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Notes on the diet of recently metamorphosed Giant African Bullfrogs (Anura: Pyxicephalidae: *Pyxicephalus adspersus*) and growth increase during the first nine months in a semi-natural habitat

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Abstract. The diet of metamorph Giant African Bullfrogs from a semi-aquatic habitat in the Karoo were recorded. All stomachs contained prey items; insects accounted for the greatest prey diversity, with Coleopterans (11 families) dominating the 29 insect families recorded. The most abundant prey items, none of which have previously been recorded in the diet, were a conchostracan "clam shrimp" (*Leptestheriella* cf. *inermis*), an aquatic snail (Physidae) and the small frog *Cacosternum boettgeri*. Metamorph bullfrogs had an average SUL of 39.3 mm and a mass of 5.19 g. After nine months, including a period of winter dormancy, the frogs had an average SUL of 81.4 mm and a mass of 71.38 g, equivalent to just over a doubling in SUL and a 1326% increase in mass.

Keywords. Anuran, juvenile, aquatic organisms, snails, clam shrimp.

The Giant African Bullfrog (*Pyxicephalus adspersus*) is widely-distributed in Southern and Eastern Africa (Channing, 2001; Channing and Howell, 2006), and its conservation status is considered of Least Concern (IUCN, 2010), although populations are decreasing due to habitat destruction. Despite its size, popularity in the pet trade, and conservation status, relatively little has been published on its diet and growth. The frog is known to be carnivorous and cannibalistic in the juvenile stage (Du Preez, 2004), but most reports on diet comprise anecdotal observations (Branch, 1976). The aim of this study was to determine the diet of metamorphing giant bullfrogs in semi-aquatic environments and to document the growth rate in a semi-natural environment over a dormancy period. We hypothesized that: 1) the main diet of metamorphing bullfrogs depended on their aquatic environment, thus we expected more aquatic prey species in the diet than terrestrial species; and 2) the growth increase in an artificial habitat with a limited food source would be lower than that in a natural habitat.

Historically, there are very few records of the Giant African Bullfrog in the central Great Karoo (Poynton, 1964; Parry, 1982). Recently metamorphosed frogs were collected from a shallow artificial dam, approximately 2 ha in diameter, on the farm Tulpleegte, 25 km south of Beaufort West (32°33'25"S, 22°34'20"E, 3222Da) on 7 January 1986. Only a single adult female was recorded in the vicinity where it was photographed *in situ* with several young frogs (see p98 in Branch, 1991 and Figure 1). This was the first record for the species from the southern plain of the Great Karoo (Branch and Braack, 1989), although other populations in the region have subsequently been recorded (Minter et al., 2004). The recently metamorphosed frogs (174 specimens) were collected in shallow water and the flooded marginal vegetation surrounding the farm dam. A number of specimens (94) were used to determine the diet of the metamorphosed frogs in a semi-aquatic habitat, while the remaining young frogs were retained in an old cement dam (approximate dia. 6 m) for later translocation to a natural habitat elsewhere in the Karoo National Park. The enclosure was covered by shade cloth to minimize predation on the frogs. A light was fixed above the enclosure to attract food for the frogs. No supplementary feeding was given. On 2 September 1986, after nine months in captivity, the surviving 57

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Figure 1. Adult female with several metamorphs photographed in situ at Farm Tulpleegte.

frogs were released into the Pyxie Dam region of the Karoo National Park.

Juvenile diet – Eighty nine of the 94 preserved specimens were weighed with a Pesola pocket scale (model 115, with ± 0.3% accuracy), measured with a Brown-Sharpe digital caliper (model 599-571-3) and dissected and the stomach contents analyzed (summarized in Table 1). Identification of invertebrates was usually only taken to family level. The frequency of occurrence of a specific taxon was calculated by dividing the total number of that taxon occurring in all stomachs by the total number of stomach examined (89).

Stomach contents included a wide diversity of prey items including an anuran (*Cacosternum boettgeri*), an invasive species of pouch snail (*Physella acuta*), a conchostracan (*Leptestheriella* cf. *inermis*), and at least 29 insect families. Plant material (18 stomachs, 20.2%) and sand (11 stomachs, 12.4%) were also present, but were considered to have been secondarily ingested. A total of 1058 food items were found in the 89 stomachs (mean 11.89 prey items per stomach) and the average prey diversity (number of specific taxa in the stomach) for all frogs was 3.64 (range 1-10). Every frog stomach contained some food remains, that ranged from 4.76 - 33.33% (average 14.45%, n = 50) of the frog's body mass. Insects accounted for the greatest diversity of prey items, with Coleopterans (11 families) dominating the 29 insect families recorded. Ants (Formicidae, 85 prey items in 33 stomachs) comprised the main insect family eaten. However, the most abundant prey item (445, 41.2% of all items) was a conchostracan, commonly called a "clam shrimp", *Leptestheriella* cf. *inermis,* that occurred in 82.0% of the stomachs. Moreover, the conchostracan formed the greatest number of prey items in a single stomach, with one individual (SUL 39 mm, mass 4.5 g) having consumed 28 individual clam shrimps (27.4% of total body mass). Another common prey item (in 60 stomachs, 67.4%) was an aquatic pouch snail (*Physella acuta*). The highest total number of prey items in a single stomach was 37, comprising 12 snails and 25 conchostracans, that constituted 33% of the frog's mass (SUL 44 mm, mass 6.2 g). A small frog (Boettger's caco, *Cacosternum boettgeri*) was present in over a third of the examined stomachs (31; 34.8%), with one bullfrog having eaten three cacos and another individual two cacos. Cannibalism of conspecifics was not recorded.

Growth rate – A total of 94 dead, recently metamorphosed bullfrogs, were measured using a Brown-Sharpe digital caliper (model 599-571-3).

Table 1. Stomach contents of juvenile Giant Bullfrogs.

Taxon	Family/*Species*	Freq. in stomachs (N=89)	Number in stomachs
Anura	*Cacosternum boettgeri*	0.348	
Mollusca			
Physidae	*Physella acuta*	0.674	60
Crustacea			
Conchostraca	*Leptestheriella* cf. *inermis*	0.820	73
Insecta			
Ephemeroptera	Baetidae larvae	0.056	5
Odonata	Libellulidae	0.034	3
Isoptera	Hodotermitidae	0.022	2
Dermaptera	Forficulidae	0.011	1
Orthoptera	Acrididae	0.157	14
	Tettigoniidae	0.011	1
Hemiptera	Miridae	0.011	1
	Notonectidae	0.011	1
	Pyrrhocoridae	0.011	1
Coleoptera	Dytiscidae larvae	0.101	9
	Dytiscidae	0.056	5
	Curculionidae	0.169	15
	Cicindelidae	0.022	2
	Carabidae	0.124	11
	Scarabaeidae	0.022	2
	Meloidae	0.045	4
	Cerambycidae	0.011	1
	Hydrophilidae	0.011	1
	Dryopidae	0.011	1
	Georyssidae	0.011	1
	Staphylinidae	0.011	1
Diptera	Ephydridae	0.022	2
	Scenopinidae	0.022	2
	Unidentified	0.067	9
Trichoptera	Hydroptilidae larvae	0.101	9
Lepidoptera	Larvae	0.101	10
	Unidentified adults	0.067	6
Hymenoptera	Ormyridae	0.056	5
	Formicidae	0.360	32
	Sphecidae	0.011	1
	Dryinidae	0.011	1
	Colletidae	0.011	1
	Unidentified	0.022	2
Plant Matter	*Unidentified*	0.202	18
Sand		0.124	11

Measurements included snout-urostyle length (SUL) and maximum head width (HW). Weights included total mass (TM, including stomach contents), and the isolated stomach content mass (SCM) after being blotted to remove excess liquid. The measurements of these specimens are considered to be representative

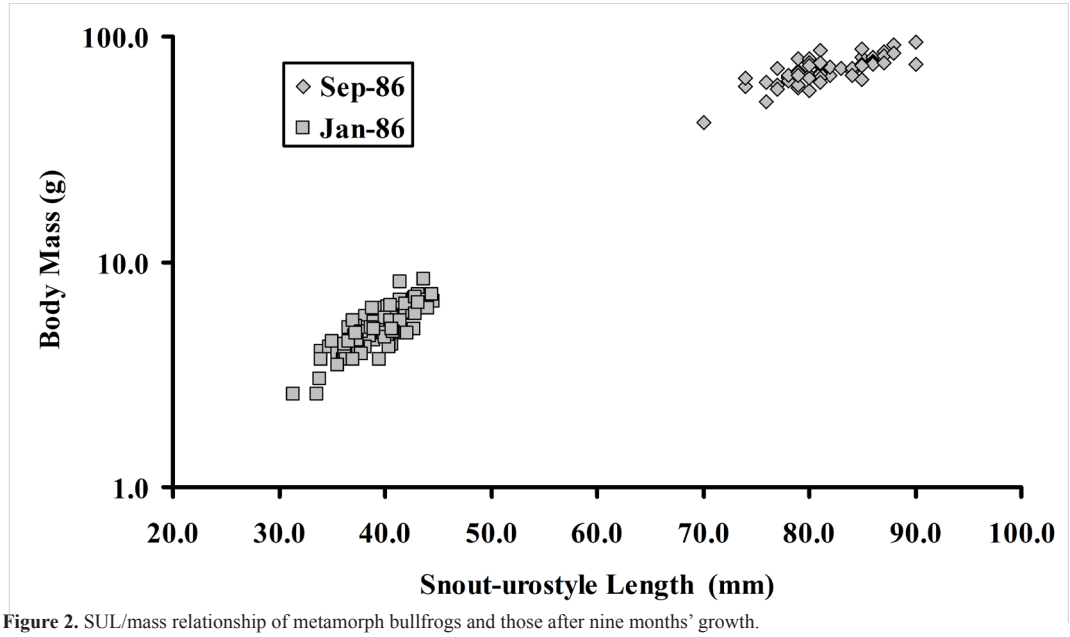

Figure 2. SUL/mass relationship of metamorph bullfrogs and those after nine months' growth.

of the age class of all the metamorph bullfrogs in the natural environment.

The metamorph bullfrogs had an average SUL of 39.3 ± 2.7 mm and mass of 5.19 ± 1.13 g (Figure 2), which is higher than previous recorded sizes for metamorphosing bullfrogs. Rose (1956) recorded metamorph sizes of 20 mm length and "20 to the ounce", whilst Van Wyk, Kok and Du Preez, (1992) recorded a size of 26.3 mm length and 1.5 g mass. The relationship between HW and SUL (HW/SUL) averaged 2.5 ± 0.1.

After approximately nine months the surviving 57 frogs were measured and weighed before being released. They had an average SUL of 81.4 ± 4.13 mm and mass of 71.4 ± 9.75 g. SUL and mass gain during the nine month period was approximately 42.0 mm and 66.0 g, respectively, equivalent to just over a doubling in SUL and a 1326% increase in mass. SUL/mass (BL/M) ratio decreased from 7.85 ± 1.41 to 1.16 ± 0.13 over the nine month period (Figure 2).

Discussion – There are numerous anecdotal observations on the diet of the adult Giant African bullfrog and they are known to prey mostly on insects and other invertebrates (Du Preez, 2004; Du Preez and Carruthers, 2009). However, they are also known to take larger prey such as small birds, rats, snakes, lizards, crabs, slugs and other frogs (Branch 1976; Du Preez 2004), including their own siblings (Channing, 2001; Passmore and Carruthers, 1995). There has been relatively little documentation of the diet of metamorph bullfrogs. Van Wyk, Kok and Du Preez (1992) recorded that the stomach contents of "juveniles" (n = 10) consisted mainly of larval and adult insects (Formicidae and Curculionidae). However, the size of the juveniles and whether they were foraging on land or in semi-aquatic habitats were not recorded. Douglas (1995) noted that the diet of 235 juveniles (size not recorded) collected in funnel and pitfall traps contained only "insect remains and a little vegetable matter". It is probable that these specimens represented a variety of juvenile size classes that were dispersing overland.

The diet recorded here for recent metamorphs foraging in a semi-aquatic habitat shows significant differences from those previously record for bullfrog juveniles. Aquatic prey such as physid snails, the conchostracan, and other frogs (cacos) have not been previously recorded in the bullfrog diet (Van Wyk, Kok and Du Preez, 1992; Douglas, 1995; Channing, 2001; Du Preez and Carruthers, 2009), and yet they were the dominant prey items of the metamorphs in this study. As previously noted by Van Wyk, Kok and Du Preez, (1992), and also recorded in this study, ants (Formicidae) were the dominant insect group consumed. Metamorphing bullfrogs appear to consume anything in their immediate environment in order to gain mass before they enter winter dormancy. In this case, the main food source was aquatic, reflecting the surrounding environment. It is probable that as the metamorphs disperse over land their diet will change to more terrestrial species. Although it

is regularly reported (Channing, 2001; Passmore and Carruthers, 1995) that cannibalism on siblings occurs among metamorph and juvenile bullfrogs, we found no instances during this study. This may be due to the presence of plentiful other food sources being available in the semi-aquatic habitat. As breeding pans begin to dry up, and/or as the juveniles start to disperse over land, the food supply may become less abundant and they may start to feed on siblings (Channing, 2001; Passmore and Carruthers, 1995).

Previous studies have indicated that growth rates in captivity vary greatly and are therefore unreliable compared to those of natural populations (Douglas, 1995). However, such wide variation in growth rates among siblings was not recorded during this study. Rose (1956) indicates that from metamorphosis, *P. adspersus* can gain over 6985% in body mass and 350% in length in the first year alone. Growth increases recorded here averaged 207.2% (276.26% over a year) and 1375% (1833.33% over a year) for SUL and mass respectively over the nine months. These are considerably lower than recorded by Rose (1956), although it was not recorded whether his juveniles entered a period of winter dormancy, or whether their diet was artificially supplemented. The young bullfrogs in this study were maintained in semi-natural conditions and experienced a natural climate regime, including winter dormancy (although this was not monitored in detail). There thus remains a need for detailed studies on growth rates in natural populations.

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