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SELECTION OF DIET BY METAMORPHIC AND JUVENILE WESTERN TOADS (*BUFO BOREAS*) IN NORTHEASTERN OREGON

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***Abstract*.—The decline of *Bufo boreas*, the Western Toad, in portions of its range has accentuated the need for more complete information on all life stages of this species. Our objectives were to describe the diet of recently metamorphosed and juvenile (one-year old) *B. boreas* and then compare it to the available arthropods. Metamorphs (n = 200) and juveniles (n = 176) preyed on small arthropods (< 5 mm) from among > 20 families within 10 orders of insects, two orders of arachnids, and a few gastropods. The majority of the numbers of prey taken by metamorphs consisted of adult Hemiptera (24%), adult Hymenoptera (19%), and Arachnida (11%). Juveniles primarily fed on Collembola (48%), Hymenoptera (20%) and Coleoptera (11%). We found that the biomass of the diet sample was correlated with the mass of the toad. Metamorphs and juveniles selected prey in a nonrandom manner. Metamorphs fed on a higher proportion of Hemiptera (specifically Aphididae), Hymenoptera (specifically Formicidae), Lepidoptera, Coleoptera, and Arachnida and on a lower proportion of Diptera compared with available arthropods. Juveniles fed on a higher proportion of Hymenoptera (specifically Formicidae), Coleoptera, Diptera, and Arachnida, but on a lower proportion of Collembola compared to available arthropods.**

Key Words.—Bufo boreas; diet; juvenile; metamorph; Western Toad

INTRODUCTION

Populations of *Bufo boreas* (Western Toads) have experienced severe population declines and even extirpations in the mountains of Colorado (Carey 1993; Livo and Yeakley 1997; Muths et al. 2003), Great Central Valley of California (Fisher and Shaffer 1996), northern Utah (Corn et al. 1997; Thompson et al. 2003), and the northern Great Basin (Wente et al. 2005). In Colorado, declines are closely linked to outbreaks of chytridiomycosis (Carey et al. 1999; Muths et al. 2003; Scherer et al. 2005), a skin disease caused by the fungal pathogen *Batrachochytrium dendrobatidis.*

These declines suggest that recruitment into the breeding populations may also be problematic, yet we know little about the survival and habitat needs of metamorphic and juvenile *B. boreas* (Muths 2005). In the central Oregon Cascade Range, Olson (1992) observed masses of dead metamorphic toads at breeding sites, with "boom" recruitment years occurring rarely. Few studies target young toads because of the difficulty of monitoring the movements of small size-classes of toads once they emerge from breeding pools. Our objectives were to identify the diet of metamorph and juvenile *B. boreas* and compare the diet with available arthropods.

MATERIALS AND METHODS

Study areas.—We described the diets of metamorphs from three reservoirs and the surrounding areas in northeastern Oregon in 2006 and 2007: Balm (44º58'55" N, 117º29'73" W; elevation 1368 m; Fig. 1), Pine (44º49'30" N, 118º4'58" W; elevation 1966 m), and Fish (45º2'92" N, 117º5'41" W; elevation 1992 m). We compared metamorph diet with available arthropods at Balm only. Dietary data for juveniles (one-year old toads) came from Balm and Pine because we found only one juvenile at Fish. We selected these three reservoirs as study areas because they had a high density of breeding toads (Bull and Marx 2002; Bull 2006). The majority of the water in these reservoirs comes from snow-melt run-off and seasonal rains, although at least one perennial stream flows into each reservoir. All three reservoirs serve for cropland irrigation downstream in the summer. Consequently, irrigation needs drain the reservoirs in some years. These reservoirs are 12 to 36 ha in size at full capacity and are located in Baker County, Oregon, USA.

All study areas are in mountainous, forested terrain with undulating uplands and moderately or steeply walled drainages. Wallowa-Whitman National Forest manages the surrounding forests, which consist primarily of Lodgepole Pine (*Pinus contorta*) and Subalpine Fir (*Abies lasiocarpa*) except at Balm, where Ponderosa Pine (*Pinus ponderosa*), Douglas-fir (*Pseudotsuga menziesii*), Western Larch (*Larix occidentalis*) and Grand Fir (*A. grandis*) are present. Non-arboreal vegetation along drainages consists primarily of grasses and sedges with some shrubs. Density of vegetation and proximity to forest stands differ among locations. Livestock grazing occurs around Balm and Fish. Drainages in all three areas contain substrate dominated by gravel, cobble, and some boulders.

FIGURE 1. Primary breeding site of the Western Toad (*Bufo boreas*) at Balm Reservoir in northeastern Oregon, USA. Metamorphosed toads used the small drainage in the foreground for dispersal. (Photographed by Evelyn L. Bull)

Diet Samples.—We collected diet samples from metamorphs at each of the three study areas in 2006 and at Balm in 2007. In August and September 2006, we collected 88 samples from metamorphs at the breeding sites or along streams within 1 km of the breeding sites. In July 2007, we collected 112 diet samples from metamorphs at Balm along two streams used for dispersal within 200 m of the breeding site. We compared these 2007 samples with available arthropods to determine selection of prey.

We collected diet samples from juvenile toads at Pine in August and September 2006 and from juveniles at Balm in late April and May 2007. We distinguished juveniles from metamorphs based on date and size. After a metamorph had overwintered, we considered it a juvenile the next spring. At the time larvae transformed, juveniles (toads about one year old) were 25–50 mm snout-vent length (SVL) and at least 1.1 g (Fig. 2). Juveniles occurred near the breeding sites, along streams flowing into the reservoirs, and in wet meadows up to 1 km from the reservoirs.

We collected diet samples by stomach flushing with a plastic flexible catheter (1.5 mm outside diameter) inserted through the mouth and esophagus of the metamorph/juvenile with the opposite end attached to a 35 cc syringe filled with water (Legler and Sullivan 1979; Bull 2006). After flushing the stomach contents, we palpated the stomach to confirm that it was empty. We recorded SVL (in mm) and mass (g) for each metamorph/juvenile sampled (Table 1). We preserved food samples in 70% ethanol, and identified prey items at least to order using a dissecting scope. We sorted prey items into three size classes (1–4.5, 5–9.5, and ≥ 10 mm) after we measured them with an ocular micrometer. Prey size refers to the actual length of the prey item (i.e., whole insect, mite, or spider); partial prey items were not measured. We quantified the numbers of arthropods by counting head capsules or forewings if they were present. We counted other body parts if the former were missing. For example, six ant legs constituted one ant if there were other ant body parts present; identification was not based on legs alone. Each diet sample was oven-dried for 24 h at 40˚C. We determined biomass using a Mettler HP35 scale (Mettler Instrument

FIGURE 2. We distinguished juvenile (larger toad) Western Toads (*Bufo boreas*) from metamorphs on the basis of size. (Photographed by Evelyn L. Bull).

Corporation, Hightstown, New Jersey, USA) with an accuracy of 0.1 mg. We estimated the mass of diet samples at 0.0001 mg if it was smaller than the detection limit of the electronic balance. Diet composition was defined as the percentage of items of a particular prey type out of the total number of dietary items.

Available Arthropods.—To determine the terrestrial insects and other arthropods available to metamorphs and juveniles at Balm, we positioned sticky traps on the ground where juveniles and metamorphs were active in May and July 2007, respectively. Traps consisted of white poster board (20.5 cm x 30.5 cm) with a sticky layer on one side (Intercept Varroa Mite Traps^{TM}, IPM Technologies Inc, Portland, Oregon). We positioned traps on the ground where young toads forage; metamorphs could extricate themselves from the traps (pers. obs.)

We sampled arthropods available to juveniles in May using sticky traps at three plots at 100-m intervals along each drainage where there were more than 200 juveniles. At each plot, we positioned three sticky traps in locations having juveniles. These were typically in the sun and within 0.5–5 m of water. We placed another three sticky traps about 10 m from the water, but in areas typically lacking juveniles, (e.g., in the shade and on drier ground). We left sticky traps out for seven days and collected them on 4 and 11 May 2007.

We sampled arthropods available to metamorphs in July at three plots along streams used for dispersal (two plots 70 m apart on one stream and one plot on a second stream) within 200 m of the breeding site. We placed traps in the same arrangement as described above and collected them after 7 days on 7 Jul 2007.

We returned traps to the lab and refrigerated them (T ~ 6°C) until processed for arthropod identification. Arthropods were measured and classified as previously described for diet samples above. Numbers of individuals were directly counted except for Collembola, which occasionally occurred in extremely large numbers covering the entire trap. On Collembola-saturated traps, we counted all of the individuals found in four random

TABLE 1. Western Toads (*Bufo boreas*) sampled for diet analyses at three reservoirs in northeastern Oregon, USA, 2006–2007.

	Metamorphs				Juveniles	
	Pine 2006	Fish 2006	Balm 2006	Balm 2007	Pine 2006	Balm 2007
Mean SVL (mm)	18.9	16.2	24.5	18.6	34.3	22.3
(range)	(10–23)	(12–22)	(17– 30)	(16–22)	(25–43)	(16–30)
Mean mass (g)	0.59	0.38	1.18	0.35	3.32	0.69
(range)	(0.42–0.86)	(0.2–0.98)	(0.4–2.3)	(0.12–0.75)	(1.19–8.4)	(0.3–1.43)
Time since metamorphosis	2–3 weeks	2–4 weeks	5–6 weeks	1–2 weeks	12 months	9 months
No. of gravid females	Unknown	50	156	168	n/a	n/a
Mean no. prey (SE)	12.4 (2.52)	33.67 (4.05)	12.10 (1.50)	11.8 (0.97)	27.9 (5.12)	22.1 (3.13)
Mean biomass of prey in mg (SE)	2.4 (1.8)	2.19 (0.59)	9.92 (3.61)	4.5 (0.58)	37.3 (17.3)	5.3 (0.43)

0.25 cm^2 squares and took an average of the four squares, and then extrapolated this to the total area to estimate number of Collembola in the sample. We expressed the abundance of each prey category in terms of relative frequency.

Analysis.—Our data analysis was generated using SAS/STAT software, Version 9.1 (SAS Institute Inc., Cary, North Carolina, USA). Statistical significance was established at $\alpha = 0.05$. We tested data for normality using the Shapiro-Wilk statistic calculated within PROC UNIVARIATE of SAS. For comparisons where data were structured as one-way analysis of variance, heterogeneity of variance was determined using Levine's test, which is insensitive to non-normality. This was executed within PROC GLM of SAS, which was used only to generate this test statistic. Deviation from normality was the rule within all data, and variances were heterogeneous among treatment factors in most comparisons. Thus, non-parametric analysis procedures were used.

We conducted three statistical tests to evaluate relationships among treatment factors. In experiments fitting into the framework of one-way analysis of variance with more than two treatments, we conducted Kruskall-Wallis tests. We used Mann-Whitney *U* tests in experiments of this sort with only two treatments. We assessed strength of relationships between two quantitative response variables by calculating Spearman's correlation coefficients.

We compared the number and size of prey items, prey biomass, and diet composition of metamorphs and juveniles among study areas in 2006 using Kruskal-Wallis tests. We compared the number and biomass of prey between metamorphs and juveniles using Mann-Whitney *U* tests. Spearman's correlation coefficients were calculated to assess relationships between: (1) prey sample biomass and number of prey items; (2) toad SVL and mass with number of prey items; and (3) toad SVL and mass with biomass of prey. We compared the SVL of metamorphs and juveniles among study areas using Kruskall-Wallis tests and between years at Balm using Mann-Whitney *U* tests.

We compared composition of diet: (1) among metamorphs in three study areas (2006) using Kruskal-Wallis tests; (2) between metamorphs at Balm in 2006 and 2007; (3) between metamorphs and juveniles at Pine (2006) and at Balm (2007); and (4) between juveniles at Pine (2006) and Balm (2007) using Mann-Whitney *U* tests (Zar 1999). We compared the size of prey taken: (1) among study areas and between years for metamorphs using Kruskal-Wallis tests; (2) between juveniles at Pine (2006) and Balm (2007); and (3) between juveniles and metamorphs at Pine (2006) and at Balm (2007) using Mann-Whitney *U* tests. We compared the number and size of available arthropods captured on traps at Balm in 2007 between weeks in May and between traps in close proximity to metamorphs and juveniles versus those traps at some distance using Mann-Whitney *U* tests. We used $\alpha \leq 0.05$ to establish significance. Standard error (SE) accompanies all mean values.

RESULTS

Larvae metamorphosed into terrestrial metamorphs at approximately the same size at each reservoir (Table 1). Most metamorphs left the breeding sites within several days of metamorphosis and started traveling in masses along intermittent or permanent streams flowing into or out of the reservoir. Juvenile toads were difficult to locate, so we were only able to collect diet samples at Pine in 2006 and at Balm in 2007.

Prey Items and Biomass.—More than 90% of the metamorphs we sampled contained at least one food item. Across all metamorphs, 200 diet samples contained an average of 15.2 ± 1.06 prey items (range = 0–79) with a mean sample biomass of 4.67 ± 0.65 mg (Table 1). In general, we could identify approximately 90% of the contents of individual diet samples; ~55% was partially digested but recognizable parts, 35% was nearly whole arthropods, and 10% was mostly digested unidentifiable material.

For all juveniles captured at Pine in 2006 and Balm in 2007, 176 diet samples contained an average of 23.4 ±

TABLE 2. Number of arthropod prey items found in diet samples from Western Toad (*Bufo boreas*) metamorphs and juveniles in three study areas in northeastern Oregon, USA, 2006–2007.

	Metamorphs				Juveniles	
Class/order/family	Pine 2006	Fish 2006	Balm 2006	Balm 2007	Pine 2006	Balm 2007
Insecta						
Hymenoptera	37	110	97	208	307	424
Formicidae	17	62	79	47	279	398
Chalcidoidea	9	23	1	108	3	7
Ichneumonidae	0	0	1	1	5	3
Apidae	0	0	1	0	0	0
Symphyta	0	0	0	0	0	3
Other adults	11	25	15	52	20	13
Coleoptera	4	38	15	123	127	285
Staphylinidae	0	10	1	58	52	104
Curculionidae	0	0	7	4	4	20
Chrysomelidae	0	0	0	2	11	23
Tenebrionidae	0	0	0	10	3	24
Anobiidae	1	0	0	0	0	3
Scolytinae	1	0	0	0	0	2
Scarabidae	0	0	0	1	0	8
Elateridae	0	0	0	0	0	7
Other adults	1	24	7	21	26	87
Other larvae	1	4	0	27	31	7
Hemiptera	22	36	30	470	15	89
Aphididae	10	28	9	235	7	11
Cicadellidae	5	2	10	6	2	28
Miridae	1	0	0	2	2	1
Saldidae	0	0	0	0	3	2
Pentatomidae	0	0	0	0	1	0
Nabidae	1	1	0	0	0	0
Delphacidae	0	2	0	0	0	3
Tingidae	2	0	0	0	0	0
Thyreocoridae	0	0	1	0	0	0
Geocoridae	0	0	0	9	0	1
Berytidae	0	0	0	1	0	0
Nymphs	0	0	2	79	0	8
Other adults	3	3	8	138	0	35
Lepidoptera	1	2	3	156	25	13
Adult	1	0	3	3	0	0
Larvae	0	2	0	153	25	13
Diptera	17	30	22	96	16	152
Adult	12	29	17	60	13	107
Larvae	5	1	5	36	3	45
Neuroptera	0	1	1	0	3	3
Adult	0	0	0	0	2	2
Larvae	0	1	1	0	1	1
Collembola	4	178	0	26	0	1718
Thysanoptera	72	21	0	41	0	9
Tricoptera	18	0	0	0	3	3
Psocoptera	0	16	0	0	0	0
Other-insect adults	41	14	11	100	18	145
Other-insect larvae	4	0	2	29	1	23
Arachnida	23	172	7	69	24	171
Acarinae	22	161	0	51	11	152
Araneae	1	11	7	18	13	19
Gastropoda	0	3	0	2	3	7
Total prey items	243	621	188	1320	542	3042
No. diet samples	28	30	30	112	38	138

2.69 prey items (range = 0–313) with a mean biomass of 12.2 ± 3.83 mg. In a comparison between metamorphs and juveniles found within two study areas in the same year, number of prey items and biomass of diet samples differed significantly at Pine (Z = -6.91, $P < 0.01$; Z = 6.90, P = 0.05, respectively); at Balm in 2007, only the number of prey items differed between metamorphs and juveniles (Z = 8.29, $P < 0.01$). The biomass of diet samples correlated with toad SVL (r = 0.41, $P < 0.01$) and mass (r = 0.38, $P < 0.01$).

TABLE 3. Statistical values for significant differences in comparisons of metamorph diets among study areas (Kruskal-Wallis tests), between years (Mann-Whitney *U* tests), and between metamorph and juvenile diets at Pine and Balm (Mann-Whitney *U* tests).

Class/order/family	Metamorph diet among areas 2006	Metamorph diet at Balm 2006/2007	Metamorph/juvenile diet at Pine 2006	Metamorph/juvenile diet at Balm 2007
Insecta				
Hymenoptera	X^2 = 22.03, df = 2, P < 0.01	-	Z = -2.56, P = 0.01	Z = -3.52, P < 0.01
Formicidae	X^2 = 8.49, df = 2, P = 0.01	Z = 3.16, P < 0.01	Z = -3.61, P < 0.01	Z = -2.55, P < 0.01
Chalcidoidea	X^2 = 13.87, df = 2, P < 0.01	Z = 7.39, P < 0.01	Z = -4.18, P < 0.01	Z = -8.30 P < 0.01
Coleoptera	-	Z = -4.13, P < 0.01	-	Z = 7.56, P < 0.01
Staphylinidae	X^2 = 8.48, df = 2, P = 0.01	Z = -2.22, P = 0.03	Z = -5.03, P < 0.01	Z = -4.26, P < 0.01
Chrysomelidae	X^2 = 7.16, df = 2, P = 0.03	Z = -3.05, P < 0.01	Z = -3.71, P < 0.01	-
Hemiptera	-	Z = -2.75, P < 0.01	Z = -2.90, P < 0.01	Z = *3.01*, P < 0.01
Aphididae	-	Z = -4.48, P < 0.01	-	Z = 8.69, P < 0.01
Cicadellidae	X^2 = 10.59, df = 2, P < 0.01	Z = -3.65, P < 0.01	-	Z = 7.83, P < 0.01
Lepidoptera larvae	-	-	-	-
Diptera adult	-	-	Z = -1.97, P = 0.05	Z = -2.99, P < 0.01
Collembola	X^2 = 12.29, df = 2, P < 0.01	-	-	-
Thysanoptera	X^2 = 25.91, df = 2, P < 0.01	Z = -2.10, P = 0.04	-	Z = -8.83, P < 0.01
Tricoptera	X^2 = 9.33, df = 2, P < 0.01	Z = -2.89P < 0.01	Z = 2.95, P < 0.01	Z = 4.22, P < 0.01
Psocoptera	-	-	Z = -2.25, P = 0.02	-
Arachnida				
Araneae	-	Z = 2.14, P = 0.03	-	Z = -2.41, P = 0.02

Diet Composition.—Metamorphs fed on arthropods in at least 20 families within 10 orders of insects, in addition to two orders of arachnids and a few gastropods. For all study areas combined, the orders with more than 5% of the prey items of metamorphs included Hemiptera (23.5%), Hymenoptera (19.1%), Arachnida (11.4%), Collembola (8.8%), Coleoptera (7.6%), Diptera (7.0%), Lepidoptera (6.8%), and Thysanoptera (5.6%; Table 2; Fig. 3). The families that were in the highest number of prey items were Aphididae (11.9%; order Hemiptera) and Formicidae (8.6%; order Hymenoptera). Diet composition of all juveniles included Collembola (47.9%), Hymenoptera (20.4%), Coleoptera (11.1%), and Arachnidae (5.4%) each making up more than 5% of the diet (Table 2, Fig. 3). Formicidae (order Hymenoptera) was the family with the most prey items consumed by juveniles.

Diet composition of metamorphs differed among study areas and between years at Balm. In 2006, diet differed significantly among study areas in number of prey items made up of the orders Hymenoptera, Coleoptera, Psocoptera, Collembola, Thysanoptera, and Tricoptera (Tables 2 and 3). Metamorph diet at Balm in 2006 and 2007 differed significantly with higher numbers of the order Hymenoptera and family Cicadellidae in 2006 and higher numbers of the orders Hemiptera and Lepidotera in 2007. The order with the greatest representation in each area and year was Hymenoptera (52%) at Balm in 2006, Hemiptera (36%) at Balm in 2007, Thysanoptera (33%) at Pine, and Collembola (30%) at Fish (Table 2). Composition of prey also differed between metamorphs and juveniles in the two study areas where both were sampled in the same year (Tables 2 and 3).

Size of Prey.—Size of prey of metamorphs in 2006 differed significantly among study areas and between years in Balm for items 1–4.9 mm (X^2 = 24.43, P < 0.01; Z = -3.87, P < 0.01, respectively) and for items 5–9.9 mm (X^2 = 18.26, P < 0.01; Z = -4.77, P < 0.01, respectively; Table 4). Similarly, metamorph SVL differed significantly among study areas in 2006 (X^2 = 57.54, df = 2, P < 0.01) and between years at Balm (Z = 5.70, P < 0.01). The mean SVL of metamorphs ranged

TABLE 4. The percentage of arthropods in each size class that occupy Balm Reservoir, Oregon, USA and that comprise the diets of Western Toad (*Bufo boreas*) metamorphs and juveniles in three study areas at Balm in northeastern Oregon, 2006–2007.

Area/year	Size class of arthropods		
	1–4.9 mm	5–9.9 mm	≥ 10 mm
Metamorph diet			
Pine 2006	89.2%	10.8%	0%
Fish 2006	98.5%	1.5%	0%
Balm 2006	72.2%	27.3%	0.5%
Balm 2007	95.6%	3.8%	0.2%
Juvenile diet			
Pine 2006	81.1%	18.1%	0.7%
Balm 2007	94.5%	5.1%	0.4%
Available arthropods at Balm, May 07	99.3%	0.7%	< 0.1%
Available arthropods at Balm, July 07	91.8%	8.1%	0.1%

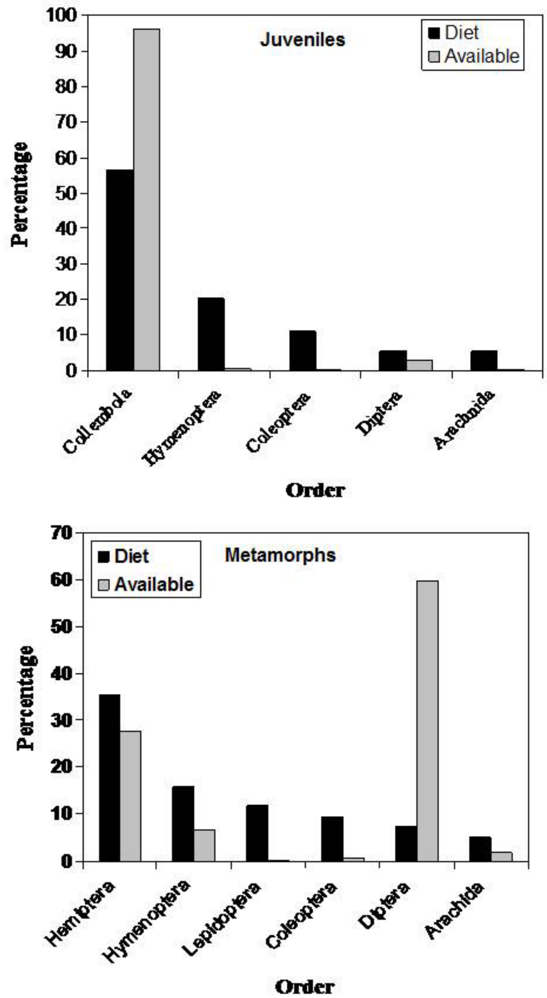

FIGURE 3.—Composition (%) of diet of Western Toad (*Bufo boreas*) juveniles in May and of metamorphs in July compared with available arthropods during the same periods at Balm in northeastern Oregon, USA, 2007. Only orders representing > 5% of the diet are shown.

from 16.2 at Fish to 24.5 at Balm in 2006 (Table 1). In 2006, a higher percentage of prey from metamorphs at Balm was in the 5–9.9 mm size class when compared to metamorphs at Pine and Fish (Table 4). At Balm, metamorphs consumed larger prey in 2006 compared to 2007, although metamorphs sampled in 2006 were an average of 6 mm larger than those in 2007 (Table 4). Toad SVL was significantly correlated with the percentage of prey 1–4.9 mm in 2007 ($r = 0.19$, $P = < 0.01$) and with prey 1–4.9 mm and 5–9.9 mm in 2006 ($r = 0.35$, $P < 0.01$; $r = 0.56$, $P < 0.01$, respectively) in all three study areas.

Size of prey taken by juveniles at Pine in 2006 and at Balm in 2007 differed significantly ($Z = 9.39$, $P < 0.01$) with larger prey being taken at Pine where juveniles averaged 34 mm SVL compared to juveniles that averaged 22 mm SVL at Balm (Table 4). Juvenile SVL differed significantly between Pine and Balm ($Z = 9.39$, $P < 0.01$). The percentage of prey 1–4.9 mm was significantly correlated ($r = 0.33$, $P = 0.04$) with juvenile SVL at Pine.

Compared to juveniles in the same area, metamorphs were significantly smaller at both Pine in 2006 ($Z = -6.91$, $P < 0.01$) and Balm in 2007 ($Z = -11.44$, $P < 0.01$) and fed on significantly smaller prey at Pine ($Z = -6.91$, $P < 0.01$) and at Balm ($Z = 11.44$, $P < 0.01$; Table 4).

***Available Arthropods.*—We collected** a total of 94,409 arthropods in the Insecta and Arachnida on sticky traps at Balm belonging to at least 10 families in 12 orders (Table 5). Of the families and orders represented on the sticky traps, metamorphs and/or juveniles preyed on all except Orthoptera. The order with the greatest representation on sticky traps was Collembola with an estimated 89,023 captured in May (120 on 4 May and 88,903 on 11 May), although only 26 were trapped in July. Excluding Collembola, adult Diptera and Hemiptera, specifically Cicadellidae, made up the majority of arthropods in both time periods. Owing to the few differences (described below) in the following statistical comparisons, we pooled the data for subsequent analyses on arthropods collected: (1) on sticky traps during the two weeks in May; (2) from sticky traps near juveniles and those away from juveniles in May; and (3) from sticky traps near metamorphs and those away from metamorphs in July. In 16 comparisons by order or family of available arthropods collected on sticky traps the week of 4 May and 11 May, only Hymenoptera ($Z = 2.11$, $P = 0.03$), Collembola ($Z = -4.86$, $P < 0.01$), and adult Diptera ($Z = -3.29$, $P < 0.01$) differed significantly. Hymenoptera and Collembola were more abundant the second week, and adult Diptera was more abundant the first week. These differences are likely to reflect the different emergence times of some of the arthropods.

In 14 comparisons by orders and families of arthropods collected on sticky traps placed near juveniles and away from juveniles in May, a significant difference occurred only in the abundance of Cicadellidae ($Z = -2.03$, $P = 0.04$). This family was more than twice as abundant on traps near juveniles when compared to traps away from juveniles. Similarly, in 15 comparisons by order and families of arthropods collected on sticky traps placed near metamorphs and away from metamorphs in July, a significant difference occurred in the abundance of Hymenoptera ($Z = -2.26$, $P = 0.02$) and adult Diptera ($Z = 2.65$, $P < 0.01$) with more Hymenoptera on traps away from metamorphs and more Diptera on traps near metamorphs. These differences are likely to reflect microhabitat differences of these arthropods.

In a comparison of sizes of available arthropods, there were significantly more arthropods 1–4.9 mm the week of May 11 ($Z = 3.93$, $P < 0.01$) and more arthropods 5–

TABLE 5. Number of available arthropods detected on sticky traps at Balm in May and July 2007.

Class/Order/Family	May	July
Insecta		
Hymenoptera	37	126
Chalcidoidea	26	123
Formicidae	3	0
Other adults	8	3
Coleoptera	23	13
Staphylinidae	8	2
Scolytinae	0	4
Elateridae	2	0
Tenebrionidae	1	0
Other adults	12	7
Hemiptera	577	533
Aphididae	15	63
Cicadellidae	438	453
Delphacidae	4	0
Geocoridae	0	1
Nymphs	118	13
Other adults	2	4
Lepidoptera adults	3	1
Diptera adults	2659	1161
Collembola	89,023	26
Thysanoptera	38	27
Tricoptera	1	0
Psocoptera	0	2
Orthoptera	2	3
Other-insect adults	0	5
Other-insect larvae	1	8
Arachnidae	101	38
Acarinae	82	8
Araneae	19	30
No. of items	**92,465**	**1944**

9.9 mm the week of May 4 (Z = -3.93, P < 0.01). However, arthropods 5–9.5 mm in length made up 12% of the arthropods on sticky traps near metamorphs versus only 4% on traps away from metamorphs in July (Z = -2.40, P = 0.02).

Metamorphs at Balm used a higher proportion of Hemiptera (specifically Aphididae), Hymenoptera (specifically Formicidae), Lepidoptera, Coleoptera, and Arachnida and a lower proportion of Diptera than occurred on sticky traps (Fig. 3); the available Hemiptera consisted primarily (80%) of the family Cicadellidae (Table 5). Juveniles at Balm preyed on a higher proportion of Hymenoptera (specifically Formicidae), Coleoptera, Diptera, and Arachnida than occurred on sticky traps (Fig. 3). Only Collembola was used in a lower proportion than occurred on sticky traps. In addition, we did not collect representatives of four orders on traps although they occurred in diet samples of prey taken by metamorphs or juveniles. Typically, the orders not collected on traps made up a small proportion of the diet with less than 10 prey items taken of Ichneumonidae and Symphyta in the order Hymenoptera; Anobiidae and Scarabidae in the order Coleoptera; Miridae, Saldidae, Pentatomidae, Nabidae, Tingidae, Thyreocoridae and Berytidae in the order Hemiptera; and the order Neuroptera. Exceptions included two families of beetles (Curculionidae and Chyrsomelidae) where 35 and 36 items were taken as prey, but none were found on the traps. Lepidoptera and Diptera adults, but no larvae, were captured on traps, yet metamorphs and juveniles preyed on 193 and 95 larvae of these orders, respectively.

Size of prey taken by metamorphs and juveniles in Balm was approximately the same proportion that occurred on sticky traps (Table 4). However, metamorphs preyed on slightly more prey < 5 mm in length and juveniles preyed on slightly more prey ≥ 5 mm compared to arthropods on the traps (Table 4).

DISCUSSION

No previous studies exist on the diet composition of *B. boreas* metamorphs or juveniles, although diets of other species of *Bufo* juveniles (family Bufonidae) have been reported. Stomachs of seven newly metamorphosed *B. woodhousei fowleri* in Connecticut contained 66% Collembola, 20% Aphidae, 10% Diptera (adults and larvae), 2% Acarina, and 1% Formicidae (Clarke 1974). In South Dakota, 50 metamorphs of *B. woodhousii* and *B. cognatus* preyed primarily on Collembola and Coleoptera (Flowers and Graves 1995). Metamorphs of 17 *B. cognatus* in Texas preyed on more scarab beetles and formicid ants, while 13 *Spea multiplicata* (family Pelobatidae) preyed more on chysomelid and elaterid beetles (Smith et al. 2004). Newman (1999) found that 26 *Scaphiopus couchii* metamorphs in Texas fed on collembolans and Arachnida (primarily mites) while the largest items in stomachs were generally soft-bodied caterpillars or beetle larvae. Our study differed from others by sampling diet in a large number of live toads (200 metamorphs and 176 juveniles), which likely contributed to a greater diversity of prey being reported.

In our study, Hemiptera (particularly Aphididae), Hymenoptera (particularly Formicidae) and Arachnida made up over 50% of the prey taken by metamorphs. However, metamorphs of *B. boreas* in our study consumed a large variety of prey items within a small size range; over 80% of prey items were smaller than 5 mm. These findings contradict Newman's (1999) suggestion that there may be little scope for diet variation because of the small range of size variation among metamorphs in a population. Differences in prey consumed among our three study areas suggest that metamorphs were versatile in foraging on different prey present at different locations. Although some differences were found between available arthropods and diet samples, it seems that the diversity of metamorph and juvenile diets reflect the arthropod diversity in the appropriate size classes in our study area at the time.

Despite the breadth of prey taken, metamorphs and juveniles at Balm appeared to select prey non-randomly (Fig. 3), assuming that our sticky traps adequately sampled available arthropods. Other explanations would include the patchy distribution of arthropods and/or young toads. An example of patchiness in time and space is the extremely high number of Collembola captured in May where 98% were captured on four of 36 traps. Of the Collembola captured, approximately 0.1% were captured during the first week compared to the second. Other factors include the relative size and mobility of potential prey. Although two prey items may be equally numerous, young toads may consume more of one than another if it is easier to capture and consume because it is comparatively smaller and/or less mobile. Our results differed from those of Newman (1999) who reported that the diet of *Scaphiopus couchii* metamorphs was in almost complete accordance in the identity of prey items with arthropods captured on sticky traps. Other factors that may contribute to differences between diet and available arthropod samples, is the condition of the diet sample and digestability of arthropods. Some soft-bodied arthropods may digest more rapidly than others may. Although the majority of the obvious stomach contents were identifiable, it is possible that easily digested and/or absorbed prey were overlooked.

Foraging strategies may change as metamorphs mature in terms of movement, time of foraging, prey/predator size relationship, and energetic needs (Christian 1982). Toft (1981) found foraging mode differed with age of the toad, with metamorphs actively searching for prey during the day while adult toads, which were primarily nocturnal, sat in one place and consumed passing prey. The diurnal activity of these metamorphs may have been a function of the combination of warmer temperatures in our study areas during the day and because small soft-bodied insects are active in the day increasing metamorph probability of encountering smaller arthropods. Metamorphs in our study did not select larger prey, most likely, because of their inability to capture and consume it, but also perhaps because they did not encounter it during the day.

Size of metamorph is influenced by the size at metamorphosis and time since metamorphosis and affects the size of prey taken because of a size-related foraging ability. Both size of prey taken by metamorphs and size of metamorphs differed among study areas and were correlated. Studies on both *Scaphiopus couchii* (Newman 1999) and *B. woodhousii* (Flowers and Graves 1995) found that prey size differed among metamorph sizes. However, while neither study found a correlation between metamorph size and number of prey items, the mass of prey in stomachs did increase with metamorph size with *Scaphiopus couchii*.

Not surprisingly, the diet of metamorphs and juveniles differed markedly from that of adults in our study areas where adults foraged primarily on larger ants and ground beetles in northeastern Oregon (Bull 2006), which are also common items in the diet of adult *Bufo* spp. in Oklahoma (Smith and Bragg 1949). In Colorado, *B. boreas* adults ate mostly ants, beetles, and spiders (Campbell 1970) and moths, grasshoppers, ants, deer flies, mosquitoes, and beetles (Burger and Bragg 1947). In Montana, seven stomachs of *B. boreas* contained 75% Hymenoptera, 23% Coleoptera, 3% Arachnida, and less than 1% of four other insect orders (Miller 1978). Based on analysis of 47 scats of *B. boreas* found in the Cascade Mountains of Oregon, diet at one area consisted almost exclusively of carpenter ants (*Camponotus* spp.; Hayes and Hayes 2004).

Overall, prey availability would not appear to be a limiting factor for *B. boreas* metamorphs and juveniles in these study sites during the two time periods considered. Our studies were conducted near breeding sites, and it is unknown how prey availability may vary as young toads disperse away from these sites. Known sources of mortality of metamorphs and juveniles in the immediate vicinity of the breeding sites include predation, trampling (by cattle and vehicles), and desiccation. The presence of chytridiomycosis in adult toads at these sites has been confirmed (Bull 2006), as well as in metamorphs and juveniles (Bull, unpubl. data). Dispersal and survivorship of toads prior to recruitment into the breeding populations warrants further investigations in light of declining numbers in some sites in northeastern Oregon and elsewhere.

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