ORIGINAL ARTICLE

Do habitat variables correlate anuran abundance in arid terrain of Rawalpindi–Islamabad Areas, Pakistan?

Ayesha Akram [a], Muhammad Rais [a,*,1], Muhammad Arslan Asadi [a], Muhammad Jawad Jilani [a], Sara Balouch [a], Maqsood Anwar [a], Aamir Saleem [b]

[a] Department of Wildlife Management, PMAS-Arid Agriculture University Rawalpindi, Rawalpindi, 46300, Pakistan
[b] Department of Forestry and Range Management, PMAS-Arid Agriculture University Rawalpindi, Rawalpindi, 46300, Pakistan

Abstract   The quantification of anuran abundance and habitat provides valuable baseline data for future monitoring in areas of planned or anticipated human activities. We carried out the present study to see if anuran abundance is associated with habitat variables (water quality, gravel size and vegetation) in Rawalpindi–Islamabad Area, Pakistan. We used area-constrained searches and quadrat method to gather data on anuran abundance and vegetation diversity, respectively, from September, 2012 to July, 2013. We recorded 28 ± 4.83 (mean number $\pm$ SE) individuals of six anuran species from the study area. We recorded *Euphlyctis cyanophlyctis* (10 ± 2.39) as the most abundant anuran species while *Microhyla ornata* ($< 1 \pm 0.09$) as the least abundant species. The Kernel regression revealed strong and statistically significant association between habitat variables and abundance of *Hoplobatrachus tigerinus* ($R^2 = 0.678$) and *Bufo stomaticus* ($R^2 = 0.624$) but weak and statistically significant association between habitat variables and abundance of *E. cyanophlyctis* ($R^2 = 0.482$); *Duttaphrynus melanostictus* ($R^2 = 0.451$); *M. ornata* ($R^2 = 0.223$) and *Limnonectes limnocharis* ($R^2 = 0.006$). We concluded that the common frogs and toads in our area belong to families Dicroglossidae and Bufonidae while uncommon frogs are of family Microhylidae. We suggest inclusion of monitoring of water quality (dissolved oxygen and pH)

* Corresponding author. Present Address: Post-doc Scholar, Institute for Applied Ecology, University of Canberra, ACT, 2601, Australia. Tel.: +92 332 5442050.
  E-mail address: sahil@uaar.edu.pk (M. Rais).
[1] Dr. Muhammad Rais is working on ecology and conservation of amphibians and reptiles in arid ecosystems in Pakistan.

and maintenance of native wild vegetation particularly herbs, shrubs and hydrophytes of the area in the on-going and proposed development schemes of Rawalpindi–Islamabad Areas.

1. Introduction

Anurans in Pakistan are represented by 25 species belonging to families Bufonidae, Microhylidae, Megophryidae and Dicroglossidae (Pratihar et al., 2014). Anurans are closely linked to wetlands (Brode and Burry, 1984). They are particularly sensitive because of their highly permeable skin which can rapidly absorb toxic substances (Blaustein and Wake, 1990). Distribution of anuran species in an area depends upon various factors such as the type of aquatic habitat for exclusively aquatic species, type of substrate, vegetation and the reliance on water of the mature individuals (Bousbouras and Ioannidis, 1997). Presence and abundance of anurans at breeding sites are likely to be influenced by a number of abiotic factors such as temperature (Pope et al., 2000), hydroperiod (Watson et al., 2003), water quality (Banks and Beebee, 1987) and biotic factors such as vegetation structure in and around the pond (Bosch and Solano, 2003).

The quantification of the distribution and abundance of anurans provides valuable baseline data for future monitoring particularly in areas of planned or anticipated human activities. Khan (2010) provided anuran species checklist and distribution in Pakistan while Yousaf et al. (2010) and Tabassum et al. (2011) reported anuran abundance in Gujranwala and Islamabad, respectively, but did not correlate it with habitat. We conducted the present study to see if anuran abundance is associated with habitat variables (water quality, gravel size and vegetation) in Rawalpindi–Islamabad Area, Pakistan.

2. Materials and methods

2.1. Study area

We conducted the present study in Rawalpindi and Islamabad areas (Fig. 1). The areas experience a humid subtropical climate with long and very hot summers, a short monsoon and mild wet winters. The area represents typical arid landscape with hard substrate and scrub vegetation. The wetlands of the area comprise of Rivers Korang and Soan with slow-flowing water during most part of the year; and water storage reservoirs such as Rawal Dam, Simly Dam and several other small dams with associated marshes (Chaudhry and Rasul, 2004; Ashraf et al., 2007).

2.2. Study design

We selected eighteen sampling sites (each having an area of 150 ha.) for data collection. These sites differed in land use, substrate and wetland type (Appendix 1). We from September, 2012 to July, 2013. We used standard area-constrained searches to gather data on anuran abundance during morning (8:00–10:00), after-noon (14:00–16:00) and evening (20:00–22:00). We systematically searched the area to record the presence/absence of species, number of individuals and area

surveyed (Campbell and Christman, 1982; Corn and Bury, 1990; Heyer et al., 1994; Fellers and Freel, 1995; Sutherland, 1996). We followed Khan (2006) for anuran identification and Pyron and Wiens (2011) for taxonomy.

2.3. Habitat quantification

We laid out four quadrats ($4 \times 4\,m^2$) at each sampling site to record occurrence of plant species, and grouped the recorded plant species as herbs, shrubs, grasses and hydrophytes. We followed Daubenmire (1959) to estimate aerial percentage cover of each species, and calculated frequency of each plant species as number of quadrats in which a plant species occurs/total number of quadrats * 100. The circumference of the gravels was measured, and then converted in diameter by using the formula Diameter = circumference/Π. The air and water temperature were recorded using mercury thermometer. The water samples were collected from each sampling unit in sampling bottles. The basic water quality parameters-total dissolved salt (TDS) and electric conductivity (EC) were recorded using hand-held multi-meter (Omega, PHH-127). Dissolved oxygen (DO) was recorded with a multiprocessor dissolve oxygen meter (HANNA, HI-9146) and pH was tested with the help of water proof pH tester 1 (Oakton, 35624-02). Our data showed non-normal distribution, we therefore used non-parametric tests. We used Kernel regression in XLSTAT to see the relationship between anuran abundance and habitat variables. We performed Kruskal–Wallis test in SPSS 22.0 to see if number of individuals of anuran species recorded from different sampling sites differed significantly ($\alpha = 0.05$).

3. Results

3.1. Anuran species richness

We recorded six anuran species belonging to three families from Rawalpindi–Islamabad during present study (Table 1). The recorded species included: Family Bufonidae: Southeast Asian Toad (*Duttaphrynus melanostictus*), Indus Valley Toad (*Bufo stomaticus*); Family Microhylidae: Ant Frog (*Microhyla ornata*); Family Dicroglossidae: Skittering Frog (*Euphlyctis cyanophlyctis*), Bull Frog (*Hoplobatrachus tigerinus*) and Cricket Frog (*Limnonectes limnocharis*). We concluded that the anuran diversity of our study area was very low.

3.2. Anuran species abundance

We recorded 28 ± 4.83 (mean $\pm$ SE) individuals of six anuran species from the study area. Skittering Frog (10 ± 2.39) was recorded as the most abundant species followed by Indus Valley Toad (7 ± 1.15), Bull Frog (4 ± 1.25), Southeast Asian Toad (3 ± 0.69), Cricket Frog (3 ± 0.58) while Ant Frog ($<1 \pm 0.09$) was recorded as the least abundant species (Table 1). The Kruskal–Wallis test revealed that medians of
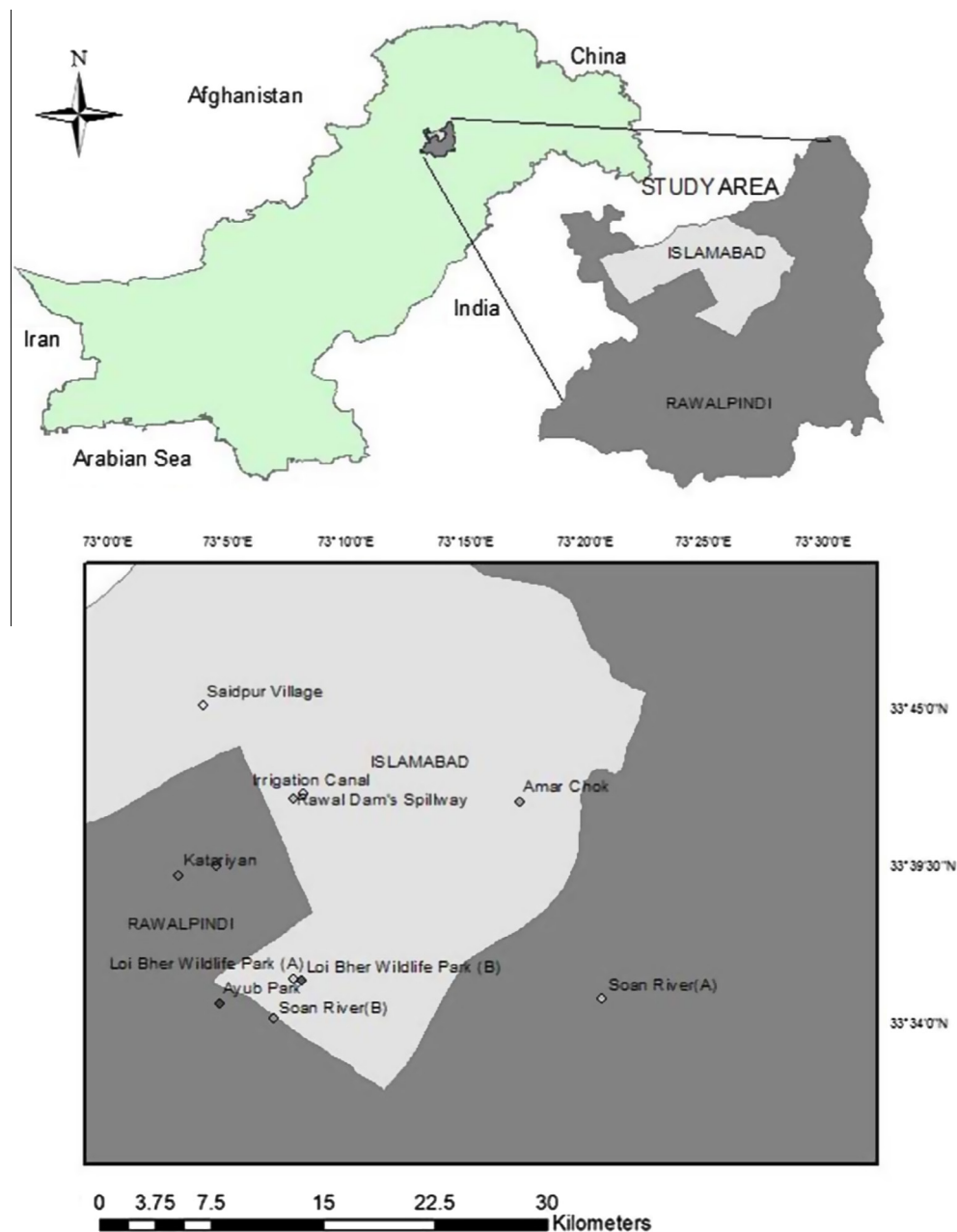
Figure 1   Map showing locations of sampling sites in the study area-Rawalpindi and Islamabad, Pakistan.

number of individuals of anuran species recorded from sampling sites differed significantly ($df = 17$, $P < 0.05$).

3.3. Habitat variables

We recorded 43 plant species from our study area, and categorized them as herbs (21), shrubs (08), grasses (08) and hydrophytes (06). The most frequent herb was *Parthenium hysterophorus* (67%), the most frequent shrubs were *Carissa opaca* and *Lantana camara* (17% each), the most frequent grass species was *Cynodon dactylon* (39%) and the most frequent hydrophytes was *Polygonum spp.* (44%). The mean percentage cover of grasses was 42 (± 4.22), of herbs was 30 (± 3.85), of hydrophytes was 21 (± 2.69) and of shrubs was 11 (± 2.48) (Table 1). The range as min–max (mean $\pm$ SE)

of pH recorded from the sampling sites of study area was 5.90–9.30 (7.44 $\pm$ 0.13); of total dissolved solids (ppm) was 150–902 (395 $\pm$ 27.17); electric conductivity (µS/cm) was 290–1490 (627.27 $\pm$ 41.55); dissolved oxygen (ppm) was 0.25–9.80 (5.12 $\pm$ 0.42) and gravel size (cm) was 0.90–15 (5.15 $\pm$ 0.62) (Table 1).

3.4. Association of anuran abundance with habitat variables

The Kernel regression revealed statistically significant association ($R^2 = 0.640$, $P < 0.05$) between anuran abundance (all species combined) and habitat variables (dissolved oxygen, pH, gravel size and herbs, shrubs and hydrophytes). The Kernel regression revealed strong and statistically significant association between habitat variables and abundance of *H.*

Table 1 Anuran abundance and habitat variables (mean ± SE) recorded from Rawalpindi–Islamabad Areas from September, 2012 to July, 2013.

	Minimum	Maximum	Sum	Median	Mean ± SE	Lower bound Mean CI	Upper bound Mean CI
Anuran species							
Family Bufonidae							
Duttaphrynus melanostictus	0.00	20.00	178.00	1.00[a]	3.30 ± 0.69	1.91	4.68
Bufo stomaticus	0.00	35.00	390.00	4.00[a,b]	7.22 ± 1.15	4.92	9.52
Family Dicroglossidae							
Euphlyctis cyanophlyctis	0.00	89.00	553.00	1.50[b]	10.24 ± 2.39	5.45	15.03
Hoplobatrachus tigerinus	0.00	56.00	230.00	0.50[a,c]	4.26 ± 1.25	1.74	6.77
Limnonectes limnocharis	0.00	16.00	146.00	0.00[a,c]	2.70 ± 0.58	1.54	3.86
Family Microhylidae							
Microhyla ornata	0.00	3.00	15.00	0.00	0.28 ± 0.09	0.11	0.45
Anurans (all species combined)	0.00	174.00	1508.00	13.00	27.93 ± 4.83	18.24	37.61
Habitat variables							
Water quality							
pH	5.90	9.30	401.85	7.55	7.44 ± 0.13	7.19	7.69
Total dissolved solids (ppm)	150.00	902.00	21319.00	345.00	394.80 ± 27.17	340.29	449.30
Electric conductivity (µS/cm)	290.00	1490.00	33872.00	547.50	627.26 ± 41.55	543.91	710.60
Dissolved oxygen (ppm)	0.25	9.80	276.54	5.05[d]	5.12 ± 0.42	4.27	5.97
Gravel size (cm)	0.90	15.00	278.01	2.95[d]	5.15 ± 0.62	3.91	6.38
Vegetation							
Grasses (% cover)	0.00	100.00	2289.50	40.00	42.40 ± 4.22	33.93	50.86
Herbs (% cover)	0.00	95.00	1617.28	20.00[e]	29.95 ± 3.85	22.23	37.67
Shrubs (% cover)	0.00	90.00	580.00	0.00	10.74 ± 2.48	5.76	15.72
Hydrophytes (% cover)	0.00	70.00	1161.66	20.00[e]	21.51 ± 2.69	16.11	26.91

The Wilcoxon signed-rank test yielded non-significant difference ($P > 0.05$) for variables with a similar superscript in the column.

tigerinus ($R^2 = 0.678$) and *B. stomaticus* ($R^2 = 0.624$) but weak and statistically significant association between habitat variables and abundance of *E. cyanophlyctis* ($R^2 = 0.482$); *D. melanostictus* ($R^2 = 0.451$); *M. ornata* ($R^2 = 0.223$) and *L. limnocharis* ($R^2 = 0.006$).

4. Discussion

The anuran fauna of Pakistan is not very rich with only 25 known species belonging to families Bufonidae, Megophryidae, Microhylidae and Dicroglossidae (Pratihar et al., 2014). The six anuran species we recorded during the present study were also reported previously by Rais et al. (2012) and Masroor (2011) from Rawalpindi–Islamabad. We recorded anurans belonging to families Bufonidae and Dicroglossidae as common while species of Microhylidae as uncommon. We recorded Skittering Frog (10 ± 2.39) as the most abundant frog species followed by Bull Frog (4 ± 1.25). Our results are consistence with previous studies. Tabassum et al. (2011) and Rais et al. (2012) reported Skittering Frog (*E. cyanophlyctis*) and Bull Frog (*H. tigerinus*) as common from Rawalpindi–Islamabad and Rawal Lake, Islamabad, respectively. The dicroglossid species have similar status in other parts of the country. Khan et al. (2010) reported Skittering Frog as abundant in Province Sindh (Southern part of Pakistan) during 2004–2006.

Our study area experiences a subtropical climate with long and very hot summers and cold winter, a short monsoon and mild wet winters. The area represents typical arid landscape with hard substrate, scrub vegetation and has high elevation and few permanent wetlands. All these are believed to have resulted in the low anuran diversity of our study area. The rain forests generally have high anuran diversity. Sluys et al. (2001) recorded population density of *Zachaenus parvulus* (Cycloramphidae) as 9.0 frogs ha$^{-0.01}$ from Ilha Grande Island, Estado do Rio de Janeiro, Brazil while Gomes et al. (2008) recorded total frog density as 4.5 frogs ha$^{-0.01}$ from Morro Sao Joao, Brazil. In contrast, arid and semi-arid areas have less anuran diversity because of less and irregular rainfall (limited to a short period in the year), having low relative humidity, extremely high temperature and solar radiation, rareness of ponds and other temporary water resources (Rodrigues, 2003).

We obtained a significant association of anuran abundance with water quality (dissolved oxygen and pH), gravel size and vegetation (herbs, shrubs and hydrophytes). Studies have established that factors such as water quality (Banks and Beebee, 1987), vegetation structure in and around the pond (Bousbouras and Ioannidis, 1997; Bosch and Solano, 2003); type of aquatic habitat and substrate (Bousbouras and Ioannidis, 1997) influence distribution and abundance of anurans. Lemckert and Mahony (2010) also documented association between anuran diversity and habitat (emergent vegetation and sandstones) while Dupuis and Wilson (1999) did not find any association between habitat variables (stream aspect, stream temperature, elevation, site gradient, % cover of boulders) and anuran abundance (tadpole number). The aforementioned studies dealt with anuran species different from those found in our study area. The low R^2 value obtained during present study revealed a low level of association of

Cricket Frog (*L. limnocharis*) with the studied habitat variables. Williams et al. (2012) recommended the prevention of woody encroachment and reduction of canopy cover in grassland areas to manage habitat for Crawfish Frogs (*Lithobates areolatus*). Ra et al. (2010) reported high abundance of Gold-spotted Pond Frog (*Rana chosenica*) from sites with greater coverage of shallow vegetated water. Gillespie et al. (2004) reported that Giant Stream Frog (*Limnonectes cf. grunniens*) and *Limnonectes cf. modestus* (Family Dicroglossidae) showed association with the rocks and ground. We recorded Skittering Frog (*E. cyanophlyctis*) from shallow water and from aquatic vegetation. Whereas, Southeast Asian Toad (*D. melanostictus*), Indus Valley Toad (*B. stomaticus*), Bull Frog (*H. tigerinus*) and Cricket Frog (*L. limnocharis*) were found at some distance from wetland margins. Previous studies by Srinivasulu and Das (2008) recorded Southeast Asian Toad (*D. melanostictus*) and Indus Valley Toad (*B. stomaticus*) from terrestrial habitats while *E. cyanophlyctis* and *H. tigerinus* from near aquatic-margins.

The quantitative data on amphibian populations are deficient in Pakistan (Molur, 2008). We conclude that the common frogs and toads in our area belong to families Dicroglossidae and Bufonidae while uncommon frogs are of family Microhylidae. We suggest inclusion of monitoring of water quality (dissolved oxygen and pH) and maintenance of native wild vegetation particularly herbs, shrubs and hydrophytes of the area in the on-going and proposed development schemes of Rawalpindi–Islamabad Areas.

Appendix 1. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.jksus.2015.02.001.

References

Ashraf, M., Kahlown, M.A., Ashfaq, A., 2007. Impact of small dams on agriculture and groundwater development: a case study from Pakistan. Agric. Water Manag. 92, 90–98.

Banks, B., Beebee, T.J.C., 1987. Factors influencing breeding site choice by the pioneering amphibian *Bufo calamita*. Holarctic Ecol. 10, 14–21.

Blaustein, A.R., Wake, D.B., 1990. Declining amphibian populations: a global phenomenon. Trends Ecol. Evol. 5, 203–204.

Bosch, J.I., Solano, M., 2003. Factors influencing occupancy in a montane amphibian assemblage. J. Herpetol. 37, 410–413.

Bousbouras, D., Ioannidis, Y., 1997. The distribution and habitat preferences of the amphibians of Prespa National Park. Hydrobiologia 351, 127–133.

Brode, J.M., Burry, R.B., 1984. The importance of riparian systems. In: California Riparian Systems. University of California Press, London, pp. 30–36.

Campbell, H.W., Christman, M., 1982. Field techniques for herpetofaunal community analysis. Herpetol. Community, 193–200.

Chaudhry, Q.Z., Rasul, G., 2004. Agro-climatic Classification of Pakistan. Sci. Vis. 9, 59.

Corn, P.S., Bury, R.B., 1990. Sampling methods for terrestrial amphibians and reptiles. Wildlife-habitat relationships. In: Sampling Procedures for Pacific North-west Vertebrates. pp. 1–28.

Daubenmire, R.F., 1959. A canopy-coverage method. Northwest Sci. 33, 43–64.

Dupuis, L., Wilson, K., 1999. Status, distribution, and management needs of the tailed frog in the east Kootenays. B.C. Min. Environ., Lands and Parks, Nelson, B.C. Unpubl. rep. 19 pp.

Fellers, G.M., Freel, K.L., 1995. A Standardized Protocol for Surveying Aquatic Amphibians. National Biological Service, Cooperative Park Studies Unit, University of California, Davis, 123 pp.

Gillespie, G.R., Lockie, D., Scroggie, M.P., Iskandar, D.T., 2004. Habitat use by stream-breeding frogs in south-east Sulawesi, with some preliminary observations on community organization. J. Trop. Ecol. 20, 439–448.

Gomes, M.A., Vrcibradic, D., Siqueira, C.C., Kiefer, M.C., Klaion, T., Santos, P.A., Nascimento, D., Ariani, C.V., Junior, V.B., Filho, R.F.F., Sluys, M.V., Rocha, C.F.D., 2008. Herpetofauna of an Atlantic rainforest area (Morro Sao Joao) in Rio de Janeiro State, Brazil. An. Acad. Bras. Ciênc. 80, 291–300.

Heyer, W.R., Donnelley, M.A., McDiarmid, R.W., Hayek, L.C., Foster, M.S., 1994. Measuring and monitoring biological diversity, standard methods for amphibian. In: Library of Congress Cataloging-in-Publication Data. Smithsonian Institution. pp. 41–73.

Khan, M.S., 2006. Amphibians: Toads and Frogs. Amphibians and Reptiles of Pakistan. Krieger Publishing Company, Malabar, Florida (Chapter 3, pp. 42–67).

Khan, M.S., 2010. Checklist of amphibians of Pakistan. Pak. J. Wildlife 1, 37–42.

Khan, M.Z., Nazia, M., Ghalib, S.A., Hussain, B., Saima, S., Shahnaz, P., Darakhshan, A., 2010. Impact of habitat destruction on the population of amphibians with reference to current status of frogs and toads in Karachi and Thatta, Sindh. Can. J. Pure Appl. Sci. 4, 1257–1265.

Lemckert, F., Mahony, M., 2010. The relationship among multiple scale habitat variables and pond use by anurans in northern New South Wales, Australia. Herpetol. Conserv. Biol. 5, 537–547.

Masroor, R., 2011. An annotated checklist of amphibians and reptiles of Margalla Hills National Park, Pakistan. Pak. J. Zoolog. 43, 1041–1048.

Molur, S., 2008. South Asian amphibians: taxonomy diversity and conservation status. Int. Zoolog. Yearbook 42, 143–157.

Pope, S.E., Fahrig, L., Merriam, H.G., 2000. Landscape complementation and metapopulation effects on Leopard Frog populations. Ecology 81, 2498–2508.

Pratihar, S., Clark, H.O., Dutta, S., Khan, M.S., Patra, B.C., Ukuwela, K.D.B., Das, A., Pipeng, L., Jianping, J., Lewis, J.P., Pandey, B.N., Razzaque, A., Hassapakis, C., Deuti, K., Das, S., 2014. Diversity and conservation of amphibians in South and Southeast Asia. Saur (Berlin) 36, 9–59.

Pyron, R.A., Wiens, J.J., 2011. A large-scale phylogeny of Amphibia including over 2800 species, and a revised classification of extant frogs, salamanders, and caecilians. Mol. Phylogenet. Evol. 61, 543–583.

Ra, N.Y., Park, D., Cheong, S., Kim, N.S., Sung, H.C., 2010. Habitat associations of the endangered gold-spotted pond frog (*Rana chosenica*). Zoolog. Sci. 27 (5), 396–401.

Rais, M., Baloch, S., Rehman, J., Anwar, M., Hussain, I., Mehmood, T., 2012. Diversity and conservation of amphibians and reptiles in North Punjab, Pakistan. Herpetol. Bull. 122, 16–25.

Rodrigues, M.T., 2003. Herpetofauna da Caatinga. Ecologia e Conservacao da Caatinga. Ed Universitária da UFPE, Recife (pp. 181–236).

Sluys, V.M., Rocha, C.F.D., Souza, M.B., 2001. Diet reproduction and density of the Litter Frog (*Zachaenus parvulus*) in an Atlantic rain forest of south eastern Brazil. J. Herpetol. 35, 322–325.

Srinivasulu, C., Das, I., 2008. The herpetofauna of Nallamala Hills, Eastern Ghats, India: an annotated checklist, with remarks on nomenclature, taxonomy, habitat use, adaptive types and biogeography. Asian Herpetol. Res. 11, 110–131.

Sutherland, W.J., 1996. Mammals in Ecological Census Techniques: A Handbook. Cambridge University Press, Cambridge (pp. 260–280).

Tabassum, F., Rais, M., Anwar, M., Mehmood, T., Hussain, I., Khan, S.A., 2011. Abundance and breeding of skittering frog (*Euphlyctis cyanophlyctis*) and bull frog (*Hoplobatrachus tigerinus*) at the Rawal Lake, Islamabad, Pakistan. Asian Herpetol. Res. 2, 177–250.

Watson, J.W., McAllister, K.R., Pierce, D.J., 2003. Home ranges, movements, and habitat selection of Oregon spotted frogs (*Rana pretiosa*). J. Herpetol. 37, 292–300.

Williams, P.J., Robb, J.R., Karns, D.R., 2012. Habitat Selection by crawfish frogs (*Lithobates areolatus*) in a large mixed grassland/forest habitat. J. Herpetol. 46 (4), 682–688.

Yousaf, S., Mahmood, T., Rais, M., Qureshi, I.Z., 2010. Population variation and food habits of ranid frogs in the rice-based cropping system in Gujranwala Region, Pakistan. Asian Herpetol. Res. 1, 123–130.