Comparison of food habit among three sympatric species of frogs in paddy fields

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Abstract: Multiple species living sympatrically have the potential to affect each other’s feeding behavior, although there is a paucity of information about the comparative food habits of frogs. In this study, we examine food habits of three sympatric frog species in paddy fields. Throughout the season, there was no diel variation in stomach content index among three frog species. Compositions of stomach contents in weight ratio were similar between three frog species. Frogs normally predate on Formicidae in August and September, although prey organisms varied with season. We suggest that frogs prey non-selectively on foods according to their abundance, and also without any interspecific interaction for food selection.

Key Words: food habit, sympatric, interspecific comparison, similarity

INTRODUCTION

Frogs are known to change their food habits from omnivory to carnivory after larval metamorphosis. Metamorphs have been reported to prey non-selectively on small organisms in the environment (Hirai and Matsui, 1999), whereas others show that several frog species have selective feeding habits (Stebbins and Cohen, 1995). Currently, food habits of many Japanese frogs have been recorded. For example, *Bubonius formosus*, preys on Formicidae and Coleoptera on the soil surface (Hirai and Matsui, 2002a), while *Microhyla ornata* is specialized to forage on Formicidae over other small soil organisms (Hirai and Matsui, 2000b). *Rana nigromaculata* and *Rana porosa brevipoda* are known generalist feeder (Hirai 2002: Hirai and Matsui, 2001a), while *Hyla japonica* does not select specific food items (Hirai and Matsui, 2000a). Despite these studies, a reexamination of the food selectivity of Japanese frogs is required. In addition, interspecific relationships over food resources between two species of frogs, such as *H. japonica* and *R. nigromaculata* (Hirai and Matsui, 2002b), and *Rana rugosa* and *R. nigromaculata* (Hirai and Matsui, 2001b), has been reported. Moreover, interspecific relationships among three or more species of frog may advance our understanding of frog communities.

Many works stated that frogs are intermediate predators in the ecosystem, serving as food for top predators such as snakes (Kishida, 1927; Ikeda, 1956; Yukawa, 1968; Fukada, 1992: Kadowaki, 1992; Ezaki and Tanaka, 1998), and occupy a very important position within the natural environment as invertebrate predators. There is also an urgent need for data on the ecological characteristic of frogs to promote the conservation of fragile wetland ecosystems.

In this study, we describe the food habits of three sympatric frog species in paddy fields as a wetland ecosystem.

1. METHODS

The survey of three species of frog, *Rana porosa brevipoda*, *R. nigromaculata* and *Fejervarya kawamura*, was carried out in paddy fields in Otsu, Shiga Prefecture, Japan. Frogs were sampled monthly using a hand net along the paddy levees and waterways from August to October 2010. One 24-hour survey consisted of eight censuses at 3-hour intervals. When 10 animals per species were collected at a census, we stopped the survey. When we could not capture 10 animals of the species within one hour, we finished the census. Foraging activity was compared between the morning sampling time (04:00, 07:00, 10:00 h), noon (13:00, 16:00 h) and night (19:00, 21:00, 01:00 h) by the Steel-Dwass multiple comparisons method using the stomach contents index.

In the study area, the paddy fields are drained in August and little water remains. In September, the
rice plants (Poaceae) are ripening and are harvested in October.

The stomach contents of captured frogs (Hirai, 2005) were extracted by forced regurgitation with forceps. The frogs were then returned to their place of capture after being tagged by toe clipping to avoid reexamination. Extracted stomach contents were stored in 80% ethanol and identified to the lowest taxonomic group if possible.

The stomach content index (SCI) of each individual was calculated using the following equation:

\[
SCI = \frac{SCW}{WW} \times 100
\]

\[SCW = \text{stomach content weight (g)}\]

\[WW = \text{wet weight of frogs (g)}\]

Composition of prey species was compared using the Cn index (Kimoto, 1967) as follows:

\[Cn = 2 \sum \frac{NA}{N} \times \left\{ \frac{NA + NB}{N} \right\}
\]

\[\frac{NA}{N} = \sum \frac{NA}{N} \times \left\{ \frac{NA + NB}{N} \right\}
\]

\[\frac{NB}{N} = \sum \frac{NB}{N} \times \left\{ \frac{NA + NB}{N} \right\}
\]

\[NA: \text{Total of weight ratio in stomach contents of species A}\]

\[nA: \text{Weight ratio in stomach contents of } i\text{th of A}\]

\[Na: \text{Total of weight ratio in stomach contents of species B}\]

\[nB: \text{Weight ratio in stomach contents of } i\text{th of B}\]

The value of Cn ranges 0 ≤ Cn ≤ 1, showing high similarity closer to 1, and lower close to 0.

Stomach contents were also compared between month and species using the Mann-Whitney U test.

2. RESULTS

2.1. Composition of the stomach content of frogs

No significant diel variations in the stomach content index were found between the morning, noon and night sampling times (Steel-Dwass P>0.05, Fig. 1), indicating that these three frog species forage throughout the day. Additionally, there was no significant difference in the stomach content index among the three frog species (Steel-Dwass P>0.05).

The stomach contents of 494 individual frogs of the three species were examined. A total of 4821 prey items from 440 individual frogs (45, 74 and 71 individuals of R. p. brevipoda; 33, 46 and 12 individuals of R. nigromaculata; 41, 74 and 44 individuals of F. kawamurai in August, September and October, respectively) were recorded. The stomachs of 54 frogs were empty (6, 6 and 6 individuals of R. p. brevipoda; 8, 8 and 0 of R. nigromaculata; 10, 6 and 6 F. kawamurai in August, September and October, respectively). Prey items...

![Fig. 1 Diel variations in the stomach content index during August (a), September (b), and October (c). Error bar show standard error (SE).](image-url)
F. kawamura), although only portions were identifiable owing to digestion.

a) Stomach contents in August
The three frog species normally predated on Formicidae (F: frequency of occurrence): 52.1% R. p. brevipoda, 57.6% R. nigromaculata and 57.6% F. kawamura). The highest categories by weight in stomach contents were similar (W: weight ratio): 58.7, 6.7 and 6.3% for R. p. brevipoda, 25.7 and 14.3% for R. nigromaculata and 32.4, 11.2 and 9.6% for F. kawamura).

b) Stomach contents in September
Similar to the case in August, the three frog species normally predated on Formicidae (F: 53.6% R. p. brevipoda, 78.3% R. nigromaculata and 61.1% F. kawamura). Stomach contents by weight ratio (W) for R. p. brevipoda consisted of Oligochaeta (15.3%), Lepidoptera larvae (14.1%) and Orthoptera (13.4%). The highest proportion of the stomach content by weight ratio for R. nigromaculata and F. kawamura was Lepidoptera larvae (33.5% and 22.1%, respectively), followed by Coleoptera adult (11.7%) and Formicidae (10.0%) in R. nigromaculata, and Oligochaeta (12.6%-W) and Coleoptera adult (10.6%) in F. kawamura.

c) Stomach contents in October
In October, R. p. brevipoda, R. nigromaculata and F. kawamura frequently predated on Orthoptera (36.4%), Lepidoptera larvae (34.9%) and Araneae (34.7%), by frequency of occurrence (F). Similar to the case in September, the stomach content, as weight ratio (W), for R. nigromaculata and F. kawamura mainly contained Lepidoptera larvae (26.8% and 17.5%, respectively), followed by Oligochaeta (12.6%) and Orthoptera (12.4%) in R. nigromaculata and Araneae (11.1%) and Orthoptera (10.4%) in F. kawamura. The highest weight ratio (W) for the stomach contents of R. p. brevipoda was Oligochaeta (16.6%), followed by Orthoptera (8.0%) and Coleoptera adult (5.8%).
Table 1: Diet composition of the three frog species collected in paddy fields from August to October.

<table>
<thead>
<tr>
<th>Prey taxa</th>
<th>R. p. brevipoda</th>
<th>R. nigromaculata</th>
<th>F. kawamurai</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F(%)</td>
<td>W(%)</td>
<td>F(%)</td>
</tr>
<tr>
<td>Insecta</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hymenoptera</td>
<td>37.2</td>
<td>3.7</td>
<td>55.1</td>
</tr>
<tr>
<td>Formicidae</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hymenoptera</td>
<td>0.5</td>
<td>0.1</td>
<td>-</td>
</tr>
<tr>
<td>Coleoptera adult</td>
<td>22.5</td>
<td>4.3</td>
<td>40.9</td>
</tr>
<tr>
<td>larvae</td>
<td>4.9</td>
<td>1.6</td>
<td>9.1</td>
</tr>
<tr>
<td>Diptera adult</td>
<td>13.5</td>
<td>2.0</td>
<td>7.4</td>
</tr>
<tr>
<td>larvae</td>
<td>3.7</td>
<td>1.5</td>
<td>0.8</td>
</tr>
<tr>
<td>Lepidoptera larvae</td>
<td>31.6</td>
<td>18.8</td>
<td>43.9</td>
</tr>
<tr>
<td>Hemiptera</td>
<td>20.0</td>
<td>1.2</td>
<td>20.4</td>
</tr>
<tr>
<td>Orthoptera</td>
<td>7.0</td>
<td>6.9</td>
<td>8.2</td>
</tr>
<tr>
<td>Grylloptidae</td>
<td>2.8</td>
<td>4.6</td>
<td>1.0</td>
</tr>
<tr>
<td>Odonata</td>
<td>-</td>
<td>-</td>
<td>1.0</td>
</tr>
<tr>
<td>Collembola</td>
<td>8.4</td>
<td>0.7</td>
<td>2.0</td>
</tr>
<tr>
<td>Arachnida</td>
<td>29.8</td>
<td>7.1</td>
<td>18.4</td>
</tr>
<tr>
<td>Araneae</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Isopoda</td>
<td>11.2</td>
<td>2.0</td>
<td>9.2</td>
</tr>
<tr>
<td>Amphipoda</td>
<td>0.9</td>
<td>0.4</td>
<td>-</td>
</tr>
<tr>
<td>Diplopoda</td>
<td>2.8</td>
<td>0.6</td>
<td>2.0</td>
</tr>
<tr>
<td>Mollusca</td>
<td>8.4</td>
<td>1.4</td>
<td>5.1</td>
</tr>
<tr>
<td>Oligochaeta</td>
<td>13.5</td>
<td>21.6</td>
<td>7.1</td>
</tr>
<tr>
<td>Amphibia</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anura</td>
<td>2.3</td>
<td>4.0</td>
<td>3.1</td>
</tr>
<tr>
<td>Hirudinidae</td>
<td>0.5</td>
<td>0.5</td>
<td>-</td>
</tr>
</tbody>
</table>

Prey items included ground-dwelling insects, such as Formicidae, Coleoptera, Collembola and Araneae, and herbivorous insects, such as Lepidoptera larvae, Hemiptera and Orthoptera. The weight ratio in the stomach contents of herbivorous insects was significantly higher in September than August (Mann-Whitney U-test, P<0.01).

2.2. Similarity in stomach content ratio

To compare the weight ratios among the three frog species, interspecific similarity in stomach contents was examined for each month using the Cn index. The stomach contents of *R. nigromaculata* and *F. kawamurai* were similar in August, September and October (Fig. 3).

In August, the similarity in stomach contents between *R. p. brevipoda* and the other two frog species was low. *R. nigromaculata* and *F. kawamurai* predated mainly on Lepidoptera larvae, while *R. p. brevipoda* on Oligochaeta.

In September, *R. p. brevipoda* preyed on various food organisms, such as Oligochaeta and Orthoptera. However, as Lepidoptera larvae were the most common food organisms for all three frog species, the similarity in stomach content ratios...
contents was high.
In October, the frequency of occurrence (%F) and stomach contents ratio (%W) had the lowest values. Thus, as a result of predating mainly on Lepidoptera larvae and Orthoptera, the similarity in food contents among three frog species was higher than August or September.

3. DISCUSSION

Previous studies have reported that 96% of the prey of *R. nigromaculata* was by arthropods and 2.8% mollusks (Hirai and Matsui, 1999); in *R. p. brevipoda*, the figures were 91.2% arthropods and 8.5% mollusks (Hirai and Matsui, 2001a). These values are similar to the result for *R. p. brevipoda* (arthropod: 94.2%; mollusks: 6.7%) and *R. nigromaculata* (arthropod: 98.2%; mollusks: 1.6%) recorded in this study; possibly because the studies of Hirai and Matsui (1999, 2001a) were also performed in paddy fields. Hirai (2004) reported that, in paddy fields, *R. kawamurai* predated mainly on Collembola (79.8%) which were abundant, whereas our study has shown that the species preyed mainly on Formicidae (57.6%) and only a few Collembola (11.7%). Such differences in dietary habit appear to depend on the composition of the food resource organisms in the specific habitat. Our study on the stomach contents of three frog species in paddy fields has shown that they prey not only on vegetation-dwelling organisms such as Orthoptera adult, Hemiptera and Diptera, but also on ground-dwelling organisms, such as Formicidae, Lepidoptera larvae, Araneae and Oligochaeta in paddy fields.

Major prey organisms varied with season, with the stomach contents ratio of phytophagous insects (Orthoptera, Lepidoptera larvae, and Hemiptera) increasing from August to September due possibly to the seasonal abundance of these insects in paddy fields. For example, adult plant hoppers, leafhoppers and rice stem borers appeared from early August to early September, and furthermore, Murata (1995) reported a concomitant increase in Araneae numbers following the increase in the number of these insects.

The utilization pattern of prey organisms in the three sympatric frog species was very similar in the three months, August, September and October (Fig. 3). In addition, it is suggested that frogs capture prey in accordance with the probability of prey encounter and predation success. In many species of frogs, stomach contents are determined by the opportunity to encounter prey and prey size (Hirai, 2002). Hence the results of our study support this theory and suggest that the food resources of the three frog species in the study area largely overlap.

CONCLUSION

These finding shows that composition of the stomach contents of weight ratio was similar among the three frog species, we suggest that frogs feed non-selectively according to prey abundance and without any interspecies interaction regarding food selection. In the future, detailed studies are required to show that there is no competition of sympatric of frogs and to ascertain the factors affecting the life cycle among frogs in artificially managed rice fields.

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REFERENCES


