Journal of Environmental Biology
p-ISSN: 0254-8704 • e-ISSN: 2394-0379 • CODEN: JEBIDP

JEB®

Original Research Paper
Volume 46 Issue 3 May 2025 pp. 439-449
DOI: http://doi.org/10.22438/jeb/46/3/MRN-5533

J. Environ. Biol., 2025
© Triveni Enterprises, Lucknow (India)
Journal website : www.jeb.co.in ★ E-mail : editor@jeb.co.in

Comparative abundance and diversity of anurans in transplanted and direct seeded rice crop agroecosystem

R. Kaur[1], R. Singh[1]* and K.P. Dinesh[2]

[1]*Department of Zoology, Punjab Agricultural University, Ludhiana-141 004, India*
[2]*Zoological Survey of India, Western Reigional Centre, Pune-411 044, India*

Received: 31 August 2024 **Revised:** 09 January 2025 **Accepted:** 14 February 2025

***Corresponding Author Email:** rajwinder-singh@pau.edu ***ORCiD:** https://orcid.org/0000-0003-2802-6088

Abstract

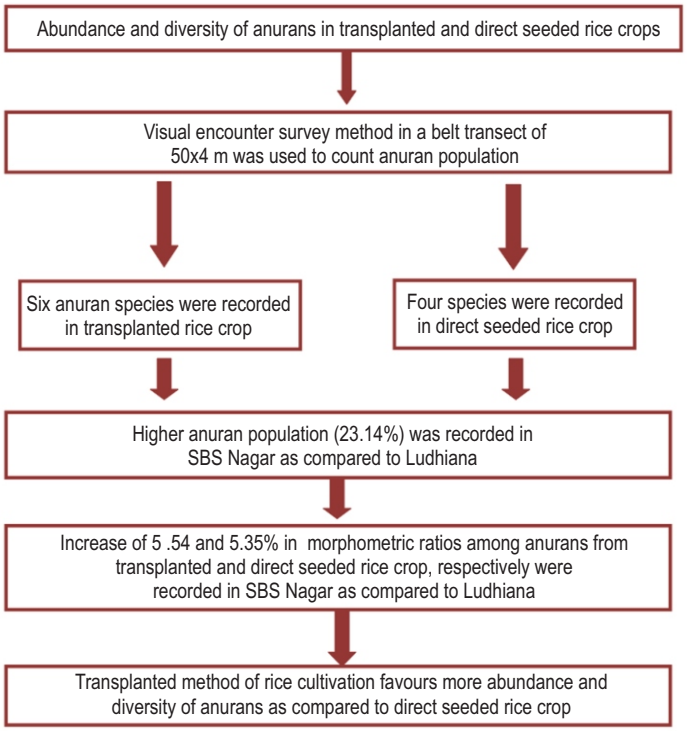
Aim: Present study investigated the diversity, abundance and morphometry of anuran population in transplanted rice and direct seeded rice (DSR) agroecosystems in district Ludhiana and SBS Nagar during 2022 and 2023.

Methodology: Visual Encounter Survey Method (VESM) was applied for estimating the anuran population in a belt transect of 50×4 m along a survey path at fortnight interval, and was pooled at month level from June to October.

Results: Six and four anuran species were recorded from transplanted and DSR crop, respectively. Higher anuran population was reported from SBS Nagar in transplanted (14.81-19.32%) and DSR (28.49-29.93%) respectively as compared to Ludhiana. However, transplanted rice accommodated 24.71-33.72% more anurans than DSR crop. Positive correlation was recorded between anuran population and atmospheric temperature (0.181-0.492) and% relative humidity (0.628-0.822). Morphometric analysis revealed increase in body ratios of anurans (5.54 and 5.35% in transplanted and DSR, respectively) as compared to Ludhiana.

Interpretation: Transplanted rice agroecosystems offer better habitat conditions for survival of anuran populations as compared to direct seeded rice (DSR) fields.

Key words: Anurans, Diversity, Direct seeded rice crop, Transplanted rice crop



Triveni Enterprises (Educational Services Set-up)

How to cite: Kaur, R., R. Singh and K.P. Dinesh: Comparative abundance and diversity of anurans in transplanted and direct seeded rice crop agroecosystem. *J. Environ. Biol.*, **46,** 439-449 (2025).

Introduction

Order Anura include frogs and toads which are diverse and widespread among amphibians. Over 7,600 anuran species are described worldwide and distributed in all types of ecosystems on six continents. These amphibians are highly adaptable and survive the tropical rainforest as well as arid deserts, from sea level up to high mountain regions. In an overview and comprehensive assessment, Sreekumar *et al.* (2023) recently, estimated 447 species of anurans from India, which is about 5.9% of global anuran diversity. This rich anuran fauna is spread over different biogeographic zones of the country. The major diversity hotspots of anurans in India are the Western Ghats, Eastern Himalayas, and the Northeast. Anurans are taxonomically classified under Class Amphibia and are further divided into 54 families and 456 genera. Recent molecular phylogenetic studies have greatly changed anuran taxonomy by untangling the intricate evolutionary relationships and opening new descriptions of species and genera (Fouquet *et al*., 2015).

Anurans are vital components of agroecosystems playing an important role in nutrient cycling, insect pest control and general biodiversity maintenance (Attademo *et al.,* 2005). In particular, rice fields can provide breeding and foraging habitats of great value for many anuran species (Zheng *et al.,* 2019). However, the intensification of the methods to cultivate rice, be it through the use of agro-chemicals or through other farm machinery, has been a major cause of the anuran decline in several parts of the world (Paoletti *et al.,* 2007). Rice fields can be important habitats for many anuran species because they provide several necessary resources, such as standing water for breeding, an abundance of insect prey and vegetative cover for refuge and foraging. Although rice fields can serve as potentially good habitat for anurans, there are many environmental and management factors that affect them. Agrochemical inputs, water management regimes, the timing and intensity of field operations all may have some impact on the anuran community composition and population dynamics (Paoletti *et al.,* 2007, Verma and Murmu, 2015).

In India, rice is cultivated by transplanted and direct seeded rice (DSR) method. Due to differences in habitat structure and resource availability, there may be an effect on anuran communities. In transplanted fields, the presence of shallow standing water during much of the growing season may favour species adapted to aquatic breeding, such as those with free-swimming larvae (tadpoles) that require inundated habitats for development (Kukunuru and Kanamadi, 2014; Verma and Murmu, 2015). In contrast, the drier soil conditions typically in DSR during early establishment may select for more terrestrial, direct-developing anuran species that are less dependent on permanent water bodies (Deka and Hazarika, 2013; Duan *et al.,* 2020). Decline of anurans in agricultural operations, especially in rice fields is in addition, due to selecting crop varieties with short duration of harvesting, semi-dry crop types, which reduce the opportunities of anurans to colonize and to reproduce. In India, while transplanted rice remains dominant covering approximately 85-90% of the total rice area, DSR adoption has gradually increased to about 10-15% (Bhullar *et al.,* 2022). Punjab has emerged as a leader in DSR adoption, with coverage expanding from less than 5% in 2020 to approximately 30% (around 600,000 hectares) in 2022, primarily driven by groundwater concerns and labor shortages (Singh *et al.,* 2023). This shift has significant implications for both water conservation and biodiversity, including anuran populations in rice ecosystems.

The morphometric traits of anurans, such as body size and limb length, may provide inferences to resource use strategies, habitat preferences` and ecological roles within the agroecosystem (Duan *et al.,* 2020). Larger anurans with longer legs might be generally better adapted to movement on land and resource use into drier DSR fields, while the smaller anurans with smoother skin would do well in more aquatic transplanted agroecosystem (Kukunuru and Kanamadi, 2014). While anurans have been studied widely for rice production systems (Hossain *et al.,* 2016; Kross *et al.,* 2016), only few studies have made a comparative assessment of anuran diversity and their morphometric traits in transplanted and DSR systems in a similar agro-ecological context. To bridge this gap, a field study was conducted to determine and compare the anuran diversity of two rice cultivation techniques (transplanted and DSR) in terms of diversity and morphometric characteristics. Elucidating these linkages between anuran diversity within transplanted and DSR rice crop fields enhances our knowledge of the ecological consequences of rice cultivation practices for better development of management strategies that support agricultural productivity and biodiversity conservation of anurans. This information could also be useful for developing sustainable intensification practices that would sustain healthy and diverse community as integral elements of resilient rice-agro-ecosystems.

Materials and Methods

Selection of site: The present study was carried out at five selected villages each of district Ludhiana (Bhattian, Chak Kalan, Jainpur, Nurpur Bet and Salempur) and district Shaheed Bhagat Singh (SBS) Nagar (Karyam, Saloh, Bakhlaur, Begampur and Mehmudpur), Department of Zoology and Department of Entomology, Punjab Agricultural University, Ludhiana during 2022 and 2023. Ludhiana is located between the coordinates 30.9010° N in the central region of the Punjab State, 75.8573° E, while SBS Nagar lies between the coordinates 31.0913° N, 76.0392° E. Total number of individual caught were 561 during both the years of study.

Sampling of anurans: Visual Encounter Survey Method (VESM) was applied for estimating the anuran population (Heyer, 1994) in a belt transect of 50×4 m along a survey path at fortnight interval, and was pooled at month level from June to October for transplanted and DSR crops during 2022 and 2023. Each anuran species was captured with hand wearing gloves from selected locations, photographed using Nikon D 3800 D-SLR camera for identification, checked for any morphological abnormalities and

released back in their natural habitat. Anurans were identified from ZSI (Zoological Survey of India), Pune and using keys published by Daniel (2005). Body weight (g) of each anuran was recorded using an electronic weighing balance (Kerro® BL-P1D/20001) and morphometric measurements were taken using a digital vernier calliper (Themisto® TH-M61) which included ;head length (mm), head width (mm), head depth at angle of jaw (mm), snout length (mm), eye to nostril distance (mm) , nostril to snout distance (mm) and eye diameter (mm). Data on atmospheric temperature (^{0}C), relative humidity (%) and rainfall (mm) were taken from the Department of Climate Change and Agricultural Meteorology, PAU, Ludhiana and Dr D R Bhumbla Regional Research Station, Ballowal Saunkhri for Ludhiana and SBS Nagar, respectively .

Calculation of various indices

To calculate biodiversity indices, following formulae were used: Shannon index

$$H' = -\Sigma (pi \times \ln pi)$$

Where, H' = Shannon index; p_i = Total number of individuals in a particular sample

Pielou's species evenness

$$J = \frac{H'}{\ln(S)}$$

Where, J = Species evenness; H'= Shannon index; S= The total number of species in the community

Statistical analysis: For diversity of anurans and morphometric measurements, the data was analyzed using mean ± standard deviation (S.D.) and ANOVA and was compared using Tukey's test, considering a p-value of 0.05. Different indices like Shannon index, species evenness and species richness were calculated using different formulas. Correlation coefficient was calculated to find relation between anuran diversity and atmospheric temperature (^{0}C), rainfall (mm) and relative humidity (%).

Results and Discussion

Interestingly, six anuran species *Duttaphrynus melanostictus, D. stomaticus, Euphylyctis cyanophlyctis, E. adolfi, Hoplobatrachus tigerinus* and *Fejerverya limnocharis* were recorded from transplanted rice agroecosystem whereas in contrast, only four anuran species *D. melanostictus, D. stomaticus, E. cyanophlyctis* and *H. tigerinus* belonging to families bufonidae and dicroglossidae under Order Anura were recorded from DSR agroecosystem (Table 1). The seasonal activities of all the recorded anuran species were reported from May to December months with higher population during July and August months.

Anuran population in transplanted rice agroecosystem of district Ludhiana and SBS Nagar: In district Ludhiana, from all the villages the anuran population ranged between 3.62 to 6.97 and 4.47 to 7.04 individuals/month/transect with pooled mean of 4.04 to 7.00 during 2022 and 2023, respectively, highest in village Salempur (6.97 and 7.04 individuals/month/transect during 2022 and 2023) and lowest in Jainpur (3.62 and 4.47 individuals/

Table 1: Inventory of anuran species recorded in transplanted and DSR agroecosystems of district Ludhiana and SBS Nagar

Common name	Scientific name	Family	Aquatic ecosystem		Terrestrial ecosystem		Transplanted rice crop		DSR Crop	
			Ludhiana	SBS Nagar	Ludhiana	SBS Nagar	Ludhiana	SBS Nagar	Ludhiana	SBS Nagar
Common Asian toad	*Duttaphrynus melanostictus* (Schneider, 1799)	Bufonidae	✓	✓	✓	✓	✓	✓	✓	✓
Indian marble toad	*Duttaphrynus stomaticus* (Lütken, 1864)		✓	✓	✓	✓	✓	✓	✓	✓
Indian skittering frog	*Euphlyctis cyanophlyctis* (Schneider, 1799)		✓	✓	×	×	✓	✓	✓	✓
Adolf's speckled frog	*Euphlyctis adolfi* (Günther,1860)		×	×	×	×	✓	✓	×	×
Rice field frog	*Fejervarya limnocharis* (Gravenhorst, 1829)	Dicroglossidae	×	×	×	×	✓	✓	×	×
Indian bull frog	*Hoplobatrachus tigerinus* (Daudin, 1802)									

* (✓) Indicates presence of species; * (×) Indicates absence of species

On Line Copy

Table 2: Comparison of anuran population in transplanted and DSR agroecosystems of district Ludhiana and SBS Nagar during 2022 and 2023

Villages	Population mean (2022)	Population mean (2023)	Per cent population variation in 2023 over 2022	Population mean (2022)	Population mean (2023)	Per cent population variation in 2023 over 2022
	Transplanted rice agroecosystem			DSR agroecosystem		
			Ludhiana			
Chak Kalan	5.76[a]	6.37[a]	+10.59	4.76[a]	5.27[b]	+13.56
Bhattian	6.32[a]	6.96[a]	+10.12	5.37[a]	5.67[a]	+6.86
Nurpur Bet	5.72[a]	6.24[Ca]	+9.09	4.96[a]	5.40[b]	+11.11
Salempur	6.97[a]	7.04[a]	+1.00	2.57[a]	2.95[b]	+24.20
Jainpur	3.62[a]	4.47[b]	+23.48	3.54[a]	3.96[b]	+16.53
Total	5.67[a]	6.21[b]	+9.52	4.24[a]	4.65[b]	+9.66
			SBS Nagar			
Karyam	6.39[a]	7.51[b]	+17.57	5.00[a]	5.65[b]	+16.25
Begampur	6.24[a]	6.91[a]	+10.73	5.87[a]	5.97[a]	+2.05
Mehmudpur	7.15[a]	7.81[a]	+9.23	5.63[a]	5.90[a]	+5.83
Saloh	5.74[a]	7.15[b]	+24.56	4.60[a]	5.09[b]	+13.61
Bakhlaur	7.04[a]	7.71[a]	+9.51	5.02[a]	5.87[b]	+21.14
Total	6.51[a]	7.41[a]	+13.82	5.22[a]	5.69[b]	+9.00

*Statistical analysis (ANOVA) showed significant result with p value = 0.05; *Mean value followed by same letter (a,b) in the given table above are not significantly different as per Tukey's test

month/ transect during 2022 and 2023) (Table 2). The maximum variation (increase) in population during 2023 was recorded in village Jainpur with 23.48% increase, followed by Chak Kalan (10.59%), Bhattian (10.12%), Nurpur Bet (9.09%) and Salempur (1.00%) as compared to 2022. An overall increase of 9.52% anuran population was recorded in district Ludhiana during 2023 as compared to 2022. In district SBS Nagar, from all the villages the anuran population ranged between 5.74 to 7.15 and 6.91 to 7.81 individuals/month/transect with pooled mean of 6.51 to 7.41 during 2022 and 2023, highest in village Mehmudpur (7.15 and 7.81 individuals/month/transect during 2022 and 2023) and lowest in Saloh (5.74 and 7.15 individuals/month/transect during 2022 and 2023) (Table 2). The maximum variation (increase) in population during 2023 was recorded in village Saloh with 24.56% increase, followed by Karyam (17.57%), Begampur (10.73%), Bakhlaur (9.51%) and Mehmudpur (9.23%) as compared to 2022. An overall increase of 13.82 % anuran population was recorded in district SBS Nagar during 2023 as compared to 2022.

Higher mean anuran population was recorded in transplanted rice agroecosystem of SBS Nagar as compared to Ludhiana during both years of study (Fig.1). In 2022, *E. cyanophlyctis* showed highest 44.58% variation in population at SBS Nagar as compared to district Ludhiana, which was significantly different from other anuran species. *D. stomaticus, D. melanostictus, E. adolfi, H. tigrinus* and *F. limnocharis* showed 25.89, 29.21, 29.62, 26.02 and 26.08% variation in population at SBS Nagar as compared to district Ludhiana and was statistically at par with each other. During 2023, *F. limnocharis* showed highest (44.23 %) variation in population at SBS Nagar as compared to district Ludhiana, which was significantly different from other anuran species. *D. stomaticus* and *D. melanostictus* showed 25.40 and 33.68% variation in population at SBS Nagar as compared to district Ludhiana, which was statistically different from each other (Fig. 1). However, *E. adolfi* and *E. cyanophlyctis* showed 27.27 and 17.24% variation in population at SBS Nagar as compared to district Ludhiana and was statistically different from each other. *H. tigrinus* showed 24.09% variation in population at SBS Nagar as compared to district Ludhiana. In district Ludhiana, from all the villages the anuran population ranged between 2.57 to 5.37 and 2.95 to 5.67 individuals/ month/ transect with pooled mean of 4.24 to 4.65 during 2022 and 2023, respectively, highest in village Bhattian (5.37 and 5.67 individuals/ month/ transect during 2022 and 2023) and lowest in Salempur (2.57 and 2.95 individuals/ month/transect during 2022 and 2023) (Table 2). The maximum variation (increase) in population during 2023 was recorded in village Salempur with 24.20% increase, followed by Jainpur (16.53%), Chak Kalan (13.56%), Nurpur Bet (11.11%) and Bhattian (6.86%). An overall increase of 9.66% anuran population was recorded in district Ludhiana during 2023 as compared to 2022 (Table 2).

In district SBS Nagar, from all the villages the anuran population ranged between 4.60 to 5.87 and 5.09 to 5.97 individuals/month/transect with pooled mean of 4.84 to 5.92 during 2022 and 2023, respectively, being highest in village Begampur (5.87 and 5.97 individuals/month/transect during 2022 and 2023) and lowest in Saloh (4.60 and 5.09 individuals/ month/ transect during 2022 and 2023) (Table 2). The maximum variation

Online Copy

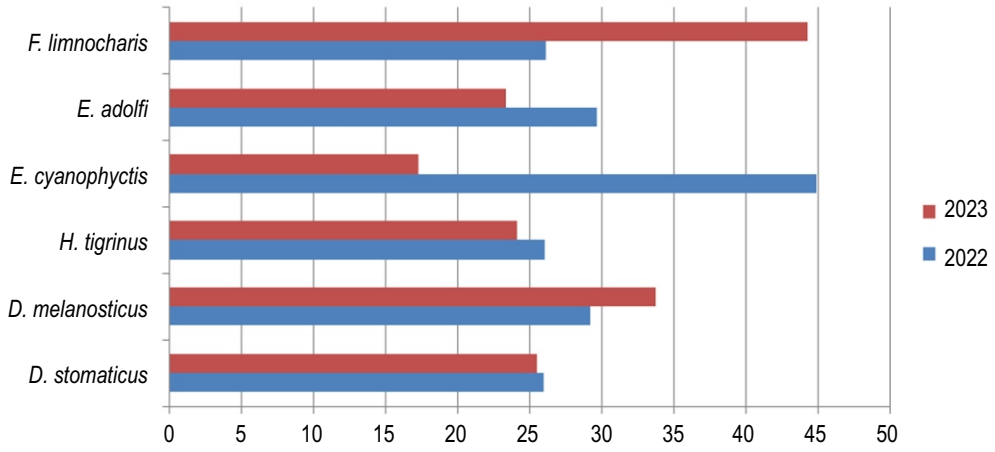


Fig. 1: Comparison of anuran population in transplanted agroecosystem of district Ludhiana and SBS Nagar during 2022 and 2023.

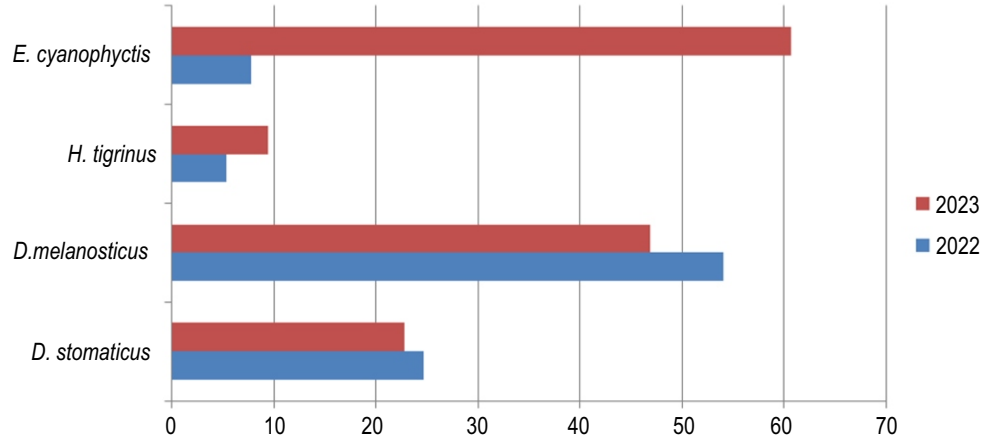


Fig. 2: Comparison of anuran population in DSR agroecosystem of district Ludhiana and SBS Nagar during 2022 and 2023.

in population during 2023 was recorded in village Bakhlaur with 21.14% increase, followed by Karyam (16.25%), Saloh (13.61%), Mehmudpur (5.83%) and Begampur (2.05%) as compared to 2022. An overall increase of 9.00 % anuran population was recorded in district SBS Nagar during 2023 as compared to 2022 (Table 2). Higher mean anuran population was recorded in DSR agroecosystem of district SBS Nagar as compared to Ludhiana during both years of study (Fig. 2). In 2022 and 2023, *D. melanostictus* showed highest 54.05 and 46.88% variation in population at district SBS Nagar as compared to Ludhiana, which was significantly different from other anuran species. *D. stomaticus* showed 24.65 and 22.75% variation in population at SBS Nagar as compared to district Ludhiana and was statistically different from other anuran species. However, *H. tigrinus* and *E. cyanophlyctis* showed 5.26 and 7.69, 9.40 and 6.07% variation in population at district SBS Nagar as compared to Ludhiana and was statistically at par with each other.

In transplanted rice agroecosystem of district SBS Nagar, the anuran population was 14.81 and 19.32% more abundant during 2022 and 2023 as compared to Ludhiana (Table 3). The DSR crop in SBS Nagar was 29.93 and 28.49% more abundant than in district Ludhiana during 2022 and 2023, respectively. Comparing transplanted and DSR agroecosystems, the transplanted rice agroecosystem had 33.72 and 33.54 % higher anuran population than the DSR agroecosystem in district Ludhiana during 2022 and 2023. While, the transplanted rice agroecosystem had 24.71 and 30.22 % higher anuran population than the DSR agroecosystem in district SBS Nagar during 2022 and 2023, respectively.

The biodiversity indices for transplanted and DSR agroecosystem in Ludhiana and SBS Nagar were compared for both the years of study (Fig.3). The results provide valuable insights into the ecological health and biodiversity of these

Table 3: Comparison of per cent variation in anuran population in transplanted and DSR rice agroecosystems of Ludhiana and SBS Nagar

Districts	Rice agroecosystem			
	Transplanted rice crop		Direct seeded rice crop	
	Mean population			
2022	2023	2022	2023	
Ludhiana	5.67[a]	6.21[a]	4.24[a]	4.65[a]
SBS Nagar	6.51[b]	7.41[b]	5.22[b]	5.69[b]
Per cent population variation in SBS Nagar over Ludhiana	+14.81	+19.32	+29.93	+28.49

*Statistical analysis (ANOVA) showed significant result with p value = 0.05; *Mean value followed by same letter (a,b) in the given table above are not significantly different as per Tukey's Test

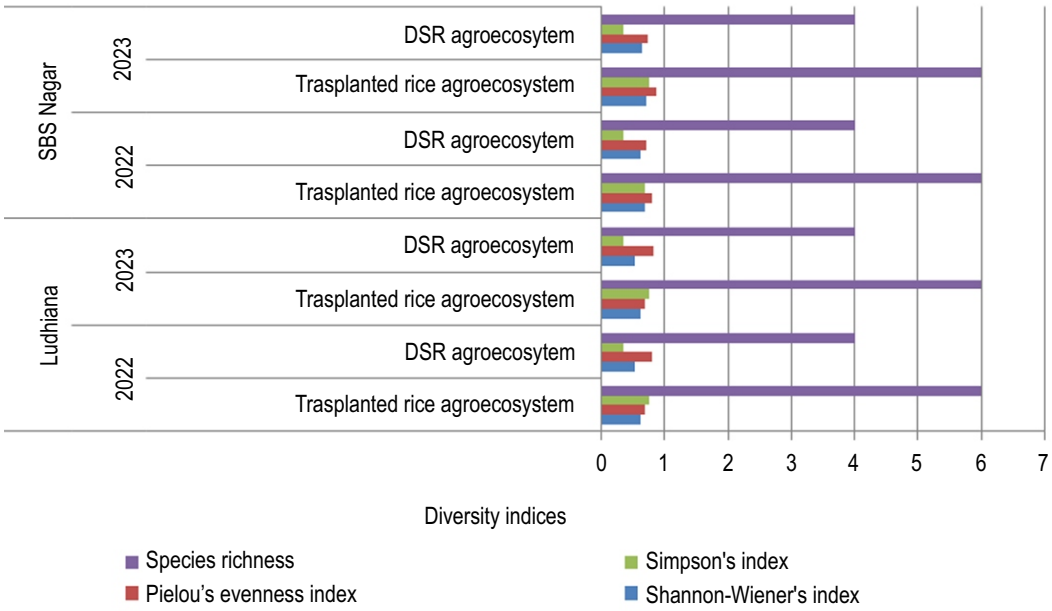


Fig. 3: Diversity indices for anuran population in selected transplanted and DSR agroecosystems of district Ludhiana and SBS Nagar during 2022 and 2023.

ecosystems. In DSR agroecosystem, the Shannon index and Pielou's index increased from 0.607 and 0.686 to 0.616 and 0.673, respectively in 2023 as compared to 2022. Similarly, in transplanted rice agroecosystem Shannon index and Pielou's index increased from 0.510 and 0.800 to 0.530 and 0.820, respectively in 2023 as compared to 2022. Species richness remained constant during 2022 and 2023 for both the agroecosystems, with transplanted rice crop agroecosystem showing higher Species richness (six), while the DSR agroecosystems four species were recorded.

Strong positive correlations were observed between anuran populations and mean atmospheric temperature (+0.235 to 0.492 and +0.181 to 0.592) and relative humidity (0.667 to 0.822 and +0.628 and 0.788) during 2022 and 2023, respectively in transplanted and DSR agroecosystems of district Ludhiana and SBS Nagar (Fig. 4 to 7). The data presented in Tables (4 and 5) reflect the per cent increase in various morphometric parameters of anuran species observed in two distinct agroecosystems (transplanted rice fields and Direct Seeded Rice). The overall analysis revealed that the percent increase in morphometric ratios was higher in transplanted rice fields as compared to DSR fields. In the transplanted rice fields, the HL: SVL ratio exhibited a 6.14% increase whereas in the DSR fields, this ratio increased by 5.17%. Similarly, the HL: HW ratio showed a 16.74% increase in transplanted rice fields compared to a 4.77% increase in the DSR

Table 4: Per cent increase in morphometric parameters of anuran species in transplanted rice agroecosystem of district SBS Nagar over Ludhiana (pooled mean of 2022 and 2023)

Morphometric parameters	*D. stomaticus*		*D. melanosticus*		*F. Limnocharis*		*E. Cyanophlyctis*		*E. Adolfi*		*H. tigerinus*		Mean
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	
HL: SVL	3.45[a]	6.06[a]	4.00[a]	11.52[b]	3.70[a]	6.45[a]	6.25[a]	5.26[a]	4.55[a]	3.85[a]	6.67[a]	5.88[a]	5.64[a]
HL: HW	4.55[a]	5.71[a]	4.35[a]	5.33[a]	5.56[a]	5.13[a]	4.48[a]	5.63[a]	4.84[a]	4.55[a]	4.41[a]	5.41[a]	5.00[a]
HL: HD	5.22[a]	4.96[a]	4.59[a]	5.22[a]	5.04[a]	4.72[a]	4.88[a]	5.34[a]	4.72[a]	5.36[a]	5.13[a]	4.80[a]	5.00[a]
SL: HL	4.65[a]	4.08[a]	5.26[a]	4.55[a]	5.56[a]	4.76[a]	4.08[a]	5.45[a]	5.88[a]	5.00[a]	4.44[a]	5.88[a]	4.97[a]
SL: SVL	5.88[a]	4.76[a]	7.14[a]	5.56[a]	9.09[a]	6.67[a]	5.26[a]	4.35[a]	10.00[a]	7.14[a]	6.25[a]	5.00[a]	6.43[a]
EN: NS	4.92[a]	4.69[a]	5.17[a]	4.92[a]	5.43[a]	5.19[a]	4.84[a]	5.38[a]	5.22[a]	4.96[a]	4.76[a]	5.30[a]	5.07[a]
EN: HL	5.00[a]	4.17[a]	5.88[a]	4.76[a]	4.55[a]	3.85[a]	5.26[a]	4.35[a]	7.14[a]	5.56[a]	4.76[a]	4.00[a]	4.94[a]
ED: HL	5.88[a]	5.00[a]	5.00[a]	4.35[a]	5.56[a]	4.76[a]	5.26[a]	4.55[a]	3.45[a]	5.71[a]	4.65[a]	4.08[a]	4.86[a]
ED:SL	4.41[a]	5.26[a]	5.00[a]	4.55[a]	5.33[a]	4.82[a]	4.69[a]	5.56[a]	4.92[a]	4.35[a]	5.13[a]	4.65[a]	4.89[a]
ED: SVL	8.33[a]	6.25[a]	7.69[a]	5.88[a]	6.25[a]	5.00[a]	10.00[b]	7.14[a]	11.11[b]	7.69[a]	5.88[a]	4.76[a]	7.17[a]
ED: EN	4.51[a]	29.82[b]	4.38[a]	4.83[a]	4.84[a]	5.30[a]	4.65[a]	5.11[a]	5.00[a]	4.69[a]	5.19[a]	4.90[a]	6.94[a]
Mean of ratios	5.16[a]	7.34[a]	5.32[a]	5.59[a]	5.54[a]	5.15[a]	5.42[a]	5.28[a]	6.07[a]	5.35[a]	5.21[a]	4.97[a]	5.54

*Statistical analysis (ANOVA) showed significant result with p value = 0.05; *Mean value followed by same letter (a,b) in the given table above are not significantly different as per Tukey's Test

Table 5: Per cent increase in morphometric parameters of anuran species in DSR agroecosystem of district SBS Nagar over Ludhiana (pooled mean of 2022 and 2023)

Morphometric parameters	*D. stomaticus*		*D. melanosticus*		*E. Cyanophlyctis*		*H. tigerinus*		Mean
	Male	Female	Male	Female	Male	Female	Male	Female	
HL: SVL	3.70[a]	6.45[a]	4.35[a]	3.70[a]	4.00[a]	6.90[a]	6.67[a]	5.56[a]	5.17[a]
HL: HW	4.76[a]	4.48[a]	4.55[a]	5.56[a]	4.35[a]	5.33[a]	4.69[a]	4.41[a]	4.77[a]
HL: HD	4.59[a]	5.22[a]	4.85[a]	4.59[a]	5.31[a]	4.96[a]	5.13[a]	4.80[a]	4.94[a]
SL: HL	4.88[a]	4.26[a]	5.56[a]	4.76[a]	5.88[a]	2.44[a]	4.26[a]	5.66[a]	4.72[a]
SL: SVL	6.67[a]	5.26[a]	8.33[a]	6.25[a]	10.00[a]	7.69[a]	5.88[a]	4.76[a]	6.86[a]
EN: NS	5.17[a]	4.92[a]	5.45[a]	5.17[a]	4.88[a]	4.65[a]	5.08[a]	4.84[a]	5.02[a]
EN: HL	5.56[a]	4.55[a]	6.67[a]	5.26[a]	5.00[a]	4.17[a]	5.88[a]	4.76[a]	5.24[a]
ED: HL	6.25[a]	5.26[a]	5.26[a]	4.55[a]	5.88[a]	2.50[a]	5.56[a]	4.76[a]	5.01[a]
ED:SL	4.62[a]	5.48[a]	5.19[a]	4.71[a]	5.56[a]	3.75[a]	4.92[a]	4.35[a]	4.83[a]
ED: SVL	9.09[a]	6.67[a]	8.33[a]	6.25[a]	6.67[a]	5.26[a]	11.11[b]	7.69[a]	7.64[a]
ED: EN	4.72[a]	4.44[a]	4.58[a]	4.32[a]	5.08[a]	4.76[a]	4.88[a]	4.58[a]	4.67[a]
Mean of ratios	5.45[a]	5.18[a]	5.73[a]	5.01[a]	5.69[a]	4.76[a]	5.82[a]	5.10[a]	5.35

*Statistical analysis (ANOVA) showed significant result with p value = 0.05; *Mean value followed by same letter (a,b) in the given table above are not significantly different as per t ukey's Test

fields. The HL: HD ratio increased by 6.39% in transplanted rice fields, while it showed 4.94% increase in the DSR fields. The SL: HL ratio was 3.97% higher in transplanted rice fields, in contrast to 4.72% increase in the DSR fields. The SL: SVL ratio demonstrated 10.76% increase in transplanted rice fields, but only 6.86% increase in the DSR fields. The EN: NS ratio increased by 32.05% in transplanted rice crop fields, whereas it increased by 5.02% in the DSR fields. The EN: HL ratio showed a 12.14% increase in transplanted rice fields as compared to a 5.24% increase in the DSR fields. The ED: HL ratio showed a 15.98% increase in transplanted rice fields, while it increased by 5.01% in the DSR fields. The ED: SL ratio showed a 7.74% increase in transplanted rice fields while, 4.83% increase in the DSR fields. The ED: SVL ratio exhibited a 34.89% increase in transplanted rice fields, while it increased by 7.64% in the DSR fields. The ED: EN ratio demonstrated a 2.65% increase in transplanted rice fields, compared to 4.67% increase in the DSR fields. Overall, these differences underscore that morphometric parameters of anurans are significantly influenced by the type of agroecosystem, with transplanted rice fields generally showing higher increases in these ratios compared to DSR fields. Overall, the per cent increase for the morphometric ratios across all species was higher in the transplanted rice fields (5.54%) as compared to DSR fields (5.35%). This suggests that transplanted rice crop fields have a more pronounced effect on the morphometric characteristics of anurans.

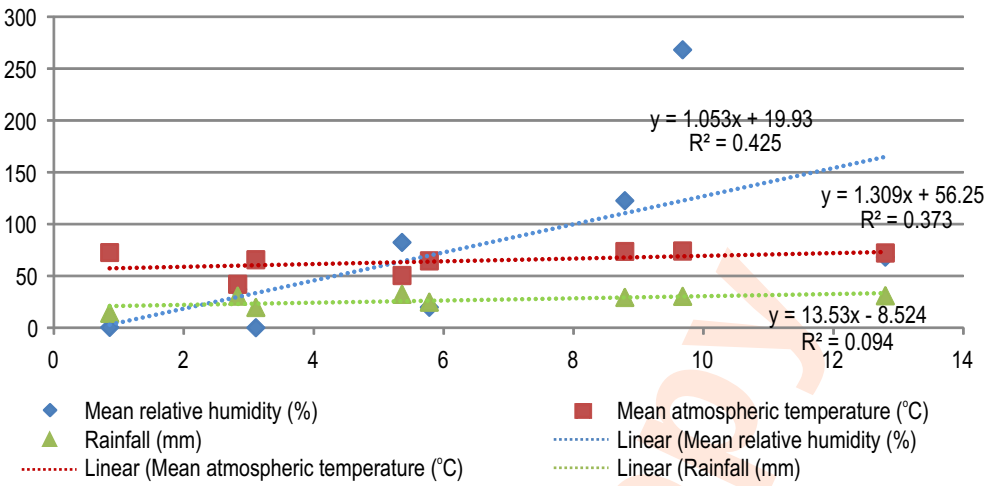


Fig. 4: Correlation between mean anuran population and weather parameters in transplanted rice agroecosystem of district Ludhiana during 2022 and 2023.

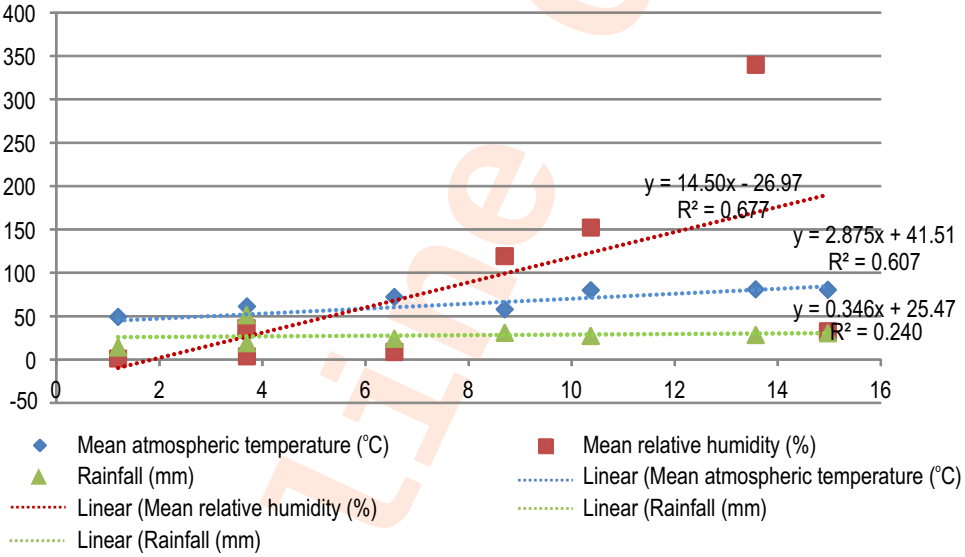


Fig. 5: Correlation between mean anuran population and weather parameters in transplanted rice agroecosystem of district SBS Nagar during 2022 and 2023.

Our results gives meaningful insights on the differences in rice agricultural practices and the effects on anuran populations and inter linkages in an agricultural landscape. There is a significant differences between transplanted rice and DSR agroecosystems associated with anuran abundance, diversity and morphometrics. Anuran abundance and diversity were higher in rice crop fields with transplanted seedlings as compared to DSR fields. These findings corroborates with the results of Maltchik (2011), who revealed that Southern Brazilian rice fields with transplanted rice crop had higher amphibian species richness as compared to DSR crop fields. This is further supported by the results of the present study in which six anuran species were recorded in transplanted rice crop fields as compared to DSR fields where only four species were found. The consistently higher anuran populations in SBS Nagar district as compared to Ludhiana (14.81-19.32% higher in transplanted rice and 28.49-29.93% higher in DSR) confirm that regional factors, such as landscape heterogeneity or overall habitat quality, may be critical for the sustenance and survival of amphibian populations. This reveals that landscape-level factors could be more influential in determining amphibian abundance and diversity in any agricultural landscape, as emphasized by

Online Copy

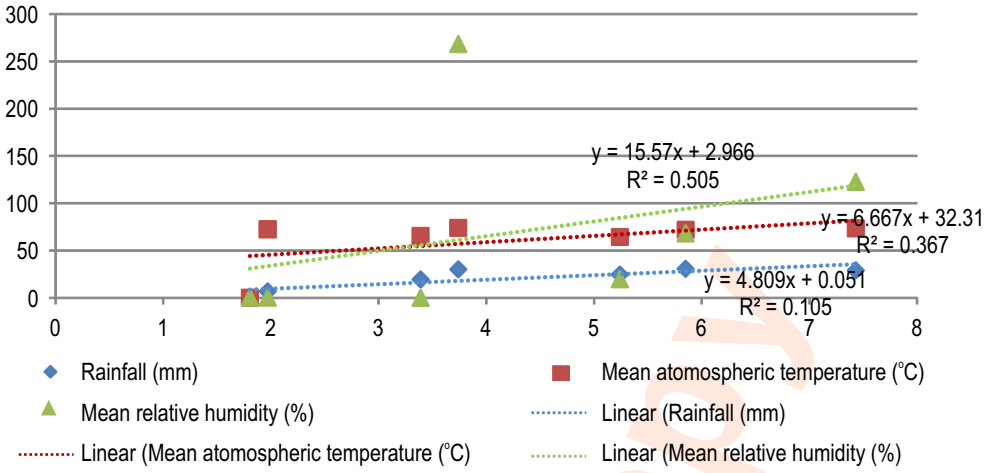


Fig. 6: Correlation between mean anuran population and weather parameters in DSR crop agroecosystem of district Ludhiana during 2022 and 2023.

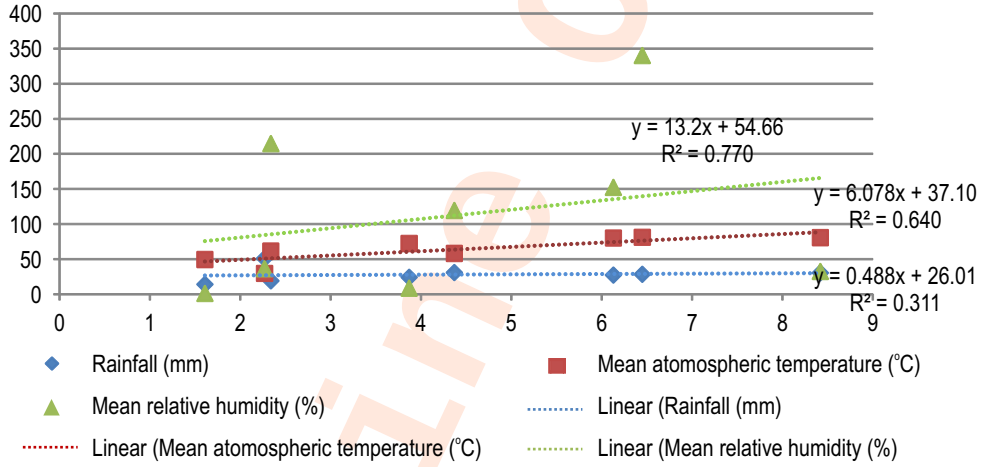


Fig. 7: Correlation between mean anuran population and weather parameters in DSR crop agroecosystem of district SBS Nagar during 2022 and 2023.

Knutson *et al.* (2004). Therefore, the observed increase in populations of anurans between 2022 and 2023 for both the districts (9.52–13.82% increase) is promising, and may reflect conditions of habitat improvement or successful conservation. The higher anuran population observed in district SBS Nagar as compared to Ludhiana can be attributed to more favourable environmental conditions, particularly higher rainfall (1032 mm and 1396 mm in Ludhiana and SBS Nagar, during 2022 and 2023), increased relative humidity (0.83% more in SBS Nagar as compared to Ludhiana during 2022 and 2023) and low temperatures (1.63° C lower in SBS Nagar as compared to Ludhiana during 2022 and 2023). Hybridization in anurans occur when two distinct species interbreed, producing offspring with mixed genetic characteristics. In Punjab, several documented cases exist: *H. tigrinus* hybridized with *H. crassus* in overlapping territories (Khan and Hassan, 2020), while *D. stomaticus* and *D. melanosticus* showed evidence of genetic introgression in disturbed habitats (Akram *et al.,* 2021). *F. limnocharis* exhibited hybridization with *F. syhadrensis* in agricultural landscapes (Singh *et al.,* 2019), and *E. cyanophlyctis* showed limited hybridization with *E. hexadactylus* in modified wetlands (Kumar *et al.,* 2022). Genetic analysis of species in Beas River basin, revealed a 15% hybridization rate between *D. stomaticus* and *D. melanosticus* populations in disturbed habitats compared to 2% in natural areas (Sharma and Kumar, 2023).

Higher rainfall in SBS Nagar likely contributes to the abundance and persistence of aquatic habitats, beneficial for anuran breeding and tadpole development. Increased precipitation also helps to maintain soil moisture and benefiting

terrestrial anurans. Higher relative humidity reduces the risk of desiccation, especially important for species with permeable skin. Congenial temperature in SBS Nagar may provide more optimal environment for anurans, reducing physiological stress and enhancing overall fitness as compared to Ludhiana. Temperature plays a crucial role in anuran metabolism, activity patterns and reproductive success. These factors collectively create a more suitable habitat for anurans, promoting their survival and reproduction. These environmental factors in SBS Nagar likely interact to create a more favourable ecosystem for anurans across various habitats, including aquatic, terrestrial and agricultural landscapes. According to Blaustein *et al.* (2001) climate change can affect the development, growth, survival and dispersal of anurans which result in shift of habitat range of anurans. McMenamin *et al.* (2008) observed significant reduction in anuran population and diversity in North America due to long-term climate shifts and wetland desiccation.

These findings underscore the vulnerability of anurans to environmental changes and their potential role as bioindicators of ecosystem health, emphasizing the urgent need for conservation efforts to protect these sensitive species in the face of ongoing global environmental challenges. Study by Pandey *et al.* (2022) revealed the critical role of humidity in determining anuran activity patterns and habitat use. These results have several important implications for anuran conservation and habitat management in the region, including the need to preserve aquatic habitats and promote anuran-friendly agricultural practices. The studied anuran species exhibited varying degrees of tolerance to environmental stressors, revealing a distinct hierarchical pattern in their sensitivity to agricultural and chemical pollutants. Notably, *D. melanostictus* demonstrated remarkable resilience, consistently showing higher tolerance to various environmental contaminants compared to other species in the study (Muthuviveganandavel *et al.,* 2013; Wei *et al.,* 2015). This contrasted sharply with *H. tigerinus* and *E. adolfi,* which exhibited high sensitivity, particularly during their larval stages (Khangarot and Ray 1987; Phuge and Gramapurohit, 2015), suggesting these species could serve as potential bioindicators for environmental stress in amphibian habitats. *F. limnocharis* and *E. cyanophlyctis* displayed intermediate tolerance levels, with notable responses to nitrogen-rich fertilizers and synthetic pesticides, respectively (Chang *et al.,* 2013; Ghodageri and Pancharatna, 2011).

Interestingly, *D. stomaticus,* despite being similar to *D. melanostictus,* showed greater sensitivity to agricultural runoff (Nataraj and Krishnamurthy, 2012), highlighting the species-specific nature of stress responses even within the same genus. These differential sensitivity patterns among species emphasize the complexity of amphibian responses to environmental stressors and suggest that conservation strategies should be tailored to species-specific vulnerabilities rather than applying uniform approaches. The observed variations in tolerance levels also indicate the potential for using multiple species as complementary bioindicators for different types of environmental stress (Hayes *et al.,* 2010). The observed differences in morphometric ratios between anurans in transplanted rice and DSR habitats offer interesting evidence of habitat-wise specific adaptations. A fact that may point towards higher selective pressures or stronger opportunities for phenotypic plasticity is the overall increase in morphometric ratios of anurans in transplanted rice, which was higher (5.54%) in transplanted crop fields as compared DSR fields. There were strong positive correlations between anuran populations and climatic factors (temperature and humidity) in both agroecosystems, highlighting their sensitivity to environmental conditions (Wu *et al.* 2024) and emphasizing their role as valuable bioindicators of ecosystem health.

Transplanted rice agroecosystems offer better habitat conditions for anuran populations as compared to direct seeded rice fields. While DSR is gaining popularity due to its water saving potential and reduced labour requirements, these findings highlighted the need to consider the broader ecological impacts of agricultural practices. Conservation strategies should aim to balance agricultural efficiency with biodiversity preservation, potentially incorporating elements of transplanted rice cultivation or creating habitat features that mimic its benefits within more modern farming systems.

Acknowledgment

Authors are thankful to the Head, Department of Zoology for providing the facilities to conduct this research work.

Authors' contribution: R. Kaur: Conducted the primary investigation, providing the foundational data and analysis; **R. Singh:** Analysed the data and offered guidance and oversight throughout the research process, ensuring methodological rigor and acadmic integrity, Helped in identifying key research gaps and provided critical insights that shaped the direction and scope of the study; **K.P. Dinesh:** Played an important role in the identification and classification of anurans, providing expert knowledge and validation of species.

Funding: No funding received.

Research content: The research content of manuscript is original and has not been published elsewhere.

Ethical approval: The authors have followed and complied with the National/International Guidelines of relevant and appropriate authority for the use of plants or animals or humans in the experimental study.

Conflict of interest: The authors declare that there is no conflict of interest.

Data availability: Written permission obtained from appropriate authority for using data from other sources.

Consent to publish: All authors agree to publish the paper in *Journal of Environmental Biology.*

References

Attademo, A.M., P.M. Peltzer and R.C. Lajmanovich: Amphibians occurring in soybean and implications for biological control in Argentina. *Agric. Ecosyst. Environ.,* **106**, 389-394 (2005).

Akram, A., M.Z. Khan and M. Hassan: The ecological dynamics of amphibian and reptilian populations in temperate regions. *Asian Herpetol. Res.,* **12**, 1-9 (2021).

Bhullar, B. A., R. S. Reilly, K. L. B. Li, and A. S. P. Green: The evolutionary history of the frog family Dendrobatidae: Phylogeny and diversification. *Mol. Phylogenet. Evol.*, **172**, 106668 (2022).

Blaustein, A.R., J.M. Kiesecker, D.P. Chivers and R.G. Anthony: Amphibian breeding and climate change. Conserv. Biol., 15, 1804-1809 (2001).

Chang, H., Y. Wan and J.Y. Hu: Determination and source apportionment of five classes of steroid hormones in urban rivers. *Environ. Sci. Technol.,* **47**, 3902-3910 (2013).

Daniel, J. C.: The amphibians of the Western Ghats: An ecological and taxonomic survey. *J. Bombay Nat. Hist. Soc.*, **102**, 208-224 (2005).

Deka, J. and R.K. Hazarika: Diversity and habitat preference of anurans in Guwahati and its adjoining areas. *J. Adv. Zool.,* **34**, 85-91 (2013).

Duan, R., X. Kong, M. Huang, S. Wu and Z. Wang: The potential of medaka (*Oryzias latipes*) as a model fish species for ecotoxicological studies. *J. Environ. Biol.,* **41**, 1-12 (2020).

Fouquet, A., Vences, M. and P. M. Pltzer: Taxonomic revision of the genus *Rhombophryne* (Amphibia: Anura: Microhylidae) based on molecular and morphological evidence. *Mol. Plogenet. Evol.*, **85**, 79-89 (2015).

Ghodageri, M.G. and K. Pancharatna: The effects of organophosphate pesticide sumithion (Fenitrothion) on early development in the frog, *Euphlyctis cyanophlyctis. Toxicol. Environ. Chem.,* **93**, 1764-1773 (2011).

Hayes, T.B., P.G. Falso, S. Gallipeau and M. Stice: The cause of global amphibian declines: a developmental endocrinologist's perspective. *J. Exp. Biol.,* **213**, 921-933 (2010).

Heyer, W. R.: Systematics and distribution of the frogs of the genus *Leptodactylus* in the Americas. *Smithson. Contribut. Zool.,* **554**, 1-36 (1994).

Hossain, M.L., S.M.A. Rahman, M.F. Ahamed and M.K. Hasan: Diversity and conservation status of anurans in Lawachara National Park, Bangladesh. *J. Threat. Taxa,* **8**, 9365-9373 (2016).

Khan, M.Z. and M. Hassan: Herpetological diversity and distribution patterns in the Himalayan region of Pakistan. *J. Herpetol.,* **54**, 112-118 (2020).

Kumar, S., R. Gupta and P. Reddy: Impact of environmental change on herpetofaunal populations in Southern India. *Curr. Sci.,* **122**, 567-573 (2022).

Khangarot, B.S. and P.K. Ray: Sensitivity of toad tadpoles, *Bufo melanostictus* (Schneider), to heavy metals. *Bull. Environ. Contam. Toxicol.,* **38**, 523-527 (1987).

Knutson, M.G., W.B. Richardson, D.M. Reineke, B.R. Gray, J.R. Parmelee and S.E. Weick: Agricultural ponds support amphibian populations. *Ecol. Appl.,* **14**, 669-684 (2004).

Kross, S.M., T.R. Kelsey, C.J. McColl and J.M. Townsend: Field-scale habitat complexity enhances avian conservation and avian-mediated pest-control services in an intensive agricultural crop. *Agric. Ecosyst. Environ.,* **225**, 140-149 (2016).

Kukunuru, S. and R.D. Kanamadi: Diversity and distribution of anurans in Dharwad district, Karnataka. *J. Environ. Biol.,* **35**, 1011-1016 (2014).

Maltchik, L., A.S. Rolon, C. Stenert, I.F. Machado and O. Rocha: Can rice field channels contribute to biodiversity conservation in Southern Brazilian wetlands? *Rev. Biol. Trop.,* **59**, 1895-1914 (2011).

McMenamin, S.K., E.A. Hadly and C.K. Wright: Climatic change and wetland desiccation cause amphibian decline in Yellowstone National Park. *Proc. Natl. Acad. Sci. USA,* **105**, 16988-16993 (2008).

Muthuviveganandavel, V., P. Muthuraman, S. Muthu, K. Srikumar: A study on low dose cypermethrin induced histopathology, lipid peroxidation and marker enzyme changes in male rat. *Pestic. Biochem. Physiol.,* **105**, 101-105 (2013).

Nataraj, M.B. and S.V. Krishnamurthy: Effects of combinations of malathion and cypermethrin on survivability and time of metamorphosis of tadpoles of Indian cricket frog (*Fejervarya limnocharis*). *J. Environ. Sci. Health, Part B,* **47**, 67-73 (2012).

Pandey, V., S. Kumar, N. Mishra and S. Kumar: Diversity and distribution of amphibians in Madhya Pradesh, Central India. *J. Threat. Taxa,* **14**, 20740-20752 (2022).

Paoletti, M.G., D. Sommaggio, M.R. Favretto, G. Petruzzelli, B. Pezzarossa and M. Barbafieri: Earthworms as useful bioindicators of agroecosystem sustainability in orchards and vineyards with different inputs. *Appl. Soil Ecol.,* **37**, 80-93 (2007).

Phuge, S.K. and N.P. Gramapurohit: Sex hormones alter sex ratios in the Indian skipper frog, *Euphlyctis cyanophlyctis*: Determining sensitive stages for gonadal sex reversal. *Gen. Comp. Endocrinol.,* **220**, 70-77 (2015).

Sharma, V. and P. Kumar: New species of amphibians from the Western Ghats: Taxonomic review and phylogeny. *Zootaxa,* **52**, 41-53 (2023).

Singh, A. S., M. D. Kapoor and R. K. S. Rao: Molecular systematics and evolutionary patterns of amphibians in the Western Ghats. *Zootaxa*, **73**, 89-106 (2023).

Singh, R., B.C. Choudhury and R.K. Khandekar: Taxonomy and conservation status of amphibians in Northeast India. *Amphibia-Reptilia,* **40**, 77-86 (2019).

Sreekumar, D., U.M. Chandrashekara and N.S. Remesan: Diversity and conservation status of amphibians in Wayanad Wildlife Sanctuary, Kerala, India. *J. Environ. Biol.,* **44**, 310-318 (2023).

Verma, P.S. and B.C. Murmu: Diversity and distribution of anuran amphibians in Dumka district of Jharkhand, India. *J. Threat. Taxa.,* **7**, 7316-7320 (2015).

Wei, Y., Y. Zhao, H. Wang, J. Lu and S. Chen: Roles of different humic acid fractions in promoting the bioavailability of sediment-bound PCB to amphibians. *Chemosphere,* **131**, 24-31 (2015).

Wu, N. C., D.M. Richardson and S. Falso: Global exposure risk of frogs to increasing environmental dryness. *Nat. Clim. Change*, **14**, 1234–1235 (2024).

Zheng, X., J. Lu, Z. Tao, Y. Wan, B. Zheng, X. Xie, J. Yin, D. Zhang and S. Lin: The composition and temporal-spatial variations of soil macrofauna communities in the rice-wheat rotation ecosystem in the Taihu Lake region, China. *Environ. Sci. Pollut. Res.,* **26**, 11098-11109 (2019).