

SHORT NOTES

HERPETOLOGICAL JOURNAL, Vol. 14, pp. 149-152 (2004)

**DIET COMPOSITION OF THE INDIAN
RICE FROG, *RANA LIMNOCHARIS*, IN
THE FLOODPLAIN OF THE KIZU
RIVER, JAPAN**

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I identified 1404 prey individuals from 57 stomachs of *Rana limnocharis* captured in the floodplain of the Kizu River, Japan. Collembolans occupied 79.8% of the total prey number. Mass consumption of collembolans occurred in late August. Pitfall trap sampling showed that collembolans increased explosively at this time of year. This synchronization suggests that the frog feeds on this tiny insect unselectively in response to the increase of its availability within the habitat. The unspecialized feeding habits may partially explain the dominant distribution of this frog in the river-floodplain, where the arthropod fauna is unpredictably devastated by inundation.

Key words: arthropod fauna, collembolans, food niche analysis

Anurans are undoubtedly the essential components of wetland ecosystems in both abundance and position in the food web as intermediate predators. Although numerous studies on their ecological roles in lentic habitats, such as ponds, marshes, and rice fields, have been conducted (e.g. Jenssen & Klimstra, 1966; Houston, 1973; Werner *et al.*, 1995; Hirai & Matsui, 1999; 2000; 2001a), few studies have documented their roles in river ecosystems.

In mainland Japan, 12 anuran taxa comprising 16 native species/subspecies currently use rice fields for reproduction (Maeda & Matsui, 1999). It is considered, however, that most of these anurans originally inhabited floodplains of large rivers (Moriyama, 1997). From the early 1900's, most river-floodplains in Japan were converted into rice fields through river improvement, flood control, and/or reclamation works. Consequently, rice fields have now become valuable substitutional wetland habitats for those anurans (e.g. Hasegawa, 1998).

Generally, habitat alteration in wetlands is most detrimental to anuran communities and caused the population declines in many anuran species (e.g. Beebee, 1996). Thus, the survival of frogs in riverine habitats that undergo large scale habitat alteration, followed by population recovery in the new artificially managed environments seems to be unusual phenom-

enon. Moriyama (1997) presumed that anurans are originally well-suited to life in rice-field habitats. This idea is based on the fact that the irrigation period in rice fields is synchronized with inundation in river plains during the rainy season, and thus their life-history requirements seem to be almost satisfied. From the viewpoint of successful spawning and larval development, this idea is very persuasive. However, some adult anurans spend prolonged periods after reproduction in rice fields, and newly recruited juveniles also remain in rice fields continuously after metamorphosis (e.g. Hirai & Matsui, 2002a; Hirai & Hidaka, 2002b). Therefore, the idea proposed by Moriyama (1997) appears to be insufficient to account for the success of anurans in rice-field habitats.

Rana limnocharis is one of the representative species of Japanese anurans inhabiting rice fields. This frog has a strong affinity for rice fields in the western part of the Mainland of Japan (Maeda & Matsui, 1999). Accordingly, available data are mostly based on observations in rice fields (e.g. Shichi *et al.*, 1988; Hata & Nagoshi, 1995; Hirai & Matsui, 2001b), and little is known about its ecology in natural wetlands such as river-floodplains.

During a herpetological survey in a river ecosystem, I had an opportunity to study a natural population of *R. limnocharis* in a river-floodplain. In this paper, I describe the diet composition of *R. limnocharis* collected in the floodplain, with reference to the arthropod fauna within this habitat. Our results would help clarify the factors that enable the frog to thrive in rice-field habitats. Based on the results, I also discussed an inherent problem in diet data analysis.

The study site is a sandbar (approximately 18 ha: 135°47'E, 34°50'N) of the Kizu River, which runs between Kyotanabe City and Jyoyou City, Kyoto Prefecture, Japan. An extensive lowland area of this sandbar is a bare sandy plain, but the riverside areas are partially covered with vine reed (*Phragmites japonica*: Gramineae), and the inland sandhill is dominated by tall goldenrod (*Solidago altissima*: Compositae) and iron creeper (*Humulus scandens*: Moraceae). Willows are scattered within the vegetation. The sandbar is inundated several times within a year, especially during the rainy season (June to mid July) and the typhoon season (late August to September). After inundation, a number of temporal pools emerged near the shore, and foraging frogs were observed around there. I captured frogs, irrespective of species, at night usually for two hours (2100-2300 hr) because frogs are basically nocturnal predators. In order to examine seasonal variation in diet, samplings were conducted twice a month from June to October 1998.

Stomach contents of frogs were extracted by forced regurgitation with forceps immediately after collection, and preserved in 10% buffered formalin for later analyses. I recorded sex, snout-vent length (SVL), mouth width and body mass for all individual frogs. After these procedures, the frogs were released to the site of capture. The frogs were observed to jump away into the

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water or surrounding bushes, indicating that they were not adversely affected by forced regurgitation technique.

In the following year (1999), prey availability was estimated by pitfall traps for ground-surface dwelling prey and by net sweeping for aerial and plant dwelling prey. Pitfall traps were set near the water's edge for 24 hrs. Sweeps were made through the air and vegetation with an insect net continuously for 10 min. These prey samplings were made every seven days (23 May, 29 June, 24 July, 23 August, 21 September 19 October, 24 November) to examine seasonal fluctuation of prey availability within the foraging habitat of frogs. In 1999, frog diet samplings were not carried out.

In the laboratory, I analyzed samples of frog stomach contents. The methods are same as those described elsewhere (e.g. Hirai & Matsui; 1999; 2001a; 2001c). I captured a total of 86 individuals of *Rana limnocharis*, 18 of *R. nigromaculata*, three of *R. catesbeiana*, and nine of *Hyla japonica*. Seventeen adults of *R. limnocharis* had empty stomachs, and 12 juveniles (13.3-22.5 mm in SVL) were too small for forced regurgitation of stomach contents. Accordingly, I recovered 1404 prey items from 57 stomachs of *R. limnocharis* (19.2-45.8 mm in SVL) and identified 21 prey taxa (Table 1).

Arthropoda constituted the vast majority of prey, and Insecta seemed particularly important. Insecta contained ten families and made up 96.5% and 78.9% of total prey number and volume, respectively. Collembolans predominated in diet, representing 79.8% of total prey number. By volume, however, no single taxon predominated in the diet. Even the largest proportion was 16.8% of earwigs (Dermaptera), and comparable proportions were occupied by orthopterans, caterpillars (Lepidopteran larvae), and earthworms (Oligochaeta). Collembolans made up only 3.0% of total prey volume because of their tiny body size. Dipterans ranked top in frequency of occurrence, followed by collembolans and spiders (Araneae). The sole vertebrate prey was a hatchling grass-lizard (*Takydromus tachydromoides*) with 24.0 mm in SVL, recovered from the stomach of a male frog 37.5 mm in SVL. The frog diet composition was biased towards terrestrial arthropods. Aquatic prey occurred in 22.8% of frog stomachs, but constituted only 1.6% by number and 10.4% by volume of the total prey in diet.

The number of prey in stomachs varied seasonally and was found to be in accordance with the number of collembolans consumed (Fig. 1). Substantial numbers of collembolans was exploited on 26 August. At the maximum, 280 collembolans were recovered from a single frog stomach captured on this day. Collembolans occurred significantly higher in frequency on 26 August (59.3%) than on the other sampling days (23.3%) (χ^2 contingency table test, $\chi^2=7.5$, $df=2$, $P<0.05$).

Pitfall trap samplings showed that collembolans explosively increased in number in late August (Table 2). This insect was the most abundant prey taxon in total,

TABLE 1. Diet composition of *Rana limnocharis* (1404 prey individuals from 57 stomachs, total volume 7012.5 mm³). Abbreviations: F = frequency of occurrence (the percentage of stomachs containing a particular prey taxon); N = numeric proportion; V = volumetric proportion.

| Prey taxon | F | N | V |
|-----------------|------|------|------|
| INSECTA | | | |
| Hymenoptera | | | |
| Formicidae | 19.3 | 1.1 | 0.2 |
| Non-Formicidae | 17.5 | 1.2 | 1.2 |
| Coleoptera | 28.1 | 2.8 | 1.7 |
| larvae | 8.8 | 0.6 | 6.3 |
| Diptera | 43.9 | 3.4 | 4.2 |
| larvae | 17.5 | 1.2 | 4.6 |
| Lepidoptera | 10.5 | 0.4 | 1.2 |
| larvae | 10.5 | 0.5 | 12.2 |
| Neuroptera | 1.8 | 0.1 | 0.1 |
| larvae | 1.8 | 0.1 | <0.1 |
| Hemiptera | 42.1 | 2.7 | 9.7 |
| Dermaptera | 17.5 | 1.1 | 16.8 |
| Orthoptera | 26.3 | 1.5 | 12.5 |
| Odonata nymphs | 5.3 | 0.1 | 5.5 |
| Collembola | 40.4 | 79.8 | 3.0 |
| ARACHNIDA | | | |
| Araneae | 40.4 | 2.9 | 4.0 |
| CRUSTACEA | | | |
| Isopoda | 1.8 | 0.1 | 1.1 |
| Amphipoda | 1.8 | 0.1 | 0.2 |
| GASTROPODA | 1.8 | 0.1 | 1.3 |
| OLIGOCHAETA | 1.8 | 0.3 | 11.0 |
| REPTILIA | | | |
| Squamata | | | |
| Lacertidae | 1.8 | 0.1 | 3.5 |
| PLANT MATERIALS | 17.5 | - | - |
| MINERALS | 43.9 | - | - |

but the vast majority (82.7%) was collected in late August. This pattern of seasonal fluctuation is similar to that observed in frog stomachs. Dipterans were the most abundant taxon in sweeping samples in all months (Table 2) and secondarily abundant in pitfall samples. Unlike collembolans, dipterans exhibited little seasonal fluctuation.

Feeding habits of *R. limnocharis* in the floodplain could be characterized by mass consumption of collembolans. The predominance of collembolans in diet has never been observed in other ranid frogs. Even if present in diet, the numeric proportion is small. For example, the largest proportion hitherto reported for *R. limnocharis* is 1.8% in Singaporean population (Berry, 1965), and that for other ranid frogs is 18.1% of *Rana septentrionalis* (Hedeen, 1972).

On the other hand, ants were known to occur more commonly in the diet of *R. limnocharis* from rice fields of Japan (26.9%; Hirai & Matsui, 2001a) and China (23.4%; Liu & Chen, 1933), and swamps of Singapore (27.9%; Berry, 1965). In the present study site, ants rep-

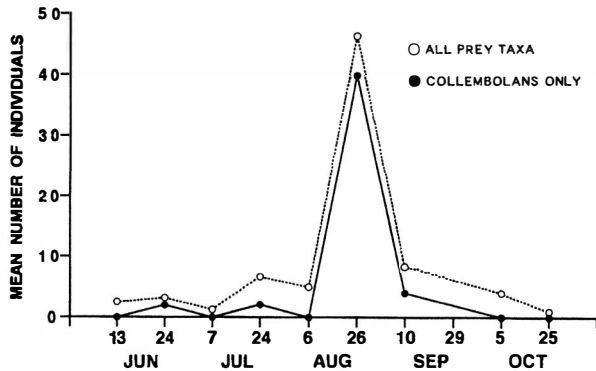


FIG. 1. Seasonal variation in the average number of prey individuals found in stomachs of *Rana limnocharis*. Diet samples were not taken on 29 September.

represented only 1.1%, or 5.3% even when calculated excluding collembolans. In fact, ants were very scarce by both pitfall and sweep sampling. Therefore, the inter-population variation in diet of *R. limnocharis* would result from the difference of prey availability in each local habitat.

The prey availability samplings revealed that mass consumption of collembolans was synchronized with an explosive increase of this insect within the habitat. This shows that *R. limnocharis* feeds unselectively on prey in response to its availability within a foraging habitat. The unselective feeding habits may be advantageous in dealing with river floodplains where the arthropod fauna is unexpectedly devastated by inundation. Therefore, the feeding habits may partially explain the dominant distribution of *R. limnocharis* in the present study site. More importantly, the unselective feeding habits may be one of the key factors that enable the frog to survive habitat alteration and thrive in rice field habitats, where the rice-field arthropod fauna is disturbed by farming practices such as insecticide applications, ploughing, weeding, reaping, and artificial control of water status. This assumption is strengthened by the fact that prey availability – rather than prey preference – is the most important determinant of dietary composition for most other frogs inhabiting rice fields, such as *R. nigromaculata* (Hirai & Matsui, 1999), *R. porosa*

brevipoda (Hirai & Matsui, 2001d), and *Hyla japonica* (Hirai & Matsui, 2000). Thus, the ecological features of both breeding and non-breeding seasons should be studied to explain the patterns of distribution in anurans. Such studies would also provide useful information for the conservation of declining anuran populations.

The consumption of collembolans is more common in burrowing or ground-surface dwelling anuran species of Bufonidae (e.g. Gittins, 1987), Pelobatidae (e.g. Newman, 1999), Dendrobatidae (e.g. Donnelly, 1991), and Microhylidae (e.g. Berry, 1965). Some of these anurans exploit collembolans in a different pattern from that of *R. limnocharis* in the present study site. For example, the tropical litter frog, *Epipedobates boulengeri*, consumes a higher proportion of collembolans by frequency (about 90%) and volume (about 11%) than by number (31.9%; Caldwell, 1996), compared to *R. limnocharis* in the present study. These differences illustrate that numerical proportion is vulnerable to mass consumption by a small number of individuals. In many diet studies of anurans, numeric proportion has been used for calculation of food niche width, food niche overlap, or prey selection index (e.g. Toft, 1980, 1981). Thus, reanalysis with the other variables might lead us to somewhat different conclusions. Hence, diet data should be interpreted cautiously in the analysis.

Acknowledgements. This study was conducted as a part of comprehensive research of the Kizu River by the River Ecology Research Group of Japan. The data on prey availability were provided by Professor Matsura, Kyoto University of Education. I thank A. Mori for his invaluable comments on the early version of the manuscript.

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TABLE 2. Seasonal variation in the number of arthropods collected by pitfall traps (Pit) and sweeps (Swp).

| Prey taxon | May | | Jun | | July | | August | | September | | October | | November | | Total | |
|----------------|-----|-----|-----|-----|------|-----|--------|-----|-----------|-----|---------|-----|----------|-----|-------|-----|
| | Pit | Swp | Pit | Swp | Pit | Swp | Pit | Swp | Pit | Swp | Pit | Swp | Pit | Swp | Pit | Swp |
| Hymenoptera | | | | | | | | | | | | | | | | |
| Formicidae | 0 | - | 2 | - | 0 | - | 1 | - | 0 | - | 0 | - | 0 | - | 3 | - |
| Non-Formicidae | - | 3 | - | 0 | - | 8 | - | 3 | - | 3 | - | 2 | - | 0 | - | 19 |
| Coleoptera | 33 | - | 44 | - | 44 | - | 23 | - | 95 | - | 0 | - | 1 | - | 240 | - |
| Diptera | 84 | 96 | 49 | 20 | 29 | 52 | 25 | 22 | 44 | 61 | 96 | 257 | 14 | 20 | 341 | 528 |
| Hemiptera | 1 | 0 | 1 | 1 | 11 | 15 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 14 | 17 |
| Dermoptera | 4 | - | 2 | - | 4 | - | 20 | - | 0 | - | 0 | - | 0 | - | 30 | - |
| Collembola | 25 | - | 75 | - | 79 | - | 2173 | - | 30 | - | 11 | - | 234 | - | 2627 | - |
| Insect larvae | 2 | - | 0 | - | 1 | - | 13 | - | 0 | - | 3 | - | 3 | - | 22 | - |
| Araneae | 31 | - | 13 | - | 75 | - | 17 | - | 8 | - | 6 | - | 1 | - | 151 | - |
| Acarina | 0 | - | 2 | - | 4 | - | 1 | - | 1 | - | 0 | - | 0 | - | 8 | - |
| Miscellaneous | 1 | 11 | 1 | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 3 | 14 |

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Accepted: 24.6.03