Salinity and Other Abiotic Characteristics of Oviposition Sites of the Rhacophorid Frog, *Buergeria japonica*, in Coastal Habitat

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Abstract: Oviposition sites of *Buergeria japonica* were surveyed in portions of two streams near the coast on Okinawa Island, Ryukyu Archipelago, Japan. Twenty-five and 52 oviposition sites were found. At all these sites the salinity was constantly 2‰ or less despite occasional exposure of these portions to the sea breeze. The pH value at the sites, ranging from 7.7–10.2, never dropped into the acid range. There were no significant differences in water depth or distance from the bank at the oviposition sites between the two streams, despite the prominent differences in some topographic characters, such as maximum water depth and stream width.

Key words: Salinity; Oviposition site; Coastal habitat; Frogs; *Buergeria japonica*

Amphibians are susceptible to chemical factors of the ambient water throughout the aquatic embryonic and larval stages of their life cycles (Tyler-Jones et al., 1989). One of the most crucial chemical factors for their successful breeding and development is salinity, because in many amphibian species including those that have a high salinity tolerance in adults (e.g., *Rana cancrivora*: Gordon et al., 1961), the rate of egg survival or of metamorphosis falls remarkably even with a slight increase in salinity (Gordon and Tucker, 1965; Beebee, 1985; Uchiyama et al., 1990; Voigt,

1991). Nonetheless, some amphibians occur in potentially highly saline habitats, such as ponds and streams located within the reach of saltwater spray and tidal movements, and desert ponds where the salinity often remarkably increases with evaporation. For such frogs, it is essential to acquire high salinity tolerance during the embryonic and larval period, or otherwise, the particular ability to avoid breeding at highly saline sites. Indeed, Uchiyama et al. (1990) reported that in *R. cancrivora* living in a coastal marsh, spawning occurs only after heavy rainfall so as to allow eggs an early embryonic development under low salinity condition. For other frogs inhabiting potentially saline habitats, however, no studies have been made regarding their adaptation for successful reproduction.

Buergeria japonica is a ground-dwelling rhacophorid frog distributed on most islands of the Ryukyu Archipelago and on Taiwan. This frog is known to utilize various habitats including those near the seacoast, and its eggs are sometimes laid in the stream mouth no more than 100 m from the coastline (Maeda and Matsui, 1989). In the present study, I investigated salinity at oviposition sites of *B. japonica* in streams near the coast. I also describe several other abiotic characters for such oviposition sites of this frog.

MATERIALS AND METHODS

For the field survey, I chose two streams (streams 1 and 2), approximately 3.5 km apart from each other, in Kunigami Village in the northern part of Okinawa Island, Japan (26°50'N, 128°17'E). The portions surveyed were from the coastline up to approximately 100 m inland for stream 1 and from the coastline up to approximately 230 m inland for stream 2. Both streams usually flow on the surface of a sandy beach, directly entering the sea. Occasionally, however, they flow underground at the beach, leaving the surfaces dry. There was a little grass around the streams, and their bottoms were mainly composed of pebbles, sand, and pieces of dead coral.

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During the study periods (see below), standard air temperatures for streams 1 and 2 (measured at fixed points 1 m above the ground in shade) varied from 26.1 to 36.8 C and from 20.4 to 31.9 C, and the water temperatures ranged from 22.3 to 33.0 C and from 19.7 to 31.3 C, respectively. No other anuran species were observed.

Periods of the survey were from April to October 2001 for stream 1, and from April to September 2002 for stream 2. During these periods, I conducted route census almost everyday between 1200 and 1800 h by slowly walking along the portions of the streams, carefully searching for eggs laid. Census was not made on rainy days, because of the expected temporary lowering of salinity at oviposition sites. Eggs were usually attached to the substrate surface in masses. Thus, free single eggs, probably washed down from upper streams, were excluded from the analysis. Egg masses found were assumed to have been laid in the previous night. For each site at which an egg mass was located, I recorded the water salinity with a Salinity Refractometer (Atago., Hand Refractometer) and pH with a Quikchek (Orion Model 103), as well as water depth and distance from the bank. Maximum water depth was also measured at the deepest point along a transverse line to the stream, crossing the oviposition site. Widths of the portions of the streams surveyed were measured at 2.5 m intervals.

The salinity at oviposition sites was compared between the two streams by a χ^2 -test, because values of this variable are integral numbers. Statistical analyses of the egg numbers and pH were made using Welch's t-test, because for either of these variables homogeneity of variance was not met between the two data sets. The other oviposition site characteristics (water depth and distance from the bank) and stream topography were compared using the Mann-Whitney U-test, because data deviated considerably from normal distribution. In all these tests the significance level was $P < 0.05$.

RESULTS AND DISCUSSION

Twenty-five and 52 oviposition sites were detected in streams 1 and 2, and the mean numbers ($\pm$ SD) of eggs found were 17.7 ± 21.1 (range: 2–65) and 28.1 ± 33.9 (2–181), respectively. These values showed no significant differences (Welch's t-test, $t = -1.65$, $df = 69.9$, $P > 0.05$).

Salinity was 2‰ or less at all these oviposition sites. No significant differences were found between the two streams (χ^2 -test, $\chi^2 = 4.10$, $df = 2$, $P > 0.05$; Fig. 1). This suggests that even in a coastal habitat occasionally exposed to salty sea breeze the salinity at oviposition sites of *B. japonica* is not so high as to cause high mortality of eggs.

The pH values at oviposition sites were 8.5 ± 0.4 (8.0–9.5) and 8.9 ± 0.8 (7.7–10.2) in streams 1 and 2, respectively, and these significantly differed (Welch's t-test, $t = -2.4$, $df = 44.2$, $P < 0.05$). It has been reported that, in frogs, low pH (approximately 3.6–4.75) in ambient water interrupts embryonic development or produces abnormalities in the spine and tail of larvae (Gosner and Black, 1957; Freda and Dunson, 1985, 1986; Tyler-Jones et al., 1989). This suggests that in the present study area *B. japonica* do not suffer high embryonic mortality or larval abnormality from low pH.

The maximum water depth significantly differed between the two streams (25 ± 20 mm [1–105 mm] in stream 1 and 47 ± 29 mm [12–

FIG. 1. Salinity at oviposition sites of *Buergeria japonica* in streams 1 and 2.

148 mm] in stream 2: Mann-Whitney U-test, $Z=-3.84$, $P<0.001$). Nevertheless, the water depth at oviposition sites showed no significant difference between sites (12 ± 8 mm [4–30 mm] in stream 1; 13 ± 8 mm [0–34 mm] in stream 2: Mann-Whitney U-test, $Z=-0.49$, $P>0.05$; Fig. 2). Likewise, although stream 1 (791 ± 501 mm [260–2250 mm]) was significantly narrower than stream 2 (4283 ± 2231 mm [760–8690 mm]: Mann-Whitney U-test, $Z=-6.63$, $P<0.001$), distance from oviposition sites to the bank did not significantly differ between sites (197 ± 156 mm [30–490 mm] in stream 1; 182 ± 285 mm [0–2000 mm] in stream 2: Mann-Whitney U-test, $Z=-0.92$, $P>0.05$; Fig. 3).

FIG. 2. Comparison of the water depth at oviposition sites of *Buergeria japonica* (left) and the maximum water depth (right: see text for definition: both in mm) between streams 1 and 2. Vertical bars denote 1 SD.

FIG. 3. Comparison of the distance from the nearest bank to oviposition sites of *Buergeria japonica* (left) and the stream width (right: see text for definition: both in mm) between streams 1 and 2. Vertical bars denote 1 SD.

These results may suggest that this frog chooses oviposition sites at least partially on the basis of water depth and distance from the bank. However, these issues definitely need further careful verification, particularly by considering correlation among these topographic parameters and such chemical parameters as the salinity and pH of the water.

ACKNOWLEDGEMENTS

I am grateful to M. Imafuku and A. Mori for their valuable comments on the manuscript. I also thank colleagues of the Laboratory of Ethology, Kyoto University for their useful comments. The Yona Research Station, University of the Ryukyus, permitted me to use the facility for the fieldwork. This work was supported in part by a Grant-in-Aid for 21st Century COE Research, Kyoto University (A2).

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Accepted: 30 November 2003