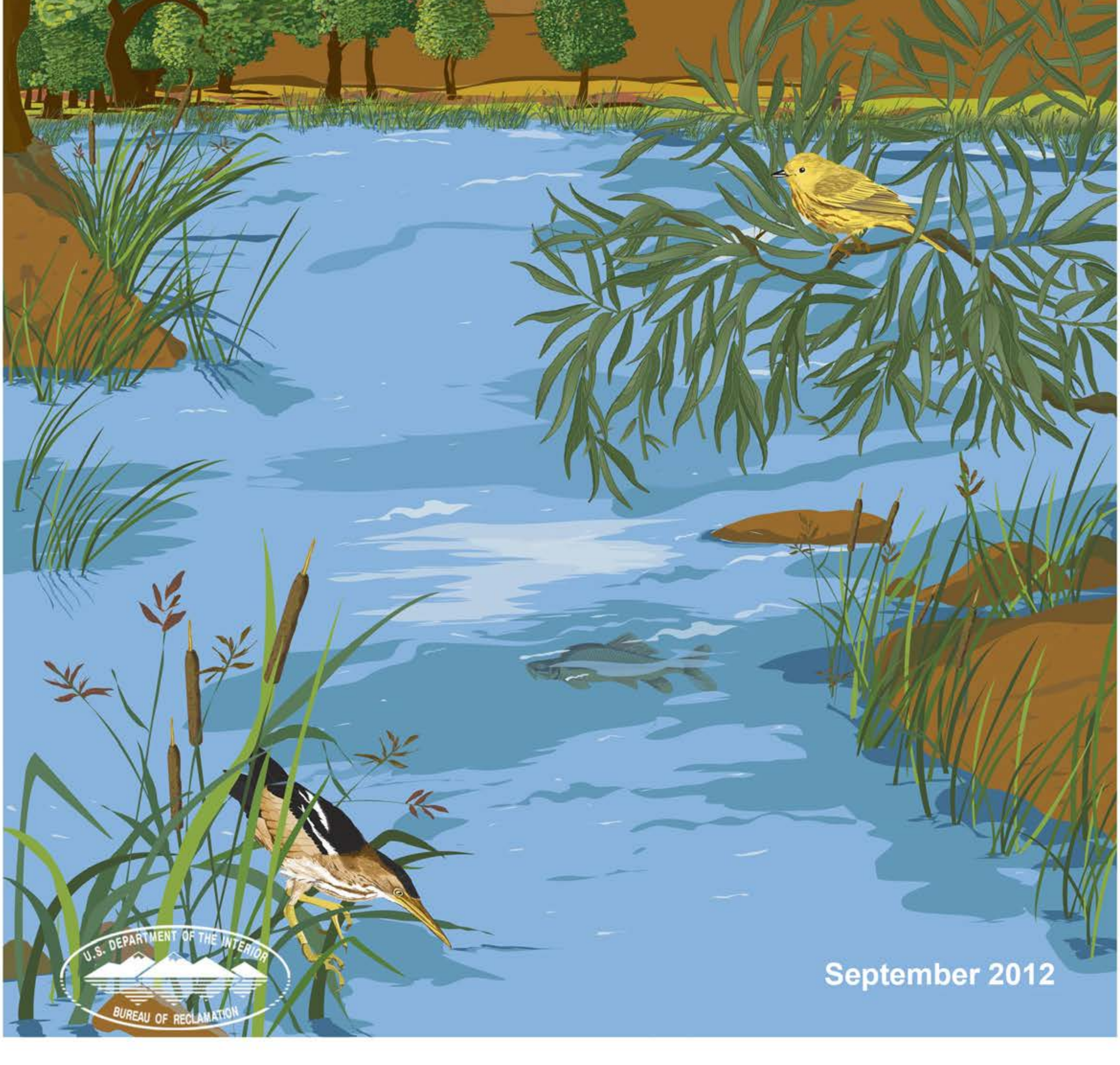
Lower Colorado River Multi-Species Conservation Program

Balancing Resource Use and Conservation

EFFECTS OF ABIOTIC FACTORS ON INSECT POPULATIONS IN RIPARIAN RESTORATION SITES 2009 ANNUAL REPORT



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September 2012

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Lower Colorado River
Multi-Species Conservation Program

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Multi-Species Conservation Program
Bureau of Reclamation
Lower Colorado Region
Boulder City, Nevada
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September 2012

ABSTRACT

I examined variation in nitrogen concentration in riparian arthropods (spiders and insects) collected at the Beal Restoration Area at Havasu National Wildlife Refuge during 2009. Most variation in nitrogen content among arthropods was associated with body size. Nitrogen content increased exponentially as body size increased. Significant variation in nitrogen mass adjusted for body size was explained by arthropod order. Concentrations of nitrogen were highest in grasshoppers and katydids (Orthoptera), bees and wasps (Hymenoptera), spiders (Araneae), and dragonflies (Odonata) and lowest in beetles (Coleoptera). Across orders, herbivores, predators, and detritivores did not differ in nitrogen mass after adjusting for body mass. Within orders, nitrogen concentrations differed only in Diptera. Phytophagous flies contained less nitrogen than predaceous or detritivorous flies. Concentrations of nitrogen in riparian spiders and insects are influenced mostly by allometry and order and least by food source. Foraging by insectivorous birds at MSCP restoration sites, such as Beal Lake, may be influenced by different nitrogen concentrations in riparian arthropods.

INTRODUCTION

Eight species of birds (Southwestern Willow Flycatcher, Yellow-Billed Cuckoo, Gilded Flicker, Gila Woodpecker, Vermilion Flycatcher, Bell’s Vireo, Sonoran Yellow Warbler, Summer Tanager) and four species of bats (western red bat, western yellow bat, California leaf-nosed bat, pale Townsend’s big-eared bat) included in the Lower Colorado River Multi-Species Conservation Program (LCR MSCP) eat arthropods (spiders and insects). Creating and maintaining habitat for these species will require providing an adequate supply and diversity of arthropods for food. This is especially difficult at several LCR MSCP habitat creation sites being developed, because riparian vegetation is being planted in non-riparian farmland (ie. where water tables are lowered, soil salinities are elevated, and spring flood flows are absent). Growing plants will not by itself guarantee producing populations of spiders and insects diverse and abundant enough to feed and support bird and bat populations. Populations of arthropods are especially limited by concentrations of nitrogen in plants. Different nitrogen contents in spiders and insects also may affect foraging by insectivorous birds. Birds require nitrogen in their food to produce proteins. Spiders or insects especially high in nitrogen may be required as food by adult birds and nestlings. The objective of this work task during 2009 was to compare nitrogen concentrations among riparian spiders and insects at a MSCP restoration site. Nitrogen contents of riparian arthropods may affect foraging by insectivorous birds and their reproduction.

STUDY AREA

The study was conducted at the Beal Lake Restoration Area within Havasu National Wildlife Refuge:

Figure 1. Beal Lake Riparian Restoration Area viewed from the east. The three colored dots represent sites where arthropods were collected: red dot (plot D) -- collections from *Salix gooddingii and Pluchea sericea* and the location of the Malaise trap, yellow dot (plot C) -- collections from *Populus fremontii*, blue dot (plot A) -- collections from *Prosopis glandulosa* and *Prosopis pubescens*

Arthropods were collected from two other plant species: *Tamarix ramosissima* bordering Topock Marsh and *Salix exigua* growing along the dirt road east of the refuge maintenance yard.

Figure 2. Arrowweed (foreground) and cottonwood trees (behind) at Beal Lake.

METHODS

I swept arthropods from the leaves of plants and trapped insects with one Malaise trap. I swept arthropods from plants with a 15-inch muslin sweep net. Numbers of sweeps varied among plant species. I collected spiders and insects from planted cottonwood (*Populus fremontii*), Goodding's black willow (*Salix gooddingii*), honey or screwbean mesquite (*Prosopis* spp.) trees, planted narrow-leaved willow (*Salix exigua*) shrubs, and voluntary arrowweed (*Pluchea sericea*) plants. I also swept arthropods from nearby tamarisk. I collected arthropods on nine dates: 30 April, 14 May, 27 May, 08 June, 22 June, 30 June, 21 July, 4 August, and 18 August 2009. All sampled plants were in flower or fruit except for cottonwood. The Malaise trap was arbitrarily located in the center of a plot supporting Goodding's black willow and arrowweed. Insects were trapped during 0855-1640 Pacific Daylight Time (PDT) on each of the above dates except 30 April, 14 May, and 18 August 2009.

I identified spiders and insects at least to family and typically to genus. Identifications were made with Steve Heydon at the Bohart Museum of Entomology, University of California, Davis. I classified arthropods by herbivore, predator, or detritivore with published descriptions.

Amounts of nitrogen in arthropod samples were estimated with a Kjeldahl method adapted from Isaac and Johnson (1976). Samples of dried arthropods were weighed (± 0.01 mg) with a microbalance and ground into water. I rinsed ground samples into digestion tubes and added 6 ml sulfuric acid, containing 4.2% selenous acid, and 3 ml hydrogen peroxide. I heated samples for 1 h at 400ºC with a block digestor. The ammonia concentration of the digested mixture was measured with a segmented flow analyzer by our Regional Laboratory. I converted ammonia concentration to mg nitrogen. I calibrated estimates of mg nitrogen in arthropod samples with chitin, a polysaccharide $[(C_8H_{13}NO_5)_n]$ that contains 6.89% N and is abundant in arthropod cuticle (Neville 1975). Dry mass and mg nitrogen of each arthropod sample was divided by the number of specimens in the sample to estimate dry mass and nitrogen mass per specimen.

RESULTS

I collected 121 samples of spiders and insects containing 1490 specimens in 9 orders or suborders, 33 families, and 43 subfamilies or genera (Table 1). All arthropods collected were adults except for eight samples in three families, subfamilies, or genera with adults and immatures and six samples in one family with only immatures.

Table 1. Arthropods collected at the Beal Lake restoration site during 2009.

Order or suborder	Family	Genus or subfamily	Source[a]	Trophic level[b]	Mean body dry mass (mg)	Mean % N
Araneae	2 families	- - - -	S	P	2.46	14.3
	3 families	- - - -	S	P	2.35	13.8
Araneae	Philodromidae	*Philodromus*	E,S	P	1.93	10.6
	Salticidae	*Habronattus*	S	P	6.29	9.3
		Metaphidippus	S	P	0.07	13.0
	Thomisidae	*Misumenops*	E	P	2.03	12.1
Odonata	Libellulidae	*Pachydiplax*	P	P	39.7	12.3
Orthoptera	Acrididae	Acridinae	S	H	13.0	13.9
	Tettigoniidae	*Scudderia*	S	H	115.0	14.6
Heteroptera	Largidae	*Largus*	S	H	49.2	9.2
	Lygaeidae	*Nysius*	S	H	0.46	9.0
	Pentatomidae	*Brochymena*	F,G,P	H	55.2	11.0
		Thyanta	E	H	17.1	11.6

	Reduviidae	*Pselliopus*	P	P	14.1	13.3
		Zelus	F,P,S	P	7.20	10.5
Homoptera	Cicadellidae	- - - -	S	H	4.37	14.6
	Cicadellidae	Cicadellinae	E,F,G	H	6.62	10.1
		Gyponinae	G	H	3.36	8.6
		Opsius [f]	T	H	0.68	11.2
		Typhlocybinae	F	H	0.35	11.4
	Cixiidae	- - - -	S	H	1.24	10.1
	Flatidae	*Ormenis*	G,T	H	5.72	8.9
	Membracidae	- - - -	G	H	5.22	10.6
Neuroptera	Chrysopidae	- - - -	G	P	1.37	11.8
	Chrysopidae	*Chrysoperla*	F,G,S	P	1.51	9.1
	Myrmeliontidae	*Myrmelion*	F	P	8.99	12.5
Coleoptera	Bruchidae	*Algarobius*	P	H	3.01	8.3
	Coccinellidae	*Chilocorus*	F,P	P	4.75	9.8
		Hippodamia	F,S	P	6.26	6.6
Diptera	Apioceridae	*Apiocera*	M	P	52.87	11.4
	Asilidae	*Proctacanthus*	M	P	42.3	11.7
	Dolichopodidae	*Asyndetus*	M	D	0.39	9.9
	Lauxaniidae	*Homoneura*	F,G	D	1.31	7.8
		Minettia	F,G	D	2.37	8.1
	Sarcophagidae	*Eumacronychia*	F,G	P	1.68	11.5
	Tabanidae	*Apatolestes*	M	P	15.0	11.6
		Tabanus	M	P	13.8	10.9
	Tachinidae	- - - -	M	P	7.66	9.2
	Tephritidae	*Acinia*	F	H	1.01	5.1
Hymenoptera	Andrenidae	*Perdita*	S	H	1.74	9.8
	Formicidae	*Formica*	E,S	H	0.76	10.9
	Halictidae	*Agapostemon*	E	H	7.42	11.7

		Dieunomia	S	H	5.57	14.1
		Lasioglossum	E	H	2.71	16.7
	Sphecidae	*Bembix*	M	P	33.5	13.4
		Cerceris	M	P	10.6	8.8
		Tachysphex	M	P	7.23	8.5
	Tiphiidae	*Myzinum*	E	P	4.54	21.2
	Vespidae	*Polistes*	G	P	28.8	14.0

[a]E, *Salix exigua*; F, *Populus fremontii*; G, *Salix gooddingii*; M, Malaise trap; P, *Prosopis glandulosa* or *P. pubescens*; S, *Pluchea sericea*; T, *Tamarix ramosissima*.
[b]D, Detritivore; H, Herbivore; P, Predator.

Two orders or suborders (Orthoptera and Homoptera) of collected spiders and insects were only herbivorous, three orders (Araneae, Odonata, and Neuroptera) were only predaceous, and four orders or suborders (Heteroptera, Coleoptera, Diptera, and Hymenoptera) included both trophic levels (Table 1). All Coleoptera were predaceous except for one sample. The only detritivores collected were flies (Diptera).

Nitrogen masses in riparian spiders and insects were related to body dry masses by the following allometric equation:

$$mg\ N = 0.0986(mg\ dry\ mass)^{1.039}$$

This allometric relationship explained 97.2% of variation in nitrogen mass. Percentages of nitrogen in riparian arthropods increased as body mass increased.

Orders or suborders of arthropods contained different amounts of nitrogen, after adjusting for body mass, and explained 20.7% of variation in nitrogen (Fig. 2). Orthoptera (mean 14.0% N), Hymenoptera (12.4% N), Araneae (11.9% N), and Odonata (12.3% N) contained the highest adjusted N contents, and Coleoptera (8.2% N) contained the lowest adjusted nitrogen content.

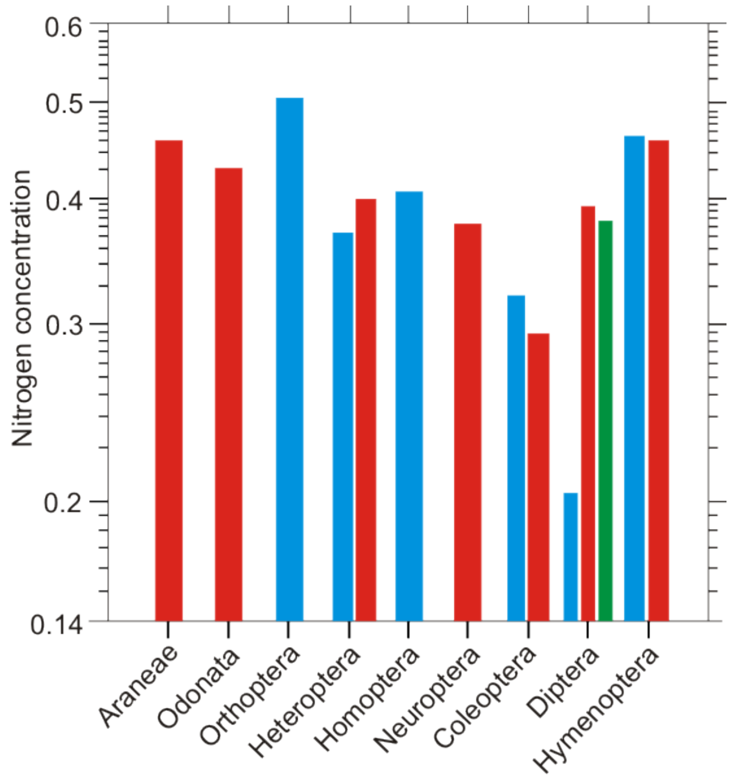

Figure 3. Concentrations of nitrogen in orders of riparian arthropods. Bar colors are trophic levels: blue, herbivores; red, predators; green, detritivores. *Y*-axis is log scale.

Orthoptera were mostly immature slant-faced grasshoppers (Acridinae) along with the sole katydid *S. furcata*. Hymenoptera included ants (Formicidae), two families of bees (Andrenidae and Halictidae), and three families of wasps (Sphecidae, Tiphiidae, and Vespidae). Spider samples contained various families. The only odonate collected was the dragonfly *Pachydiplax longipennis* Burmeister. Coleoptera included one sample of the herbivorous seed beetle (Bruchidae) *Algarobius prosopis* LeConte, collected from *Prosopis* spp., and six samples containing two species of predaceous ladybird beetles (Coccinellidae), *Chilocorus cacti* L. and the widespread *Hippodamia convergens* Guerin-Meneville. Insects in other orders, including the two Hemiptera suborders, contained intermediate nitrogen concentrations.

Differences in nitrogen content among the trophic levels of herbivore, predator, and detritivore depended on classification (Fig. 2). Nitrogen concentrations did not differ among trophic levels across orders or suborders. Trophic levels explained 1.0% of variation in nitrogen mass after accounting for body mass. Mean nitrogen concentrations (%N) were 11.1% in herbivores, 10.9% in predators, and 9.44% detritivores, the smallest arthropods collected. Nitrogen concentrations did vary among trophic levels of Diptera. Concentrations were lower in herbivorous flies (5.1% N) compared with predaceous (10.9% N) or detritivorous (9.4% N) flies. All phytophagous flies collected were two samples of the fruit fly (Tephritidae) *Acinia picturata* (Snow), swept from *P. fremontii*. Adjusted nitrogen concentrations in predaceous or parasitic flies (Apioceridae, Asilidae, Sarcophagidae, Tabanidae, and Tachinidae) and detritivorous flies (Dolichopodidae and Lauxaniidae) were similar.

DISCUSSION

The allometric relationship between nitrogen mass and body mass in riparian arthropods resembles a similar relationship between cuticle mass and body mass in spiders (Anderson et al. 1979). Cuticle dry-mass and body wet-mass were positively related by:

$$g\ cuticle = 0.078(g\ body\ mass)^{1.135}$$

Anderson et al. attributed this allometric relationship to scaling. The cuticle of terrestrial arthropods must increase in thickness as body weight increases to support the organism and withstand the stresses of bending and twisting. Allometric relationships between nitrogen mass and body mass, and between cuticle mass and body mass, may be primarily due to cuticle nitrogen. A large percentage of nitrogen in terrestrial arthropods may reside within the cuticle due to its greater density compared with internal tissues and hemolymph. The allometric relationship between cuticle mass and body size may have produced the similar relationship between nitrogen mass and body mass.

Cuticle composition may have contributed to different nitrogen concentrations among orders of spiders and insects. Arthropod cuticle is composed primarily of protein and chitin (Neville 1975), and concentrations of nitrogen are higher in protein (17%) than in chitin (7%). Greater concentrations of protein in arthropod cuticle, producing higher nitrogen contents, have been associated with concentrations of resilin. Resilin is a flexible, elastic protein that occurs in cuticle in near-pure concentrations or combined with other proteins and chitin. Resilin contains 19% N. Various mechanical structures in arthropods are elastic due to resilin, and the protein is especially prevalent in the wing tendons and hinges of Odonata and Orthoptera. Abundances of resilin in riparian Odonata and Orthoptera may have contributed to their high nitrogen contents. Although resilin has not been found in spiders, the high degree of abdominal stretching by spiders suggests their cuticles contain a similar elastic protein. Cuticles of Coleoptera are likely less elastic. A dominant feature of beetles is the elytra, hardened front-wings that act only to cover the folded hind-wings and abdomen. The likely absence of resilin, and resultant high concentrations of chitin, in elytra may have lowered %N in Coleoptera.

I did not detect an overall difference in nitrogen concentration among herbivorous, predaceous, and detritivorous arthropods after accounting for body mass. Trophic level did not appear to generally affect arthropod %N. Similar nitrogen contents between trophic levels agree with the concept that most insects satisfy nutrient requirements by adjusting food intake. For example, concentrations of nitrogen in Homoptera, phytophagous Heteroptera, and predaceous Heteroptera were similar (Fig. 2) despite different diets and physiologies.

An exception was Diptera. Herbivorous flies, all Tephritidae, contained lower nitrogen concentrations than predaceous or detritivorous flies after considering body mass. The *A. picturata* tephritids that I collected eat seeds in flower heads of *Pluchea* spp., corresponding with the flowering *P. sericea* at the study site. The species does not appear to concentrate nitrogen from food, because its nitrogen concentration (5.1%) is within the range (1-7% of dry mass) reported for seeds. Equivalent nitrogen concentrations in predaceous or parasitic flies and detritivorous flies suggest their diets contain similar amounts of nitrogen.

Not all nitrogen in arthropods is digested by insectivorous birds. Bird diets are frequently determined by identifying undigested fragments of cuticle in fecal samples (eg. Wiesenborn and Heydon 2007). Digestion of arthropod cuticle by vertebrates likely depends on its sclerotization. Sclerotized proteins are bonded together, frequently with chitin, forming an irreversibly-hardened cuticle that cannot be digested. Unsclerotized proteins, like resilin, can be digested. Relative proportions of sclerotized and unsclerotized proteins vary greatly among species producing cuticles with different digestibilities. Arthropod orders with high amounts of elastic protein, such as Odonata and Orthoptera and probably Araneae, may provide insectivorous birds with high concentrations of digestible protein.

Riparian arthropods presented insectivorous birds with prey containing a range (5.1-14.0%) of nitrogen concentrations. Foraging by insectivorous birds in relation to prey nitrogen concentration can be difficult to discern, because birds frequently forage in response to prey availability which is transitory and hard to estimate. Selective foraging may be inferred by comparing arthropods eaten by adults with those concurrently captured by adults but fed to nestlings. An example is the southwestern willow flycatcher, a MSCP covered species. Adult flycatchers have been found to eat mostly heteropterans, flies, and beetles but provide more odonates and beetles as food to nestlings (Drost et al. 2003). Diet nitrogen may be increased by including odonates, especially dragonflies due to their large biomass. The high-nitrogen orders of Araneae, Odonata, and Hymenoptera, taken together, were eaten with similar frequency by flycatchers at different localities and habitats. These orders comprised 21% of prey in California (Drost et al. 2003), 31% of prey in Arizona (Durst et al. 2008), and 21% of prey at three localities in Arizona and Nevada (Wiesenborn and Heydon 2007).

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