Introduction

Poison frogs (Dendrobatidae) have received considerable attention in the scientific community because of their brilliantly colored aposematic patterns, the presence of alkaloids in the skin, and their complex reproductive behaviors (Biavati et al., 2004). Several studies have shown that a number of arthropod dietary sources explain the origin of alkaloids sequestered in the skins of poison frogs (Saporito et al., 2004, 2007a, 2007b, 2009; Smith and Jones, 2004). Particularly, dendrobatid poison frogs have developed an over-expressed system of alkaloid accumulation that facilitates the sequestration of alkaloids directly from their diet, such as ants, mites and millipedes (Daly, 1998, 2000; Saporito et al., 2004, 2007a, 2007b, 2009; Takada et al., 2005; Savitzky et al., 2012).

Studies concerning diet and prey consumption are important in understanding the relationship between diet and alkaloid sequestration in poison frogs, as well as competition with congeners. The variation in alkaloid profiles in poison frogs is related to differences in availability of dietary arthropods consumed among populations of these frogs (Saporito et al., 2007a). Studies have found geographic variation in alkaloid profiles related to diet in all species studied (Saporito et al., 2006, 2007b; Mebs et al., 2008). Few studies have explored diet patterns across the geographic range of a single poison frog species, and how these patterns would correspond to differences in dietary arthropod communities and subsequent alkaloid sequestration in poison frogs.

Herein we provide insights to the diet of A. bombetes from three localities within its range. Andinobates bombetes (Anura: Dendrobatidae) in the Andes of Colombia

Abstract. We describe the diet of Andinobates bombetes (Myers and Daly, 1980) based on stomach contents taken from sixty-nine individuals from three localities in the central northwestern Colombian Andes. 1471 individual prey items were found in the stomach contents from 16 taxonomic groups: arthropods (14), crustaceans (1) and mollusks (1). Taxonomic groups of prey were identified to the lowest taxonomic rank possible. We used the Index of Relative Importance (IRI) and found that Formicidae (ants), and the subclass Acari (mites) dominated the prey taken in our samples. There was not a significant correlation between snout-vent length (SVL) and prey volume sampled. The dietary ant ratio was different between localities, whereas that of mites was consistent across the three localities studied. These results indicate that A. bombetes is a dietary ant and mite specialist, similar to other dendrobatid frogs.

Keywords: Trophic ecology, Dendrobatidae, poison frog, ants, mites, diet
 bombetes is a small-bodied frog and occurs in Central and Western Andes of Colombia (Suárez-Mayorga, 2004; Marin-Gómez and Gómez-Hoyos, 2011). We quantified the diet of A. bombetes at three localities in the Central and Western Andes of Colombia (Fig. 1), and then compared our findings of local dietary items among the three study localities.

**Materials and Methods**

We used visual encounter surveys (VES) (Heyer et al., 1994) during July and October 2009 to collect A. bombetes individuals for gut content analyses. Sampling occurred at three sites in the Central and Western Andes of Colombia: 1) La Samaritana farm (SF), Salento municipality, Quindío; secondary forest; 1626 m (4°34’N, 75°38’W); 2) Cañón del Río Barbas (CRB), Filandia municipality, Quindío; mature forest; 1998 m (4°42’N, 75°38’W); and 3) Reserva Forestal de Yotoco (RFY), Yotoco municipality, Valle del Cauca; secondary forest; 1600 m (3°53’N, 76°38’W) (Fig. 1).

All frogs were captured by hand and standard snout-vent (SVL) in millimeters (mm) was measured, except for RFY locality. Stomach contents were sampled immediately after capture (from 9:00 to 16:00 h) by stomach flushing using a small blunt needle (Popper® 3.048 mm gauge). This procedure is effective to flush stomach contents without producing injury (Solé et al., 2005). Stomach contents were preserved in 70% ethanol. We identified each prey item to the lowest taxonomic rank possible. We measured length and width in mm of each intact prey item. These measurements were used to calculate prey volume using the spheroid volumetric equation as follows:

\[ V = \frac{4}{3}\pi \left( \frac{\text{length}}{2} \right) \left( \frac{\text{width}}{2} \right)^2 \]

We quantified the number of each prey item in the diet using the Index of Relative Importance (IRI) described by Pinkas et al. (1971) with the following equation:

\[ \text{IRI}_i = \left[ \%O_i \times (\%N_i + \%V_i) \right] \]
where \( %O_t \) is the occurrence percentage (i.e. the number of stomachs containing each prey category defined as \( i \)), \( %N_t \) is the percentage of the number of \( t \) items in all stomachs, and \( %V_t \) is the percentage of the volume of \( t \) items in all stomachs examined.

We also calculated the trophic niche breadth using Levins’ standardized formula (Hurlbert, 1978):

\[
B_A = \left(1/\sum p_i^2\right)-1/n-1
\]

where \( p_i \) is the proportion in volume of each prey item with respect to the total volume of prey in each location; \( n \) is the number of prey items in the diet of the frogs. The index produces values ranging from zero to 1; \( B_A = 1 \) means that all prey categories were consumed in equal proportions and that selection of prey was not significant, whereas a value near zero indicates that one or few prey were consumed in large quantities indicating intentional prey selection (Valderrama-Vernaza et al., 2009). After testing for normality and homogeneity of variances, we applied a Spearman rank correlation to examine the relationships between SVL and prey volume consumed in each locality. We tested for differences in proportions of prey items between localities using a Kruskal-Wallis test. All statistical analyses were conducted with Deducer package on R language v. 3.0.2 (R Core Team, 2013).

**Results**

A total of 69 stomach contents were analyzed from live \( A. \ bombetes \): 18 from CRB (6 males, mean SVL=19.24±0.89; 6 females, mean SVL=18.67±1.51; 6 immatures), 27 from FS (11 males, mean SVL=17.44±0.83; 10 females, mean SVL=19.24±0.89; 6 immatures) and 24 from RFY. We identified 16 prey taxa to the subphylum, class, subclass, order and family level (Table 1). After testing for normality and homogeneity of variances, we applied a Spearman rank correlation to examine the relationships between SVL and prey volume consumed in each locality. We tested for differences in proportions of prey items between localities using a Kruskal-Wallis test. All statistical analyses were conducted with Deducer package on R language v. 3.0.2 (R Core Team, 2013).

<table>
<thead>
<tr>
<th>Dietary Sample Classification</th>
<th>Cañón Río Barbas</th>
<th>Samaritana Farm</th>
<th>Reserva Forestal Yotoco</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>%F</td>
<td>%V</td>
</tr>
<tr>
<td><strong>Arthropoda</strong></td>
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<td>Arachnida</td>
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<tr>
<td>Araneae</td>
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<tr>
<td>Acari</td>
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<tr>
<td><strong>Insecta</strong></td>
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<td></td>
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<tr>
<td>Coleoptera (includes larvae)</td>
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<td>9.38</td>
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<tr>
<td>Collembola</td>
<td>18</td>
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<td>8.84</td>
</tr>
<tr>
<td>Diptera (includes larvae)</td>
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<tr>
<td>Hemiptera</td>
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<td>Hymenoptera (Formicidae)</td>
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<td><strong>Malacostraca</strong></td>
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<td>Myriapoda</td>
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<tr>
<td><strong>Mollusca</strong></td>
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<tr>
<td>Gasteropoda</td>
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<td>43.8</td>
</tr>
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</table>
and 21.45 (±18.08) prey items per individual frog. Formicidae and Acari had the highest IRI scores (Table 1). Only Acari and Formicidae were consumed in a higher proportion than other prey categories. Pheidole were consumed most commonly (79.03% of total ants) and other ant genera were rarely found (Solenopsis, Carebara, Cyphomyrmex, Strumygenis, Crematogaster, Octostruma, Linepithema, Discothyrea, Pyramica, Brachymyrmex). For example, the formicine genus Pheidole was represented by only a single record (0.26% of total ants). Niche breadth was close to zero (CRB=0.1774; FS=0.1631; RFY=0.1624).

We found no significant correlation between poison frog SVL and prey volume (R=0.10, p > 0.05) in the individuals we examined. We found significant differences in the dietary percentage of ants consumed between localities (Kruskal-Wallis Chi² = 6.8, df = 2, p = 0.03), with a higher proportion of ants consumed at FS than at RFY (Fig. 2, A). The percentage of mites consumed for poison frogs did not vary among sites (Kruskal-Wallis Chi² = 1.72, df = 2, p = 0.42; Fig. 2, B).

**Discussion**

The diet of *Andinobates bombetes* is primarily composed of ants and mites, which occur at a higher percentage than other prey items at our study sites. This result is well-supported by our very small niche breadth values. Our data suggest that *A. bombetes* is a dietary ant and mite specialist as many other dendrobatid species from several genera (e.g., Ameerega, Andinobates; Kahn et al., 2014 in press). Ants and mites are an abundant prey resource in Neotropical the leaf litter habitat where dendrobatid frogs live (Daly et al., 1999; Hölldober and Wilson, 1990; Franklin et al., 2006). *Andinobates bombetes* usually is found in microhabitats (e.g., bromeliads, leaf litter, soil substrate) (Myers and Daly, 1980) where many of the prey items were found. Variation in ant and mite consumed by *A. bombetes* across the study sites is consistent with findings in other dendrobatid frog species (Valderrama-Vernaza et al., 2009; Lieberman, 1986; Daly, 1998; Biavati et al., 2004; Darst et al., 2005; Saporito et al., 2004, 2007a, 2009; Forti et al., 2011).

Ants and mites are primary sources of dietary alkaloids in a number of poison frog species (Daly et al., 1999; Hölldober and Wilson, 1990; Franklin et al., 2006). Variation in alkaloid profiles of *A. bombetes* has been observed over broad geographic areas (Myers and Daly, 1980) and can be attributed to differences in the kinds of arthropods, and their respective alkaloids, consumed by the frogs. A previous study of *A. bombetes* conducted at two sites in Colombia, revealed a total of 22 piperidine alkaloids sequestered in the skins of these poison frogs; little variation occurred in the 15 and 17 compounds evaluated from the two localities (Myers and Daly, 1980). Since the time of that study, the link between diet

![Figure 2. Proportion of ants (A) and mites (B) consumed by *Andinobates bombetes* in three localities in the Central and Western Andes of Colombian Andes (CRB: Cañón Río Barbas; FS: Finca La Samaritana; RFY: Reserva Forestal Yotoco). Solid circle: mean; error bars: 95% confidence interval.](image-url)
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