Factors determining the diversity and abundance of hyperolid frogs in the emergent vegetation in Amani pond, Tanzania

Victoria Nneoma Ujoh, University of Benin, Nigeria

Geert van de Wiel, Wageningen University and Research Centre, The Netherlands

Abstract

Amphibians have diverse habitats and are universally threatened as a result of human activities. This study was carried out on the emergent Cyperacean reeds in the Amani pond. The main objective was to investigate the factors which could determine the diversity and abundance of hyperolid frogs in the pond. Investigations revealed that cutting of the Cyperaceans resulted in a complete absence of frogs. Density of the Cyperaceans, water depth, height and time (day or night) were found to have a positive correlation with the abundance and diversity of the hyperolid frogs. Our results also showed an invasion of the Cyperaceans by *H. spinigularis* during the second week of the study.

Key words: Amani pond, Hyperolids, Habitat preference, Tree frogs, ecological variables

Introduction

Amphibians occupy many diverse habitats and are universally threatened as a result of human activities. It is important to understand the way they use their habitats and how this affects their abundance and distribution. Although in the breeding season, mixed species groups of anurans may congregate in the hundreds, the behaviour of amphibians is seldom observed because they are most active at night. Of all the vertebrates, the amphibians and reptiles of the forests of eastern Africa are the poorest known and have received the least attention from laymen and biologists alike (Howell 1993).

The East Usambara Mountains, which are part of the Eastern Arc Mountains, in Tanzania are well known for their high species endemism. Rogers and Homewood (1984) reported that 30 % of amphibians are endemic to the Usambaras. Four genera in the family Hyperoliidae are found in the East Usambara Mountains. All have digits with expanded tips and are well adapted for climbing in trees or among aquatic vegetation. Our study mainly focused on *Hyperolius* and *Leptopelis* species. *Hyperolius* are small to medium sized (max 40 mm) and are brightly coloured. The horizontal pupil is a character only found in this genus. *Leptopelis* are large (females 50 – 85 mm) treefrogs with vertical pupils (Schiotz, 1999).

We conducted our study at an artificial pond, which can be considered as a very important habitat for certain species of tree frogs from the family Hyperoliidae. It is almost completely covered by a lawn of *Myriophyllum* weeds with a relatively small bed of emergent large Cyperaceae reeds. The local villagers illegally harvest these plants from time to time as cattle fodder. We aimed to investigate the effect of cutting the Cyperaceans on the diversity and abundance of the tree frogs. These plants provide a good shelter for the frogs in general, as well as elevated calling sites for males. A study in the pond by Durrans & Riva in 1998 however, suggested that there is no significant preference for any particular height for calling among the hyperolids. Therefore, we also tried to investigate what particular factors determine the abundance and diversity of hyperolids in the area covered with the emergent Cyperaceans. Knowledge of these factors could be used for management purposes, for example to improve the habitat (quality/variety) for the hyperolids.

Material and methods

Study site

The Eastern Usambara Mountains are part of the Eastern Arc Mountains, which run in an arc mainly in eastern Tanzania. They are forested from the lowlands up into the highlands, with semi deciduous forest up to 850 m and from 850m on with sub montane (evergreen) forest. Amani pond is an artificial pond (located in the Amani Nature Reserve), which was created when Germans colonists dammed the River Dodwe, and it hosts a variety and abundance of tree frogs: 7 species of *Hyperolius* and 5 species of *Leptopelis* (Harper & Vonesh, 2003).

Mapping

The Cyperaceae bed in Amani pond was measured and mapped (Map 1). It is located on the western edge of the pond. The size of the Cyperaceae bed is 578m². We stratified between disturbed (size =80 m²) and undisturbed (size = 498 m²), and between dense area (size = 360 m²) and sparse area (size = 138 m²).

Map 1. Cyperacean cover in Amani pond

Pilot survey

We investigated the Cyperaceae bed during night, as the hyperolids are nocturnal. We visited the site for a pilot survey, to tackle practical problems in advance, and for catching different frog species. Those caught specimens were taken to the laboratory, where they were kept in a small terrarium containing water, a dry part, shelter and food. There the specimens where observed during night and day, to identify the species and become familiar with them and to see what mating call belongs to which species. Also we looked at the changing of colour patterns between night and day, as the frogs often appear more brightly and sometimes with completely different colours or colour patterns during the day. The frogs were kept for two nights, and then released back to the pond.

Establishment of plots

We established 10 plots in the sparse covered area, and 20 plots in the dense covered area, because the dense area is about twice as large as the sparse area.

The size of the plots was 2m x 1m = $2m^2$. The plots where chosen on the map, rather than in the field, to overcome bias and enhance representative coverage. As the area of the Cyperaceans is relatively small and unique in the pond, and as it is considered to be an important habitat for some hyperolid species, we wanted to reduce the disturbance and damage to the area to minimum. The plots were not chosen randomly, but in the dense area situated mostly on the edges, with some plots in the middle, where we could make a minimum of pathways to reach them all. The plots where numbered randomly, and the order in which we would visit them was also chosen randomly. We tagged and numbered individual plots in the field using brightly coloured tapes and waterproof markers for easy identification.

Time schedule

We visited plots twice during two stages. Stage one was visited from the 16th to the 20th September 2003, and stage 2 the 21st to the 25th of September 2003. Stage 1 lasted for 4 days (visiting respectively 8,7,8,7 plots per night), and stage 2 lasted for 3 days (visiting 10 plots per night). During those two stages, we visited each plot twice, once during night, and once at daylight the following day. At night, the plots where visited from approximately 20:00 hr till 23:00 hr, for 15 minutes. During the day, the plots where visited from approximately 10:00 hr till 13:00 hr, visiting each plot for 15 minutes.

Data collection

At each plot, we searched for both juveniles and adults of the family Hyperoliidae. We walked carefully between the plots, hence causing the least disturbance and damage possible to the frogs and the Cyperaceans. During the night, searching activities included observation by sight, and listening to the calls of calling males to trace them. During the day, searching activities where more active and included refuge examination (turning leaves of the plants etc.) to search for frogs, and disturbing the area by moving the reeds and other plants (but without breaking or any other irreversible damage) to make the juveniles move.

We used pre-prepared data sheets during the sampling period to ensure accurate data collection. In each plot, the following was recorded

- Plot number
- Stage
- Time (day or night)
- Species of frog
- Juvenile or adult
- Height at which it was found
- Calling or not
- Found on the Cyperaceans or not
- Weather
- Density of the Cyperaceans
- Water depth of the plot

For the juveniles, we did not identify them to species level, as there are no keys available for identifying juvenile hyperolids. Therefore, we distinguished between 4 types. (App. 1). Height and water depth were measured with a measuring pole. Water depth was measured at opposite corners of the plot, and at the centre of the plot, and we took the average of those three measurements. Density of the Cyperaceans was measured by counting the number of individual plants in the plot. Statistical analysis was done using Minitab statistical software. Data analysis was carried out using ANOVA, General Linear Models. Graphs were made on Microsoft Excel Software Package.

Results

General figures

During the study, we found a total of 856 individuals (though this figure includes multiple sightings of the same individual, since each plot was sampled 4 times), comprising 247 adults, and 609 juveniles. We found 8 different adult species and 4 types of juveniles in the Cyperaceae area.

Impact of cutting the Cyperaceans on abundance and diversity of hyperolids

During our pilot survey, we found no hyperolids in the disturbed area, where the Cyperaceans had been cut. Therefore, we restricted our study to the undisturbed area, and we did not further investigate the impact of cutting the Cyperaceans, as this observation clearly showed that the cutting of the Cyperaceans had a great impact on the abundance and diversity of the hyperolids. Cutting of the Cyperaceans leads to a total absence of hyperolids.

Test stratification between sparse and dense

When the study site was mapped, we distinguished between sparse and dense Cyperacean cover. During the actual study we measured the density of Cyperaceans (individual plants/plot) for each plot. We tested the stratification of the plots to the measured Cyperaceans density, where we showed that the measured Cyperaceans density in the plots chosen in the dense covered area, was significantly higher than the measured Cyperaceans density in the sparse area. (ANOVA, $F_{,118} = 299$, $p < 0.001$)

Test of importance of different ecological variables on the abundance and species richness of hyperolids.

The results are summarized in table 1.

Table 1. Results of General Linear Model (- not significant (p>0.1); ms = marginally significant (p<0.1);*significant (p<0.05); ** very significant (p<0.01); *** highly significant (p<0.001); *H. punct = H. puncticulatus* ; *H. mitch = H. mitchelli; H. spini = H. spinigularis;* Ab = abundance; Juv = Juveniles; Spp R = Species richness).

	Response variables							
Explanatory variables	**Total Ab**	**Juv. Ab.**	**Adult ab**	**Spp R**	**Calling males ab.**	***H. punct***	***H. mitch***	***H. spini***
water depth	-	-	**	**	*	*	**	-
Cyperacean density	**	***	-	ms	-	-	-	-
weather	ms	-	-	ms	-	-	-	-
weather: Cyperacean density	-	-	-	-	-	-	-	-
day/night	-	-	-	-	**	-	*	-
day/night: Cyperacean density	ms	*	-	-	-	-	-	-
stage 1/stage 2	-	-	ms	-	-	-	-	***

Correlation between water depth and density of Cyperaceans

We showed a highly significant correlation between the water depth and the Cyperacean density. (Pearson correlation = 0.394, $p < 0.001$, Fig 1) With increasing water depth, the Cyperacean density increases, although only 15.5 % of the variance of the data is explained.

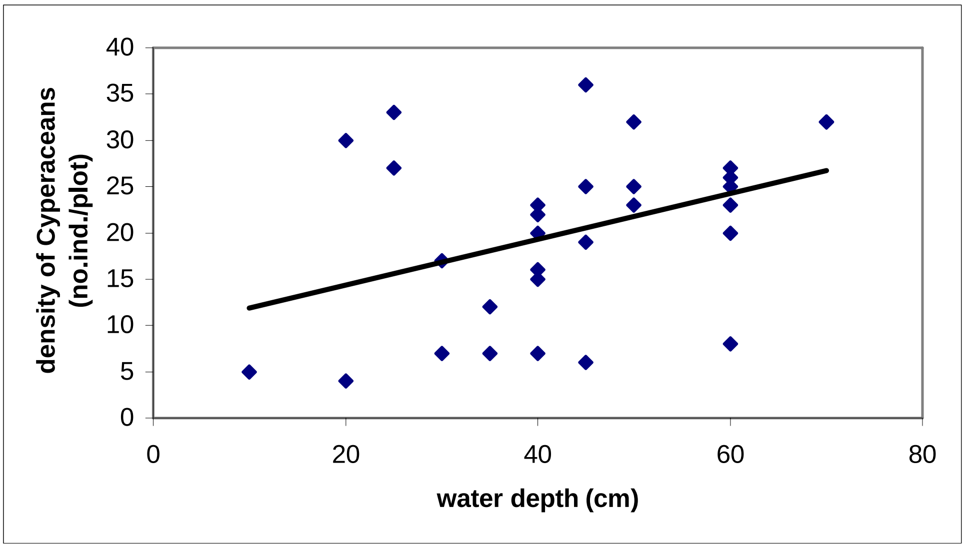

Figure 1. The correlation between water depth and density of Cyperaceans. (R^2 = 0.155)

Relationship between Cyperacean density and abundance of hyperolids

There was a very significant positive correlation between the abundance of individual hyperolids and the Cyperacean density (Table 1, Figure 2). The number of hyperolids increases with increasing Cyperacean density.

Relationship between density of Cyperaceans and abundance of juvenile hyperolids

The results show a highly significant positive correlation for the density of Cyperaceans and the abundance of juvenile hyperolid frogs, and an interaction between the day/night and the density of Cyperaceans (Table 1, Figure 3). The increase in abundance of juveniles with Cyperacean density is stronger during the day than during the night. There was no significant relationship between the density of Cyperaceans and the abundance of adult hyperolids.

Relationship between water depth and abundance of adult hyperolids

For the correlation of the water depth and mean amount of adult hyperolid frogs, the results showed a very significant positive correlation (Table 1, Figure 4), although it only explains 4.4% of the variance of the data. With increasing water depth, the abundance of adult hyperolid frogs increases as well.

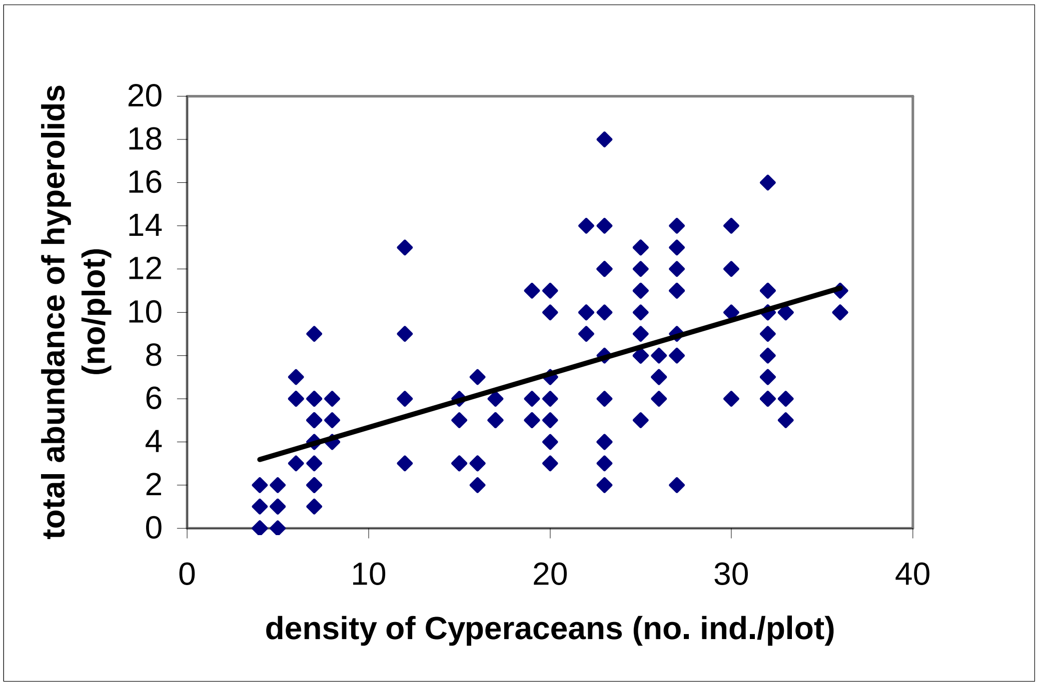

Figure 2. Relationship between density of Cyperaceans and abundance of hyperolids in the Amani pond. ($R^2 = 0.3735$)

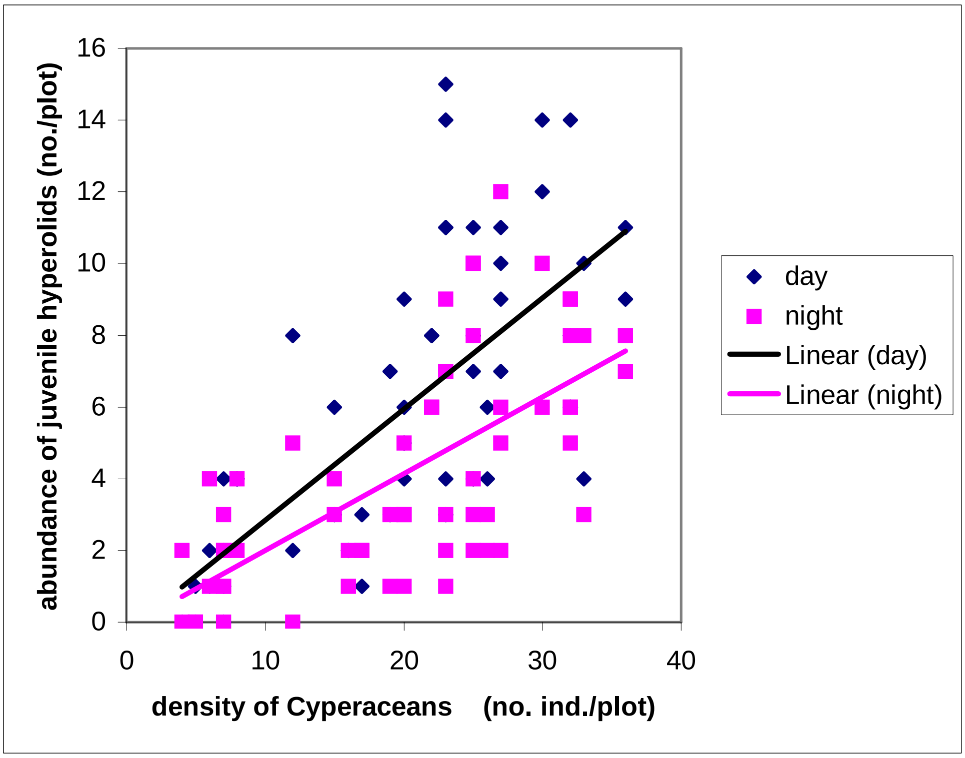

Figure 3. Relationship between Cyperacean density and abundance of juvenile hyperolids in the Amani pond.

Relationship between water depth and species richness:

We found a small but very significant positive correlation between the amount of species richness and water depth (Table 1, Figure 5). With increasing water depth, we are likely to encounter an increasing number of species.

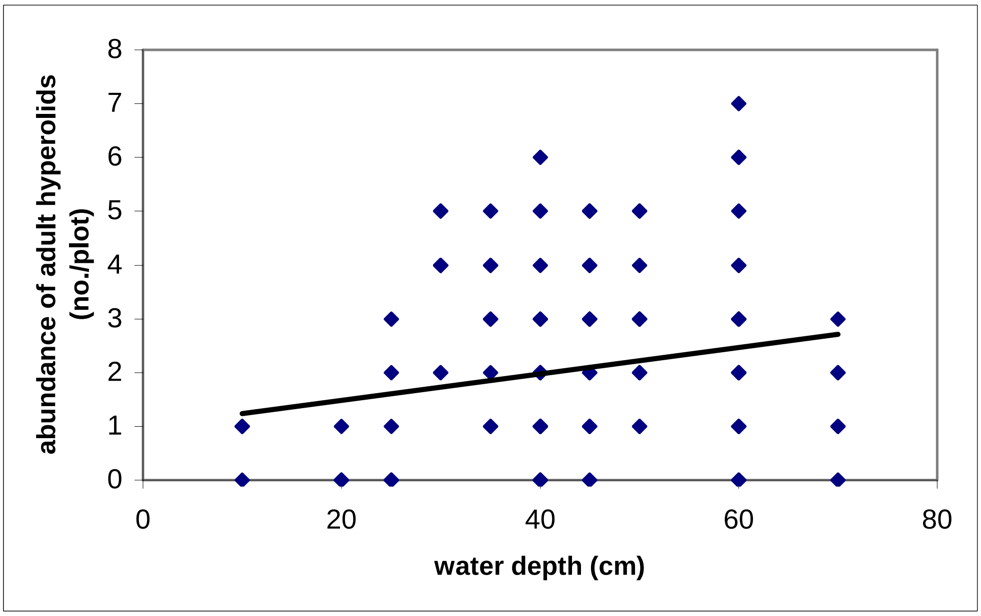

Figure 4. The influence of the water depth on the abundance of adult hyperolids

in the Amani pond. (R^2 = 0.0441)

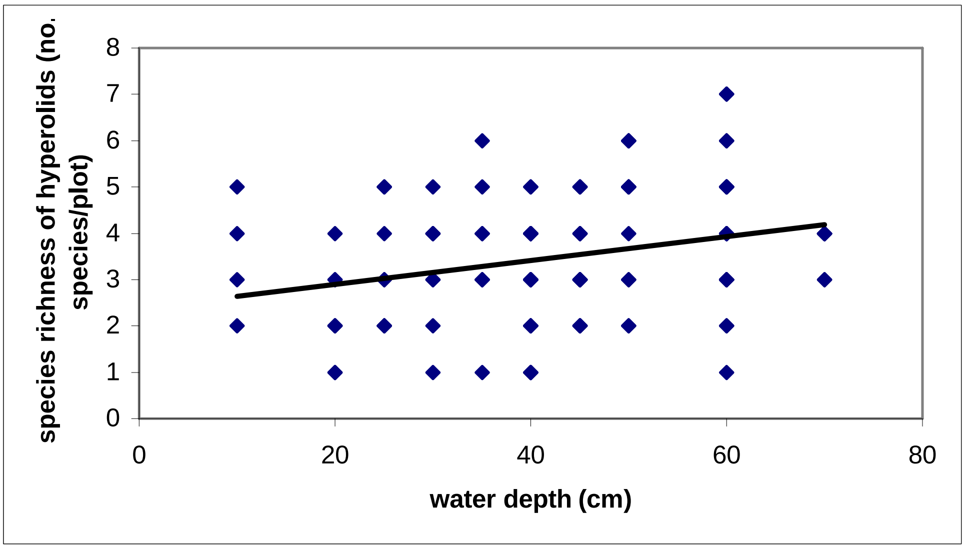

Figure 5. The influence of water depth on the diversity of hyperolid species in the Amani pond. (R^2 = 0.0819)

Relationship between water depth and abundance of calling males

We showed a significant positive correlation between the number of adults calling and the water depth (Table 1, Figure 6). The number of calling adults increases with increasing water depth.

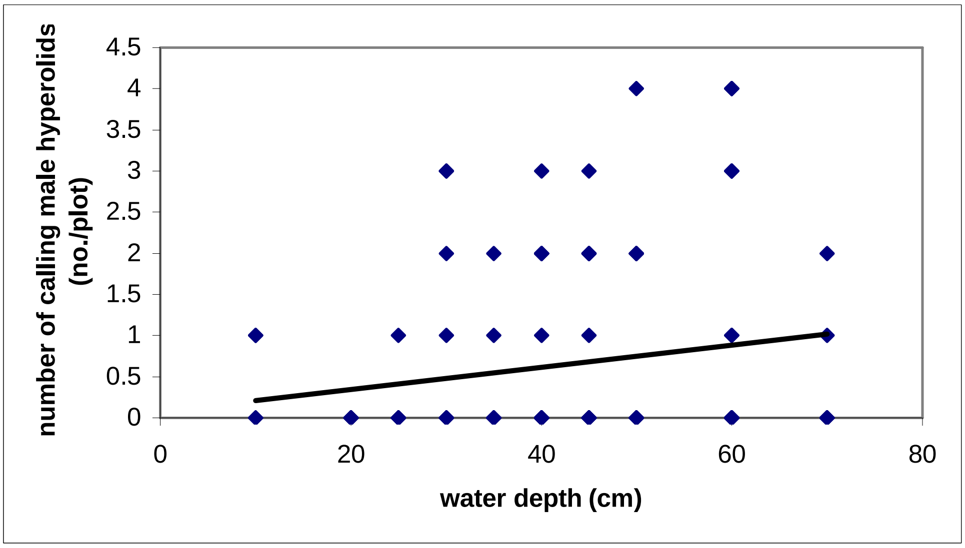

Figure 6. The influence of water depth on the number of calling males. (R^2 = 0.0316)

Invasion of the Cyperacean area by H. spinigularis

During stage 2, the Cyperacean area was invaded by *H. spinigularis*. During stage one, only 2 individuals of this species were found whereas in stage two, 42 individuals of this species were found. This was found to be highly significant (Table 1, Figure 7).

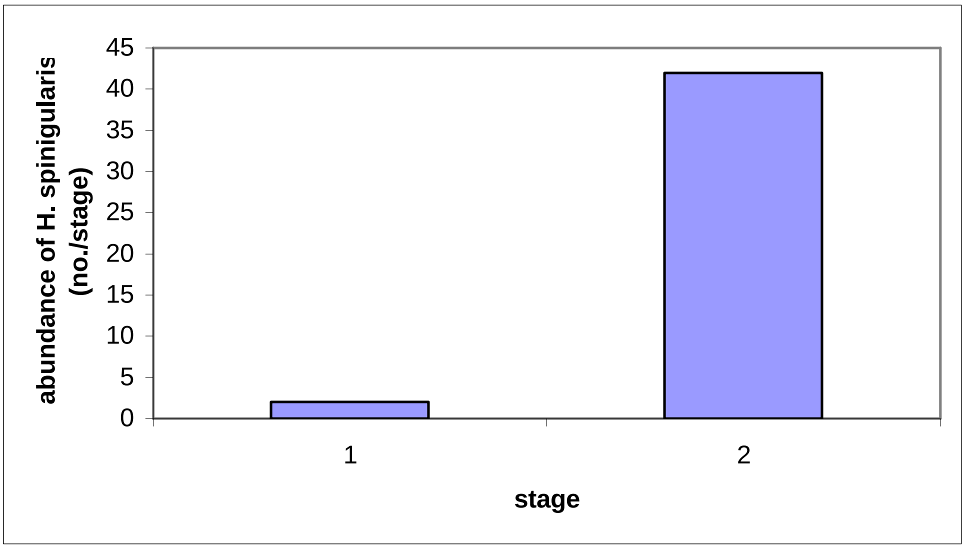

Figure 7. Total number of individuals of *H. spinigularis* found during the 2 stages.

Height preference of hyperolid frogs

Our results showed a highly significant interaction between adults/juveniles and the time (day/night) for the heights at which they were found (ANOVA, $F_{1, 428} = 24.60$, $p < 0.001$). During the night, the adults were found significantly much lower than during the day, and for juveniles it was the other way round, although this was not significant. During the night, the juveniles were found slightly higher than during the day.

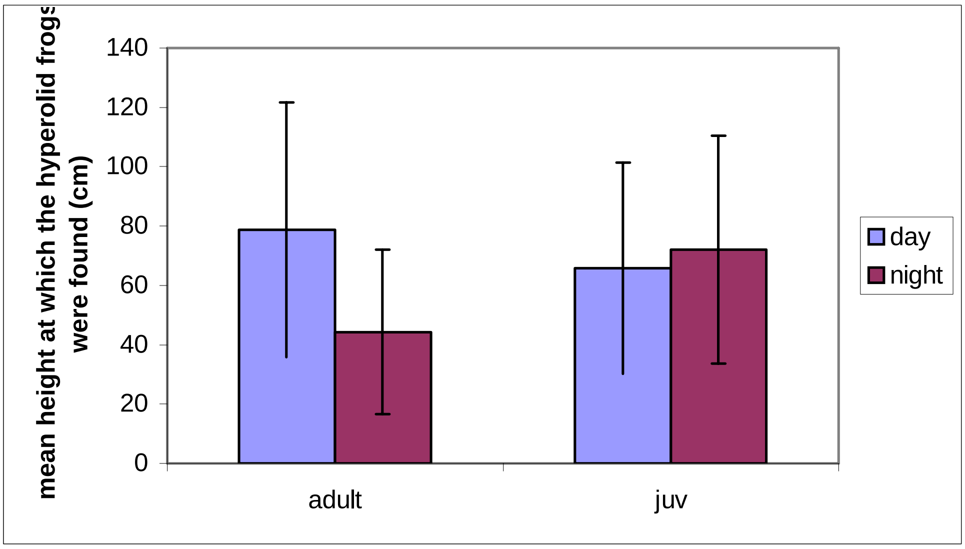

Figure 8. Mean height at which the hyperolids were found during the day and night. (bars indicate ± SD)

Discussion

Our pilot survey revealed that the cutting of the Cyperaceans leads to a total absence of hyperolids. This absence can be explained by the fact that the Cyperaceans provide a favourable habitat for both the adult and juvenile hyperolids. The Cyperaceans provide excellent calling sites for adult male hyperolids. In addition, most hyperolids lay eggs adhered by jelly to the Cyperaceans above the water level (Schiotz, 1999). Removal of the Cyperaceans can increase the risk of predation on the hyperolids and their eggs, by making the habitat more accessible for predators. Removal of the Cyperaceans may also result in a reduction of the abundance of food (eg. invertebrates) for the hyperolids, as these invertebrates also inhabit the Cyperacean area.

The results showed that the abundance of hyperolid frogs increases with increasing Cyperacean density. This is probably due to the highly significant correlation for the juveniles, since the results showed a non significant correlation between Cyperacean density and abundance of adults.

For the juveniles, one can argue that a high vegetation density provides a good shelter against predators. The juveniles are heavily preyed upon, among others by birds, spiders and snakes. Staying in a densely vegetated area can reduce the risk of predation. For the adults on the other hand, they are less prone to be preyed upon as for example the spiders only predate on juvenile hyperolids. However, further research is recommended to test this. For adults it may simply be the presence of Cyperaceans that is important rather than the actual density. This is because the Cyperaceans are a good egg-laying habitat. During the night, the adult males position their selves mainly on the Cyperaceans, and start calling to attract females. In this case, it can be important to call from a place where the density of Cyperaceans is high enough to provide enough calling sites and shelter for predators, and low enough to be easily found by an attracted female.

The fact that we observed more juveniles in the day compared to the night is probably caused by the fact that we have seen more juveniles during the day than during the night, because they are more visible during the day. We suggest a mark and recapture experiment to investigate if there really are more juveniles during the day than during the night, or if this result was due to a sampling artefact.

The water depth may be a more important factor for adults than just the density of Cyperaceans. Water depth was found to be positively correlated with the density of the Cyperaceae, abundance of adult hyperolids, species richness and the number of calling males. This can be explained by the fact that the pond is a good breeding site for the hyperolids, which need water for the development of tadpoles. Schiotz (1999) states that most of the Hyperolius species lay eggs adhered by the jelly to vegetation above water. Our investigation confirmed the use of the Cyperaceae for this purpose. When the yolk is consumed, the tadpoles drop into water. Therefore it is to the advantage of the hyperolids to congregate in the areas with high water depth so as to ensure the survival of the tadpoles. High species richness can be explained by the fact that many species will be drawn to the area for breeding as it is very suitable for this purpose.

During the second stage, we found that *H. spinigularis* was invading the Cyperacean area. In 2 days, the amount of individuals of *H. spinigularis* found had multiplied with a factor 20. We do not know where they came from. They could come from either the *Myriophyllum* cover or from the forest around the pond. Why they invaded the Cyperacean area so suddenly is also unknown. In stage 2 we recorded 4 adult *H. spinigularis* females guarding their eggs, and 3 couples mating. This suggests that for this species, the breeding season might have started, and that *H. spinigularis* invaded the Cyperacean area for breeding purposes. In the literature no such events were ever recorded nor explained. We would like to recommend that this suggestion be investigated by further research, preferably covering the entire pond.

The results showed a highly significant difference in the height preference at different times (night or day) for hyperolids. Adults were found to sit lower at night and higher during the day. This can be explained because during the night, the adults choose a low height which they use for calling and mating purposes. During the day, adult hyperolid frogs are mostly inactive and spend most of the time basking in the sunlight high up on the emergent vegetation. Juveniles are active for most part of the day but they generally are found lower during the day than during the night.

In conclusion, we showed that the Cyperacean bed hosts a very large abundance and diversity of hyperolid frogs, and therefore can be considered as important habitat for hyperolid frogs in the Amani pond. However, we did not compare hyperolid species diversity and abundance in the Cyperacean area, with hyperolid species diversity and abundance of other habitats in the pond. We would like to suggest that further research aims to investigate this comparison. To maintain the abundance and variety of hyperolid frogs, the cutting of those Cyperaceans must be controlled. Water depth and density of Cyperaceans proved to be the determinant factors for the abundance and variety of hyperolid frogs.

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Appendix 1. Juvenile type description

Type A	green juvenile with two bright lateral stripes and 1 bright dorsal stripe
Type B	plain green juvenile
Type C	green juvenile with small black dots on the back (speckled)
Type D	green juvenile with fewer black dots on the back, and 2 or 3 bright dorsolateral stripes