J. Limnol., 2015; 74(2): 371-380
DOI: 10.4081/jlimnol.2015.1115

ORIGINAL ARTICLE

Distribution and assemblages of large branchiopods (Crustacea: Branchiopoda) of northern Western Ghats, India

Sameer M. PADHYE,[1,2*] Neelesh DAHANUKAR[3,4]

[1]Wildlife Information Liaison Development Society, Coimbatore 641 035, Tamil Nadu; [2]Department of Zoology, University of Pune, Pune-07; [3]Indian Institute of Science Education and Research, G1 Block, Dr. Homi Bhabha Road, Pashan, Pune, Maharashtra 411 008; [4]Systematics, Ecology & Conservation Laboratory, Zoo Outreach Organization (ZOO), 96 Kumudham Nagar, Villankurichi Road, Coimbatore, Tamil Nadu 641 035, India
*Corresponding author: sameer.m.padhye@gmail.com

ABSTRACT

The present study is a report on the distribution and assemblages of large branchiopods from the Western Ghats of Maharashtra. Different types of water bodies were sampled including pools on lateritic outcrops. Eight species of large branchiopods were found in 72 samples collected over a period of 4 years. We found 7 large branchiopod species in rock pools, while the cyclestheriid Cyclestheria hislopi *was observed only in rivers and water reservoirs. In twenty-five percent of the samples multiple species co-occurred with a maximum of 4 species in a single sample.* Streptocephalus dichotomus *was the most commonly observed species while* Streptocephalus sahyadriensis *was noted only in rock pools. Altitude and aquatic vegetation were identified as important factors for the distribution of large branchiopods in the studied area.* Triops granarius *was the species most commonly found to be co-occurring with other species, followed by* S. sahyadriensis. Cyclestheria hislopi *and* Eulimnadia indocylindrova *always occurred alone.*

Key words: Temporary water bodies, Rocky outcrops, Streptocephalus, Triops, Eulimnadia.

Received: October 2014. Accepted: December 2014.

INTRODUCTION

Large branchiopods are a group of freshwater crustaceans found mostly in seasonal water bodies throughout the world (Brendonck *et al.,* 2008). These animals are found in characteristic assemblages with representatives of a few or mostly all orders co-habiting a single habitat with up to 10 species found in a single site (Thiéry, 1991; Maeda-Martínez *et al.,* 1997). Many factors are known to influence branchiopod assemblages including habitat type, size of the water body, hydroperiod, pH, salinity and temperature and biotic conditions such as vegetation presence, competition and predation (Thiéry, 1991; Maeda-Martínez *et al.,* 1997 and references therein; Boven *et al.,* 2008). Various aspects of such assemblages have been investigated from the temperate regions of the old world and the new (Hamer and Appleton, 1991a; Thiéry, 1991; Maeda-Martínez *et al.,* 1997; Petrov and Cvetković, 1997; Eder *et al.,* 1997; Hamer and Martens, 1998; Thiéry and Puente, 2002; Marrone *et al.,* 2006; Boven *et al.,* 2008; Waterkeyn *et al.,* 2009). However, limited information is available from the Oriental biogeographical region, including India. Studies on the large branchiopods of India are scattered and have mainly focused on taxonomical and/or faunistic records (Bond, 1934; Nayar and Nair, 1968; Raj, 1971; Battish, 1983; Belk and Esparza, 1995; Durga Prasad and Simhachalam, 2009; Simhachalam and Timms, 2012; Padhye *et al*., 2015). Other studies have been addressed on biology, phylogeny and/or applied aspects of selected species (Bernice, 1972; Paul and Nayar, 1977; Munuswamy, 1988; Prasath *et al.,* 1994; Radhika *et al.,* 1998; John *et al.,* 2004; Vikas *et al.,* 2012).

India is considered to be one of the *megadiversity* countries of the world (Mittermeier *et al.,* 1998) and includes areas such as the Western Ghats known to have several endemic species of plants and animals (Mittermeier *et al.,* 2005). Some parts of the Western Ghats of Maharashtra possess unique and interesting habitats in the form of rocky outcrops (Widdowson and Cox, 1996; Jog *et al.,* 2002) which are generally known to host rich large branchiopod fauna (Pinder *et al.,* 2000; Timms 2006; Brendonck *et al.,* 2010; Jocque *et al.,* 2010). Despite these facts, ecological and distributional studies on the large branchiopod in these parts of Ghats and surrounding areas are rare to the best of our knowledge, with only a few published reports (Pai, 1958; Karande and Inamdar, 1959, 1960, 1964; Padhye *et al.,* 2011a, 2011b, 2015).

The large branchiopod fauna of the Western Maharashtra (India) has recently been compiled (Padhye *et al*., 2015, and reference therein). In the present work we investigate the distributional patterns and the coexistence of the large branchiopod assemblages observed in the region.We report the observations on the frequency of associations between the species and evaluate the relative importance of selected environmental variables in explaining the distributional patterns of the large branchiopod species considered in this study.

METHODS

Study area

The Western Ghats are a steep western edge of an elevated Plateau (Prasad *et al.,* 2009) running for almost 1600 km and covering six states of India, namely Gujarat, Maharashtra, Goa, Karnataka, Tamil Nadu and Kerala (Mani, 1974). The northern region of the Western Ghats considered for this study lies in the states of Maharashtra and Goa. This region of the Ghats has been the center of the Deccan volcanism event and is made up mostly of basaltic rock (Jog *et al.,* 2002). Some parts of the Ghats show peculiar rocky outcrop formations (either basaltic or lateritic) on hilltops (Widdowson and Cox, 1996) known to have unique fauna and flora (Porembski and Watve, 2005; Watve, 2013). This region of the Ghats gets a majority of its rainfall in the Monsoon season (June - September/October) and has a prolonged dry season lasting from 5 to 8 months (Mani, 1974).

Sampling area and methods

Sampling was performed from November 2009 to September 2013 in a region lying in the Western Ghats of the state of Maharashtra between 15°N to 20°N (henceforth referred to as NWG) (Fig. 1). We also sampled a single locality in Goa (a water reservoir, located approximately 150 km south of Masai plateau, near the western coast of Goa, adjacent to the Western Ghats). A total of 72 samples were collected from 28 different localities in the studied area (Supplementary Tab. 1). In a given locality, samples collected from different sites were considered as separate samples. Similarly, samples collected from the same sites on different dates were considered as different samples in order to account for putative temporal variations. Samples were categorized into 4 types of habitats, *i.e.* pools, ponds, lakes (water reservoirs) and rivers according to Williams *et al.* (2004) and De Bie *et al.* (2008). The sampling sites (pools and ponds) were selected via chance encounter while walking in the respective localities. Sampling was performed during the monsoon season for the localities having temporary water bodies. Qualitative sampling was collected by sweeping with a hand net with a circular plastic frame (r=7.5 cm) and a mesh size of 150 µm. An effort was made to sample representatively each microhabitat of the water-bodies during every collection. Only littoral samples were taken from riverine and reservoir localities. Samples were collected in plastic containers (100 mL) in the field and immediately fixed with 8% formalin. Animals were sorted, observed and/or dissected under Stereo Binocular Microscope and identified according to Velu and Munuswamy (2005) for Anostraca, Longhurst (1955) and Raj (1971) for Notostraca, Battish (1981), Martin and Belk (1988), Balaraman and Nayar (2004), Babu and Nandan (2010), Rabet (2010), Rogers *et al.* (2012) and Simhachalam and Timms (2012) for Laevicaudata and Spinicaudata.

In addition, the physical and chemical parameters of water like pH, Temperature and Salinity were checked on the field by using portable Multiparameter probe. Latitude and longitude were obtained either with a handheld GPS unit or from Google Earth for few localities. Altitude of the localities was also recorded by using the handheld GPS unit or were extracted *via* DIVA-GIS (v7.5) using BIOCLIM data (Hijmans *et al.* 2005, http://www.worldclim.org). Data for average annual precipitation were extracted using BIOCLIM data *via* DIVA-GIS (v7.5). Presence/absence of submerged and/or floating aquatic vegetation was recorded in the field itself.

Data analyses

Large branchiopod occurrence data obtained from the 72 samples were used for calculating the Fager's index of affinity. This index is calculated as a measure of co-occurrence for the branchiopods observed in a species assemblage (Maeda-Martínez *et al.*, 1997). The index is calculated by the formula:

$$IF=\frac{2(n1+2)}{(n1+n2)} \qquad \text{(eq. 1)}$$

where $n1+2$ is the number of joint occurrences of species 1 and 2, $n1$ is the total number of occurrences of species 1 and $n2$ is the total number of occurrences of species 2.

Large branchiopod assemblage pattern table format was adopted from Maeda-Martínez *et al.* (1997). Mapping was carried out using DIVA-GIS (v7.5) freeware (www.diva-gis.org). The distribution of the large branchiopod species was investigated in relation to local environmental and spatial characteristics using canonical correspondence analysis (CCA) based on the large branchiopod occurrence data for the 72 samples. Environmental variables used for the analysis were pH, Temperature, Salinity, Average Annual precipitation, Altitude and Aquatic vegetation. The significance of the analysis was tested using Monte Carlo permutations (n=999). Dummy coding was applied for presence/absence of aquatic vegetation. CCA analysis was performed using PAST (v 2. 17c) (Hammer *et al.,* 2001).

RESULTS

Species richness and faunistic notes

A total of 8 species belonging to all the 5 orders of large branchiopods were found from 72 samples (pools, 53; ponds, 15; reservoir, 3; rivers, 1) from 28 localities from NWG (Tab. 1; Fig. 1). Nineteen of the 28 localities had only one species. Alandi road 1 locality hosted the maximum number of species (5) followed by Tableland (4) and Masai (4) (Supplementary Tab. 1). Eighteen of the 72 (25%) samples hosted more than one species (Tab. 2). Five of these 18 samples had 3 or more co-occurring species. Seven species were present in pools, 4 in ponds, while water reservoirs and rivers hosted only *Cyclestheria hislopi*. Anostracans were the most commonly occurring group of large branchiopods (they occurred in 43 out of 72 samples) with *Streptocephalus dichotomus* being more frequent (27 out of the 72 samples) than *S. sahyadriensis* (16 out of the 72 samples).

Factors affecting distribution

Besides *C. hislopi*, all species of large branchiopods lived in neutral or slightly basic pH (Tab. 3). Seven of the eight recorded species showed a wide altitudinal range with restriction seen in *S. sahyadriensis* only. *S. sahyadriensis* distribution was limited to rock pools of lateritic outcrops while its congener, *S. dichotomus* was spread quite uniformly throughout the sampled region (Fig. 2d). *Cyzicus* sp. was limited to only two, closely situated localities (Fig. 2a).

The first two CCA axes explained 77.2% variance (permutations=999; trace=0.84; P=0.001). Altitude and annual precipitation negatively correlated to the first axis (-0.63 and -0.41) while total number of species/sample weakly correlated with the second axis (0.41) (Fig. 3). Four of the eight species, *i.e., Streptocephalus sahyadriensis*, *Triops granarius*, *Leptestheriella nobilis*, and *Lynceus alleppeyensis* were mostly observed as assemblages on lateritic outcrops which were characterized by higher altitudes, little or no aquatic vegetation, and relatively lower salinity and pH (Fig. 3). *Streptocephalus dichotomus* was found in pools located at lower altitudes as well and also occurred as a single species in many habitats (Fig. 2).

Assemblages and species co-occurrences

Six of the eight species co-occurred in different combinations (Tab. 2). *Triops granarius* was the most represented species in all combinations of the species assemblage. The groups of *S. sahyadriensis* - *L. nobilis* and *S. sahyadriensis* - *T. granarius* - *L. nobilis*, both detected three times, were the most common combinations observed. Assemblages consisted of one representative of each order only. *S. dichotomus* along with *L. nobilis* showed the weakest Fager's index (0.05). *T. granarius* co-occurred mostly with *L. nobilis* (0.41) followed by *S. sahyadriensis* and *L. alleppeyensis* (0.30 and 0.29, respectively). Occurrence of *Cyzicus* sp. was sporadic and it never occurred as a single species. Both of its occurrences were with *L. alleppeyensis* (Fager's index of 0.44). *Eulimnadia indocylindrova* and *C. hislopi* occurred only as single species with the latter being more common of the former.

DISCUSSION

Faunistics, environmental variables and distributional patterns

The diversity of large branchiopods in India is poorly documented (Durga Prasad and Simhachalam, 2009), but presently, the number would roughly be 80 species (Raj, 1971; Battish, 1983; Belk and Esparza, 1995; Durga Prasad and Simhachalam, 2009). Eight species from this study thus represents about 10% of the known large branchiopod fauna of India. This species richness is less than the only other known comprehensive fauna from Oriental region (SE Asia) having 8 described and 3-4 undescribed species (Rogers *et al.,* 2013). This difference in species number between NWG and SE Asia, may just be the result of limited sampling area and of the difference of geographical extent of the two regions rather than to be ascribed to true species deficiency in NWG.

Out of the eight species found, *S. dichotomus* is widespread in the Indian sub-continent and Myanmar (Belk

Tab. 1. Species seen in the study along with the localities where they were found.

Order	Family	Species	Code	Localities (observed)
Anostraca	Streptocephalidae	*Streptocephalus dichotomus* Baird, 1860	Stdi	Ju,Vi, Gh, De, Ar1, Ar2, Ko, Mi, Si, Aj, Ma, Ro
		S. sahyadriensis Rogers & Padhye, 2014	Stsa	Tb, Me, Mh, Ch
Notostraca	Triopsidae	*Triops granarius* (Lucas, 1864)	Tgra	Ar1, Tb, Me, Ya, Ja,Ch, Mh, Ma
Laevicaudata	Lynceidae	*Lynceus alleppeyensis* Balaraman & Nayar, 2004	Lall	Ar1, Ar2,T b,Ya, Aj, Ma
Spinicaudata	Cyzicidae	*Cyzicus* sp.	Cyzi	Ar1, Ar2
Spinicaudata	Eulimnadidae	*Eulimnadia indocylindrova* Durga Prasad & Simhachalam, 2004	Euin	Bd, Ta, Ma
Spinicaudata	Leptestheriidae	*Leptestheriella nobilis* (Sars, 1900)	Lnob	Ar1, Up, Tb, Me, Ya, Aj, Ch
Cyclestherida	Cyclestheridae	*Cyclestheria hislopi* (Baird, 1859)	Chis	Di, Sh, Ga, Ps, La, Pa, My

For locality names corresponding to the numbers, refer to Supplementary Tab. 1.

and Esparza, 1995; Rogers *et al.,* 2013 and references therein). Three species, *S. sahyadriensis*, *E. indocylindrova* and *L. nobilis* are Indian endemics. Distribution of *Triops granarius* has to be re-evaluated since this species seems to be paraphyletic with at least two distinct clades known to occur in India (Korn *et al.,* 2013). A recent detailed phylogenetic study on *C. hislopi* has revealed that 3 distinct *phylogenetic species* occur on different continents, and that the populations from India and Southeast Asia form a separate clade (Schwentner *et al.,* 2013).

Temperature, pH and salinity did not effectively explain the species distribution perhaps due to the overlapping pH, temperature and salinity ranges observed for all species (Tab. 2). Pools could be roughly categorized into pools with large branchiopod assemblages and pools with only single species (Fig. 3). Pools with assemblages were mostly found on lateritic rocky outcrops located at higher altitudes having little or no aquatic vegetation; conversely, pools with single species did not show any such specificity. Further sampling from additional localities (*e.g.*, those given by Watve, 2013) would help in resolving these associations.

Distribution of both *Streptocephalus* species was distinct in the study area in spite of a high chance of dispersal owing to proximity of habitats (Fig. 2d). *Streptocephalus* species are usually considered generalists occurring in pools having a comparatively longer inundation period due to their slower maturation rate, though, exceptions are also known (De Roeck *et al.,* 2010; Jocque *et al.,* 2010). *Streptocephalus dichotomus* here could be considered as a generalist species on account of its wide distribution

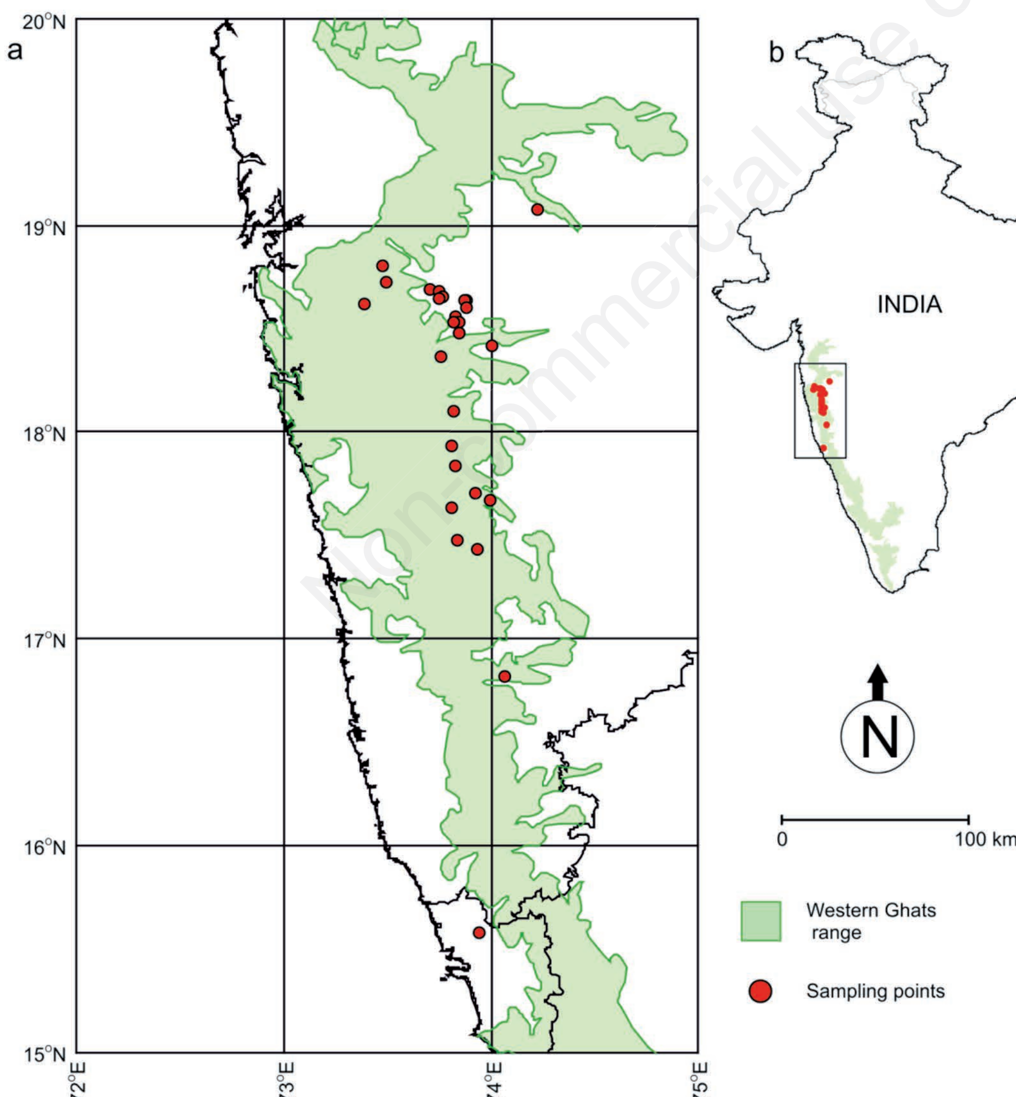

Fig. 1. a) Sampled sites in the NWG. b) Studied area within India. Scale bar given for a).

within the sampling region while *S. sahyadriensis* could be considered as a more stenoecious taxon, with a highly restricted distribution and a specificity for rock pools. The absence of *C. hislopi* from higher altitude localities cannot be explained at this stage.

Species assemblages and co-occurrences

Twenty-five percent value of co-occurrence of species from all large branchiopod habitats sampled in NWG is comparable to 31% from a study by Boven *et al.* (2008) but was less than the value reported by other authors like Petrov and Cvetković (1997) (67%) and Thiéry (1991) (90%). The reason for such low co-occurrence ratio has been attributed to invertebrate predator density, availability of food and resource partitioning due to size disparity (Thiéry, 1991 and references therein; Simovich 1998; Hamer and Martens, 1998). This value could also be due to the low number of large branchiopod species found in NWG. Co-existence of 4 species of large branchiopods in a single sample is the highest level of coexistence documented from Western Ghats to date. A similar number of species of large branchiopods have been reported from

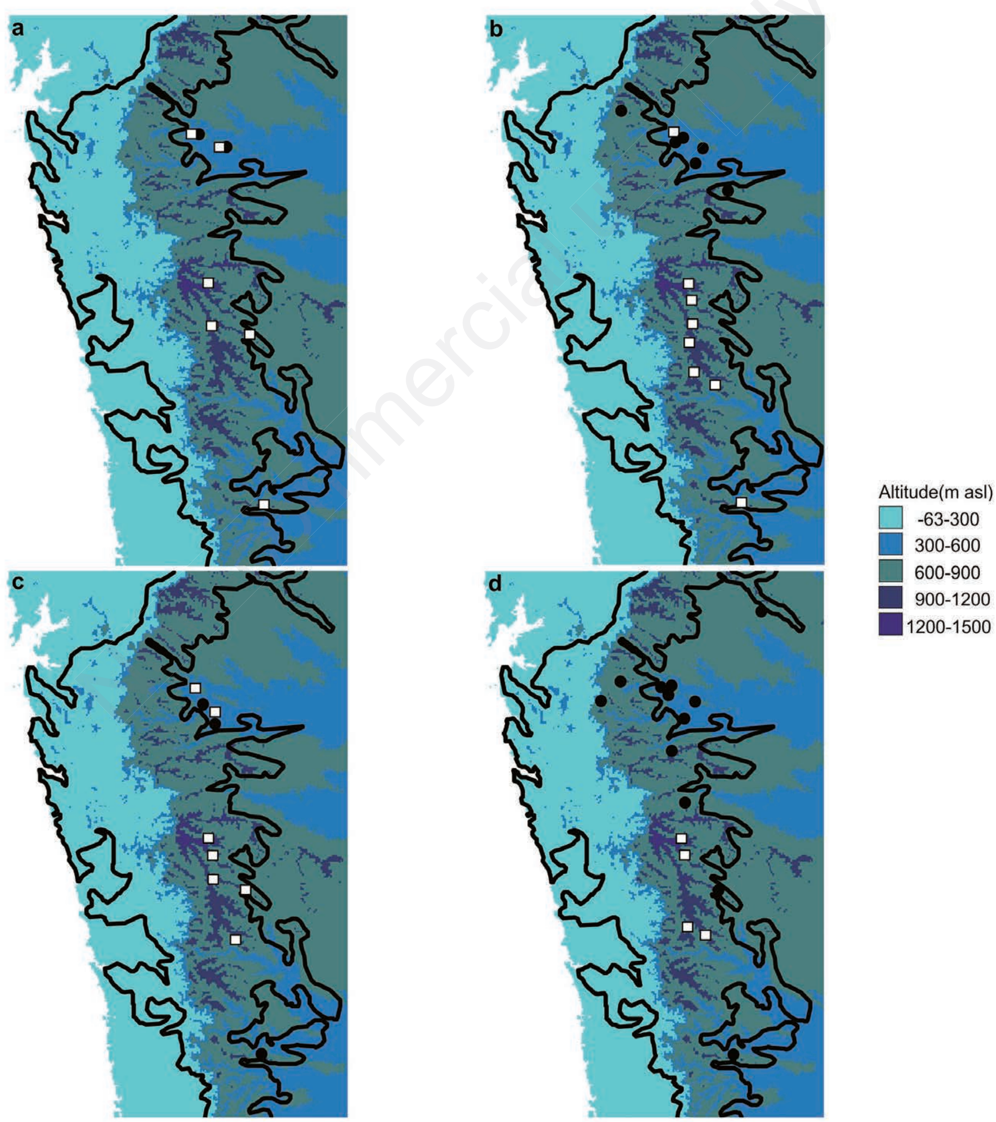

Fig. 2. Distribution of the large branchiopod species detected in the studied area. a) *Cyzicus* sp. (black circle) and *Lynceus alleppeyensis* (white square). b) *Cyclestheria hislopi* (back circle) and *Triops granarius* (white square) (locality of Goa for *C. hislopi* not shown in the map). c) *Eulimnadia indocylindrova* (black circle) and *Leptestheriella nobilis* (white square). d) *Streptocephalus dichotomus* (black circle) and *Streptocephalus sahyadriensis* (white square).

Sambhar lake, Rajasthan in Central India with the co-occurrence of three fairy shrimps and a clam shrimp (Baid, 1968). All combinations of species of the three orders of large branchiopods were seen recurring over studied area, especially on rocky outcrops. Similar recurring assemblages of different orders have been reported from USA, Mexico and Africa (Hamer and Appleton, 1991b; Thiéry, 1991; Maeda-Martínez *et al.,* 1997). *Triops granarius*, in the current study was observed only in assemblages, an observation also noted for the congeneric species *T. cancriformis* (Petrov and Cvetković, 1997; Boven *et al.,* 2008; Waterkeyn *et al.,* 2009). Congeneric appearances of anostracans are widespread (Daborn, 1977; Donald, 1983; Timms and Sanders, 2002) with co-occurrences of *Streptocephalus* species seen commonly (Moore, 1966; Mertens and Dumont, 1989; Hamer and Appleton, 1991a), but his was not observed in this study.

CONCLUSIONS

Many large branchiopod species exhibit endemism and are confined to small regions or their type localities (Dumont and Negrea, 2002; Brendonck *et al.,* 2008; Durga Prasad and Simhachalam, 2009); conversely, other species have a wider distribution. These animals rely on banks of resting eggs as a buffer against environmental stresses (Brendonck, 1996). Hence, habitat loss caused by land conversion can destroy these egg banks threatening the diversity of large branchiopods. Such temporary water habitats are diminishing worldwide (Williams *et al.,* 2004). Many species from Europe and North America are considered critically endangered and listed in the IUCN red list (www.iucnredlist.org). Baseline data about habitat destruction caused due to land conversion for activities like agriculture are not known for developing countries (Brendonck *et al*., 2008). Freshwater rock pools known to have high diversity of unique fauna are considered as untouched habitats (Brendonck *et al.,* 2010; Jocque *et al.,* 2010) and therefore are of conservational significance (Jocque *et al.,* 2007; Watve, 2013 and references therein). The finding of 6 large branchiopod species, including the endemic *Streptocephalus sahyadriensis*, on lateritic outcrop localities emphasizes the need of a further comprehensive study focused specifically on these outcrops.

A detailed research of such temporary habitats is thus very much required especially in less studied regions such as the Western Ghats. Such studies will definitely help our understanding of large branchiopod diversity and ecology

Tab. 2. Assemblage structures observed in the studied samples.

Number of species in an assemblage	Number of samples	Anostraca	Notostraca	Spinicaudata	Laevicaudata
2	12	*	Tgra	Lnob	*
		Stsa	*	Lnob	*
		Stsa	*	Lnob	*
		Stsa	Tgra	*	*
		Stsa	Tgra	*	*
		*	Tgra	Lnob	*
		*	Tgra	*	Lall
		Stdi	*	Lnob	*
		Stdi	Tgra	*	*
		Stdi	Tgra	*	*
		Stdi	*	*	Lall
		Stsa	*	Lnob	*
3	5	Stdi	*	Cyzi	Lall
		*	Tgra	Lnob	Lall
		Stsa	Tgra	Lnob	*
		Stsa	Tgra	Lnob	*
		Stsa	Tgra	Lnob	*
4	1	Stdi	Tgra	Cyzi	Lall

Stsa, S. sahyadriensis; *Stdi*, Streptocephalus dichotomus; *Tgra*, Triops granarius; *Lnob*, Leptestheriella nobilis; *Cyzi*, Cyzicus sp.; *Lall*, Lynceus alleppeyensis.

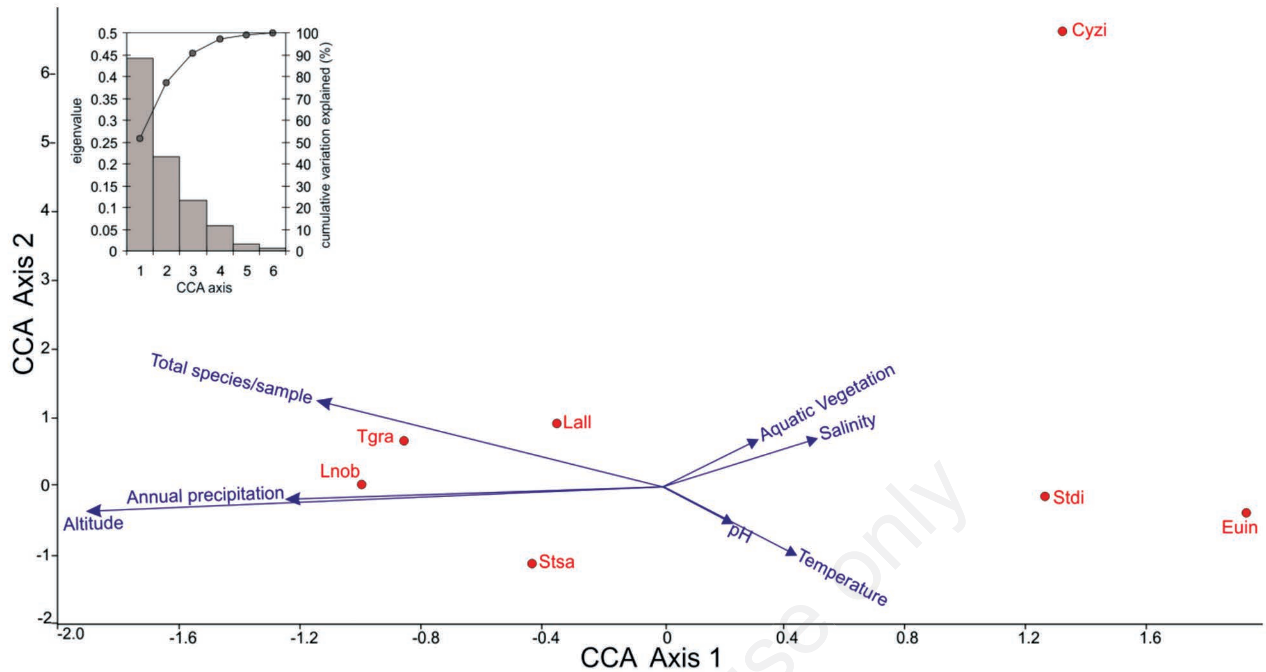

Fig. 3. CCA ordination diagram showing the relationships between the large branchiopod species and the environmental variables for all the pool samples. Scree plot is shown in the inset. Species codes as in Tab. 2.

Tab. 3. Range of environmental variables for each species of large branchiopods with their number of occurrences and co-occurrences in 72 samples.

Species	Total occurrence	Co-occurrence	Altitude (m asl)	Annual precipitation (mm)	pH (range)	Temperature (°C)	Salinity (mg/L)
Streptocephalus dichotomus Baird, 1860	27	6	587-1185	520-3693	6.5-8.8	20.2-30.8	15.5-383.0
S. sahyadriensis Rogers & Padhye, 2014	16	8	1082-1289	2156-3977	7.1-8.8	20.3-33.0	24.0-38.0
Triops granarius (Lucas, 1864)	14	12	612-1289	754-3977	7.1-8.7	21.6-27.1	17.0-166.0
Lynceus alleppeyensis Balaraman & Nayar, 2004	7	5	612-1289	754-3977	7.6-8.7	22.1-28.1	15.5-166.0
Leptestheriella nobilis (Sars, 1900)	15	10	578-1289	745-3977	7.4-8.8	21.6-29.8	22.6-383.0
Cyzicus sp.	2	2	587-612	754	8.2-8.7	26.0-27.0	147.0-166.0
Eulimnadia indocylindrova Durga Prasad & Simhachalam, 2004	3	0	577-940	844-1859	8.0-8.2	20.9-29.9	17.0-157.0
Cyclestheria hislopi (Baird, 1859)	13	0	50-658	519-3414	7.1-9.0	23.7-30.0	39.0-310.0

in the region and will hopefully lead to informed conservation measures.

ACKNOWLEDGMENTS

Sameer Padhye acknowledges Prof. Kalpana Pai and the Zoology Department of Pune University for providing the lab facilities as collections done in the study were part of the Ph.D. work of the author. Modern College, Shivajinagar is also acknowledged for providing the lab facilities during the Ph.D. Sameer Padhye thanks Dr. Hemant Ghate for his suggestions on the work. S. Padhye acknowledges the Council of Scientific and Industrial Research, India (CSIR) for providing the funding during his Ph.D.

Both the authors thank Dr. Sanjay Molur and Wildlife Information Liaison Development society for their support. The authors also acknowledge Dr. Yugandhar Shinde Dr. Avinash Vanjare, Mr. Shriraj Jakhalekar, Mr. Siddharth Kulkarni, Mr. Mihir Kulkarni, Ms. Kalyani Bhakre, Ms. Shruti Paripatyadar, Ms. Sayali Sheth and Mr. Chandrakant Redican for their help during the field collections and S. Padhye thanks Mr. Chandrakant Redican for his help in the linguistic revision of the manuscript.

REFERENCES

Babu KKS, Nandan SB, 2010. Two new clam shrimp species (Crustacea: Branchiopoda: Spinicaudata) from Kerala, India. Zootaxa 2713:55-64.

Baid IC, 1968. The Arthropod Fauna of Sambhar Salt Lake, Rajasthan, India. OIKOS 90:292-303.

Balaraman U, Nayar CKG, 2004. A new species of the clam shrimp genus *Lynceus* (Branchiopoda Conchostraca, Laevicaudata) from Kerala, India. Crustaceana 77:407-416.

Battish SK, 1981. On some conchostracans from Punjab with the description of three new species and a new subspecies. Crustaceana 40:178-196.

Battish SK, 1983. On the occurrence of three species of fairy shrimps (Anostraca: Crustacea) in Punjab, with a check-list of Indian anostracans. Res. Crust. 12:77-84.

Belk D, Esparza CE, 1995. Anostraca of the Indian Subcontinent. Hydrobiologia 298:287-293.

Bernice R, 1972. Ecological studies on *Streptocephalus dichotomus* Baird. Hydrobiologia 39:217-240.

Bond RM, 1934. Report of Phyllopod Crustacea including a revision of the Anostraca of the Indian Empire. Mem. Connect Acad. Arts. Sci. 10:29-62.

Boven L, Vanschoenwinkel B, De Roeck ERM, Hulsmans A, Brendonck L, 2008. Diversity and distribution of large branchiopods in Kiskunsa´g (Hungary) in relation to local habitat and spatial factors: implications for their conservation. Mar. Freshw. Res. 59:940-950.

Brendonck L, 1996. Diapause, quiescence, hatching requirements: what we can learn from large freshwater branchiopods (Crustacea: Branchiopoda: Anostraca, Notostraca, Conchostraca). Hydrobiologia 320:85-97.

Brendonck L, Rogers DC, Olesen J, Weeks S, Hoeh WR, 2008. Global diversity of large branchiopods (Crustacea: Branchiopoda) in freshwater. Hydrobiologia. 595:167-176.

Brendonck L, Jocque M, Hulsmans A, Vanschoenwinkel B, 2010. Pools 'on the rocks': freshwater rock pools as model system in ecological and evolutionary research. Limnetica 29:25-40.

Daborn GR, 1977. The life history of *Branchinecta mackini* Dexter (Crustacea: Anostraca) in an argillotrophic lake of Alberta. Can. J. Zool. 55:161-168.

De Bie T, Declerck S, Martens K, De Meester L Brendonck L, 2008 A comparative analysis of cladoceran communities from different water body types: patterns in community composition and diversity. Hydrobiologia 597:19-27.

Donald DB, 1983. Erratic occurrence of anostracans in a temporary pond: colonization and extinction or adaptation to variations in annual weather? Can. J. Zool. 61:1492-1498.

Dumont HJ, Negrea SV, 2002. Introduction to the Class Branchiopoda, p. 1-398. In: H.J. Dumont (ed.), Guides to the identification of the micro invertebrates of the continental waters of the world, 19. Backhuys Publ.

De Roeck ER, Waterkeyn A, Brendonck L, 2010. Life-history traits of *Streptocephalus purcelli* G.O. Sars, 1898 (Branchiopoda, Anostraca) from temporary waters with different phenology. Water SA 36:323-328

Durga Prasad MK, Simhachalam G, 2009. Distribution of Indian clam shrimps (Branchiopoda: Crustacea). Curr. Sci. 96:71-73.

Eder E, Hödl W, Gottwald R, 1997. Distribution and phenology of large branchiopods in Austria. Hydrobiologia 359:13-22.

Jocque M, Timms B, Brendonck L, 2007. A contribution on the biodiversity and conservation of the freshwater fauna of rocky outcrops in the central wheatbelt of Western Australia. J. Roy. Soc. West. Aust. 90:137-142.

Jocque M, Vanschoenwinkel B, Brendonck L, 2010. Freshwater rock pools: a review of habitat characteristics, faunal diversity and conservation value. Freshwater Biol. 55 1587-1602.

Jog SR, Wakhare A, Chaudhuri S, Unde M, Pardeshi SD, 2002. Maharashtra landscape: A perspective, p. 19-57. In: J. Diddee, S.R. Jog, V.S. Kale and V.S. Datye (eds.), Geography of Maharashtra. Rawat Publications.

John CJA, Abatzopoulos T, Marian PM, 2004. Characterization of a new parthenogenetic Artemia population from Thamaraikulam. Indian J. Biol. Res. 2:63-74.

Hamer ML, Appleton CC, 1991a. Physical and chemical characteristics and phyllopod fauna of temporary pools in north-eastern Natal, Republic of South Africa. Hydrobiologia 212:95-104.

Hamer ML, Appleton CC, 1991b. Life history adaptations of phyllopods in response to predators, vegetation, and habitat duration in north-eastern Natal. Hydrobiologia 212:105-116.

Hamer ML, Martens K, 1998. The large Branchiopoda (Crustacea) from temporary habitats of the Drakensberg region, South Africa. Hydrobiologia 384:151-165.

Hammer Ø, Harper DAT, Ryan PD, 2001. PAST: Paleontological statistics software package for education and data analysis. Palaeontol. Elec. 4:1-9.

Hijmans R, Cameron SE, Parra JL, Jones PG, Jarvis A, 2005. Very high resolution interpolated climate surfaces for global land areas. Int. J. Clim. 25:1965-1978.

Karande A, Inamdar NB, 1959. Observation of the taxonomic characters of *Triops orientalis* (Tiwari), with note on its biology. J. Bombay Nat. Hist. Soc. 56:215-225.

Karande A, Inamdar NB, 1960. A new species of the genus *Leptestheriella* from India. An. Mag. Nat. Hist. 2:305-308.

Karande A, Inamdar NB, 1964. On *Eocyzicus* sp. (Conchostraca: Branchiopoda) at Panchgani, W. India. J. Bombay Nat. Hist. Soc. 62:167-168.

Korn M, Rabet N, Ghate H V, Marrone F, Hundsdoerfer A, 2013. Molecular phylogeny of the Notostraca, Mol. Phylogenet. Evol. 69:1159-1171.

Longhurst A R, 1955. A review of the Notostraca. Bull. Br. Mus. (Natural History) 3:1-57.

Maeda-Martínez MA, Belk D, Barboza OH, Dumont HJ, 1997. Large branchiopod assemblages common to Mexico and the United States. Hydrobiologia 359:45-62.

Mani MS, 1974. Ecology and biogeography in India. W. Junk, The Hague: 647 pp.

Marrone F, Barone R, Flores LG, 2006. Ecological characterization and cladocerans, calanoid copepods and large branchiopods of temporary ponds in a Mediterranean island (Sicily, southern Italy). Chem. Ecol. 22:181-190.

Martin JW, Belk D, 1988. Review of the clam shrimp family Lynceidae Stebbing, 1902 (Branchiopoda: Conchostraca) in the Americas. J. Crustac. Biol. 83:451-482.

Mertens J, Dumont H, 1989. Confirmation of *Streptocephalus* *rubricaudatus* as a good species (Anostraca). Crustaceana 56:211-212.

Mittermeier RA, Myers N, Thomsen JB, da Fonseca GAB, Olivieri S, 1998.Biodiversity Hotspots and Major Tropical Wilderness Areas: Approaches to Setting Conservation Priorities. Conserv. Biol. 12:516-520.

Mittermeier RA, Gil PR, Hoffman M, Pilgrim J, Brooks T, Mittermeier CG, Lamoreux J, da Fonseca GAB, 2005. Hotspots revisited: Earth's biologically richest and most endangered terrestrial ecoregions. Cemex, Mexico: 392 pp.

Moore WG, 1966. New World fairy shrimps of the genus *Streptocephalus* (Branchiopoda, Anostraca). S. West. Nat. 11:4-48.

Munuswamy N, 1988. Studies on the Structural Properties of the Egg Shell of the Brine Shrimp *Artemia salina* (Linneaus, 1758) (Branchiopoda, Anostraca) Crustaceana 54:39-42.

Nayar CKG, Nair KKK, 1968. On a collection of Conchostraca (Crustacea: Branchiopoda) from south India, with the description of two new species. Hydrobiologia 32:219-224.

Padhye S, Ghate HV, Pai K, 2011a. New locality record and additional information on the habitat of *Cyclestheria hislopi* (Baird, 1859) (Crustacea: Branchiopoda: Cyclestherida) in India. J. Threat. Taxa 3:1445-1448.

Padhye S, Ghate HV, Pai K, 2011b. New locality records and additional information on habitats of three species of clam shrimps (Crustacea: Branchiopoda) from a region in northern part of Western Ghats (Sahyadris), India. J. Threat. Taxa 3:1756-1763.

Padhye S, Rabet N, Ghate H, 2015. First faunal inventory of large branchiopods (Crustacea: Branchiopoda) of Western Maharashtra, India with taxonomical and distributional comments. Zootaxa 3904:208-222.

Pai L, 1958. On the post embryonic stages of phyllopod crustaceans, *Triops* (*Apus*), *Streptocephalus* and *Estheria*. Proc. Indian. Natl. Sci. Acad. B 48:229-250.

Paul MA, Nayar CKG, 1977. Studies on a natural population of *Cyclestheria hislopi* (Baird) (Conchostraca: Crustacea). Hydrobiologia 53:173-179.

Petrov B, Cvetković DM, 1997. Community structure of branchiopods (Anostraca, Notostraca and Conchostraca) in the Banat province in Yugoslavia. Hydrobiologia 359:23-28.

Pinder AM, Halse SA, Shiel RJ, McRae JM, 2000. Granite outcrop pools in south-western Australia: foci of diversification and refugia for aquatic invertebrates. J. Roy. Soc. West. Aust. 83:149-161.

Porembski S, Watve A, 2005. Remarks on the species composition of Ephemeral Flush Communities on paleotropical rock outcrops. Phytocoenologia 35:389-401.

Prasad V, Farooqui A, Tripathi SKM, Garg R, Thakur B, 2009. The Western Ghats are thus, precipitous western edge of an elevated Plateau, Evidence of Late Palaeocene-Early Eocene equatorial rain forest refugia in southern Western Ghats. Indian J. Biosci. 34:777-797.

Prasath EB, Munuswamy N, Khudus A, Nazar A, 1994. Preliminary Studies on the Suitability of a Fairy Shrimp *Streptocephalus dichotomus* as Live Food in Aquaculture. J. World Aquac. Soc. 25:204-207.

Rabet N, 2010. Revision of the egg morphology of *Eulimnadia* (Crustacea, Branchiopoda, Spinicaudata). Zoosystema 32: 373-391.

Raj PJS, 1971. Triops granarius (Lucas) (Crustacea: Branchiopoda) from Tamil Nadu, and a review of the species from India. J. Bombay Nat. Hist. Soc. 68:161-168.

Radhika M, Nazar AKA, Munuswamy N, Nellaiappan N, 1998. Sex-linked differences in phenol oxidase in the fairy shrimp *Streptocephalus dichotomus* Baird and their possible role (Crustacea: Anostraca). Hydrobiologia 377:161-164.

Rogers DC, Padhye SM, 2014. A new species of *Streptocephalus* (Crustacea: Anostraca: Streptocephalidae) from the Western Ghats, India, with a key to the Asian species. Zootaxa 3802:75-84.

Rogers DC, Rabet N, Weeks SC, 2012. Revision of the extant genera of Limnadiidae (Branchiopoda: Spinicaudata). J. Crustac. Biol. 32:827-842.

Rogers DC, Thaimuangphol W, Saengphan N, Sanoamuang L, 2013. Current knowledge of the Southeast Asian large branchiopod Crustacea (Anostraca, Notostraca, Laevicaudata, Spinicaudata, Cyclestherida). J. Limnol. 72(Suppl.2):69-80.

Schwentner M, Clavier S, Fritsch M, Olesen J, Padhye S, Timms BV, Richter S, 2013. *Cyclestheria hislopi* (Crustacea: Branchiopoda): a group of morphologically cryptic species with origins in the Cretaceous. Mol. Phylogenet. Evol. 66:800-810.

Simhachalam G, Timms BV, 2012. Two new species of Spinicaudata (Crustacea: Branchiopoda) in south India with a key to *Leptestheriella* and *Eocyzicus*. Zootaxa 3161:20-36.

Simovich MA, 1998. Crustacean biodiversity and endemism in California's ephemeral wetlands, p. 107-118. In: C.W. Witham, E.T. Bauder, D. Belk, W.R. Ferren Jr. and R. Ornduff (eds.), Ecology, conservation, and management of vernal pool ecosystems. Proceedings 1996 Conf., California Native Plant Society, Sacramento, CA, USA.

Thiéry A, 1991. Multispecies coexistence of branchiopods (Anostraca, Notostraca & Spinicaudata) in temporary ponds of Chaouia plain (western Morocco): sympatry or syntopy between usually allopatric species. Hydrobiologia 212:117-136.

Thiéry A, Puente L, 2002. Crustacean assemblage and environmental characteristics of a man-made solar salt work in southern France, with emphasis on anostracan (Branchiopoda) population dynamics. Hydrobiologia,486:191-200.

Timms BV, 2006. The large branchiopods (Crustacea: Branchiopoda) of gnammas (rock-holes) in Australia. J. Roy. Soc. West. Aust. 89:163-173.

Timms BV, Sanders PR, 2002. Biogeography and ecology of Anostraca (Crustacea) in middle Paroo catchment of the Australian arid-zone. Hydrobiologia 486:225-238.

Velu CS, Munuswamy N, 2005. Updated diagnoses for the Indian species of *Streptocephalus* (Crustacea: Branchiopoda: Anostraca). Zootaxa 1049:33-48.

Vikas PA, Sajeshkumar NK, Thomas PC, Chakraborty K, Vijayan KK, 2012. Aquaculture related invasion of the exotic *Artemia franciscana* and displacement of the autochthonous *Artemia* populations from the hypersaline habitats of India. Hydrobiologia 684:129-142.

Waterkeyn A, Grillas P, De Roeck ERM, Boven L, Brendonck L, 2009. Assemblage structure and dynamics of large branchiopods in Mediterranean temporary wetlands: patterns and processes. Freshwater Biol. 54:1256-1270.

Watve A, 2013. Status review of Rocky plateaus in the northern Western Ghats and Konkan region of Maharashtra, India with recommendations for conservation and management. J. Threat. Taxa. 5:3935-3962.

Widdowson M, Cox KG, 1996. Uplift and erosional history of the Deccan Traps, India: Evidence from laterites and drainage patterns of the Western Ghats and Konkan Coast. Earth Planet Sci. Lett. 137:57-69.

Williams P, Whitfield V, Biggs J, Bray S, Fox G, Nicolet P, Searb D, 2004. Comparative biodiversity of rivers, streams, ditches and ponds in an agricultural landscape in Southern England. Biol. Conserv. 115:329-341.