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Bionomics and Morphometrics of the Tanzanian Muller's Clawed Frog *Xenopus muelleri* Peters (*Anura*: *Pipidae*) Corroborates Holotype with Monophyletic Oversized Lungs

Nicodemus D. Matojo[1*]

[1]Department of Life Sciences, Mkwawa University College of Education, University of Dar es Salaam, P.O.Box 2513 Iringa, Tanzania.

Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

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ABSTRACT

The pipoid frogs belonging to the super family *Pipoidea* of the order *Anura* are mostly represented in fossil forms with only limited data from the extant materials. *Pipidae* is a pipoid family of the clawed, tongueless and toothless aquatic frogs with pertinent morphological characters that include the lateral line system. They bridge an evolutionary gap between fish species and the semi-aquatic amphibians, the latest precursors of the terrestrial vertebrates. The bionomics and morphometrics of a less described Tanzanian type material of the Muller's clawed frog *Xenopus muelleri* (Peters, 1844) are here characterised, elucidating its taxonomic status and habitat sustenance. The species corroborates a holotype material with notable affinity to the African Clawed Frog, *X. laevis*. Its vulnerability to dry habitats alarms for deliberate intervention to rescuing it from massive mortality and deterioration in that period. However, *X. muelleri* demonstrates great tolerance to hypoxia mainly due to its high respiratory efficiency, indicating pronounced flexibility to inhabiting a wide range of aquatic environments hence cosmopolitan. This is largely attributed to its monophyletic oversized saclike lungs here reported for the first time. Effective husbandry of the species as a domestic pet or laboratory animal is highly encouraged alongside strategic conservation of freshwater habitats for supporting its sustainability.

**Corresponding author: Email: matojodn@yahoo.com;*

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1. INTRODUCTION

The biology and biogeography of the pipoid anurans (superfamily *Pipoidea*) are only little understood since their characters have been chiefly drawn from the fossil remains with minimal data from the extant materials [1,2,3,4-6]. The Muller's Clawed Frog, *Xenopus muelleri* (Peters, 1844), is a living pipid in the family *Pipidae* of the superfamily *Pipoidea* [7,8,9].

X. muelleri inhabits various aquatic environments of the tropical, subtropical and savannah ranges in Africa, including the forests, shrubs, grasslands, rivers, swamps, lakes, ponds, marshes, springs, canals, ditches, gardens, reservoirs, open excavations and arable lands [6,7,10]. It has been reported in various African countries [8,9,11] with limited description of the Tanzanian material due to lacking reliable data. The study herein characterises the bionomics and morphometrics of this species in Tanzania, elucidating its taxonomic status and habitat sustenance.

2. MATERIALS AND METHODS

On 14th April 2013 (wet season), a live subpopulation of *X. Muelleri* (N ≈ 124) was identified live in a shallow sluggish freshwater pond in Mawelewele area some 250 m east of the Iringa District Commissioner's office within the southern highlands of Tanzania (7° 46' 0" South, 35° 42' 0" East). A total of 5 adults per sex (total 10 specimens) were immediately captured using a wide Tupperware and collected randomly from the pond. Instantly after collection, the specimens were sacrificed and fixed by submerging them in 10% formalin for 24 hours and then shifted into 70% ethanol for preservation, following Reed [9].

Bionomic analysis of the species was based on the *in situ* parameters of its habitat as well as its behaviour. Morphological analysis was conducted in the biology laboratory at Mkwawa University College of Education based on the preserved specimens. To establish reason for high respiratory efficiency observed in the species, a total of 4 specimens (2 per sex) were dissected and their lungs analyzed for morphological compatibility.

3. RESULTS AND DISCUSSION

3.1 Bionomics

3.1.1 Ecology

The pond (Fig. 1) that hosted *X. muelleri* was situated under the tree shelter in a bushy biotope near River Ruaha's tiny tributary namely Mchambawima. It measured approximately 35 m^3 in volume (≈ 5 m length x 5 m width x 1.4 m depth). It was roughly half-filled with fresh water with an upper empty space of 0.7 m depth that was too high for the pipids to 'wall jump" and venture out. In addition, the pond had sufficient affinities for free inflow and outflow of water, which almost maintained its physicochemical parameters constant.

From June - September 2013 (dry season), however, pond water diminished and eventually dried up (see Fig. 2) notably with no significant mortality of *X. muelleri* since only 3 of 104 or 2.9% individuals died up, indicating high tolerance of the species to semi-aquatic stresses. The deaths observed were mainly caused by cutaneous desiccation due to significant water loss. All (101) survivors were consequently rescued into a conducive, aquatic environment. The mean *in situ* physicochemical parameters of the pond water were (based on weekly measurements for one month): temperature 19.6°C (±6.24), pH 7.5 (±2.07), salinity 0.4 mgl^{-1} (±0.05), DO 82% saturation (± 6.65), un-ionised ammonia 0.01 mgl^{-1}(±0.002), CO_2 4 mgl^{-1} (±1.2) and chlorine 0 mgl^{-1}. On 4th November 2013, the dry ditch was incidentally cleared for house construction, which caused a sudden habitat loss for *X. muelleri*.

3.1.2 Behaviour

In this study, *X. muelleri* has shown to be a very active swimmer aided by its well-developed hind limbs that are fully webbed for active flipping, typically like the fish fins. *X. muelleri* expends almost one-third (≈ 33%) of its time under water and the remaining part of its time i.e. almost two-third (≈ 67%) is spent surfacing. As reported earlier by various workers [10,12], this species prefers eating near the bottom, and during mating or when excited, the males normally make a low clicking call which can be heard by human up to 10 m away.

3.2 Morphometrics

3.2.1 Body colouration

Body colouration of the Tanzanian *X. muelleri* (Figs. 3-6) is within the normal range reported earlier in other countries [6,7,9] with some variation. The dorsal surface of the trunk and limbs are diagnostically light to dark brown with a medial yellow-off-orange tinge underneath; the ventral surfaces of the head and trunk are generally creamy-off-white; the hind webs are creamy-off-yellow; and there are black haphazardly interspersed speckles all over the body.

3.2.2 External anatomy

The Tanzanian *X. muelleri* reveals all key external anatomic traits of the *Pipidae* with notable intraspecific variation. These include (Figs. 3-6) the clawed, tongueless and toothless characters reported previously in the species [6-9]. The body is dorsoventrally flat and purely streamlined essentially for ensuring unrestricted aquatic movement as in most fish species (e.g. the neck is nearly lost). The body length (measured from snout to vent) compares well with the girth diameter ranging from 4.5 - 9.5 cm hence the species appears fat. Adult females are fatter and larger than the males by around 1.5 times with a protrusive yellow cloacal lip (papilla).

The skin of this frog is smooth and foamy with a fishy smell (notably for deterring predators). The head is short and broad with a slightly pointed short snout and a light line spot on the upper lip. Eyes are small, globular, dorsal and upgazing (notably for easy peering out of the watery habitat). The lateral line organ comprises a pair of dissimilar "Frankenstein stitching" rows each with more or less 24 stitches. Each fore limb has short, unwebbed, bracket-shaped fingers. In contrast, the hind limbs are extremely larger in size than the fore limb. The hind feet webbing is fully interdigital with a fade reticulate venation well pronounced between the outer 1st and 3rd digits. Each of the 3 inner hind digits is tipped with a black small apical claw.

3.2.3 Lungs

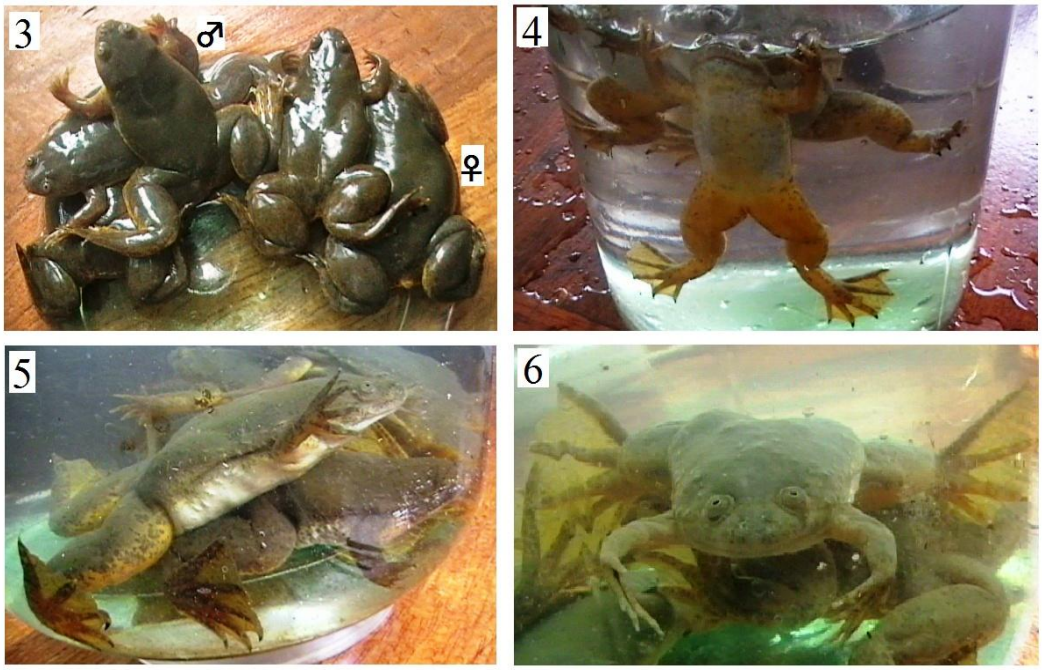
In the study, *X. muelleri* has shown great capacity to stay under water for a very long time without surfacing. This is largely attributed to its oversized and highly efficient saclike lungs that measures 4.0 – 5.5 cm in length and are well extended to the lower abdominal end (Fig. 7). Lung development and growth are directly affected by the availability of oxygen [13]; hence the findings of this study suggest that *X. Muelleri* is well adapted to survive under hypoxia (low oxygen) conditions as evidenced in most semi-aquatic environments of tropical Africa. Further analyses are needed to reveal the respiratory efficiency of this frog in relation to the histological profile of its oversized lungs.



Fig. 1. Fresh water pond containing *X. muelleri* in Iringa-Tanzania, 14th April 2013



Fig. 2. The dry ditch resulted after drying up of the pond (shown in Fig. 1), September 2013



Figs. 3-6. *X. muelleri:* 3. dorsal view; 4. ventral view; 5. side view; 6. front view, (♂ = male, ♀ = female)

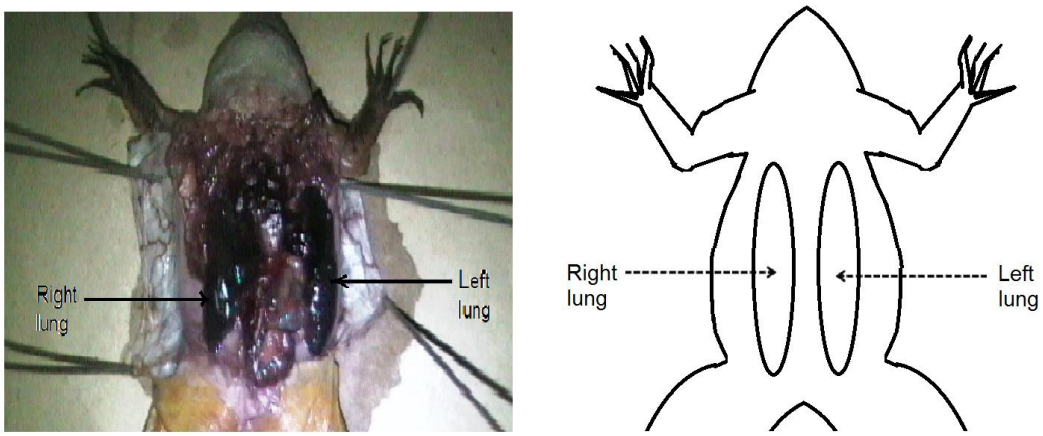


Fig. 7. Vertical dissection of *X. muelleri* showing its robust lungs

3.3 Taxonomic Status

The established ecological and morphological characters of the Tanzanian *X. muelleri* concur well with the reported holotypte material in the family *Pipidae*, superfamily *Pipoidea* of the order *Anura* [7,8]. The oversized lungs of this species facilitate additional information to its identity. Generally, the various species of the genus *Xenopus* may be easily differentiated from one another by the patterns of their skin colouration, Frankenstein stitching, fattened complexion and lung morphology. These characters clearly demonstrate that the closest relative of *X. Muelleri* is the African Clawed Frog *X. laevis* which inhabits similar ranges of the aquatic habitats in Tanzania and other African countries, as reported by other workers [9,11-14]. Similar characters may also be used to diagnose other *Xenopus* spp. such as the Marsabit Clawed Frog *Xenopus borealis* earlier misidentified as *X. muelleri* [15-17].

3.4 Conservation Status

Records are indicating that *X. muelleri* is not threatened, and does not warrant conservation action [8,10,17-19]. However, the notable exposure of this species to mortality risk attributed to seasonal habitat loss and uncontrolled anthropogenic pressures largely affect its normal existence. This alerts for a need to take remedial measures to limit massive depopulation of this species which, unlike *X. laevis,* does not seem to hibernate under mud during dry weather pending wetness reoccurrence.

4. CONCLUSION

The Tanzanian *X. muelleri* is a holotype material of the species, comprising all key characters reported elsewhere. These characters broadly include the brown to yellow colouration with distinct tinges and off-creams widely interspersed with speckles, female-biased (x1.5) size dimorphism, smooth slippery foamy skin, and lateral line organ of paired rows each with more or less 24 stitches. The lungs are monophyletically oversized, reaching the lower abdominal end. Hence the species appears to be highly tolerant to hypoxia and related stresses that precede its full exposure to terrestrial life and it is cosmopolitan in nature with good ability to occupy a wide range of aquatic and semi-aquatic habitats. This species has close affinity to the African Clawed Frog *X. laevis,* living together sympatrically in Tanzania. Effective interventions are urgently needed to support the sustainability of this species particularly by strengthening its husbandry both indoor and outdoor.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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