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Prey of American Bullfrogs (*Rana catesbeiana*) from Henry and Patrick Counties, Virginia (Anura: Ranidae)

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ABSTRACT

We identified the stomach contents of 65 American Bullfrogs collected in two counties in Virginia. Both vertebrate and invertebrate prey were consumed, including a worm, mollusks, crustaceans, millipedes, centipedes, spiders, insects, a fish, amphibians, and a mammal. In an analysis of 40 of the stomachs containing food, 91 prey items were identified, a third of which were beetles. Crayfish and millipedes were other major prey, representing 27% and 15% of the total prey items, respectively. Several highly poisonous animals, including the cyanide-producing millipede, *Apheloria tigana,* and the tetrodotoxin-producing salamander, *Notophthalmus viridescens*, were found as prey.

Keywords: beetles, crayfish, diet, *Lithobates catesbeianus,* millipedes, prey.

INTRODUCTION

The American Bullfrog (*Rana catesbeiana* Shaw = *Lithobates catesbeianus* [Shaw]) is widely distributed throughout North America east of the Rocky Mountains but has been introduced as an invasive species to western North America and Hawaii (Casper & Hendricks, 2005). In Virginia, it occurs statewide, being documented in almost every county (Mitchell & Reay, 1999). By the nature of its sheer size (record snout-vent length = 22 cm; Powell et al., 2016), the American Bullfrog is considered a game species in some states. In Virginia, 15 bullfrogs can be harvested per person per day. Adult bullfrogs are ambush predators with a generalist diet consisting of any animal that can fit into their mouth. The full range of prey may never be fully known, but naturalists have and should continue to document prey for this species. A review of the published literature on the bullfrog diet reveals that a variety of techniques have been used to collect such information, ranging from non-lethal techniques, such as stomach flushing and direct observation, to lethal techniques including gigging, hand grabbing, use of an "electro-frogger" (a device that stuns frogs which can then be dip-netted), shooting animals with a .22 caliber rifle, and dissection of preserved museum specimens (Korschgen & Moyle, 1955; Rice & Taylor, 1993; Jancowski & Orchard, 2013). Needham (1905) used a hook and line baited with a little piece of red silk that he "flirted near the bullfrog's head" and reported successful capture of every frog using this technique, but only if the frog was properly approached.

Numerous studies of bullfrog diet have been summarized by Bury & Whelan (1984), Casper & Hendricks (2005), and Dodd (2013), but little has been published concerning bullfrog diets in Virginia. Brooks (1959, 1964) studied the diet of five ranid frogs, including bullfrogs. He concluded that insects and spiders were the most abundant prey found in the stomachs of 138 bullfrogs he captured at five ponds in

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southeastern Hanover County. Most published studies identify arthropods and other prey only to the family level, as Brooks (1964) did; very few studies identify prey items to the genus or species level. Multi-disciplinary teams of herpetologists working with entomologists and other taxonomic experts are needed to accurately identify all prey items to the species level.

MATERIALS AND METHODS

In late July 2009, 25 frozen bullfrog stomachs were given to the first author (JG) by a citizen of Henrico County, Virginia, who was an avid hunter of bullfrogs. The hunter had attended a master naturalist training event taught by JG and learned of JG's interest in frogs. JG dissected the 25 stomachs to quickly assess the type of prey these frogs had eaten. The contents from these stomachs were preserved in a container of alcohol. From late July to mid-August, the hunter harvested an additional 64 bullfrogs. This time he froze the entire bullfrog carcasses except for the hind legs. All of the frogs were collected between 24 July and 18 August 2009 from private farm ponds and the margin of Philpott Lake in Patrick and Henry counties, Virginia. This second batch of 64 bullfrog carcasses were more methodically dissected by JG's high school biology students, who placed all prey into plastic bags containing alcohol.

Of the 64 bullfrog carcasses, 24 had empty stomachs (37.5%). The bags with prey items from the remaining 40 bullfrogs and the preserved contents from the other 25 bullfrog stomachs were later examined by the second author, who attempted to identify each prey item to the lowest possible taxonomic level. Many of the prey were too digested to identify.

RESULTS

Table 1 summarizes the prey found in the 65 bullfrog stomachs which contained food items. Table 2 shows the total number of animals collected from the 40 more carefully dissected bullfrog stomachs. Of 91 prey items, 33% were beetles, 27% were crayfish, and 15% were millipedes. The largest prey item by mass was a 7.4 cm mouse (*Peromyscus* sp.) and the longest prey was a 11.9 cm Three-lined Salamander (*Eurycea guttolineata*). In addition to animal prey, there was a variety of inanimate objects in some bullfrog stomachs, including rocks, *Pinus virginiana* needles, unidentified tree leaves, a male pine cone, grass, sticks, and a flower bud. Presumably these objects were inadvertently ingested when live prey were being subdued and swallowed. Several stomachs contained bird feathers, but no bird carcasses, perhaps suggesting failed capture attempts.

DISCUSSION

An analysis of the prey items suggests that the American Bullfrog has behavioral or physiological adaptations which allow it to tolerate venomous and poisonous animals. For example, one bullfrog stomach contained a red eft (*Notophthalmus viridescens*) and two *Apheloria tigana* millipedes. Efts are known to produce skin secretions composed of tetrodotoxin, a very potent voltage-gated sodium channel blocker which causes flaccid paralysis (Brodie, 1968). *Apheloria* millipedes are cyanogenic, meaning they are capable of producing hydrogen cyanide (HCN) and benzoyl cyanide (Shear, 2015). These chemicals disrupt cellular metabolism by stopping the electron transport chain, thus causing the failure of ATP production. Marek & Bond (2009) report that one *Apheloria* millipede "can secrete 18-fold the amount of hydrogen cyanide necessary to kill pigeon-sized birds." Eisner et. al (1967) estimated that a 1 g millipede secreted 0.4 times the lethal dose to kill a 25 g frog. Benzaldehyde, another chemical defense molecule secreted by *Apheloria*, is a mucus membrane irritant. Other millipedes consumed by the bullfrogs in our study produce many other irritating chemicals. *Oxidus gracilis*, in addition to being cyanogenic, produces phenol and benzoic acid (Duffy et al., 1977). Millipedes of the genus *Narceus* produce benzoquinone (Monro et. al., 1962). Other prey that are rarely eaten by vertebrates are carabid beetles of the genus *Brachinus* (Juliano, 1985). Also known as bombardier beetles, they produce a hot, explosive, irritating chemical spray containing quinones (Brandmayr et al., 2009).

Venomous animals capable of biting or stinging, including several species of centipedes (Chilopoda) and hymenopterans, such as ants and bees, were consumed in small numbers by the bullfrogs examined in our study. Prey with sharp and pointy exoskeletons such as the crayfish *Cambarus cf. bartonii* were consumed by numerous frogs and the large (45 mm long, 17 mm wide) longhorn beetle *Prionus laticollis* was found in one frog's stomach. A whole Green Sunfish (*Lepomis cyanellus*) with very sharp spines was also found as prey.

One vertebrate prey item, the Three-lined Salamander (*Eurycea guttolineata*), documented during our study has not been reported in the literature as being prey of the bullfrog (Petranka, 1998; Ryan & Douthitt, 2005). However, it seems likely that this salamander and others would be easily and frequently consumed by the American Bullfrog. In general, our list of prey items suggests that American Bullfrogs collected in the study areas rely primarily on terrestrial organisms and forage away from water. When our prey list is compared with other diet studies for this species, it appears that the

Table 1. Prey items collected from 65 *Rana catesbeiana* stomachs in Henry and Patrick counties, Virginia. Bold headings are classes followed by order, family, genus and species.

INVERTEBRATES		
Clitellata		
Haplotaxida	Lumbricidae	
Mollusca		
Gastropoda		
Crustacea		
Decapoda	Cambaridae	*Cambarus cf. bartonii*
Isopoda	Oniscidea	
Diplopoda		
Polydesmida	Cleidogonidae	*Cleidogona major*
	Paradoxosomatidae	*Oxidus gracilis*
	Xystodesmidae	*Apheloria tigana*
Spirobolida	Spirobolidae	*Narceus americanus*
Chilopoda		
Scolopendromorpha	Cryptopidae	*Scolopocryptops sexspinosus*
	Scolopendridae	*Hemiscolopendra marginata*
Arachnida		
Araneae	Pisauridae	*Dolomedes sp.*
Insecta		
Blattaria	Blattidae	*Cryptocercus punctulatus*
Coleoptera	Carabidae	*Brachinus* sp.
		Carabus limbatus
	Cerambycidae	*Prionus laticollis*
	Curculionidae	*Naupactus leucoloma*
	Elateridae	*Hemicrepidius memnonius*
	Scarabaeidae	*Macrodactylus subspinosus*
		Osmoderma scabra
Hymenoptera	Apoidea	
	Formicidae	
Lepidoptera		
Odonata		
Orthoptera		
VERTEBRATES		
Actinopterygii		
Perciformes	Centrarchidae	*Lepomis cyanellus*
Amphibia		
Caudata	Plethodontidae	*Eurycea guttolineata*
	Salamandridae	*Notophthalmus viridescens*
Anura		
Aves (feathers only)		
Mammalia		
Rodentia	Muridae	*Peromyscus* sp.

Table 2. Stomach contents of 40 *Rana catesbeiana* from Henry and Patrick counties, Virginia. N = total number of prey.

Taxonomic Group	N	% Total
ANNELIDA	1	1
MOLLUSCA		
Gastropoda	3	3.3
CRUSTACEA		
Decapoda	25	27.4
Isopoda	2	2.2
DIPLOPODA	14	15.4
CHILOPODA	1	1
INSECTA		
Coleoptera	30	33
Hymenoptera	1	1
Lepidoptera	1	1
Orthoptera	1	1
Odonata	1	1
Unidentified larva	1	1
VERTEBRATA		
Anura (tadpole)	1	1
Anura (adult)	1	1
Caudata	3	3.3
Aves (feathers)	4	4.4
Mammalia	1	1
TOTAL	91	100

dominant prey consumed is a product of prey availability for that habitat, not an innate preference for specific food. Much remains to be learned about the diet of the bullfrog in Virginia, thus we encourage others to publish their observations of dietary items for this species.

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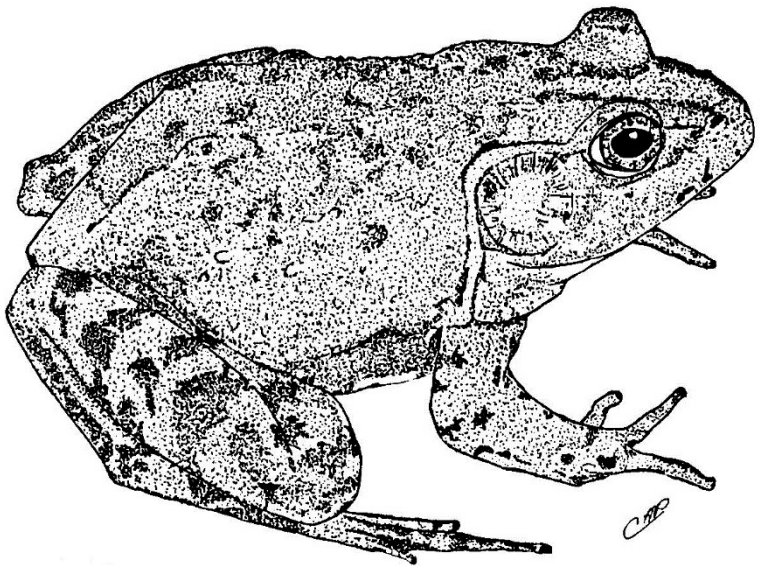

American Bullfrog (*Rana catesbeiana* Shaw, 1802)

Original drawing by Christopher A. Pague