Utilisation of weep holes in retaining walls by the Japanese gecko (*Gekko japonicus* Dumeril & Bibron, 1836) in Fukuoka, Japan

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**Abstract.** Retaining walls are ubiquitous throughout Japan, and geckos are reported to frequently inhabit such walls. We surveyed 3,648 weep holes of retaining walls in the city of Fukuoka from November to March to ascertain the rate of use by *Gekko japonicus*, and determine the characteristics of holes preferred by *G. japonicus*. We observed that 19.21% of the holes were utilised as sites of shelter or oviposition. Overall, the geckos preferred to utilise holes 6 cm in diameter or smaller. Additionally, holes with openings exposed to the East or West were more frequently utilised than others. Although an excess of holes was available, geckos inhabited holes containing conspecifics at a rate much higher than expected if they selected holes at random. The results of this study indicate that retaining walls with weep holes are a significant resource for *G. japonicus*, and this gecko prefers smaller holes, possibly to mitigate exposure to temperature fluctuations during brumation or to minimize predator ingress.

**Keywords.** *Gekko japonicus*, microhabitat use, oviposition, brumation, retaining walls, aggregations

**Introduction**

*Gekko japonicus* is one of five species of the genus *Gekko* found on the island of Kyushu and the only species known to occur in and around the island’s largest city, Fukuoka (Tokunaga, 1984; Toda et al., 2006; Matsuhashi and Tomita, 2007; Ota, 2010a, 2010b). *Gekko japonicus* may have been introduced to Japan by humans and its presence is often associated with anthropogenic activity (Sasaki et al., 2005). Retaining walls are ubiquitous throughout the island along roads and in hilly and mountainous areas. To cope with the region’s heavy rainfall, these walls are usually replete with weep holes. Geckos are known to utilise drainage holes as sites of refuge (Williams and McBrayer, 2007) and oviposition (Huang and Pike, 2007). We conducted a survey in Fukuoka, Japan from November 2011 to March 2012 to determine the rate of weep hole utilisation by *G. japonicus* and to determine the characteristics of holes used by *G. japonicus*.

**Materials and Methods**

We surveyed 3,648 weep holes (referred to hereafter as “holes”) in 109 retaining walls at seven different locations throughout Fukuoka City. The southern, eastern and western edges of the city are bordered by mountains and forests, and the northern side by a large bay. Locations already known by the authors to have retaining walls were surveyed. Additionally, Google Earth® and StreetView® were used to find locations with a high number of retaining walls throughout the city. Two of the locations, “West Park” (33.5982°N, 130.3755°E, WGS84) and “Atago Shrine” (33.5851°N, 130.3348°E, WGS84), are tree-covered hills near the coast. The location identified as “Airport & Forest Park” (33.5894°N, 130.4583°E, WGS84) is bordered on the west side by a street adjacent to the Fukuoka Airport; this area has several hills, is heavily vegetated and contains several lakes and ponds. The “Castle Ruins” location (33.5860°N, 130.3857°E, WGS84) falls within Maizuru Park and contains athletic fields, the ruins of Fukuoka Castle and its moat system. The “Zoo” location (33.5289°N, 130.36945°E, WGS84) covers the largest area of any of the sites; it is located near the centre of the city and encompasses the area around the Fukuoka City Zoo, as well as Jonan-sen, an extremely busy street. The “Mount Abura” location (33.5289°N, 130.36945°E, WGS84) consisted of walls

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that were found along roads running up the northeast side of Mount Abura. This mountain is one of several found along the southern border of Fukuoka and was the most heavily forested area surveyed. The “North Site” location (33.6376°N, 130.4441°E, WGS84) was the northernmost area we surveyed. Its west side was bordered by a busy street, and the area encompassed a hill on which a residential area surrounded a park.

Surveys were conducted from 28 November 2011 through 6 March 2012 because *G. japonicus* has been reported to enter brumation from late October or November through late March (Hisai, 1998) and stop feeding at temperatures below 13°C (Ji and Wang, 1990). These conditions suggest a maximum encounter rate because lizards are less likely to be foraging or searching for new refugia. Surveys were primarily carried out in daylight hours between 1000 h to 1730 h. Due to logistical reasons, some surveys were conducted as late as 2105 h.

All holes included in the survey were located 40 cm to 2 m above the ground. Hole diameters were measured with Vernier calipers and were examined with high-powered LED flashlights. When geckos were in a hole, observation time was limited to less than one minute in an attempt to minimise disturbance of the animals. Six walls were excluded from this study because holes immediately opened into cavernous space and it was impossible to visually ascertain if the holes were utilised. Directional exposure of each wall was initially estimated using a compass, subsequently determined using Google Earth®, and was assigned to one of eight directional categories.

Holes containing geckos, eggshell fragments, or unhatched eggs, were counted as utilised (Fig. 1). Data collected at utilised holes included the number of geckos, and when possible, the number of eggs in each hole. Often it was not possible to determine the number of eggs that had been present, particularly when all that remained were crushed shells or if the eggs were in massive clusters. Two walls were surveyed on more than one occasion, and the number of holes in which geckos were observed varied; in such cases we used the higher figure for the wall for the following analyses.

In order to analyse the effect of hole diameter on
utilisation, survey data was clustered in regular intervals starting with [3, 4] cm and going on up to [10, 11] cm. The [9,10] range was excluded because it contained no holes, and the [6,7] range was so small (representing less than .5% of all data) it was lumped in with the [7,8] range. Analyses were conducted on data for all survey areas combined. In each analysis, hole diameter was plotted against percent of holes utilised, percent of holes containing geckos, percent of holes with eggs, and percent of holes containing multiple geckos.

To analyse how hole utilisation varied over the different ranges of hole diameters, a list of expected numbers of geckos in each range was compiled for the case of a random distribution across all ranges. This was done by taking the total number of observed geckos and distributing them proportionally based on the number of holes in each range. The expected and observed lists were then compared using a chi-squared goodness-of-fit test with a significance level of $\alpha = 0.05$. This procedure was repeated for percent of holes with geckos and percent of holes with eggs. Where applicable, observations were also put into two groups with diameters above and below 6 cm. These two groups were then compared with a chi-squared goodness-of-fit to determine if they have a significant difference in utilisation percentages.

For directional exposure, all data gathered from holes of the same exposure were pooled in a similar manner to hole diameter. An expected distribution list was again compiled for the case of random utilisation, and this was compared against the observed list with a chi-squared goodness-of-fit test ($\alpha = 0.05$. This analysis was repeated with percentage of holes with any geckos present, holes with multiple geckos and holes with eggs as the response variable.

To determine the expected proportion of holes with multiple geckos, 355 geckos, the number of G. japonicus found in holes, were randomly assigned to 3648 holes multiple times using a Monte Carlo simulation to determine the average number of holes that would be occupied by multiple geckos if all of the geckos occupied holes randomly.

Results and Discussion

Of the holes we examined ($N = 3,648$), 19.21% were utilised by G. japonicus. One or more geckos were found occupying 6.63% holes, 15.24% of the holes were sites of oviposition, and 1.75% of holes contained multiple geckos (Table 1). Hole diameters ranged

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**Table 1. Summary results of survey of weep hole utilisation by Gekko japonicus in Fukuoka, Japan conducted from November 2011 through March 2012.**

<table>
<thead>
<tr>
<th>Site</th>
<th># holes</th>
<th># utilised</th>
<th>% utilised</th>
<th># with eggs</th>
<th>% with eggs</th>
<th># with geckos</th>
<th>% with geckos</th>
<th># with multiple geckos</th>
<th>% with multiple geckos</th>
<th># geckos observed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airport &amp; Forest</td>
<td>1452</td>
<td>324</td>
<td>22.31%</td>
<td>255</td>
<td>17.56%</td>
<td>118</td>
<td>8.12%</td>
<td>30</td>
<td>2.06%</td>
<td>174</td>
</tr>
<tr>
<td>Castle Ruins</td>
<td>68</td>
<td>18</td>
<td>26.47%</td>
<td>11</td>
<td>16.18%</td>
<td>10</td>
<td>14.70%</td>
<td>2</td>
<td>2.94%</td>
<td>13</td>
</tr>
<tr>
<td>Zoo Area</td>
<td>998</td>
<td>110</td>
<td>11.02%</td>
<td>76</td>
<td>7.61%</td>
<td>47</td>
<td>4.71%</td>
<td>14</td>
<td>1.40%</td>
<td>67</td>
</tr>
<tr>
<td>West Park</td>
<td>241</td>
<td>75</td>
<td>31.12%</td>
<td>60</td>
<td>24.90%</td>
<td>31</td>
<td>12.86%</td>
<td>8</td>
<td>3.31%</td>
<td>49</td>
</tr>
<tr>
<td>North Area</td>
<td>305</td>
<td>37</td>
<td>12.13%</td>
<td>24</td>
<td>7.86%</td>
<td>17</td>
<td>5.57%</td>
<td>2</td>
<td>0.65%</td>
<td>20</td>
</tr>
<tr>
<td>Mount Abura</td>
<td>174</td>
<td>20</td>
<td>11.49%</td>
<td>15</td>
<td>8.62%</td>
<td>11</td>
<td>6.32%</td>
<td>4</td>
<td>2.29%</td>
<td>18</td>
</tr>
<tr>
<td>Atago Shrine</td>
<td>410</td>
<td>117</td>
<td>28.53%</td>
<td>115</td>
<td>28.04%</td>
<td>8</td>
<td>1.95%</td>
<td>4</td>
<td>0.98%</td>
<td>14</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>3648</td>
<td>701</td>
<td>19.21%</td>
<td>556</td>
<td>15.24%</td>
<td>242</td>
<td>6.63%</td>
<td>64</td>
<td>1.75%</td>
<td>355</td>
</tr>
</tbody>
</table>
from 3 cm to 10.4 cm. Statistical analysis indicates that the distributions of utilisation, gecko inhabitation, and egg-laying all differed significantly from what would be expected if the distribution was random (see Fig. 3). Specifically, the chi-squared values for each response variable were 49.2, 31.5, and 57.7 respectively, resulting in a value of $P < .01$ in all cases. Furthermore, overall utilisation, gecko inhabitation, and egg-laying percentages were significantly higher in holes smaller than 6 cm in diameter ($\chi^2 = 39.6, 8.83, \text{and} 41.6$ respectively, $P < .01$ in each case). Pending a multivariate analysis, these results suggest *G. japonicus* tends to select holes less than 6 cm in diameter.

Possibly, *G. japonicus* avoids larger holes during their brumation period to mitigate exposure to fluctuations in temperature and humidity as well as ingress by large predators. Conversely, holes across a range of sizes may be utilised as sites of oviposition to take advantage of variations in temperature during the incubation period; *G. japonicus* exhibits pattern II temperature-dependent sex determination, with incubation temperatures at 24°C or lower resulting in females, temperatures 28°C or higher resulting in males, and temperatures 32°C or higher resulting in females (Goris and Maeda, 2004). The relationship between hole diameter and temperature fluctuations, and its effect on incubation temperatures, warrants further investigation.

When analysing the effect of directional exposure on hole utilisation, chi-squared tests indicated that the distributions of utilisation, gecko habitation, and egg-laying all varied significantly from the case of random distribution ($\chi^2 = 43.1, 56.9, \text{and} 18.8$ respectively, $P < .01$ in each case). Walls with western or eastern exposures appeared to be most heavily utilised (Fig. 4), although multivariate analysis will be necessary to confirm these results.

Percentage of holes containing multiple geckos (1.75%) was greater than expected if geckos selected holes randomly (0.44%). This difference is statistically significant ($P < 0.01$). Similar to *Nephrurus milii* (Shah et al., 2003), *G. japonicus* selects holes already containing conspecifics, although the tendency was not strong. Every time aggregations were observed, there were vacant holes available in the immediate vicinity. The largest aggregation of *G. japonicus* observed during this study was 11 geckos, which consisted of eight adults and three small juveniles. The view of the hole was partially obscured by an aluminium soda can, thus it is possible that more geckos may have been present. Shah et al. (2003) reported that *N. milii* tends to huddle closely together in response to dropping temperatures and found that huddled geckos’ body temperatures changed more slowly than those of individual lizards. This indicates that aggregation may provide *N. milii*

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**Figure 3.** Hole utilisation against hole diameter.

<table>
<thead>
<tr>
<th>Hole Diameter Range (cm)</th>
<th>Percent Utilised</th>
<th>Percent with Geckos</th>
<th>Percent with Eggs</th>
<th>Percent with Multiple Geckos</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 to 4</td>
<td>0.25</td>
<td>0.15</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>4 to 5</td>
<td>0.20</td>
<td>0.10</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>5 to 6</td>
<td>0.20</td>
<td>0.10</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>7 to 8</td>
<td>0.15</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>8 to 9</td>
<td>0.10</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>10 to 11</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
</tr>
</tbody>
</table>
with facultative control over thermal exchange rates, which is likely the case for *G. japonicus*. Taking this into account with observations that *G. japonicus* remains active throughout its brumation period and sometimes moves between brumation sites (Hisai, 1998; Caldwell. In press), then the rate at which the geckos shared holes with conspecifics may be even higher than indicated by this survey, since walls were primarily sampled during daylight hours.

*Gekko japonicus* typically lays two eggs per clutch, rarely one (Xu and Ji, 2001), and may produce up to three clutches per year (Otani, 2009). *Gekko japonicus* is known to engage in communal nesting behaviour (Graves and Duvall, 1995), and many of the holes that contained clusters of eggs are likely the result of communal oviposition (Fig. 2). However, it was not possible to determine whether these clusters were due to communal oviposition or repeated use of the hole by an individual. Some holes were clearly sites of repeated oviposition in that different clusters of eggs appeared to be in different stages of deterioration, or layers of newer eggs had been laid on older eggs. The largest clusters, containing more than 100 eggs, were almost certainly the result of both communal nesting and repeated site use.

The only other vertebrate directly observed occupying a hole during the survey period was an adult Japanese Skink, *Plestiodon japonicus*. However, on two occasions shed snakeskin was found in the holes. One of the sheds was identified as that of an *Elaphe* sp., however, the second shed was too fragmentary to allow for identification. It should be noted that prior to the survey, a large (ca. 1.8m long) Japanese Rat Snake *Elaphe climacophora*, was observed partially entering a hole, withdrawing and entering another.

At the Mount Abura site, snails were observed in the holes in great abundance. Some snails are suspected of consuming gecko eggshells (Somaweera, 2009). Consequently, the rate of utilisation of holes at this site may be considerably higher than the results of this survey indicate. *Armadillidium* sp., a species of woodlice, seemed especially prominent in West Park, where they were found in large aggregations among hatched gecko eggs and egg shells. The large planarian, *Bipalium nobile*, was also observed in the holes on three occasions, although never observed in holes containing geckos or eggs. On three occasions *Heteropoda venatoria*, a species of spider large enough to take small lizards, was observed in the holes. Prior and subsequent to the study period, in warmer weather, the giant centipede, *Scolopendra subspinipes*, a known predator of reptiles (Otani, 2009), was frequently observed in holes.

Overall the results of this survey demonstrate that holes in retaining walls are important sites of overwinter refuge and oviposition for *G. japonicus* in Fukuoka. *Gekko japonicus* seemed to prefer to occupy holes containing conspecifics and smaller holes, with holes 3 to 4 cm in diameter most frequently being occupied. Geckos were completely absent from holes over 8

![Figure 4. Hole utilisation against directional exposure.](image-url)
cm in diameter. *Gekko japonicus* mostly frequently utilised holes between 5 to 6 cm in diameter as sites of oviposition, but holes across the entire range of diameters were exploited for this purpose. Additionally, this survey indicates retaining walls are clearly sites where *G. japonicus* may be readily observed during their brumation period.

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**References**


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