body size and these characteristics influences selection on male and female body size and consequently sexual dimorphism.

The tendency among lizards, in general, is that larger females of the same species not only produce larger broods, but also produce them with greater consistency or at shorter intervals (Fitch, 1970). Tokunaga (1978) reported the presence of a size hierarchy among juvenile and female *G. japonicus* at their feeding site. I strongly believe that larger body size is selected for to increase fecundity and competitive ability for feeding sites among female *G. japonicus*. 
Among males of some squamate species, competition for mates exists and larger males have greater competitive ability and greater reproductive success (Anolis garmani: Trivers, 1976; Sceloporus jarrovi: Ruby, 1981). Body size of males of these species are larger than that of females. These authors explained the sexual size dimorphism by intrasexual competition for mates among males. Male lizards of some species have larger relative head length (Eumeces laticutatus: Hikida, 1978; Cnemidophorus ocellifer: Vitt, 1983) or larger relative jaw length (A. garmani: Trivers, 1967), which make biting more effective. These authors explained the sexual dimorphism in relative length of head or jaw by intrasexual competition among males.

In this study, SVL of adult females of G. japonicus was larger than that of adult males. Male and female relative head length was almost identical (male/female ratio=1.013). I suggested that, among G. japonicus, the intrasexual selection for larger body size in males is small compared to the selection for larger body size in females possibly to increase fecundity and competitive ability for feeding sites.

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LITERATURE CITED


要 約

ニホンヤモリの形態変異と性的二型——福岡市の個体群について——

福岡市内で捕獲された121頭のヤモリについて形態的吟味を行なった。全個体は以下の形態的特徴により Gekko japonicus と判定された。(1)胴体、前腕、下腿背面に大型鱗 (enlarged tubercle) が分布し、(2)尾部基部側面には片側につき2～5個の突起 (cloacal spur) があり、(3)成体♂に3～8 個の前肛小孔 (preanal pore) が存在した。

45%の個体には尾の背面に対になった大型鱗 (caudal tubercle) が少数認められたが、存在頻度は♂より♀の方が高かった。♂（1匹を除く）及び体長53 mm 未満の♀の endolymphatic sac は肥大していなかった。体長53 mm以上の♀のうち58.5%の個体に endolymphatic sac の肥大が見られた。

2歳以上の個体については♀は♂よりも体長が大きかった。体長に対する頭長の相対長は♂♀でほぼ等しく、♂♀比は1.013であった。