

# Potential of the yellow throat as an honest indicator for male strength in *Phrynobatrachus krefftii*

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## Abstract

*Phrynobatrachus krefftii* is one of the few frog species that uses mainly visual signals for communication rather than acoustic ones. The highly territorial males exhibit their bright yellow throat during male-male antagonistic interactions. This conspicuous signal could provide a certain amount of information of a male's strength, thereby working as an honest indicator. We predicted that there should be correlations between the colour pattern of the throat and body features, explicitly the leg constitution. We found evidence for the potential of the yellow throat to work as an honest indicator in intraspecific communication, as it provides information about the body size and the leg size.

## INTRODUCTION

Probably the best studied field in herpetology is communication among frogs, which is mainly based on acoustic signals. They use them especially for advertising and species recognition. Therefore, each different frog species has a specific mating call. However, certain species of tropical frogs use visual cues in addition to acoustic ones. Well known examples are the leg waving frogs *Hylodes spp* in Mata Atlântica, South America. Visual signals are mainly used to transmit information over a longer distance in situations where acoustic signals are likely to be disrupted, e.g. by high background noises near flowing water bodies or waterfalls. Furthermore, this type of communication is mostly found in territorial frog species.

The species of interest, *Phrynobatrachus krefftii*, which shows mainly visual communication, is endemic to the submontane and montane rainforests of the East and West Usambara Mountains of Tanzania. It is diurnal and spends its active period in and around slow flowing water bodies (Barbour & Loveridge, 1928). At night, it rests higher up on leaves (Hirschmann & Franzén, 2001). Despite the first impression that the small (max. 50 mm) and light to dark brownish *Phrynobatrachus krefftii* is rather cryptic in its natural muddy environment, there is one feature that makes it vulnerable: the sexually mature males of this species have a characteristic bright yellow throat, which is very conspicuous, showing a great contrast between the yellow vocal sac and the

brighter yellow margin below the lower jaw (lip). Most males also have a brighter band across the throat (stripe) (Channing & Howell, 2006). The colour pattern plays an important role in the territorial behavior of this frog as it indicates the species and sex over distance. Inflating this conspicuous throat is the predominantly used signal during male-male agonistic interaction (Hirschmann & Hoedl, 2005). Thus it might play a role as honest indicator of male physical attributes by which other males may judge their opponents to avoid a costly fight.

The main objective of this project was an analysis of the coloration to assess the potential of throat colour as an honest signal of male physical attributes such as body size, weight and the size of the legs. We predict that the coloration of the throat should be more intense and obvious in stronger males to make a counterpart judgment possible.

## **Material and methods**

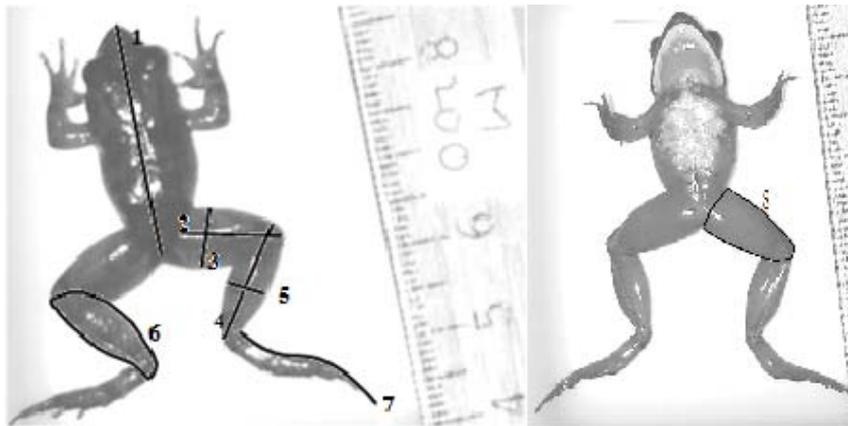
This project was conducted in Amani Nature Reserve, East Usambara Mountains, Tanzania. A total 38 male individuals of *Phrynobatrachus krefftii* were captured in a creek of the Emau River during four night sessions and taken to the laboratory of the TBA field station.

Each specimen was photographed, both dorsally and ventrally, using a camera that was fixed 83 cm above the frog on a tripod. The pictures were taken in controlled light conditions in a dark room, using the same settings for every frog. White balance calibration was done by using white filter paper (Whatman # 1). The pictures were taken in manual mode (Speed 100 Xs, aperture f 4.0) with obligatory flash and zoom between 4.5 - 4.9 Xs. Every frog was weighed after being photographed.

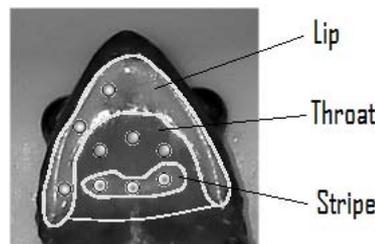
All the pictures were then processed and analysed using the software Image J. The following features were measured using a standardised guideline as shown in fig. 1: snout-to-urostyle-length (SUL), femur length, femur width, femur area, tibia length, tibia width, tibia area and foot length. To have a size reference, the scale was set to 10 mm known distance according to the ruler that was included in every photograph. The femur area was measured in ventral view pictures as the muscles were there better definable.

The colour and the area measurements of the throat were also assessed in ventral view. Most individuals showed three main coloured areas that varied in brightness. These will be referred to as the lip, the throat and the stripe (see Fig. 2), though the latter was absent in some males. The areas of the lip and the stripe were measured separately while the throat area combined the whole yellow coloured area.

To analyse the coloration we measured the total brightness plus the brightness in the red, green and blue spectra (Fig. 2). Therefore, three circles of similar size were spread evenly in the three areas - the lip, the throat and the stripe and the measurements were made for each, to achieve a representative mean. As the light of the flash was reflected in some parts of the throat, those areas were avoided for the colour analysis. Of these three sets of values the averages were calculated using Excel©. Only these averages were used for the later analysis.



**Fig. 1** Example of the body measurements: Black lines indicate the measured lengths and areas: SUL-1, femur-length -2, femur width -3, tibia length -4, tibia width -5, tibia area -6, foot length -7, femur area – 8.

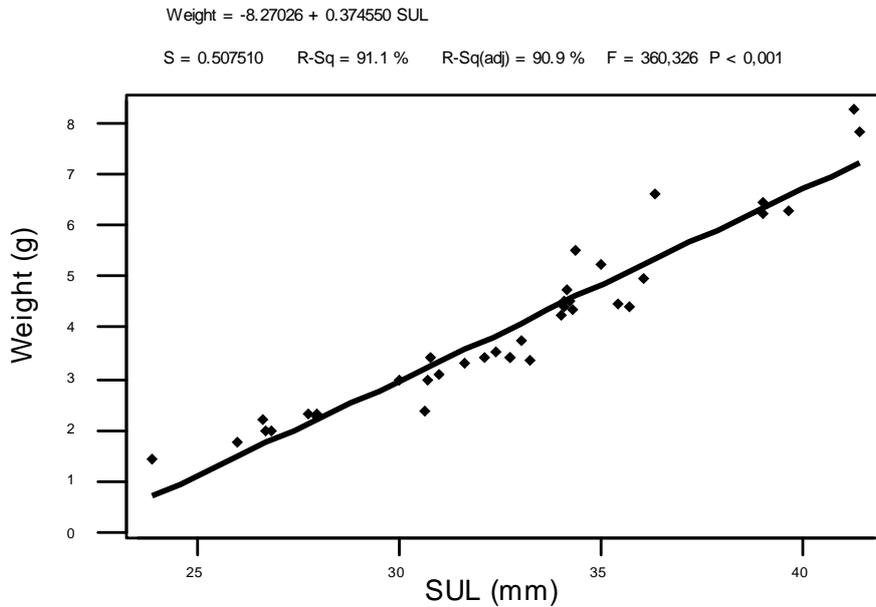


**Fig. 2** Sampling areas to estimate brightness and areas of the three regions of the throat of males *P. krefftii*. Circles represent measuring points.

Statistical analyses were conducted using Minitab©. Regression analyses were conducted to test for correlations between the measured body features and the throat colour pattern.

## RESULTS

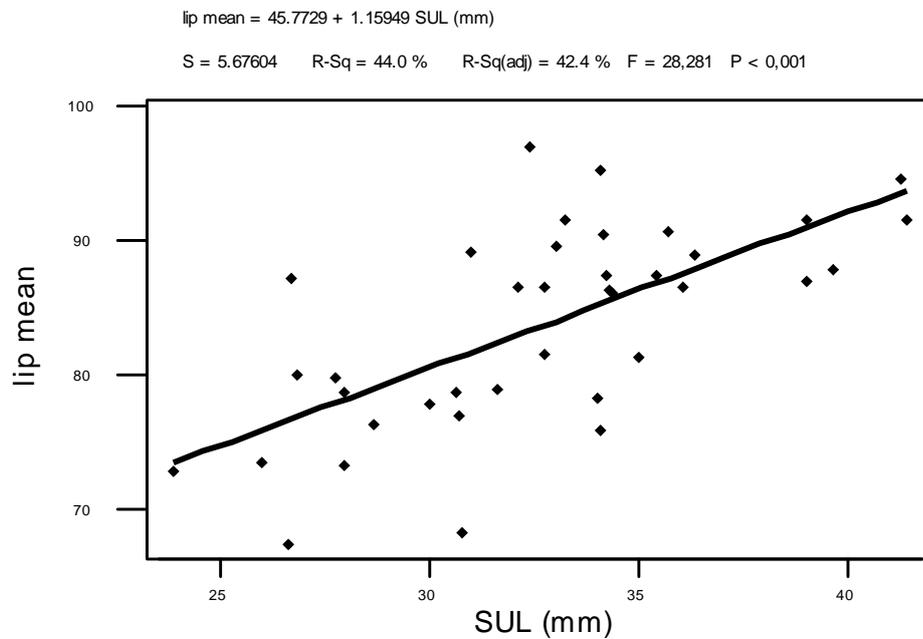
The weight and the SUL were strongly correlated (Fig. 3). The residuals of this regression were used as estimates for Body Condition Index – BCI. A positive residual value indicates that a male is relatively heavier than the average according to its size.



**Fig. 3** Relation between SUL and weight in males of *P. krefftii*. The residuals of this regression were used as estimates of the body condition, providing a body condition index (BCI)

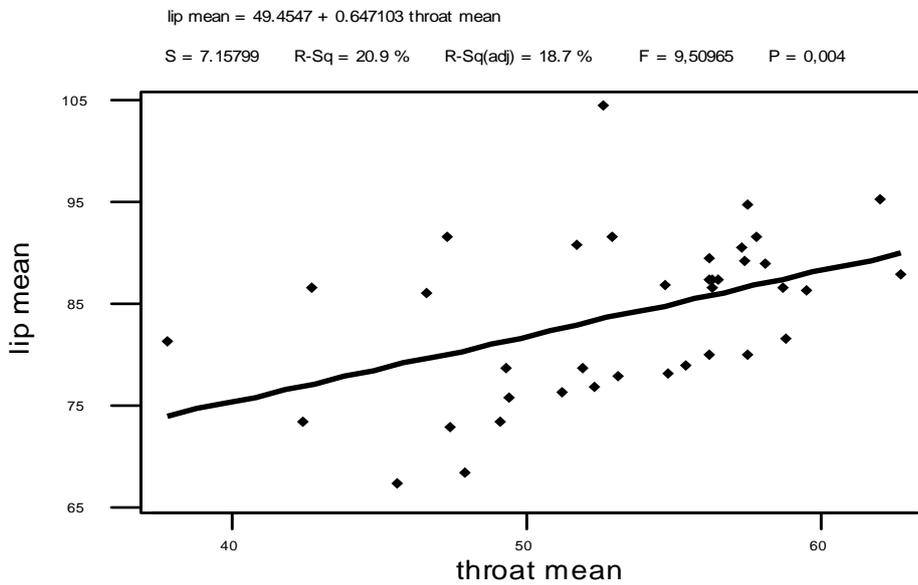
The BCI and the lip mean brightness were tested in order to see if the lip mean provides any information about the body condition. We found no significant correlation. ( $F = 0.365$  ;  $P = 0.59$ ;  $n = 38$ ).

The actual size (SUL) was then tested against the lip brightness (lip mean) and this correlation was significant ( $F = 28,28$  ;  $P < 0.001$ ;  $n = 38$ ) (Fig. 4).



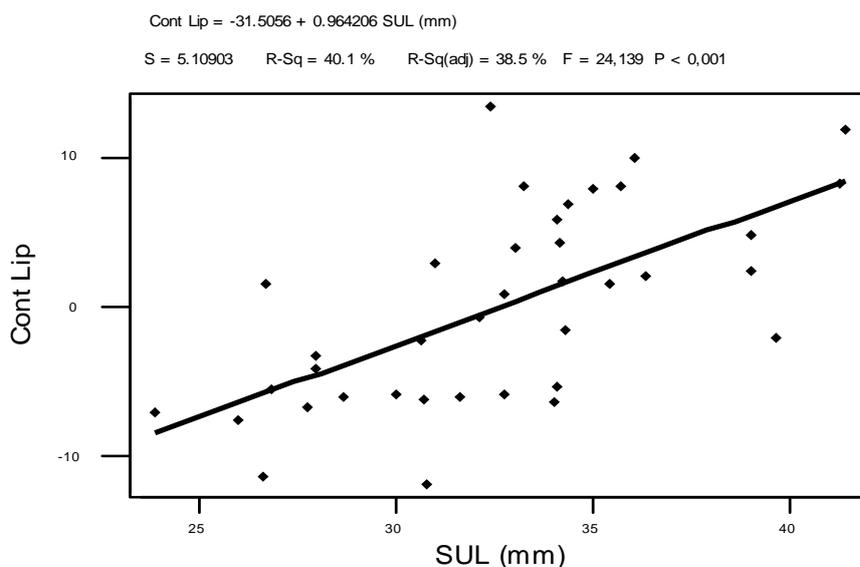
**Fig. 4** Relation between mean lip brightness (lip mean) and SUL of males *P. krefftii*

Residual values of the regression between the lip mean and the throat mean ( $F = 11.494$ ;  $P = 0.002$ ;  $n = 38$ ) were used as a measurement of the contrast compared to the average. The same procedure was followed with the stripe mean ( $F = 9.058$ ;  $P = 0.005$ ;  $n = 38$ ).



**Fig. 5 Relation between lip mean and throat mean in order to receive the residuals**

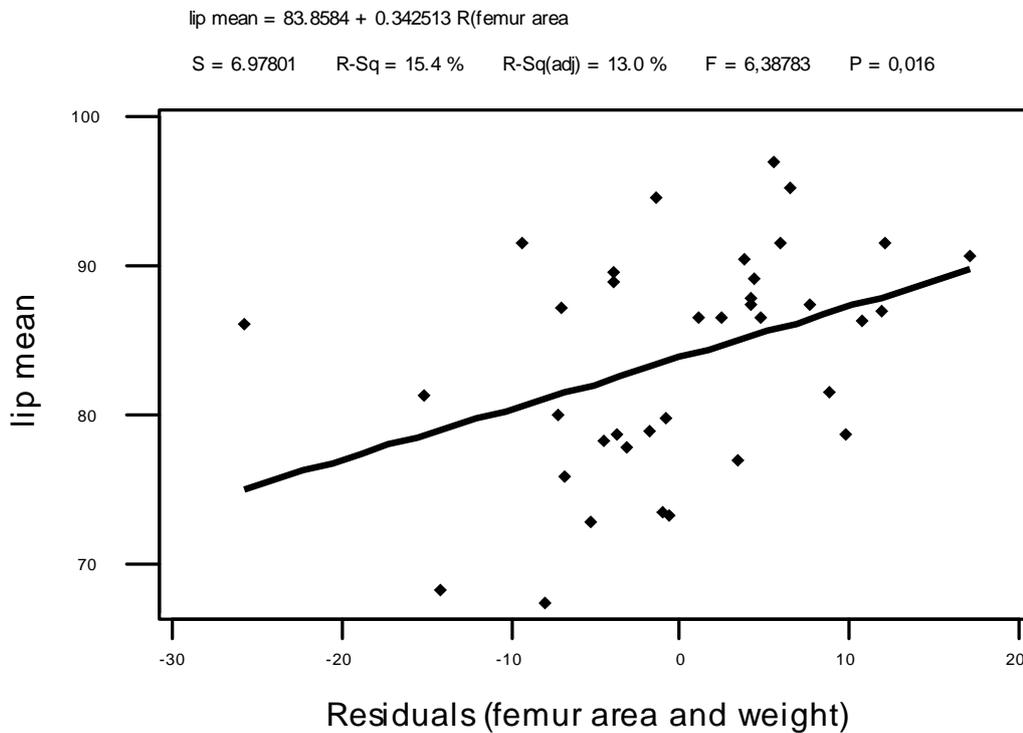
These values were then tested against the BCI: no significant correlation was found ( $F = 1.08 \text{ E-}04$ ;  $P = 0.992$ ;  $n = 38$ ;  $F = 0.975$ ;  $P = 0.331$ ;  $n = 38$ ). Nevertheless a strong significant correlation was found when these contrasts were tested against SUL (Cont Lip vs. SUL:  $F = 24.138$ ;  $P < 0.001$ ;  $n = 38$ ; Cont Stripe vs. SUL:  $F = 9.423$ ;  $P = 0.004$ ;  $n = 38$ ). (Fig. 6)



**Fig. 6 Regression between lip contrast and SUL in males of *P. krefftii*. Residual values (ContLip) of the regression of the lip mean and the throat mean were used as the contrast between the lip and the throat.**

Resembling the relative leg strength, the residuals of the relationship between the femur area and the SUL were tested against the lip mean and no significant correlation was found ( $F= 0.903$ ,  $P= 0.348$ ).

The residuals of the regression between the femur area and the weight were then also tested against the lip mean. Here, a significant relation was found ( $F = 6.388$ ;  $P = 0,016$ ) (Fig. 7).



**Fig. 7 Regression between lip mean brightness (lip mean) and residuals of the correlation femur area / weight**

## DISCUSSION

Despite our first expectation that the colouration might indicate an over-average weight to make a counterpart judgement among males possible, there is no significant correlation between the BCI and the colouration. However, the relation of the mean brightness with the body length (SUL) is significant, which might mean that the body weight is less important for other males to judge from a distance, than the actual size. This is underlined by the significant correlation between the contrast of lip/stripe and throat, as the most obvious signal, and the body length.

The relative leg area regarding the SUL showed no significant correlation to the lip brightness, whereas the relative leg size compared to the weight did. This seems to be contradictory to the conclusions above that show that the weight is of little importance. Regarding the legs, the relatively higher femur area in comparison to the weight shows that more of the weight in this frog is in the legs muscle mass, which, it is assumed, gives an advantage in movement. For opponents in

male-male interactions this may be important information. Furthermore, animals with a brighter lip have relatively larger legs but are more easily detected by predators, so they might have compensated this higher predation risk with an increased capacity to escape due to a larger muscle mass. We are not able to tell if stronger males can afford to have brighter throats as they have better escaping abilities or if they have the need to be better able to escape because they are more conspicuous.

*Phrynobatrachus krefftii*'s yellow throat colouration itself probably results from an accumulation of pigments such as carotenoids. Most animals cannot *de novo* synthesize these pigments and must obtain them with their food (Godwin 1984). We have shown that the brightness is strongly linked with size in *P. Kreffti* and thus it might be correlated with age. If this was the case, larger animals would be brighter because they would have had more time to accumulate pigments. Moreover, the level of pigments might be influenced by the foraging abilities of males, assuming that colour pigments are scarce in their environment.

In animals, testosterone is involved in development of muscle mass and growth. As size and the leg condition both play a role in the coloration, testosterone could be another causal determinant of the coloration, combining these factors. A subject for further studies on this species could be to investigate whether the brightness of the throat of *P. krefftii* provides any information about the testosterone levels in males. Furthermore it would be interesting to detect how well developed the brightness recognition abilities in *P. krefftii* are amongst both, females and other males.

## **CONCLUSION**

The conspicuous colours of the yellow throated males of *P. krefftii* revealed important potential as an honest indicator for size and leg condition of males as there is a direct and positive relation between the brightness and the size and muscle mass of the legs.

## **ACKNOWLEDGEMENTS**

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