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Diet and Prey Availability of Columbia Spotted Frogs in Northeastern Oregon

Abstract

Baseline information on the diet and prey availability of Columbia spotted frogs is lacking from most of the species range. Diet was determined from June through October 2002 for 296 frogs in northeastern Oregon. Number of prey items, diet composition, and biomass indices were compared by sex, size classes, water type (ponds versus rivers), month, and study site. Available invertebrates were determined from sticky traps and dip netting in ponds and rivers. A total of 1,299 prey items were identified with an average of 4.4 prey items in each sample (range = 0 - 28). A wide variety of prey were identified including 33 families from 20 orders of invertebrates with only 3 orders representing ≥10% of the composition: beetles (21%), ants/wasps (21%), and flies (10%). Only 14% of the prey were in the larval stages. Female frogs ate about 60% more biomass than males of the same size, presumably because of their need to produce eggs. Biomass of male frog diet samples were greater in rivers than in ponds with a higher percentage of stoneflies, water striders, and beetles. Frogs actively foraged all summer with the highest biomass in September and the lowest in July. Over the summer, composition of spiders, beetles, and flies decreased, while true bugs and ants/wasps increased in the diet. Among study sites, ants/wasps were most abundant at the higher elevations. A higher proportion of invertebrates occurred in the larger sizes in the diet compared with samples of available invertebrates.

Introduction

Amphibians make up an important component of the aquatic habitats in the Blue Mountains. These species serve as good indicators of overall health of forest and rangeland ecosystems because they depend on water for reproduction, and because their permeable skin makes them particularly sensitive to environmental toxins (Morell 1999). We know relatively little about the biology or the relative health of their populations, particularly with regard to disturbances. Increasing incidence and intensity of fires and other disturbance agents (floods, drought, introduction of fish, habitat alteration, livestock grazing, noxious weed control) in eastern Oregon may threaten these animals and the integrity of the aquatic habitat. Large-scale disturbances such as fire, may have direct and indirect consequences on frogs resulting in predation, loss in habitat, or changes in diet and prey availability.

This study provides basic ecological information on the diet of the Columbia spotted frog (*Rana luteiventris*). This frog species is of interest to managers because it is classified as imperiled by the Oregon Natural Heritage Program, as sensitive by the USDA Forest Service in Region 6, and as a candidate for listing under the Federal Endangered Species Act. Declines in this species have been reported in Yellowstone National Park (Patla and Peterson 1999), Utah (Hovingh 1993), and Nevada (Reaser 2000). The causes of the declines include habitat loss and fragmentation, introduction of predators, cattle grazing, and the loss of natural flood disturbances. Many of these factors could also influence prey availability.

Studies of food habits of the Columbia spotted frog have shown this species to be an opportunistic feeder, taking whatever invertebrates are on, near, or underwater (Turner 1959, Miller 1978, Whitaker et al. 1983) .

Baseline information on diet and prey availability of Columbia spotted frogs is lacking in northeastern Oregon and other portions of its range. This frog typically breeds in permanent ponds but may spend the summer, fall, and winter in ponds or rivers (Bull and Hayes, 2001, 2002). The factors driving the selection of pond or river habitat are not fully known, although diet may be one of several contributing factors. The focus of this study was to compare Columbia spotted frog diet and invertebrate availability between pond and river habitats at six study sites. This study was designed to answer the following five questions: 1) were frogs consuming invertebrates in proportion to their abundance; 2) did frogs select for larger prey items to maximize their energy expenditure foraging; 3) did pond or river habitat provide a greater

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abundance of prey or larger prey items for frogs; 4) was frog diet the same at different study areas; 5) for what duration of the summer did frogs forage and did diet differ?

Methods

Study Area

This study was conducted at six sites in two watersheds in northeastern Oregon between June and October 2002 (Table 1). Study areas were selected based on the presence of known breeding sites and previous knowledge of frog movements. Each study site has at least one breeding pond in lentic habitat (Palustrine system) (Cowardin et al. 1979) and an adjacent lotic habitat (Riverine system) within 400 m, except the Rainbow site, which lacks a lotic system. All ponds (lentic) and river habitats (lotic) are in forested habitats and have permanent water in typical years. The breeding ponds range from 60 to 30,000 m^2 in size. The earliest breeding activity occurs at the Hohman pond in late March and the latest occurs at Rainbow pond in late April or early May (Table 1). The information on breeding dates was obtained by checking the ponds every 1-2 days after ice melted. Timing of breeding activity at these study sites is a function of elevation, exposure, and temperature of the water source. The ponds at Hohman rarely freeze, while all other pond surfaces typically freeze in November and thaw between March and May.

Diet Sample

Diet samples were collected every 2 wk from frogs captured in pond and river habitats at the Gun, Starkey, Tailings, and Rainbow study areas. Five percent of frogs captured lacked any stomach contents, and these frogs were not included in the sample. Diet was not determined in two study sites due to difficulty in locating frogs for diet samples. Sampling started in early June after all breeding was completed and ended in mid-October when nighttime temperatures dropped below freezing. Because activity level of arthropods varies with time of day, the order that study sites were sampled was rotated each sampling period.

Frogs were captured with dip nets while I walked along the pond perimeter or river edge at each of the four study sites. Sex and snout-vent length (SVL) were recorded for each frog, and a diet sample was obtained by flushing the stomach of the frog with a catheter (2 mm wide, 56 cm long) attached to a 65-cc syringe inserted through the mouth and esophagus of the frog (Legler and Sullivan 1979, Whitaker et al.1983). Diet samples were preserved in vials of 75% ethanol alcohol and returned to the lab for identification. I assumed the entire diet sample was flushed from the frog because Legler and Sullivan (1979) were confident that they recovered all the material in the stomachs of lizards based on dissection of a few lizards after flushing the stomach; however, no frogs were killed to test this assumption. We attempted to collect five diet samples from the first five frogs captured in both the pond and river at each study site, but limited the time searching for frogs to 2 hr at each site. Food fragments were identified to order or family and categorized into six size classes (1-4.5, 5-9.5, 10-14.5, 15-19.5, 20-24.5, ≥ 25 mm) when enough of the invertebrate was present to estimate size.

Biomass (mg) was determined by oven-drying each sample for 24 hr at 40° C. The largest samples were dried for 48 hr. Because size of frog largely determined the size and amount of prey the frog could consume, I devised an index to standardize for frog size (biomass divided by SVL *100) .

The number of prey items, diet composition, and biomass indices were compared by (1) sex,

TABLE 1. Pond size and depth, dates of breeding, elevation, and location of six study sites used to monitor Columbia spotted frogs in northeastern Oregon, 2002.

Study Area	Pond size (m^2)	Pond depth (m)	Dates of egg laying	Elevation (m)
Gun	887	0.8	7-17 Apr 02	924
Hohman	300	1	31 Mar-12 Apr 02	935
Starkey	4,132	1.1	30 Mar- Apr 98	1,001
Whitehorse	30,000	0.7	8-14 Apr 02	1,188
Tailings	86-264	0.6-2	15-25 Apr 02	1,380
Rainbow	28,526	3	12-28 May 02	1,810

(2) frog size class (≤55 mm, 56-70 mm, and >70 mm SVL), (3) water type (pond versus river), (4) month, and (5) study site. For number of prey items and biomass indices, t-tests were used for comparisons between sexes and water types. Analysis of Variance (ANOVA) and a post-hoc Tukey's B pair-wise comparison test were used to compare frog size classes, months, and study areas. Chi-square tests were used for all diet composition comparisons. If the initial comparison between sex revealed differences, subsequent comparisons were done for each sex separately. Significance level was set at $P = 0.05$.

Invertebrate Availability

Invertebrates were sampled using two methods (sticky trap and dip net) at the same 2-wk interval that diet samples were collected from June until late August (when wasps started consuming most of the invertebrates on the sticky traps). This time period was selected for sampling because it coincided with frog presence at the sites. Sampling occurred between the hours of 0900 and 1800, and the sequence that the six study sites were sampled was rotated to reduce bias. Placement of sticky traps and dip netting occurred where frogs would likely be feeding based on telemetry locations in a previous study (Bull and Hayes 2001)

Sticky traps were used to sample aerial invertebrates at the pond or river at each site. A sticky trap consisted of a clear four-sided plastic cover for plants that was 24 cm high and attached to a piece of white styrofoam floating on the water surface. Four pieces of clear plastic sprayed with Tanglefoot were attached on the four sides of each plant cover with velcro. These traps were collected every 2 wk, returned to the lab where invertebrates in a 10 by 10 cm square in the center of each piece were identified to order (Borror and Delong 1971), and categorized into six size classes.

Aquatic invertebrates were sampled with four sweeps of a dip net (35 by 20 cm frame and 2 mm mesh) at each pond or river stretch. Sweeps were perpendicular to the shore, 1 m in length on the substrate, ending at the shoreline, and at least 10 m from previous sweeps. Invertebrates were identified to order (Merritt and Cummins 1978), categorized into the same six size classes, and released to reduce impact on invertebrate populations.

The two methods of sampling provide a measure of the relative abundance of aerial and aquatic invertebrates, but they are not directly comparable. For invertebrates captured on sticky traps and dip nets, the number of invertebrates, the number by invertebrate size class, and the composition were compared by water type, month (June through August), and site using t-tests and ANOVA and a post-hoc Tukey's B pair-wise comparison test. The composition of orders comprising >5% of the total number of prey items was used for comparison. Because data were aggregated by day, the mean for multiple samples collected on individual days was used as the variable. The relative abundance (proportion) of invertebrates occurring in the diet and within each trap type was compared using chi-square analyses for the orders that were relatively common.

Results

Number of Prey Items

Between June and October, 296 diet samples were collected at the 4 study sites from 171 female and 125 male frogs. A total of 1,299 prey items were identified ($\bar{x} = 4.4 \pm 0.23$) ranging from no identifiable prey to 28 prey items per sample. No significant differences were detected in number of prey items by sex, water type, month, or site. Frogs >70 mm SVL ate significantly more prey items ($\bar{x} = 5.1$ prey items) than frogs 56-70 mm SVL ($\bar{x} = 3.8$ prey items) ($P = 0.04$).

Diet Composition

A wide variety of prey was found in the diet samples with only three orders representing ≥10% of the composition: beetles (21%), ants/wasps (21%), and flies (10%) (Table 2). Only 14% of the prey items were in larval stages. Prey items were primarily in the smaller size classes: 40% were 1-4.5 mm in length, 29% were 5-9.5 mm, 21% were 10-14.5 mm, and 10% ≥ 15 mm (Figure 1). Composition of frog diet by order of invertebrates differed significantly by water type ($P < 0.01$) (Table 2) and among frog size classes ($P = 0.02$), but not by sex. For those 477 prey items that could be identified to family, composition of diet by family differed significantly by water type ($P < 0.01$), by sex ($P < 0.01$) and among frog size classes ($P < 0.01$). A higher proportion of stoneflies, water striders, and beetles occurred in diet samples in

TABLE 2. Number of 1,299 prey items identified to order or family that were found in diet samples of Columbia spotted frogs captured in ponds and rivers in northeastern Oregon, 2002. Prey items comprising ≤1% of the diet are not listed. Invertebrates identified to family are not included in the totals for the order.

Phylum/Class/Order/Family	Pond	River	Total
Mollusca (mollusks)	9	—	9
Gastropoda (snails)	15	9	24
Arthropoda (arthropods)			
Crustacea (crustaceans)	—	6	6
Amphipoda (scuds)	49	1	50
Arachnida (arachnids)	—	1	1
Acari (mites and ticks)	14	—	14
Araneae (spiders)	51	63	114
Insecta (insects)			
Ephemeroptera (mayflies)	22	3	25
Odonata (dragonflies and damselflies)	42	2	44
Orthoptera (grasshoppers)	9	16	25
Hemiptera (true bugs)	16	21	37
Corixidae (water boatmen)	8	7	15
Gerridae (water striders)	15	26	41
Homoptera (aphids, scales, hoppers)	1	1	2
Aphididae (aphids)	36	29	65
Coleoptera (beetles)	96	85	181
Carabidae (ground beetles)	18	43	61
Curculionidae (snout beetles)	3	12	15
Elateridae (click beetles)	3	2	5
Hydrophilidae (water scavenger beetles)	—	15	15
Trichoptera (caddisflies)	11	6	17
Lepidoptera (butterflies and moths)	33	23	56
Diptera (flies)	68	66	134
Hymenoptera (ants, bees, wasps)	9	9	18
Formicidae (ants)	99	52	151
Vespidae (wasps)	71	29	100
Unknown	35	24	59

rivers, and a higher proportion of scuds, mayflies, dragonflies, damselflies, backswimmers, and ants/wasps occurred in diet samples in ponds. Composition of diet differed among study sites for orders with >20 prey items ($P < 0.01$; Figure 2). Composition of diet differed over the summer among four families and 11 orders of prey items ($P < 0.01$). For the six orders with > 50 prey items found ($P < 0.01$) in diet samples, spiders, beetles, and flies decreased in abundance over the summer, and true bugs and ants/wasps increased in abundance over the summer (Figure 3).

Two recently transformed Columbia spotted frogs were found in the stomach of a female at Rainbow pond, and a Pacific treefrog (*Hyla regilla*) metamorph was found in the stomach of a female at Gun pond. These observations indicate that cannibalism occurs in this species.

Diet Biomass

Female biomass indices were 60% larger than males ($\bar{x}$ male = 5.8; female $\bar{x} = 9.3$; $P < 0.01$), so that further analyses were separated by sex. Biomass indices of female frogs ≤55 mm SVL were significantly smaller than those in the two larger size classes (biomass index = 4.3 for frogs ≤55 mm; 10.0 for frogs 56-70 mm; 10.4 for frogs > 70 mm; $P < 0.01$). No significant differences occurred in biomass indices among the three size classes of males. By water type, males in rivers had significantly larger biomass indices ($\bar{x} = 8.1$) than males at ponds ($\bar{x} = 4.6$) ($P = 0.01$), but there were no significant differences between female biomass indices by water type. Biomass indices were significantly higher in September than in July ($P = 0.02$); no significant differences occurred in biomass indices between rivers and ponds by month or among sites.

Invertebrate Availability

Sticky traps captured aerial invertebrates that flew or drifted into the traps, although visual observations suggest that wasps (i.e.,yellowjackets) were typically not captured and are under represented. I captured 38,583 invertebrates with the majority being flies (74%) and leaf hoppers (16%) (Table 3). Ninety-three percent of the invertebrates were 1-4.5 mm (Figure 1). No differences in number by size class or total number of invertebrates were detected between pond and river habitats. No differences were detected in total number of invertebrates among study sites. By composition (order), only leafhoppers were significantly more abundant at ponds than rivers ($P < 0.01$). By month, spiders were more abundant in July than June, and beetles and leaf hoppers were more abundant in July than August ($P < 0.01$).

I captured 4,527 invertebrates with dip nets, the majority in larval form. A considerable diversity of invertebrates was represented in the sample with the majority being snails (27%), crustaceans (16%), and mayflies (10%). By invertebrate size class, a higher percentage of these dip net samples

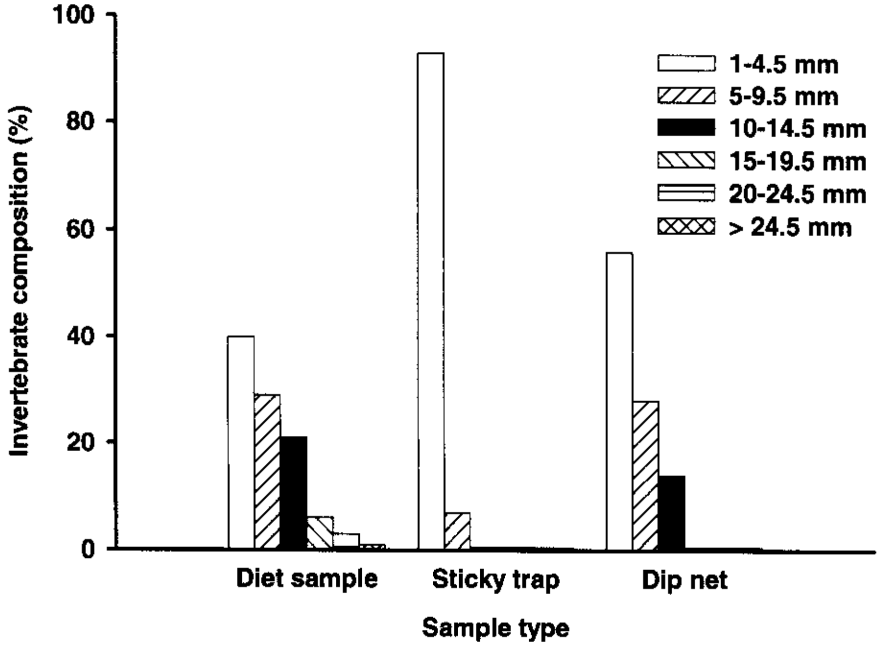

Figure 1. Proportion of invertebrates by size class consumed by frogs and captured on sticky traps and in dip net samples.

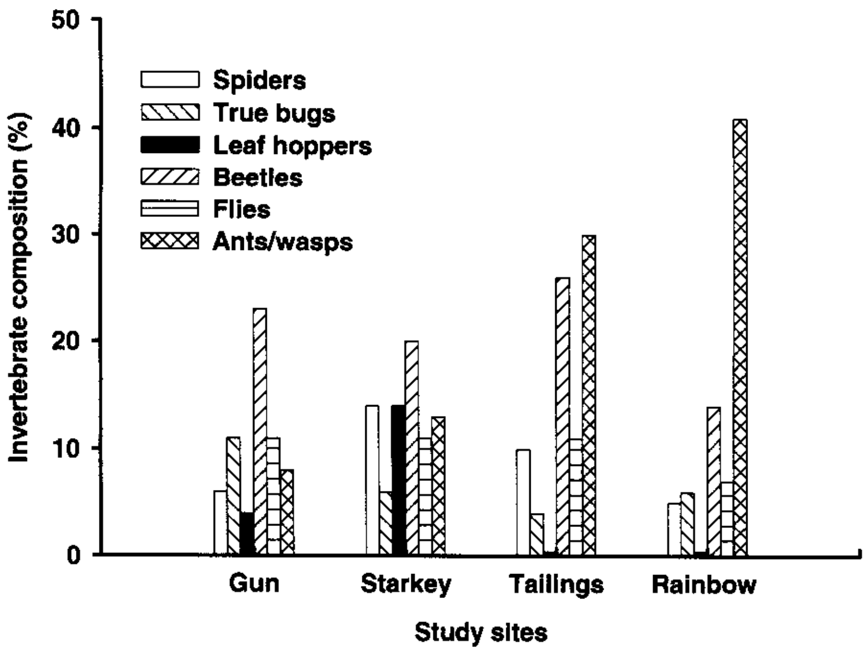

Figure 2. Proportion of invertebrates in six orders found in Columbia spotted frog diet in four study sites. Only orders with > 50 prey items are displayed.

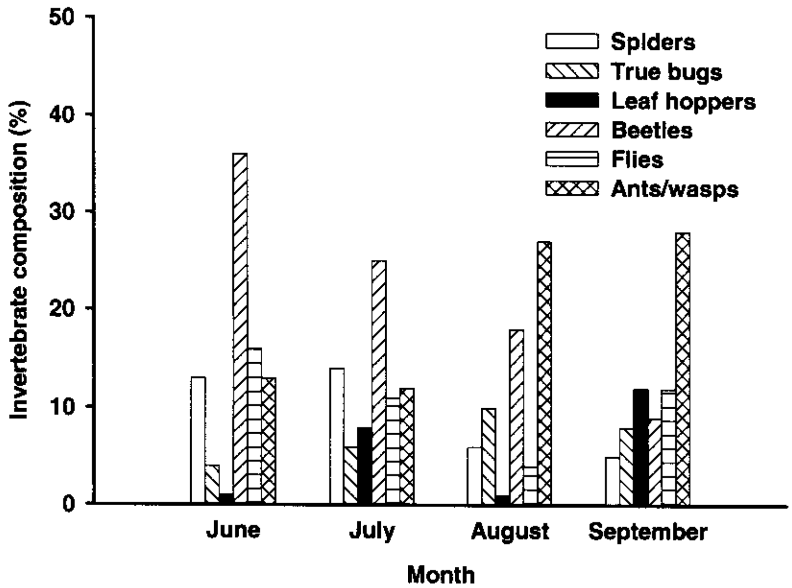

Figure 3. Proportion of invertebrates in six orders found in Columbia spotted frog diet in each of four months. Only orders with > 50 prey items are displayed.

were larger when compared to sticky traps (Figure 1). Higher numbers of all invertebrates ($P < 0.01$) and of dragonflies ($P < 0.01$), damselflies ($P < 0.01$), back swimmers ($P < 0.01$), diving water beetles ($P = 0.03$), leeches ($P = 0.03$), crustaceans ($P < 0.01$), and mayflies ($P < 0.01$) occurred in ponds than in rivers. No significant differences occurred in total number by size class or size class by site in ponds or in rivers. No significant differences occurred in composition by site.

Availability of invertebrates by order captured in sticky traps and dip nets differed significantly from what was found in the frog diet ($P < 0.01$; $P < 0.01$). Size class also differed between available invertebrates and those in the diet sample (sticky trap: $P < 0.01$; dip net: $P < 0.01$). Invertebrates captured on sticky traps and dip nets represented only a portion of prey available to Columbia spotted frogs. By taxonomic group, 52% and 22% of the frog diet comprised invertebrates captured in sticky traps and dip net samples. Terrestrial invertebrates (e.g., ants, beetles, larvae of butterflies and moths) and wasps made up 17% and 8% of the frog diet but were not detected with my sampling techniques.

Discussion

Prey items found in diet samples suggested that the Columbia spotted frog is a generalist, consuming a wide variety of prey within the size range that it can catch and ingest (Table 2). Frog diet consisted of a higher percentage of larger invertebrates than was captured on sticky traps or in dip nets (Figure 1), which suggests a selection for larger prey to maximize caloric return for capture effort. It appeared that male frogs in rivers were able to obtain more biomass than males in ponds based on biomass indices, although no differences were detected in biomass obtained by females among water types.

Findings of this study concur with the great diversity of food items found in the three other quantitative studies evaluating diet of this frog species. In western Montana, 517 prey items identified in 50 stomach contents included 35% beetles, 22% ants/wasps, 14% spiders, 9% flies, 5% true bugs, 5% butterflies and moths, and <5% in other orders (Miller 1978). In central Oregon, 206 diet samples revealed representatives of 63 families in 19 orders (Whitaker et al. 1983). In Yellowstone Park in Wyoming, 70-90% of 802 prey items from178 frogs were spiders, true bugs, beetles,

TABLE 3. Percent of invertebrates in frog diet samples, on sticky traps, and in dip net samples identified to order or family that were found in Columbia spotted frog diet samples or captured in traps in ponds and rivers in northeastern Oregon, 2002. Invertebrates comprising ≤5% of the diet, sticky traps, or dip nets are not listed.

Phylum/Class/Order/Family	Frog Diet	Sticky Trap	Dip Net
Mollusca (mollusks)			
Gastropoda (snails)	2	—	27
Arthropoda (arthropods)			
Crustacea (crustaceans)			
Amphipoda (scuds)	4	—	16
Arachnida (arachnids)			
Araneae (spiders)	9	1	<1
Insecta (insects)			
Ephemeroptera (mayflies)			
Larvae	1	—	10
Odonata (dragonflies and damselflies)			
Larvae	2	—	6
Hemiptera (true bugs)	2	<1	—
Corixidae (water boatmen)	1	—	8
Gerridae (water striders)	3	—	4
Notonectidae (backswimmers)	1	—	6
Homoptera (leaf hoppers)	5	16	—
Coleoptera (beetles)			
Adults	9	1	—
Larvae	5	—	3
Carabidae (ground beetles)	5	—	—
Trichoptera (caddisflies)			
Larvae	—	—	7
Diptera (flies)			
Adults	10	74	—
Hymenoptera (ants, bees, wasps)	1	1	—
Formicidae (ants)	12	—	—
Vespidae (wasps)	8	—	—
Total	1,299	38,589	4,527

flies, and ants/wasps (Turner 1959). In Wyoming, 84% of prey items were ≤9.5 mm in length in comparison to 69% in this study. Turner (1959) suggested the peak of foraging in Wyoming was July and August with less foraging in June and September. In contrast, the greatest biomass indices occurred in September in this study. Some of these differences in prey size and temporal foraging behavior may be due to the higher elevation, colder climate, and smaller frogs found in Yellowstone Park than in northeastern Oregon.

Female frogs appeared to maximize the amount of prey they could ingest because of the need to produce eggs annually. Females >55 mm SVL had larger diet samples than males of the same size, while females ≤55 mm SVL consumed less prey than males of the same size. These smaller females will probably not be reproductive the following year (Licht 1975), so that there may not have been the energy needed for egg production.

Our findings suggest that frogs foraged actively from June through September and into October at the Gun and Rainbow sites with greater biomass indices in September than in July. It is likely that active foraging occurred prior to June, although diet samples were not collected then. These observations suggest frogs were maximizing their foraging late in the season, presumably for overwintering, or for egg production in the case of females. The differences in composition of diet by month may well reflect relative availability of invertebrates at different times during the summer (Figure 2). Spiders and leafhoppers were most abundant in July on both sticky traps and in diet samples. Beetles were most abundant in June in the diet but in July on sticky traps.

Differences in diet among study sites were observed in this study (Figure 2) and Whitaker et al. (1983). They suggested that past management practices, particularly livestock grazing, contributed to differences in diet. The Starkey site was the only one with livestock grazing in our study, and this site had a more even distribution among the primary orders used for prey than the other study sites. An obvious difference among the study sites was the high percentages of wasps at Tailings and Rainbow, the two sites with the highest elevations. Either these sites had a higher density of wasps than the other sites or a lower density of other prey. Wasps were able to escape from sticky traps, so that relative availability of this prey item can not be determined among the sites.

The results of sampling available invertebrates suggest that ponds provided more aquatic invertebrates, but abundance of aerial invertebrates was fairly even between ponds and rivers. In spite of this presumably greater prey base in ponds, diet samples of males had greater biomass on rivers, which may be a primary reason frogs inhabited rivers over ponds (Bull and Hayes 2001). Additional factors that could enter into the selection of habitat include predation and water temperature, as it relates to metabolic rate. Research comparing kinds and rates of predation and water temperatures between ponds and rivers would be informative and may shed some light on the declines of this species within portions of its range.

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