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Amphibian Diversity and Morphometric Analysis in the Kadayam Region of the Tirunelveli District, India

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Authors' contributions

This work was carried out in collaboration among all authors. Author SM conceptualized the study, designed the methodology, conducted the investigation, curated the data, and drafted the initial manuscript. Authors DS and DI performed the formal analysis, validated the results, and reviewed and edited the manuscript. Author ARR supervised the project, managed administrative tasks, and provided review and editing support for the final manuscript. All authors read and approved the final manuscript.

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ABSTRACT

This study examines the morphometric and genetic diversity of frog species in the agro ecosystems of Kadayam region part of the Western Ghats, a biodiversity hotspot in India. By conducting an amphibian survey in Kadayam, Southern Western Ghats, eight species from three families were

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documented, with Dicroglossidae showing the highest species representation. Amphibians were sampled from various habitats-forests, water bodies, and cultivated lands between January and March 2017, with notable species *Duttaphrynus melanostictus* showing a high abundance in human occupied areas. Morphometric analyses were performed on features such as snout-vent length, head length, (SVL–SNOW-VENT LENGTH; HL - HEAD LENGTH; HW-HEAD WIDTH; LHU–LENGTH OF THE HUMERUS; FOL-FOREARM LENGTH; THL-THIGH LENGTH; TL-TIBIA LENGTH; IOD-INTERORBITAL DIAMETER; IND-INTER NOSTRIL DISTANCE; ED-EYE DIAMETER; END–EYE–NOSTRIL DISTANCE; and FL -FOOT LENGTH) and limb proportions across species, correlating these to understand habitat adaptations. Results indicated high endemism and diversity within frog populations of the Western Ghats, highlighting conservation needs due to threats like habitat modification and pollution. The high positive correlations among primary body dimensions (such as SVL, head length, and total length) suggest that these species exhibit proportional growth in these features, a common trait in morphometric analyses. This study underscores the significance of morphometric approaches in amphibian biodiversity assessments in ecologically sensitive regions.

Keywords: Amphibian diversity; morphometric analysis; Western Ghats; Duttaphrynus melanostictus; and Euphylytic hexadactylus.

1. INTRODUCTION

Amphibians, including frogs, toads, and caecilians, are vital components of terrestrial and aquatic ecosystems, serving as both predators and prey (Pough et al., 2004). Their soft-bodied nature necessitates careful handling and preservation techniques (Duellman & Trueb, 1994). The Western Ghats of India, recognized as one of the world's 25 biodiversity hotspots, is renowned for its high amphibian diversity and endemism (Myers et al., 2000). Two primary centers of amphibian diversity exist in India: the Northeast and the Western Ghats (Inger & Dutta, 1986; Jeyaram, 1974).

Amphibians play a crucial role in maintaining ecological balance by controlling insect populations, including agricultural pests (Mazzoni et al., 2003). They also serve as a vital food source for various predators, such as birds, mammals, reptiles, spiders, and large insects (Daszak et al., 2003). Moreover, amphibians hold significant economic value, being consumed as food in some cultures (Zhou et al., 2006), utilized in traditional medicine, particularly in Chinese medicine (Clarke, 1997), and explored as potential sources of pharmaceutical compounds (Frost, 2007).

Globally, 7,044 amphibian species have been documented (Dinesh et al., 2012), with 342 species reported from India (Dinesh & Radhakrishnan, 2011). A significant portion of these species, 135 (85.99%), are endemic to the Western Ghats (Crumb, 2010). Anurans, with their biphasic life cycle, are particularly vulnerable to environmental changes (Crumb, 2010). Human-induced pressures, such as urbanization, habitat loss, pollution, and noise pollution, pose significant threats to amphibian populations (Aravind & Gururaja, 2011). This study aims to investigate the amphibian morphology and diversity.

2. MATERIALS AND METHODS

2.1 Study Area

Kadayam, situated in the Southern Western Ghats, is a region within the Tirunelveli district of Tamil Nadu. This area experiences distinct seasons: winter (December to March), summer (April to June), southwest monsoon (June to September), and northeast monsoon (October to November). November typically receives the highest rainfall, with annual precipitation ranging from 801 to 1000 mm. The study area is predominantly characterized by agricultural lands.

2.2 Amphibian Survey

In the selected sampling sites, amphibians were systematically sampled between 18:30-20:30 h from January to March 2017 to quantify seasonal changes in diversity. An extensive survey was conducted in the agricultural lands of Kadayam, region of Tirunelveli, Southern Western Ghats.In this study, the weekly field observations that were made throughout the study period was analyzed. Using *ad hoc* searches, we sampled the amphibian diversity in different sites, Quadrate search (size: 2 X 2 m) were demarcated on the agricultural areas and search thoroughly by two observers for a period of three months between January to March 2017 (Bhupathy & Sathishkumar, 2013). The exact location of different amphibian species was noted. The amphibian species were treated humanely according to MS University guidelines (MSU/DAS/EC/2016) and followed the animal research regulations (https://www.understandinganimalresearch.org.uk/openness/regulation/). All species encountered were identified using Bossuyt & Dubois (2001), Daniels (2001) and Biju & Bossuyt (2009).

The amphibians morphometric analysis (SVL–SNOW-VENT LENGTH; HL - HEAD LENGTH; HW-HEAD WIDTH; LHU–LENGTH OF THE HUMERUS; FOL-FOREARM LENGTH; THL-THIGH LENGTH; TL-TIBIA LENGTH; IOD-INTERORBITAL DIAMETER; IND-INTER NOSTRIL DISTANCE; ED-EYE DIAMETER; END–EYE–NOSTRIL DISTANCE; and FL - FOOT LENGTH) were recorded using various tools. For length and width measurements, we used a Vernier Caliper (Model: AERO SPACE, Size: 200 x 0.02mm, 8" x 0.001in, Made in China). Photographs were captured with a Samsung Galaxy Camera 2 (Model: EK-GC200, 720 x 1280 pixels, 16.3 MP CMOS sensor, 21x Optical Zoom, 4.8” Touch Screen LCD, OS: Android 4.3, 1.6 GHz quad-core processor, Made in China). Additional measurements were taken with a thread method, a geometrical divider, a measuring tape, and a standard ruler.

3. RESULTS AND DISCUSSION

Eight species of amphibians belonging to three families and four genera were documented, in Kadayam region Southern Western-Ghats among the three families, Dicroglossidae had the highest number of species (two species), followed by Bufonidae (one species) and Microhylidae (one species). The frog species, *Duttaphrynus melanostictus* were the most common. It was a commonly encountered species and showed high relative abundance near human habitation.

Family Dicroglossidae comprised of two species, it was widespread in the study area. *Sphaerotheca* species was rare, and the species were found only in burrows on river bank. Amphibians detected during the sampling period were broadly categorized as being found in three habitats: forest, water and cultivation areas. The highest number of species were sighted on freshwater bodies (two species) and forest areas (one species) and cultivation areas (one species).

Morphometric variables Ghats (Table 1 and Figs. 1-3) show strong positive correlations with each other. For example, snout vent length (SVL) is positively correlated with total length (V1), head length (V4), and total weight (V2). This shows that as the body size (SVL) of the frogs increases, their overall length and weight also tend to increase, indicating a proportional growth pattern. Variables like eye diameter (V8) and eye-nostril distance (V9) also show positive correlations with head dimensions like head width (V5) and head length (V4). This may indicate that larger frogs generally have proportionally larger head features. In the Tables 1-4, certain head related variables occasionally show weaker or negative correlations with body size. For instance, inter-nostril distance (V7) appears to be weakly or negatively correlated with some other body dimensions, like total weight (V2). This suggests that while overall body and head sizes are positively correlated, finer features like nostril spacing may vary independently. Some variables related to smaller limb and body features may also show weak negative correlations with overall length, as these features might not scale as predictably with the larger body dimensions.

The findings affirm the Western Ghats as a crucial habitat for diverse amphibian species, particularly frogs, which display both unique morphological traits distinctions shaped by their environment (Bhupathy & Sathishkumar, 2013; Ganesh et al., 2020; Bisht et al., 2021). The high relative abundance of *Duttaphrynus melanostictus* near human habitation points to its adaptability, contrasting with more habitatspecific species like *Sphaerotheca*, found only in specific burrowed niches on riverbanks (Aravind & Gururaja, 2011; Ganesh et al., 2020; Bisht et al., 2021).

This study underscores the need for habitat conservation, particularly as urbanization, pollution, and agricultural expansion threaten these amphibian populations (Gardner et al., 2007). Western Ghats. Conservation strategies informed by both genetic and morphometric data are essential to safeguard the ecological roles and evolutionary trajectories of these species (Watters et al., 2016).

Table 1. Morphometric analysis of frog species collected from Kadayam, South Western Ghats

S.NO	SPECIES name	L (cm)	W (g)	SVL (cm)	HL (cm)	HW (cm)	IOD (mm)	IND (mm)	ED (mm)	END (mm)	TD (mm)	LHU (mm)	FOL (cm)	THL (cm)	TL (cm)	FL (cm)
1	*Duttaphrynus melanostictus*	12.5	27.85	6.5	2.5	2.6	0.8	0.5	1	0.5	0.5	1	1.7	2.2	2.3	3
2	*Sphaerotheca* sp	10.5	19.05	5	2.1	3.2	0.5	0.5	0.8	0.3	0.5	1	1.2	2	2	3
3	*Uperodon variegate*	7	13.94	5.1	1.5	3.1	0.6	0.4	0.5	0.2	0.3	0.8	1.1	2.5	1.6	2.7
4	*Duttaphrynus melanostictus*	8	17.10	6	2.1	3.0	0.5	0.5	0.7	0.3	0.3	0.8	1.2	2.1	2.1	3
5	*Duttaphrynus melanostictus*	6.5	8.54	5	1.8	2.6	0.5	0.2	0.6	0.2	0.5	0.5	1.1	1.8	1.6	2.5
6	*Duttaphrynus melanostictus*	8	8.55	5.5	1.7	2.5	0.5	0.4	0.7	0.2	0.2	0.6	1.1	2	1.8	2.6
7	*Euphylytic hexadactylus*	27.5	239.77	16	6.5	7	2	0.6	1.5	1	1.2	1.3	2.6	3.5	4.5	8.2
8	*Euphylytic hexadactylus*	29.2	300	18.2	7.1	7	2.4	0.8	1.5	1.2	1.3	2	2.6	3.5	5	8.4

(SVL –SNOW-VENT LENGTH; HL - HEAD LENGTH; HW -HEAD WIDTH; LHU –LENGTH OF THE HUMERUS; FOL-FOREARM LENGTH; THL -THIGH LENGTH; TL -TIBIA LENGTH; IOD -INTER ORBITAL DIAMETER; IND -INTER –NOSTRIL DISTANCE; ED -EYE DIAMETER; END –EYE –NOSTRIL DISTANCE; FL -FOOT LENGTH)

Table 2. Frog *Dattaphyrnux* sp correlation coefficient matrix between the variables

	***Dattaphyrynus* sp**														
	V1	**V2**	**V3**	**V4**	**V5**	**V6**	**V7**	**V8**	**V9**	**V10**	**V11**	**V12**	**V13**	**V14**	**V15**
V1															
V2	0.924022														
V3	0.895294	0.925743													
V4	0.883541	0.993178	0.882883												
V5	-0.13019	0.218553	0.273273	0.261426											
V6	0.96225	0.897913	0.768832	0.881104	-0.22549										
V7	0.680414	0.716986	0.921434	0.655826	0.425195	0.471405									
V8	1	0.924022	0.895294	0.883541	-0.13019	0.96225	0.680414								
V9	0.952579	0.993285	0.903005	0.983739	0.106299	0.942809	0.666667	0.952579							
V10	0.32075	0.42931	0.056468	0.510113	-0.12527	0.555556	-0.31427	0.32075	0.471405						
V11	0.911322	0.976435	0.984371	0.951589	0.288136	0.826811	0.85039	0.911322	0.956689	0.225494					
V12	0.971537	0.957979	0.846118	0.944501	-0.06542	0.98644	0.574427	0.971537	0.984732	0.522233	0.902829				
V13	0.845154	0.856603	0.988111	0.801036	0.286077	0.68313	0.966092	0.845154	0.828079	-0.09759	0.946256	0.764471			
V14	0.866578	0.940937	0.99332	0.90984	0.362632	0.750479	0.909718	0.866578	0.909718	0.107211	0.991194	0.839839	0.973035		
V15	0.695174	0.867239	0.92408	0.855198	0.614474	0.570352	0.896221	0.695174	0.806599	0.063372	0.928856	0.694999	0.909124	0.957987	

(V1-TOTAL LENGTH; V2- TOTAL WEIGHT; V3 –SNOW-VENT LENGTH; V4 - HEAD LENGTH; V5 -HEAD WIDTH; V6 -INTER ORBITAL DIAMETER; V7 -INTER –NOSTRIL DISTANCE; V8 -EYE DIAMETER; V9 –EYE –NOSTRIL DISTANCE; V10 - TYMPANUM DIAMETER; V11 –LENGTH OF THE HUMERUS; V12-FOREARM LENGTH; V13 -THIGH LENGTH; V14 -TIBIA LENGTH; V15 -FOOT LENGTH).

Table 3. *Euphylytic hexadactylus* correlation coefficient matrix between all variables

Frog Morphometry															
		V2	**V3**	**V4**	**V5**	**V6**	**V7**	**V8**	**V9**	**V10**	**V11**	**V12**	**V13**	**V14**	**V15**
V1															
V2	0.9826932														
V3	0.9839443	0.997075													
V4	0.9929375	0.993605	0.995190												
V5	0.967914	0.982292	0.976535	0.978535											
V6	0.9842591	0.995117	0.994711	0.98983	0.968812										
V7	0.839321	0.815027	0.815323	0.814631	0.785577	0.813362									
V8	0.9801859	0.933686	0.943715	0.963361	0.908138	0.940783	0.828329								
V9	0.9906382	0.979142	0.982631	0.988368	0.947236	0.986171	0.857394	0.974549							
V10	0.9684353	0.966159	0.957237	0.974940	0.955076	0.963816	0.733176	0.937056	0.963116						
V11	0.9063365	0.905772	0.892191	0.893776	0.862429	0.909372	0.940268	0.869584	0.930180	0.871519					
V12	0.9868083	0.958310	0.967752	0.977853	0.936718	0.972180	0.808172	0.983261	0.987851	0.955144	0.875600				
V13	0.9389387	0.950816	0.950862	0.938192	0.963563	0.956873	0.798914	0.870575	0.926632	0.893028	0.855659	0.927966			
V14	0.9931221	0.990115	0.993611	0.996957	0.970714	0.987037	0.854162	0.968337	0.992334	0.959976	0.912732	0.977788	0.937151		
V15	0.9864673	0.992580	0.992674	0.994724	0.993251	0.984895	0.802520	0.943773	0.972652	0.964735	0.874814	0.965093	0.958371	0.989819	

(V1-TOTAL LENGTH; V2- TOTAL WEIGHT; V3 –SNOW-VENT LENGTH; V4 - HEAD LENGTH; V5 -HEAD WIDTH; V6 -INTER ORBITAL DIAMETER; V7 -INTER –NOSTRIL DISTANCE; V8 -EYE DIAMETER; V9 –EYE –NOSTRIL DISTANCE; V10 - TYMPANUM DIAMETER; V11 –LENGTH OF THE HUMERUS; V12-FOREARM LENGTH; V13 -THIGH LENGTH; V14 -TIBIA LENGTH; V15 -FOOT LENGTH).

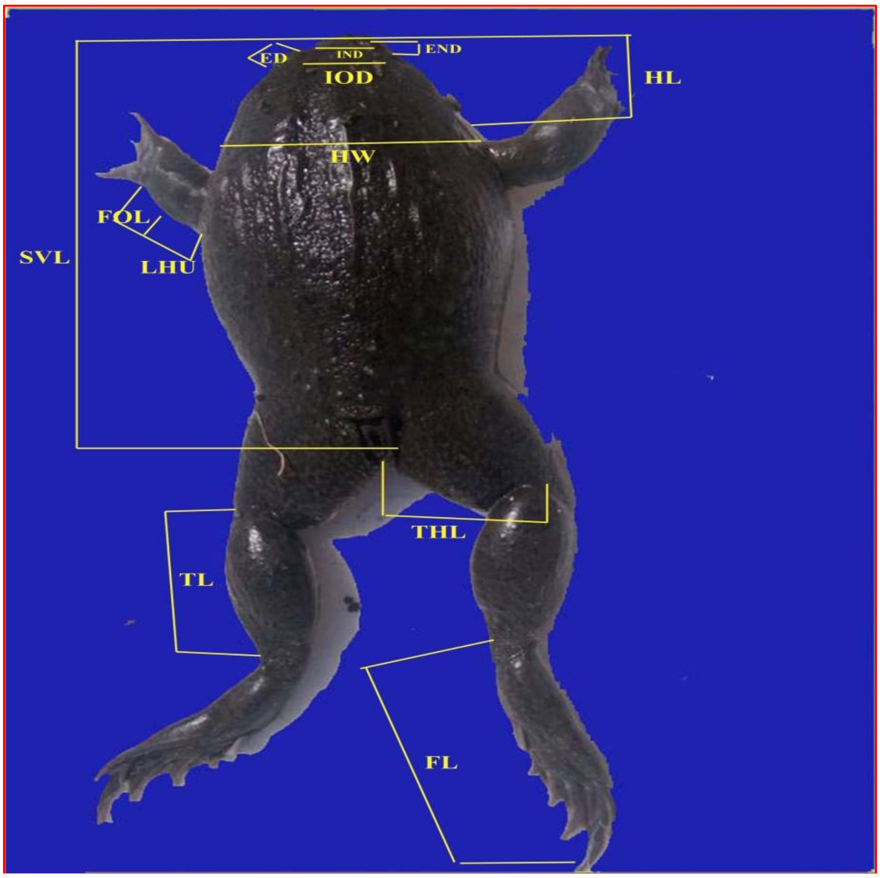

Fig. 1. Morphometric Characteristics of *Euphlyctis hexadactylus*

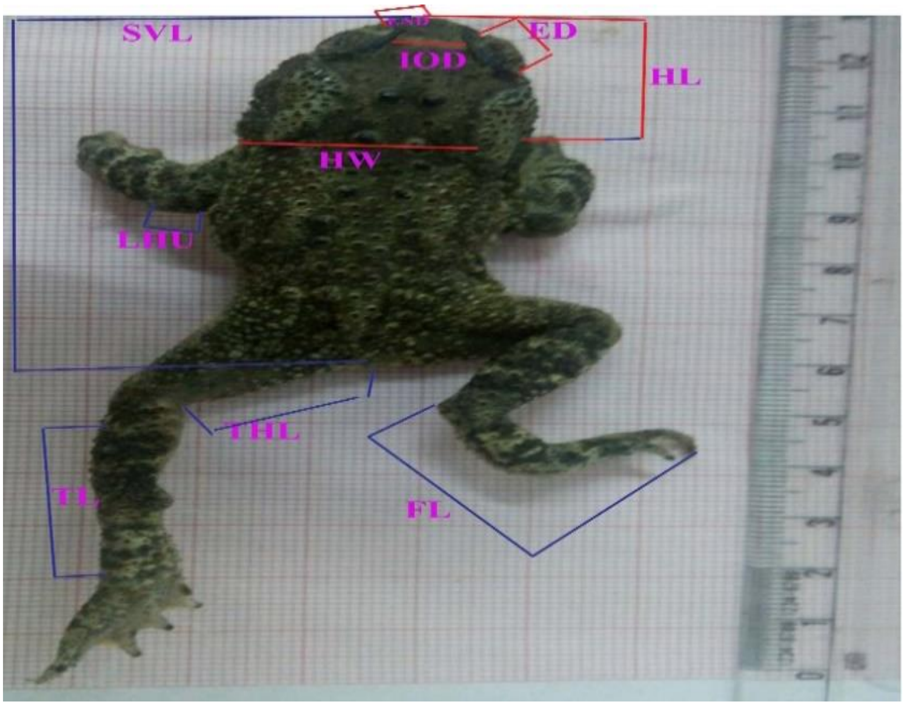

Fig. 2. Morphometric Characteristics of *Duttaphrynus melanosiictus*

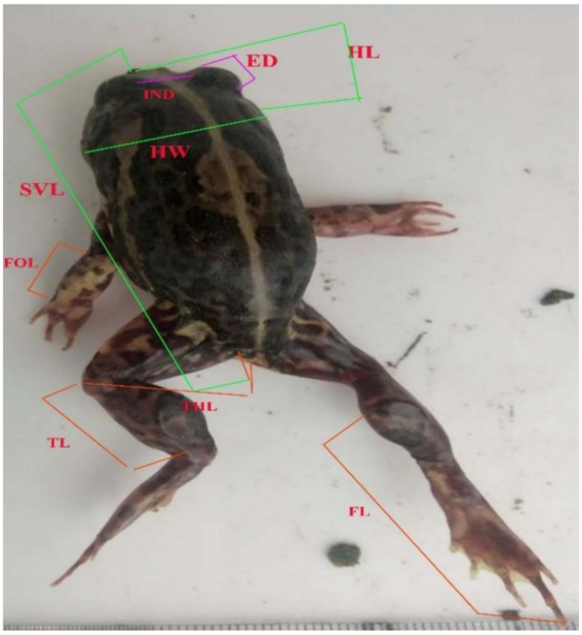

Fig. 3. Morphometric Characteristics of *Sphaerotheca sp.*

Table 4. Morphometric characteristics of *Euphlyctis hexadactylus*

	Mean	SD	Sum	Min.	Max.
L/SVL	1.6005	0.29347	12.804	1.3	2.1
W/SVL	6.04988	6.05894	48.399	1.554	16.48
HL/SVL	0.36413	0.0449	2.913	0.294	0.42
HW/SVL	0.49275	0.09302	3.942	0.384	0.64
IOD/SVL	0.10863	0.01772	0.869	0.083	0.131
IND/SVL	0.06612	0.02321	0.529	0.037	0.1
ED/SVL	0.11863	0.02776	0.949	0.082	0.16
END/SVL	0.0535	0.01446	0.428	0.036	0.076
TD/SVL	0.07075	0.02254	0.566	0.036	0.1
LHU/SVL	0.13012	0.03835	1.041	0.081	0.2
FOL/SVL	0.20508	0.03885	1.6406	0.142	0.261
THL/SVL	0.33887	0.09555	2.711	0.192	0.49
TL/SVL	0.32725	0.04089	2.618	0.274	0.4
FL/SVL	0.50438	0.04576	4.035	0.461	0.6

The high positive correlations among primary body dimensions (such as SVL, head length, and total length) suggest that these species exhibit proportional growth in these features, a common trait in morphometric analyses. However, weaker or negative correlations in finer details (e.g., inter-nostril or tympanum diameter) may indicate adaptations that vary independently of overall size, possibly due to specific ecological or behavioral factors. This analysis supports the understanding that morphometric characteristics are interrelated, though some may vary independently, possibly due to environmental pressures or species-specific adaptations. The observed morphometric flexibility in smaller features may represent evolutionary strategies to cope with environmental stressors, such as pollution and habitat modification, which are prevalent in this region (Gardner et al., 2007; Watters et al., 2016; Bisht et al., 2021).

4. CONCLUSION

This study on frog species in the Kadayam region of the Western Ghats reveals high species diversity, emphasizing their critical ecological roles in this biodiversity hotspot. Positive correlations in primary body dimensions suggest proportional growth adapted to diverse habitats, while variations in finer traits indicate specific environmental adaptations. The findings highlight the necessity for targeted conservation efforts, as these amphibians face increasing threats from habitat loss and pollution. Integrating morphometric and species diversity can guide conservation strategies to preserve these species, promoting habitat protection and sustainable land management within the Western Ghats for long-term biodiversity conservation.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc have been used during writing or editing of this manuscript. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology.

Details of the AI usage are given below:

1. Gemini
2. ChatGPT

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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