Diet composition of *Xenopus borealis* in Taita Hills: effects of habitat and predator size

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Abstract

Frogs in the genus *Xenopus* are ubiquitous in sub-Saharan Africa, yet very little is recorded on their ecology. They are commonly found in anthropogenically disturbed habitats, but how do these compare to conspecifics from natural habitats? The diet of *Xenopus borealis* from three different sites in Taita Hills, Kenya was established based on a sample of 77 (54 females and 23 males) specimens from two disturbed and one pristine sites. *Xenopus borealis* from all the sites was found to be a dietary generalist, feeding predominantly on invertebrates. A total of twelve invertebrate orders both terrestrial and aquatic were recorded in addition to amphibian eggs, tadpoles and fish. Frogs from the pristine forest were smaller and had ingested more terrestrial prey items than frogs in the disturbed open habitat ponds. The stomach content (both by mass and quantity) was independent of body size. The results suggest that *X. borealis* is an opportunistic generalist predator which may be constrained by food availability in its natural habitat. However, disturbed habitats provide abundant food items which are enough to significantly increase the mean size of the population.

Key words: habitat, stomach contents, Taita Hills, *Xenopus borealis*

Résumé

Les grenouilles du genre *Xenopus* sont présentes partout en Afrique subtropicale, mais il existe peu de travaux sur leur écologie. On les trouve fréquemment dans des habitats perturbés par les hommes, mais comment ces grenouilles-ci se comparent-elles à leurs congénères des habitats naturels ? On a pu établir le régime alimentaire de *Xenopus borealis* sur trois sites différents des Taita Hills, au Kenya, d'après un échantillon de 77 individus (54 femelles et 23 mâles) de deux sites perturbés et d'un site intact. *Xenopus borealis* s'est avéré être un consommateur généraliste sur tous les sites, se nourrissant principalement d'invertébrés. On a noté la présence d'un total de 12 ordres d'invertébrés, terrestres et aquatiques, auxquels s'ajoutent des œufs d'amphibiens, des têtards et des poissons. Les grenouilles des forêts intactes étaient plus petites et mangeaient des proies plus terrestres que celles des points d'eau d'habitats ouverts perturbés. Le contenu stomacal (aussi bien par la masse que par la quantité) était indépendant de la taille corporelle. Les résultats suggèrent que *X. borealis* est un prédateur généraliste opportuniste qui peut être limité par la disponibilité de la nourriture dans son habitat naturel. Par contre, des habitats perturbés fournissent une nourriture abondante, suffisante pour augmenter significativement la taille moyenne de la population.

Introduction

The amphibian genus *Xenopus* has colonized a variety of habitats both natural and man made. They are found in stagnant, slow or even fast moving water bodies (Tinsley, Loumont & Kobel, 1996). *Xenopus* has been used in various laboratory studies including, but not limited to, developmental, cell and molecular biology (Gurdon, 1996). Studies of their life history, general biology and ecology have focused on invasive populations of *X. laevis* (e.g. McCoid & Fritz, 1995; Measey & Tinsley, 1998; Measey, 2001). Few studies have been carried out on the genus in Africa, and the true taxonomic status and the distribution of many species still remain unresolved. In addition, no known feeding ecology studies have been conducted for any of the *Xenopus* species in East Africa. Elsewhere, studies of stomach contents of congeners have

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reported benthic invertebrates and zooplankton to constitute a major portion of their diet (McCoid & Fritz, 1980; Measey, 1998a; Lobos & Measey, 2002). In addition, terrestrial invertebrates, aquatic and terrestrial vertebrates have also been reported as food items (Inger & Max, 1961; Lafferty & Page, 1997; Measey, 1998a; b; Crayon, 2005). *Xenopus* are also famed for their cannibalistic tendencies especially when little other food is available (Tinsley *et al.*, 1996). Unlike other frogs which employ the use of a tongue in prey capture, tongueless *Xenopus* employ their toothed jaws, fore limbs (fork prey into mouth) and strong hind limbs and thus are able to feed on larger sizes of prey that would otherwise be impossible (Avila & Frye, 1978).

Originally described by Parker in 1936 as a subspecies of the *Xenopus laevis* complex, *X. borealis* was first recognized as a full species by Tymowska & Fischberg (1973) based on chromosome number and morphology. The species is native to Kenya and Tanzania however its occurrence in Uganda is suspected but yet to be confirmed (Channing & Howell, 2006). *Xenopus borealis* is a principally aquatic clawed frog associated with high altitude habitats. It is known to live and breed in pools and slow flowing streams (IUCN, 2004; Channing & Howell, 2006). Little is known about *X. borealis* within its range. The diet composition of this frog is also not well known. This study examined the diet of *X. borealis* with an aim to providing preliminary knowledge on their diet as well as finding if this requirement is subject to habitat, and size of the frog. It was hypothesized that *X. borealis* like its congeners is a generalist predator and that it ingests more prey in pristine over disturbed habitats.

Materials and methods

Study area

The study was carried out in four ponds located in the Taita Hills, south eastern Kenya 3°20′S, 38°15′E (see Githiru, Bennun & Lens, 2002). The four ponds were chosen based on their locality; i.e. both disturbed and pristine permanent ponds assessed to be suitable habitats for *Xenopus* frogs. Disturbed Pond 1, hereafter referred to as (DP1) is a permanent water-body within Wundanyi Township. This is a channel of about 0.5 m depth, overgrown with emergent vegetation, including reeds. Disturbed Pond 2 (DP2) is a pool of water in farmlands on the outskirts of Wundanyi Township. This is a small (about 2 m diameter and 1.5 m depth) water body devoid of any vegetation but with allocthonous wastes. The third sampling site, a permanent pond in pristine habitat (PP1), is a large water body with a diameter of about 5 m. The deeper sections (about 1 m deep) had no vegetation at all but were covered with floating algae, while the shallow section (less than 0.5 m deep) was overgrown with different kinds of aquatic plants. The forest is characterized by mist and cloud formation throughout the year. Although this is an artificial pond that is fed by a natural stream it is of potential natural formation (being a simple dam) and hence represents a comparatively natural site. The last sampling site was an expansive pond (>10 m diameter and over 1 m deep) in Chawia forest (PP2).

Stomach contents sampling

Sampling was carried out between 7 and 15 November 2007. Specimens were collected using improvized funnel traps made from a 10 l plastic bucket and a circular lunch box (10 cm diameter and 7 cm deep) with a hole cut into the bottom. A circular hole was made on the side of the bucket, into which the lunch box was fitted (Lobos & Measey, 2002). The buckets were placed in a vertical position with the hole submerged but with air left in the top to allow captured frogs to breath. Dried fish and beef were used as baits to attract the frogs into the traps. The traps were set every evening and checked in the morning. All *X. borealis* found were euthanized using a solution of chlorobutanol to be accessioned into the herpetology collection of the National Museums of Kenya. Snout-vent length and mass (where possible) were measured using a plastic ruler and a Pesola spring balance, respectively. The stomach contents were then removed via dissection and preserved in 10% formalin (Cogalniceano, Palmer & Ciubu, 2002). The prey items were identified at the invertebrate zoology section of the National Museums of Kenya under stereomicroscope and classified to order or family level (Borror & Delong, 1970).

Sampling potential prey items

Sampling for potential prey items was carried out in a random fashion including the edge and bottom of the ponds during the day once per study site. Both medium sized sieve and a D shaped scoop net were used to obtain the sample from the water. Water was disturbed for 2–5 minutes and then escaping invertebrates were scooped using the sieve and the D-net. All the invertebrates found were preserved in 10% formaldehyde for later analysis.

Data analysis

Percentage frequency of occurrence (%FO) was determined as the percentage of stomachs in which the prey item is present in relation to the total number of stomachs with identifiable content while descriptive statistics was carried out using STATISTICA (StatSoft, 2001). Diversity was estimated using Shannon–Weinner diversity index H' (Krebbs, 2002).

Results

Sample sizes and body sizes

A total of *77 X. borealis* were collected from the study sites as follows, 20, 23, 34 and 0 from DP1, DP2, PP1 and PP2, respectively. Female frogs were lager than males ($t = 3.44$, $P = 0.002$) with the largest individual captured measuring 102 mm snout-vent length (SVL, Mean 77.1, SD = 14.41) while the largest male measured 78 mm SVL (Mean 66.0; SD = 6.03). Specimens from DP2 were the largest in size while those from site PP1 were the smallest in size (Figs 1 and 2).

Stomach contents

Four (5.2%) out of the 77 stomachs opened were completely empty, two had substances that could not be identified with certainty while seven had only plant material and/or bait. All these (thirteen) specimens were exempted from further analysis. All frogs from PP1 had prey items in their stomachs while two frogs from both DP1 and DP2 had empty stomachs. The stomach contents consisted mainly of invertebrates (>90%), fish, tadpoles, frog eggs, plant material (33.8%) and bait (Table 1). Aquatic prey items constituted 59% of the stomach contents by number. Class Insecta (both adults and larvae) made up the highest proportion of the diet both by number and mass. Coleoptera, Hymenoptera and Odonata were recorded from specimens in all the three habitats sampled. Blattoidea, Ephemeroptera, Isopoda and Annelida were only recorded from frogs collected at PP1. Tadpoles and molluscs were only recorded in DP1 while fish was recorded only from single specimen collected at DP2.

Diptera and Odonata both recorded the highest %FO 20.3 after being recorded in thirteen out of the 64 stomachs with recognized prey items followed by amphibian eggs at 18.7%FO. Both Fish and Isoptera recorded the lowest %FO after being recorded in one specimen each. Feeding intensity (prey items per stomach) was highest at DP1 at 3.2 followed by PP1 at 1.61 and was lowest at DP2 at 1.33. The average mass of stomach content per individual was also highest in DP1 (0.84 g) followed by DP2 (0.37 g) and least in PP1 (0.24 g). *Xenopus borealis* in PP1 consumed more terrestrial invertebrates compared to those in DP1 and DP2 (See Table 1). There was a significant difference in the abundance

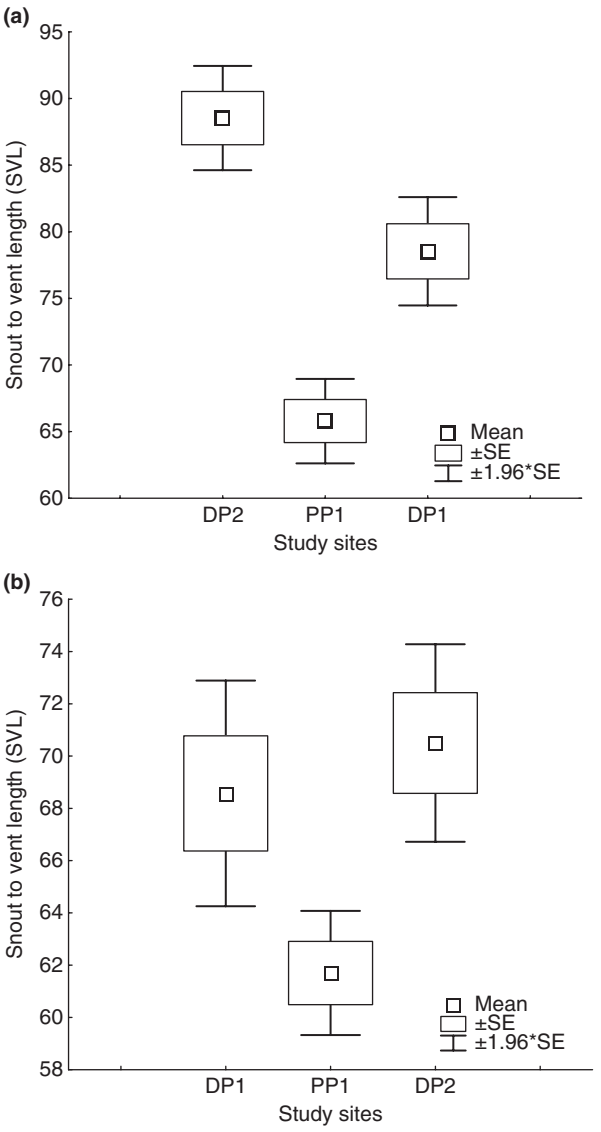

Fig 1 (a) Box Whisker of SVL of Female *Xenopus borealis* from the disturbed pond 2 (DP2) and permanent pond 1 (PP1) (SVL: KW–H(2,54) = 32.38, $P < 0.001$; $F(2,51) = 39.66$, $P < 0.001$), (b) Box Whisker of SVL of Male *Xenopus borealis* from the DP1, DP2 and PP1 (SVL: KW–H(2,23) = 10.12, $P = 0.0063$; $F(2,20) = 7.88$, $P = 0.003$)

Table 1 Showing the stomach contents of 76 frogs examined including those with empty stomach. Percentage frequency of occurrence (%FO) was calculated after specimens with empty stomachs plus those with only bait and plant parts inside (64). The numbers indicate the number of stomachs with prey item and not the number of individual prey items

Order	DP1	DP2	PP	Total	%FO
Aranaea	0	2	4	6	9.4
Blattodea	2	4	3	9	**14.1**
Coleoptera	6	2	4	12	**15.6**
Odonata	5	3	5	13	**20.3**
Hymenoptera	3	7	1	11	**17.2**
Hemiptera	3	0	5	8	**12.5**
Isoptera	0	0	1	1	1.6
Isopoda	0	0	3	3	4.7
Ephemeroptera	1	0	1	2	1.6
Orthoptera	0	1	4	5	7.8
Diptera	3	1	9	13	**20.3**
Trichoptera	4	0	8	12	**15.6**
Annelida	0	1	2	3	4.7
Mollusca	2	1	0	3	4.7
Fish	0	1	0	1	1.6
Amphibian eggs	9	0	3	12	**18.8**
Tadpoles	3	0	0	3	4.7
Bait	2	5	3	10	
Plant material	2	3	22	27	
Empty stomach	2	2	0	4	
Non identified prey item	0	2	0	2	

DP1, disturbed pond 1; DP2, disturbed pond 2; PP, permanent pond.

of invertebrates in the stomach contents of male and female specimens in PP1 ($t = 2.747$, $P = 0.016$) and the DP2 ($t = 3.873$, $P = 0.012$) but not in DP1.

Potential prey items

Since invertebrates constituted a higher percentage of the frogs' diet, potential prey sampling was focussed on aquatic invertebrates. A total of 76 individual invertebrates were recorded. Five orders of invertebrate prey taxa were recorded from DP1 including Odonata, Hemiptera, Coleoptera, Diptera and Mollusca. Odonata, Coleoptera, Hemiptera and Fish were collected from DP2. In PP1 the following seven orders were recorded: Hemiptera, Odonata, Trichoptera, Isoptera, Coleoptera, Hymenoptera and Araneae.

Prey diversity in water versus stomach contents

There was a higher diversity of invertebrates (Shannon–Wiener Diversity H' 3.316) collected from the stomach contents than the potential invertebrate prey items collected from the three water bodies [(H') = 2.111] combined. Per site analysis also recorded high diversity of invertebrates in stomach contents than potential prey sampled. PP1 had the highest (3.446) prey diversity in stomachs while DP2 (2.016) recorded highest prey in a water body. However this difference in diversity was not significant ($t = 0.69$, df = 13, $P = 0.499$).

Discussion

This study shows that like its congeners *X. borealis* is a dietary generalist with strong reliance upon aquatic invertebrates especially zooplankton and benthic forms which formed close to 90% of its diet both by number and mass (Schnobee, Prinsloo & Parker, 1992; Debryun, Kazadi & Hulselmans, 1996; Measey, 1998a). Terrestrial prey items constituted 46% of total prey taxa in the diet of *X. borealis* in this study. Debryun *et al.* (1996) found terrestrial prey taxa to constitute 57% of the stomach contents of *X. fraseri.* Only a single fish species, *Aplocheilichthys bukobanus*, was found in the stomach of one frog during this study, despite many of them being observed in the pond. Three fish species (*Eucyclogobius newberryi*, *Gambusia affinis* and *Clevelandia ios*) have been recorded in the diet of invasive *X. laevis* inhabiting California (McCoid & Fritz, 1980; Lafferty & Page, 1997; Crayon, 2005). Cannibalism was not observed in this study but predation on other frogs was observed both in terms of eggs and tadpoles. Tadpoles were recorded from two frogs from DP1 however none (even adult frogs) were recorded in both DP2 and PP1. Eggs of *Amietophrynus gutturalis*, *Ptychadena mascareniensis* and *H. glandicolor* were recorded in the stomachs of twelve *X. borealis*, 75% of which were females. McCoid & Fritz (1980), recorded only *X. laevis* eggs in the stomach of invasive *X. laevis* in California despite the presence of *Anaxyrus microscaphus*, *Anaxyrus. boreas* and *Pseudacris regilla* in the water body while a study conducted by Measey (1998a), on invasive *X. laevis* in South Wales, reported that 95% of the females fed on *X. laevis* eggs. We cannot rule out that *X. borealis* may be cannibalistic at certain times of the year since neither their eggs nor larvae were recorded in the three ponds during our study.

This study was conducted following a hypothesis that *X. borealis* would thrive better in pristine than in disturbed habitats. Our study shows that the habitat did not influence the prey diversity consumed by *X. borealis.* However, there was a difference among the three sites in terms of the

feeding intensity and average mass of prey item per stomach. The high average prey item by mass recorded in DP1 and DP2 suggests that these frogs feed on larger prey items capable of providing the nutrients responsible for the significant difference in the sizes noted. As all *X. borealis* captured were adults, we think it unlikely that the significant size difference reported here was a result of differing population demographics. However, there may be other factors not considered here, such as mean pond temperature. High intra-specific competition (due to the high population) among *X. borealis* in PP1 seems to be one of the driving forces for consumption of terrestrial prey. The higher abundance of terrestrial prey in PP1 may be due to the paucity of aquatic prey available forcing individuals to feed outside the water (see Measey, 1998b). Another explanation could be that *X. borealis* in disturbed areas might be inhibited to leave the water to feed due to increased predation risks in open areas.

In conclusion, *X. borealis* is a dietary generalist, like its congeners, but thrives in disturbed habitats over pristine ponds in forests of the Taita Hills.

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