STUDY ON THE POPULATION STRUCTURE OF THE PARADOXICAL FROG

Ravi Prakash Tiwary and Dr. Meenakshi Solanki
Department of Zoology, Dr. A. P. J. Abdul Kalam University, Indore (M.P.)
Corresponding Author Email: raviom07@rediffmail.com

Received : 05.10.2020 Revised : 04.11.2020 Accepted : 05.12.2020

Abstract

The goal of this study was to assess the population structure of Pseudisbolbodactyla Lutz, 1925 using natural markings to identify individuals. Recruitment, survival, and population size estimations were obtained using the JollySeber stochastic method. A total of 166 individuals were captured, and the striped, spotted, and dotted patterns that make their recognition possible were recorded. Of the specimens captured, 27 were recaptured, including some at pre and post-metamorphic stages. The estimate maximum population size was 52. The indices of survival and recruitment varied among samplings. Sexual dimorphism in size and in the operational sex ratio were detected. Despite the limited scope of our characterization of the P. bolbodactyla population, our data might be useful in the interpretation and elaboration of new hypotheses about ecological processes acting on anuran populations.

Keywords: Amphibian; capture-recapture; Cerrado; photograph; estimate.

1. Introduction

Several methods have been used for marking and identifying anurans, for instance toe clipping, burning, tagging and banding. These techniques, which import in various degrees of disfigurement, have been assessed in order to determine their impacts on the survival of the marked animals, their efficacy, and the ethical issues involving the use of animals in scientific research.

An alternative to these methods is identification through photographs, a relatively new technique that has been adopted by a number of researchers, but is still looked upon with some suspicion. It involves the utilization of organic physical markings (scratches, mutilations, or defects) and color patterns (stripes, spots, etc.) to distinguish among individuals of the same species. The viability of this technique depends on the quality of the markings and the time it takes to compare images.

Identification through photographs was recently used by Miranda et al. (2005) for the identification of PseudiscardosoiKwet, 2000 individuals. Their results showed that the variabledesigns on the inner surface of the thighs of these frogs serve as a fingerprint that makes it possible to unequivocally identify them. Later, GARDA et al. (2010) suggested that these patterns of stripes on the thigh area vary between and within populations of different species of Pseudis, allowing population studies to be conducted.

Based on the patterns of the stripes on the ventral longitudinal section of the thigh, GALLARDO (1961) divided the Pseudisparadoxa species group into several sub-species, but this division was subsequently deemed unreliable. The species that comprise PseudisWagler, 1830 are distributed in South America, east of the Andes, from Venezuela to eastern Argentina and Uruguay.

Species of Pseudis are extremely dependent on water and display several morphologic, reproductive, and developmental adaptations to aquatic environments that distinguish them from other Hylidae. The dispersion of individuals to different water bodies occurs mainly after heavy rains, although populations ordinarily tend to remain within their own watershed.With the exception of Pseudisbolbodactyla Lutz, 1925, P. paradoxa,andLysapsuslimellum Cope, 1862, all paradoxical anuran species are restricted to one watershed. However, this group is still poorly sampled in most of the Central and North regions of South America.

Pseudisbolbodactyla has been found in four Brazilian states: Bahia, Minas Gerais, Goiás, and Mato Grosso. It is medium sized when compared with other species of Pseudis, and is characterized by a vestigial carpal tubercle, head as wide as long, and dorsal skin sharply wrinkled. Very few studies have been conducted on the population ecology of P. bolbodactyla, and the existing ones are mainly focused on behavior, diet, and breeding.

In this study, we present information on the biology and ecology of a population of P. bolbodactyla in an artificial pond located on the boundary of the Serra de Caldas Novas State Park, in the municipality of Caldas Novas, state of Goiás, Brazil. The natural markings of individuals were recorded with the aid of photographs. Based on our data, we endeavored to:

1) verify the existence of biometric variations among males, females, and juveniles; 2) determine whether the variability in length and weight of males and females is indicative of sexual dimorphism; 3) verify whether there is a tendency for operational sex ratio in the species; 4) estimate population size during the breeding season; and 5) evaluate whether photographic identification methods using natural markings can be used in population studies of P. bolbodactyla.

2. Research Methodology

This study was conducted at Lajeado farm (17°52’10.1"S/ 48°41’26.5"W, 663 m a.s.l.; WGS84 datum), situated in the buffer zone of Serra de Caldas Novas State Park, Goiás, Brazil (Fig. 1). Five excursions, lasting two days each, were conducted to the research site between April and May, 2009, and January and May, 2010. The samples were collected from an artificial pond measuring about 280 m2, beginning at 6:00 p.m. and lasting for a variable number of hours.

The anurans were captured manually, kept in buckets of water, and taken to the laboratory for biometrics and photographic registration. The snout-vent length (SVL) was measured with a caliper (0.1 mm precision) and their body mass with a Diamond model 500 digital scale (0.1 g precision). After these procedures, the specimens were released in the same place where they had been collected.

The photographic registration method used for individual recognition consisted in photographing the inner thighs of each individual specimen where the spotted designs are used for identification, according to the method implemented by MIRANDA et al. (2005). Photographs were taken with a Sony DSC Hx1 digital camera mounted on a tripod, 15 cm from thesubject. Voucher specimens were deposited in the Herpetological Collection of the PontifíciaUniversidadeCatólica de Goiás (CEPB-NUROG; male: CN18 and female: UF08).

We assumed that the population studied varied due to mortality, birth rates, emigration, and immigration. Therefore, the population size was estimated using the Stochastic Method of Jolly-Seber. This method was also used to estimate the probability of survival (Φi, i+1) and recruitment (Bi, i+1) rates of thepopulation between sampling sessions.

Based on the observations of VAZ-SILVA et al. (2007), individuals with yellowish throat regions were identified as adult males and those with whitish throat regions were considered adult females. Sexual dimorphism was verified using SVL and body mass measurements used as reference. In order to compare the SVL and body mass measurements between males and females, a Student t-test was applied. Sexual Size Dimorphism (SSD) was analyzed by dividing the average SVL of females by the average SVL of males, where SSD > 0 = females larger than males, and SSD < 0 = males larger than females.

The operational sex ratio (OSR) was obtained by dividing the number of males by the number of females present at the breeding sites (assuming that males and females breed every year after reaching maturity) each night and by the grand total recorded in the samplings. The qui-square (y2) (ZAR 1984) was used to evaluate possible differences in sex ratio.

The Pearson correlation coefficient (r) was used to verify the relationship between abundance and climatic variables, the abundance of males and females, the abundance and operational sex ratio, and the weight/length relation of the individuals. All statistical analyses were conducted with a significance level of 0.05.

3. Results& Discussion

3.1 Results:

A total of 169 P. bolbodactyla specimens (88 males, 40 females, and 41 juveniles) were collected and photographed. Individuals were considered juveniles in the absence of secondary sexual characteristics. There was a positive correlation between the number of individuals and the following climatic variables: precipitation (r = 0.92, gl = 4) and relative humidity (r = 0.89, gl = 4). Individuals were more abundant in April and May, 2018.

All individuals presented striped, spotted, and dot patterns on the ventral surface of their thighs, making their identification possible. Of the 169 individuals captured, 27 represent recaptures (21 males, five females and one undefined), totaling 142 individual identifications. One specimen captured during the pre-metamorphic phase (Fig. 2) was recaptured in the post-metamorphic phase without any alteration of the thigh imprint (Fig. 3).

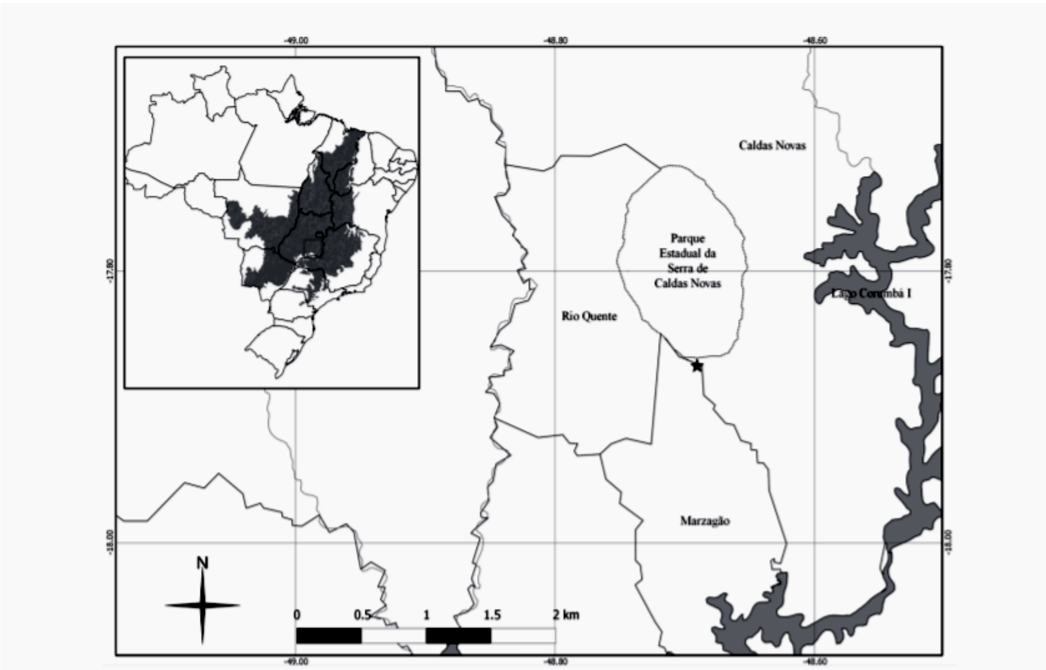

Figure1: Geographic localization of the artificial pond used as breeding

Figure 2:Pseudisbolbodactyla specimen captured during metamorphic phase (2) and recaptured in its post-metamorphic phase (3).

The low recapture rate and the proximity to a second pond suggest that this is an open population. The estimates revealed a population apex (N3 = 52) in the third sampling performed in May, 2009. The survival index between samplings varied between 0.02 and 0.05, with greatest value (= 0.45) in the interval between the first and second samplings. Recruiting rates were 0.94 between the first to second samplings, and 0.36 from third to fourth samplings. The lowest estimates were observed in the fourth sampling due to the low survival and recruiting rates in that period (Table I).

Table 1. Numbers of captured individuals (ni), released (Ri), and recaptured (ri) during the samplings (I) of Pseudisbolbodactyla and corresponding estimates of survival (□i, i+1), recruitment (Bi, i+1),and population size (Ni).

I	n_i	M_i	R_i	r_i	ϕ_i, i+1	B_i, i+1	N_i
1	61	0	59	25	0.45	–	–
2	29	17	29	6	0.21	0,94	45.21
3	52	8	52	1	0.02	0,36	52.00
4	20	1	20	0	–	–	20.00
5	7	1	7	–	–	–	–

Males and females had similar color patterns, with sexual dimorphism in the coloration of the throat region, which is yellow in males and white in females. The SVL varied as follows: males, 35.0-48.8 mm (average = 39.89 ± 2.76, n = 67),females, 36.7-56.1 mm (average = 45.06 ± 4.50, n = 30); andjuveniles, 21.2 and 37.8 mm (average = 32.45 ± 2.82, n = 36). The body mass of males ranged between 6-17 g (average = 8.61± 2.18, n = 67), of females between 6-26 g (average = 11.95 ± 4.49, n = 30), and of juveniles between 5-26 g (average =

8.19 ± 3.47, n = 36). Males and females differed in size (t test = 5.82, gl= 96) and body mass (t test = 3.88, gl = 96): females were larger and heavier. The SSD index for the species was 1.12, also suggesting sexual dimorphism in size.

There was a positive correlation between the SVL and body mass of males (r = 0.66, gl = 66) and females (r = 0.85, gl= 29). There was no correlation between the SVL and body mass (r = -0.13; gl = 35) of toadlets and juveniles, granted that it is not possible to determine their genderis possibly the result of and atrophy of the tail. In toadlets, the length of the tail varied between 7.1 and 89.4 mm (average = 47.77 ± 27.07, n = 32) equivalent to three times the SVL in some examples.

The number of males and females correlated positively during the samplings (r = 0.98, gl = 4). The females, although present in all samples, were often in fewer numbers, which resulted in an operational sex ratio of 2.2:1 males/female (average= 2,6 ± 0,61, n = 5) and a greater than expected Chi-squared value (y2 = 63.64, gl = 4). It is a fact that the numbers of males and females differed from the expected proportion of 1:1. During the sampling performed in May, 2010, which coincided with the end of the rainy season and the pond area is smaller, a reduction in the number of males reflected in an operational sex ratio of 1:1.

3.2 Discussion:

Photographs have been used in some studies involving anurans, including species of Pseudis, in the place of marking methods, which are considered invasive. Photographs are probably more effective than "toe clipping" to identify P. cardosoi individuals, since individuals easily lose the phalanx of their fingers, quickly regenerating them. The species is ideal for photo identification because individuals can be easily identified by the unique pattern of spots, stripes, and dots located on their inner thighs, allowing the recapture of 19% of the photographed individuals. In this study, the natural patterns used for individual identification remained unchanged over time, indicating that the photographic identification method using natural markings can be effectively applied to this species. However, we suggest the use of a second control method in order to reduce uncertainties.

Population studies using capture-mark-recapture methods to estimate the size of open populations must meet certaincriteria. Due to the non-standardization of sampling intervals in this study, the assumption of equal probability of survival cannot be met, which means that the survival and recruiting estimates obtained for the intervals are not comparable. The low survival rate verified in the interval between the third and fourth samplings (Φ = 0,02) reflects the assumption that survival is a constant over the interval between i and i+1, with the proportion of surviving animals decreasing over time, following a negative exponential function. Therefore, the population structure obtained for this period cannot be considered constant. Beyond time, factors such as competition, predation, and density can cause fluctuations in amphibian populations.

The color pattern and sexual dimorphism of P. bolbodactyla individuals in our data are consistent with previous descriptions.Furthermore, we have identified sexual dimorphism in this population: females are larger and heavier. Larger females are found in 90% of all anuran species. Due to undetermined growth associated with fast growth rates and late maturity, females of most species become larger than males. Larger females produce larger eggs, or spawns, when compared with smaller females, and have a higher probability of producing more than one offspring per breeding season. In species where males are larger than females, size is associated with territoriality, combat, and mating success.

Body size is a fundamental morphological feature, important in a physiological, ecological, and social contexts. Several factors can be responsible for geographic variations in morphology, including predation, climatic changes, or other environmental parameterssuch as sexual selection, sexual dimorphism, genetic drift, founder effect, and distance from the Equator. However, the causes and maintenance of these variations are complex and are not always understood. The amplitude in body size found in this population of P. bolbodactyla is within the parameters for the genus (BRANDÃO et al. 2003), and for the species.

However, the individuals studied by us were larger than individuals in other populations in different locations of Minas Gerais and in the municipality of Pirenópolis, Goiás. The variation in size and maturity may be due to the size of the tadpoles in metamorphosis, post-metamorphic growth, or an interaction between these factors. According to ROCEK et al. (2006), ecological factors of specific locations allow species of Pseudis to grow in gigantic proportions, especially in large temporary lakes, and in the absenceof predators. GARDA et al. (2010) confirmed the descriptions of ROCEK et al. (2006) for several populations of Pseudis, where the largest specimens of P. bolbodactyla were found in large flooded areas under a bridge that crosses the São Francisco River, between the cities of Pirapora and Buritizeiro, Minas Gerais. The smallest individuals were found in small temporary ponds on sandy soils in the Municipality of Iaciara, Goiás. The fact that this study has been limited to the reproductive period of the species does not explain the larger size of the individuals, as in the case of the study of SILVA & ROSSA-FERES (2010) on another species, because in Pseudis, individuals practically do not grow after metamorphosis.

The operational sexual ratio (OSR) is the proportion of males and females that are ready to mate in a population within a determined timeframe (EMLEN & ORING 1977), and may be an important determinant regarding competition for mating and the intensity of sexual selection. This is the case for several species of amphibians. The operational sex ratio found in this population of P. bolbodactyla was biased towards a larger number of males, with an average of 2.6:1 males/female. This large male-to-female ratio had been previously recorded for a population of P. bolbodactyla (2.3:1 males/ female; TEIXEIRA et al. 2004). However, this information must be treated with caution when the estimate is based on the number of captures, because collectors may be more tuned to calling males, creating a bias.

While this data affords only a limited interpretation, our results suggest that the studied area, located in the buffer zone of Serra de Caldas Novas State Park, represents an appropriate environment for populations of P. bolbodactyla. However, for a better evaluation of the population structure with estimation, recruiting, and survival rates taken into consideration, longer studies with equivalent intervals between samplings must be implemented. We must consider that the differences in size found between the individuals of this and other populations of P. bolbodactyla may be the result of biological and ecological factors, such as reproductive periods, lake size, and the absence of predation. Lastly, this data can be considered useful in the interpretation and elaboration of new hypotheses on the ecological processes acting on amphibian populations. It can also help establish conservation measures for the species, in addition to demonstrating that population structure and sex ratio data provide valuable information on animal populations.

References

[1] Alford, R.A. & R.N. Harris. 1988. Effects of larval growth history on anuran metamorphosis. The American Naturalist 131: 91-106.

[2] Avise, J.C. 2000. Phylogeography: the history and formation of species. Cambridge, Harvard University Press.

[3] Bastos, R.P. & C.F.B. Haddad. 1999. Atividadereprodutiva de Scinaxrizibilis (Bokermann) (Anura, Hylidae) na Floresta Atlântica, sudeste do Brasil. RevistaBrasileira de Zoologia 16: 409-421.

[4] Blackburn, T.M.; K.L. Gaston & N. Loder. 1999. Geographicgradients in body size: a clarification of Bergmann's rules.Diversity and Distributions 5: 165-174.

[5] Bradfield, K.S. 2004. Photographic identification of individual Archey's frogs, Leiopelmaarcheyi, from natural markings. Wellington, Department of Conservation, DOC Science Internal Series 191, 36p.

[6] Brandão, R.A.; A. Garda; V. Braz& B. Fonseca, B. 2003.Observations on the ecology of Pseudisbolbodactyla (Anura, Pseudidae) in Central Brazil. Phyllomedusa 2: 3-8.

[7] Caramaschi, U. & C.A.G. Cruz. 1998. Notas taxonômicas sobre Pseudis fusca Garman e P. bolbodactyla A. Lutz, com a descrição de uma nova espéciecorrelata (Anura, Pseudidae). Revista Brasileira de Zoologia 15: 929-944.

[8] Castellano, S.; C. Giacoma& T. Dujsebayeva. 2000. Morphometricand advertisement call geographic variation in polyploidy green toad. Biological Journal of the Linnean Society 70: 341-360.

[9] Clemas, R.J.; J.M. Germano; R. Speare& P.J. Bishop. 2008. Use ofthree individual marking methods in Australian frogs (genus: Litoria) with notes on placement of visible implant alphanumeric tags. New Zealand Natural Sciences 34:

[10] Darst, C.R. & D.C. Cannatella. 2004. Novel relationships among hyloid frogs inferred from 12S and 16S mitochondrial DNA sequences. Molecular Phylogenetics and Evolution 31:462-475.

[11] Davis, T.M. & K. Ovaska. 2001. Individual recognition of amphibians: effects of toe clipping and fluorescent tagging on the salamander Plethodonvehiculum. Journal of Herpetology 35: 217-225.

[12] Demetrius, L. 2000. Directionality theory and the evolution of the body size. Proceedings of the Royal Society of London, Series B 267: 2385-2391.

[13] Donelly, M.A.; C. Guyer; J.E. Juterbock& R.A. Alford. 1994.Techniques for marking amphibians. Appendix 2, p. 277-

[14] 284. In: W.R. Heyer; M.A. Donnelly; R.W. Mcdiarmid; L.A.C. Hayek & M.S. Foster (Eds): Measuring and monitoringbiological diversity: standard methods for amphibians.Washington, D.C., Smithsonian Institution Press, 364p.

[15] Downie, J.R.; I. Ramnarine; K. Sams& P.T. Walsh. 2009. Theparadoxical frog Pseudisparadoxa: larval habitat, growth and metamorphosis. The Herpetological Journal 19: 11-19.

[16] Emerson, S.B. 1988. The giant tadpole of Pseudisparadoxa.Biological Journal of the Linnean Society 34: 93-104.

[17] Emlen, S.T. & L.W. Oring. 1977. Ecology, sexual selection, and the evolution of mating systems. Science 197: 215-223.

[18] Erismis, U.C. 2011. Abundance, demography and population structure of Pelophylax ridibundus (Anura: Ranidae) in 26August National Park (Turkey). North-Western Journal of Zoology 7 (1): 1-12.

[19] Fabrezi, M.; S.I. Quinzio& J. Goldberg. 2009. Giant tadpole anddelayed metamorphosis of Pseudis platensis Gallardo, 1961 (Anura, Hylidae). JournalofHerpetology 43: 228-243.

[20] Fernandez, F.A.S. 1995. Métodos para estimativas de parâmetrospopulacionais por captura, marcação e recaptura. OecologiaBrasiliensis: 01-26.

[21] Ferner, J.W. 2007. A review of marking and individual recognition techniques for amphibians and reptiles. Salt Lake City. Society for the Study of Amphibians and Reptiles, 78p.

[22] Frisch, A.J. & J.P.A. Hobbs. 2007. Photographic identification based on unique polymorphic color patterns: A novel method for tracking a marine crustacean. Journal of Experimental Marine Biology and Ecology 351: 294-299.

[23] Frost, D.R. 2013. Amphibian Species of the World: an online reference. Version 5.6. Available online at: http:// research.amnh.org/vz/herpetology/amphibia [Accessed: 16/ VI/2013].

[24] Funk, W.C.; M.A. Donnelly & K.R. Lips. 2005. Alternative views of amphibian toe-clipping. Nature 433: 193.

[25] Gallardo, J.M. 1961. On the species of Pseudidae (Amphibia, Anura). Bulletin of the Museum of Comparative Zoology 125: 111-134.

[26] Garda, A.A. & D. Cannatella. 2007. Phylogeny and biogeography of paradoxical frog (Anura, Hylidae, Pseudae) inferred from 12S and 16S mitochondrial DNA. Molecular Phylogenetics and Evolution 44: 104-114.

[27] Garda, A.A.; D.J. Santana & V.A. São-Pedro. 2010. Taxonomiccharacterization of paradoxical frogs (Anura, Hylidae, Pseudae): geographic distribution, external morphology, and morphometry. Zootaxa 2666: 1-28.

[28] Golay, N. & H. Durrer. 1994. Inflammation due to toe-clipping in Natterjack toads (Bufo calamita). Amphibia-Reptilia 15: 81-83.

[29] Halliday, T.R. & P.A. Verrel. 1988. Body size and age in amphibians and reptiles. Journal of Herpetology 22: 253265.

[30] Jolly, G.M. 1965. Explicit estimates from capture-recapture data with both death and immigration – stochastic model. Biometrika 52: 225-247.

[31] Kenyon, N.; A.D. Phillott; R.A. Alford. 2010. Temporal variationin dorsal patterns of juvenile green-eyed tree frogs, Litoriagenimaculata (Anura: Hylidae). Herpetological Conservation and Biology 5: 126-131.

[32] Kupfer, A. 2007. Sexual size dimorphism in amphibians: an overview, p. 50-59. In: D.J. Fairbairn; W.U. Blanckenhorn&T. Szekely. (Eds). Sex, Size and Gender Roles: Evolutionary Studies of Sexual Size Dimorphism. Oxford, Oxford University Press.

[33] Lebreton, J.D.; R. Pradel& J. Clobert. 1993. The statisticalanalysis of survival in animal populations. Trends in Ecology and Evolution 8: 91-95.

[34] Mccallum, M.L. & J.L. Mccallum. 2012. Does body size reflect foraging ability in post-metamorphic marine toads? Herpetology Notes 5: 15-18.

[35] Mccarthy, M.A. & K.M. Parris. 2004. Clarifying the effect of toe clipping on frogs with Bayesian statistics. Journal of Applied Ecology 41: 780-786.

[36] Measey, G.J.; D.J. Gower; O.V. Oommen& M. Wilkinson. 2001.Permanent marking of a fossorial caecilian, Gegeneophisramaswamii (Amphibia: Gymnophiona: Caeciliidae). Journal of South Asian Natural History 5: 141-147.

[37] Miranda, T.; M. Ebner; M. Solé& A. Kwet. 2005. Estimativapopulacional de Pseudiscardosoi (Anura, Hylidae), comemprego de método fotográfico para reconhecimento individual. Biociências13: 49-54.

[38] Monnet, J. & M.I. Cherry. 2002. Sexual size dimorphism in anurans. Proceedings of the Royal Society of London B 269: 2301-2307.