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Short communication

The effect of anthropogenic habitat modification on habitat use by *Afrana angolensis* along the Dodwe River, Tanzania

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Amphibians occupy many diverse habitats across the globe. They are an important ecological resource and are sensitive to a number of environmental factors, both natural and anthropogenic. Amphibian decline has numerous potential and complex causes including ultraviolet radiation (Belden & Blaustein 2002), predation (Gillespie 2001), pollution (Hayes *et al.* 2002), pathogens (Lips 1999) and habitat modification (Anderson *et al.* 1999, Delis *et al.* 1996). Delis *et al.* (1996) found that several species of anurans had decreased abundances in wetlands associated with developed areas as opposed to wetlands in undeveloped areas. Thus, it is important to understand the habitat use and life history of species, as different life history strategies can cause spatial patterns to emerge in distributions (Krebs & Davies 1997). For amphibians this is of particular importance, as most species are associated with the terrestrial and aquatic habitats, imbuing them with a unique role in the ecosystem.

We tested if surrounding habitat modification caused a difference in habitat use by *Afrana angolensis*. This species ranges from the Sahara, south through East Africa (excluding East African lowlands below about 300 m), Angola, the western Cape Province, Kalahari, and the southern part of the central plateau. *Afrana angolensis* is dark olive-green with a mottled back, often with a broad light vertebral stripe and toes are webbed almost to, or to, the tip. These frogs are active throughout the year and are always found in, or in the immediate vicinity of, running water or permanent ponds. *Afrana angolensis* breeds in slow flowing streams or other permanent bodies of water, favouring those with aquatic vegetation. Eggs are deposited in the water where tadpoles hatch and eventually metamorphose. Their diet consists primarily of large active arthropods (Stewart 1967).

The objective of our study was to determine the affect of anthropogenic habitat modification on habitat use for *A. angolensis*. We hypothesized that there would be a difference in habitat use of *A. angolensis* in two different types of sample sites; those surrounded by disturbed land and those surrounded by undisturbed forests. Habitat was categorised according to the condition of the forest: undisturbed forest, largely untouched by human activities, and disturbed land, either under agriculture or recently cleared forest (within five years). Kolozsvary & Swihart (1999) found that certain anuran species responded to landscape level attributes with changes in abundance and Grialou *et al.* (2000) showed that population responses of salamander species to forest management are variable. Given that each amphibian species differs in their response to changes at the habitat level, we speculated that a lack of food and places for refuge may limit or alter habitat use by *A. angolensis* along stretches of river surrounded by disturbed land. Four sampling areas, two surrounded by disturbed land and two surrounded by undisturbed forest, were designated along a continuous stretch of the Dodwe River in Amani Nature Reserve, Tanzania (Fig. 1).

The sample area consisted of approximately 2400 m of the Dodwe River (elevation 950 m (05° 00' S - 38° 50' E), which runs through the Amani Nature Reserve in the East Usambara Mountains in Tanzania, Africa. The sample area is a floodplain of the Dodwe River, which empties into an artificial pond created by a dam. The dam and pond are at least 25 years old. The river itself ranged between 1 - 3 m wide, while the width of the valley ranged from 10 - 75 m wide. Grasses and shrubs usually from 0.5 - 1 m in height cover the river's edge throughout the sample area. The sample area was categorized into four distinct sites according to the status of the surrounding land (Fig. 1). Two sites (Site 1 with a total length of 440 m and Site 3 with a length of 655 m) were surrounded by undisturbed, relatively mature forest. The trees of this forest were at least 25 years old with lush undergrowth and the canopy of the forest was about 15 m. The remaining two sites (Site 2 with a length of 645 m and Site 4 with a length of 666 m) were surrounded by recently disturbed forest or farmland. This ranged from areas in present agricultural use (i.e., sugar cane crops) to areas that had been recently logged (within the last 5 years). The agricultural areas were clear of undergrowth with almost no canopy and the recently logged forest areas had a sparse canopy with moderate undergrowth. The river ultimately flows into a pond area (> 200 m^2), which was marshy in many places and open deep standing water (> 3 m) in others. The shores of the pond are covered with diverse vegetation, which is extremely dense in some areas.

Sampling involved a team of two observers walking side by side, one within 1 m of the river edge and the second approximately 2 m farther from the river, searching for *A. angolensis* along a 4 m-wide transect. Sampling took place in September 1999 during the dry season and except for a few light rain showers, the weather was clear and dry. Each site was sampled twice at different times of the day (09h00 and 14h00) over a five-day period and all *A. angolensis* encountered were recorded. We also attempted to capture all observed frogs with dip nets in order to measure mass (to nearest 0.5 g) and snout-vent-length (SVL) (nearest 0.5 mm). All individuals, regardless of whether they eluded capture or not, were classified by size into one of three categories: small < 50 mm (S), medium 50 - 75 mm (M), and large > 75 mm

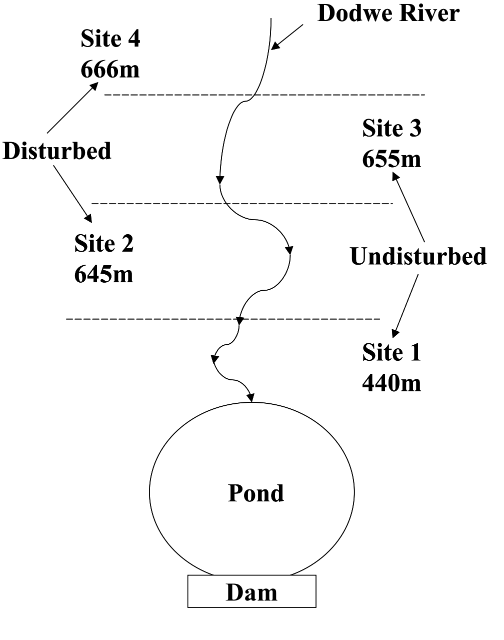

Figure 1. Site map of Dodwe River (not to scale).

(L). For all individuals, the shortest distance to the river from the observed initial resting site was measured.

Chi-square analyses were used to test for effect of habitat disturbance and site on density and the three size categories of the frogs. Analysis of variance (ANOVA) was used to test for differences in mass and SVL between sites and habitat disturbance. Analysis of co-variance (ANCOVA) was used to determine site and habitat disturbance effects on the relationship between mass and SVL of frogs. Linear and exponential regressions were performed on mass and SVL. Kruskal-Wallis one-way ANOVA and Jonckheere test for ordered alternatives were used to examine distance to shore for the three size classes (Siegel & Castellan 1988). Systat 5.2.1 for IBM was used for all statistical procedures.

In an effort to reduce the possibility of pseudoreplication due to duplicate samplings of the study area, all statistical analyses were performed on the combined data set and on both individual sampling data sets. Only those analyses that were significant for all three data sets are presented. All levels of $\alpha = 0.05$ were considered statistically significant (Sokal & Rohlf 1995).

A total of 200 *A. angolensis* were observed and 59 were captured. While habitat disturbance did not have a significant effect on density ($\chi^2 = 0.27$, df = 1, $P = 0.61$), there was a significant difference in density between sites ($\chi^2 = 62.31$, df = 3, $P < 0.001$). Site 3, the second undisturbed site, had the highest density (119 frogs km^{-1}), followed by Site 2 (disturbed, 113 frogs km^{-1}), Site 1 (undisturbed, 61 frogs km^{-1}) and finally Site 4 (disturbed, 33 frogs km^{-1}). Habitat disturbance ($\chi^2 = 2.67$, df = 2, $P = 0.26$) and site ($\chi^2 = 10.4$, df = 6, $P = 0.11$) had no effect on size distribution (proportion of S (34%), M (44.5%) and L (21.5%)), and effects of habitat disturbance on size distribution were independent of replicates ($\chi^2 = 0.5342$, df = 1, $P = 0.46$). Habitat disturbance did not have a significant effect on mass ($F_{(1,57)} = 0.05$; $P = 0.61$) or SVL ($F_{(1,57)} = 0.62$; $P = 0.35$), however the average mass of captured frogs differed significantly between sites ($F_{(3,55)} = 4.19$; $P = 0.01$). Site 4, the farthest site from the pond, had the highest mean frog weight (42.6 g) and Site 1, the closest site to the pond, had the lowest (16.6 g) (Fig. 2). Regression analysis revealed a significant relationship between frog mass and distance from the pond along the river ($R^2 = 0.184$, $P = 0.0203$, $N = 29$). There was a significant relationship between body mass (g) and SVL (mm) ($R^2 = 0.867$, $P < 0.001$, $N = 59$) with ranges from 0.34 to 72 and 18 to 92, respectively. There was no effect of site ($P = 0.53$) or habitat disturbance ($P = 0.34$) on the relationship between mass or SVL. Finally, average distance from the river edge was significantly different for all three size classes (Fig. 3), with smaller frogs found farther from the river edge than larger frogs (K-Wallis = 25.22, df = 2, $P < 0.001$).

We found that the habitat disturbance of the surrounding area did not have any significant effects on the parameters measured in this study, including mass and SVL. These are not novel results as Chazal & Niewiarowski (1998) found that there were no differences in body mass, body length or lipid stores in *Ambystoma talpoideum* between an old growth habitat and recently clear-cut habitat. The positive relationship between frog mass and position along the river supports the observation that larger frogs are found farther from the pond area. A potential explanation is that tadpoles actively swim downstream in order to metamorphose in the pond where they may have better food resources. *Afrana angolensis* has a larval period ranging from nine months up to two years, depending on temperature and food availability (Stewart 1967), and this life history trait could produce a natural accumulation of tadpoles in the pond. Also, tadpoles or eggs may be washed downstream during heavy precipitation events, thus skewing the size distribution towards a smaller/younger population of metamorphosed frogs near the pond. The pond, with its much more heterogeneous and densely foliated shores, may provide better habitat for both small frogs and tadpoles as described by Anderson *et al.* (1999).

As well as being closer to the pond, smaller frogs were found farther from the river's edge. One explanation is that larger individuals are slower than smaller ones and therefore hide next to the shore in order to be closer to the water, into which all individuals tend to flee when disturbed (Stewart 1967). Other reasons for this size distribution could be related to gender (Griffin & Case 2001) or food abundance (Bouskila *et al.* 1998).

The frogs in Site 4 were spaced farther apart than those in the other three study sites. This site is very near the headwaters of the Dodwe River and the habitat might not be optimal for breeding or feeding purposes. There is a well-documented correlation between mass and SVL for many frog species (Duellman & Trueb 1986), which allows an estimate of biomass for a species in an area by visually sampling and estimating SVL.

In conclusion, we found no differences in size distribution, mass or SVL for *A. angolensis* in relation to habitat disturbance. We did find size-related differences in distance from the pond along the river and distance from the river edge. Smaller, perhaps younger, frogs are found further away from the river edge and closer to the pond area.

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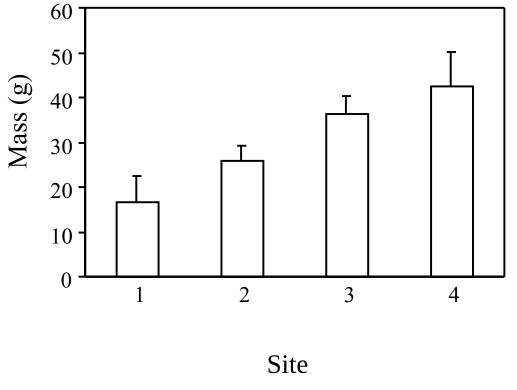

Figure 2. Comparison of four sample sites for average weight of *Afrana angolensis*. Bars indicate one standard error. $F_{(3,55)} = 4.19$; $P < 0.01$.

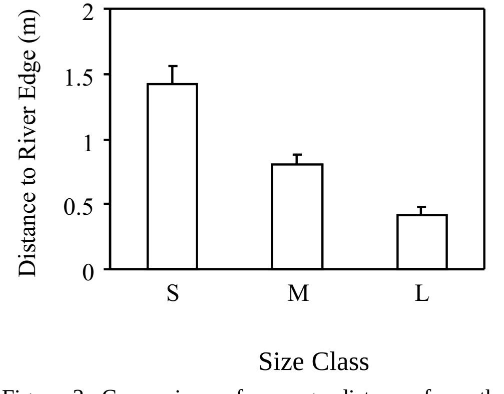

Figure 3. Comparison of average distance from the shore for three size classes of *Afrana angolensis*. S = small, M = medium, and L = large. Bars indicate one standard error. K-Wallis = 25.22; d.f. = 2; $P < 0.001$

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