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Diversity and distribution of Cladocera (Crustacea: Branchiopoda) in the rock pools of Western Ghats, Maharashtra, India

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Abstract – Species diversity and distribution of Cladocera in the freshwater rock pools of the northern Western Ghats have been reported. Fifty-nine samples collected from 12 different localities contained 22 species belonging to five families. Chydoridae was the most species rich family with 12 species followed by Daphniidae with five species. Species of the genus *Alona* were relatively rare, but two other alonines, *Leydigia* (*N.*) *ciliata* and *Karualona* cf. *karua* were commonly observed. Congeneric species never co-occurred in the same pool. Distributional maps and taxonomic comments are presented for the commonly observed species. Jaccard's similarity index (C_J) comparing localities showed overall similarity.

Key words: Temporary habitats / *Daphnia* / *Alona* / Jaccard's index

Twenty-two species of Cladocera were observed on few rock pools of Western Ghats of Maharashtra, India. Chydoridae was the most species rich family. Genus *Alona* was rare but species like *Leydigia* (*N.*) *ciliata* were regularly found. Localities showed an overall faunal similarity. This is a first detailed study of Cladocera of rocky outcrops from India.

Introduction

Temporary aquatic habitats worldwide are known to harbor unique fauna and flora contributing to the regional biodiversity (Waterkeyn *et al.*, 2009). These habitats should be characterized by the recurrence of the dry phase of varying durations signifying their temporariness (Williams, 2002). Freshwater rock pools form one type of such temporary water bodies (Coronel *et al.*, 2007) and consist of all types of concavities found on rocky substrates that hold rainwater for short durations (Jocque *et al.*, 2010). Temporary rock pools show many unique traits owing to their small size and the variable environment resulting from the cyclical nature of their drought (Williams, 2002). Despite being good model systems for studies on ecological and evolutionary biology (De Meester *et al.*, 2005), these pools remain poorly studied in many parts of the world (Brendonck *et al.*, 2010). Rocky outcrops and rock pools are of common occurrence in many areas of India including the Western Ghats of Maharashtra, but very little is known about their biodiversity (Porembski and Watve, 2005; Watve, 2013).

Six families of Anomopoda including 470 species have been reported from rock pools worldwide (Jocque *et al.*, 2010). Of the estimated 130 species known from India (Chatterjee *et al.*, 2013), 51 species have been recently reported from the Western Ghats and adjacent regions of Maharashtra (Padhye and Dumont, 2015). In this paper, the results of a study conducted on the Cladocera in the temporary rock pools found on some of the hills and rocky outcrops of the Western Ghats, Maharashtra, India are presented.

Materials and methods

Study area

Figure 1 shows the 12 localities selected for this study in the Western Ghats of Maharashtra, India (Range: Latitude 19°N–15°N and Longitude 73°E–74°E). These localities were situated at altitudes ranging from 800 to 1300 m a.s.l. and included some lateritic rocky outcrops. A total of 59 qualitative samples were collected from these

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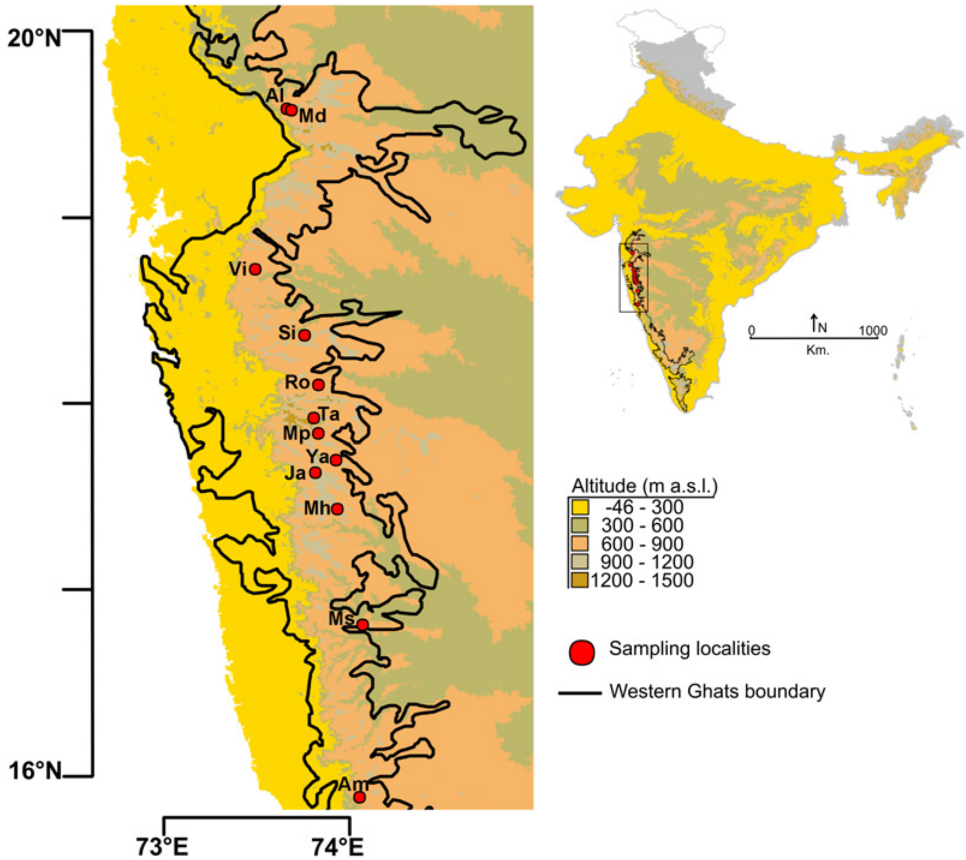

Fig. 1. Map showing the study area and the sampled localities (codes of localities as per Table 1).

Table 1. Names of localities with codes and coordinates for the study area (*indicates locality data taken from 2012).

Name of locality	Code	Latitude N	Longitude E
Alang*	Al	19.5847	73.6583
Madangad*	Md	19.5847	73.6583
Visapur	Vi	18.7212	73.4897
Sinhagad	Si	18.3656	73.7552
Rohida*	Ro	18.1024	73.8211
Tableland	Ta	17.9230	73.8050
Medha-Panchgani	Mp	17.8376	73.8226
Yavteshwar*	Ya	17.7011	73.9180
Jagmin	Ja	17.6308	73.8119
Mhavshi	Mh	17.4359	73.9288
Masai	Ms	16.8167	74.0667
Amboli*	Am	15.8797	74.0475

localities in 2012 and 2013. Nineteen of these samples were collected in 2012, while 40 were collected in 2013. Table 1 lists the locality names, sample codes and co-ordinates, dates and the number of samples collected.

Methods

Sampling

Each habitat sampled in a locality was considered as a separate sample. Plankton tow-net and a hand-net with mesh sizes of 52 and 150 μm, respectively, were used for sample collection. Samples collected in 100 ml plastic containers were immediately fixed using 5% formalin. Presence of floating and/or submerged aquatic vegetation was noted in the field.

Identification

Cladocerans were identified using a stereo binocular microscope (Magnus MS24; Leica) and a bright-field compound microscope (Olympus CH 20i; Olympus CX 41). Scanning electron micrographs were taken on

Table 2. Species composition with localities and occurrence in number of samples; locality codes as in Table 1.

Species	Localities	Occurrence; number of samples
Diaphanosoma sarsi Richard, 1895	Ms	1
Ceriodaphnia cf. *cornuta* Sars, 1885	Ta, Si	6
Ceriodaphnia quadrangula (O. F. Müller, 1785) s. lat.	Si, Ro	5
Daphnia (*Ctenodaphnia*) *carinata* King, 1853 s. lat.	Ta, Ms	3
Daphnia (*Ctenodaphnia*) *similoides* Hudec, 1991	Si, Al, Vi	6
Simocephalus (Simocephalus) mixtus Sars, 1903	Ta, Si, Al, Md, Ro, Vi	11
Moina micrura Kurz, 1874 s. lat.	Ta, Ya, Si, Vi	6
Macrothrix spinosa King, 1853	Ta, Si, Ms, Mh, Am, Ja, Ro, Vi	21
Macrothrix odiosa Gurney, 1916	Mh	5
Ilyocryptus spinifer Herrick, 1882	Ta, Ya, Am, Ja, Vi	11
Alona cheni Sinev, 2001	Ms, Vi	3
Alona cambouei Guerney et Richard, 1893	Ta,Si	3
Alona quadrangularis (O.F. Müller, 1776) s. lat.	Am	1
Anthalona harti harti, Van Damme, Sinev et. Dumont, 2011	Si, Vi	2
Coronatella cf. *rectangula* Sars, 1862	Mp	1
Karualona cf. *karua* (King, 1853)	Ta, Ja, Ro, Vi	8
Leydigia (Neoleydigia) *ciliata* Gauthier, 1939	Ta, Ya, Si, Ms, Mh, Mp, Ja, Ro, Vi	24
Chydorus eurynotus Sars, 1901	Si, Ms, Mh, Ro, Vi	7
Chydorus parvus Daday, 1898	Vi, Md	4
Chydorus ventricosus Daday, 1898	Ta	1
Alonella cf. *excisa* (Fischer, 1854)	Am, Ja, Vi	5
Ephemeroporus barroisi (Richard 1894)	Md, Vi	4

a JEOL scanning electron microscope (SEM) in the Department of Physics, University of Pune, India. Cladocerans for SEM studies were prepared using the chemical drying method of Nation (1983). Maps were made using the GIS information of the localities obtained from Google Earth and DIVA-GIS (v7.5c on Windows; http://www.diva-gis.org).

Since all habitats sampled in a given locality were in close proximity as clusters, one species list was compiled for the entire locality. Thus, species identified from all 59 samples were placed in 12 species lists each representing a locality (Table 2).

Taxonomic identifications were carried out using keys available in the literature (Goulden, 1968; Berner, 1986; Michael and Sharma, 1988; Smirnov, 1971; Smirnov, 1992, 1996; Korovchinsky, 1992; Sinev, 1999, 2001; Dumont and Silva-Briano, 2000; Orlova-Bienkowskaja, 2001; Benzie, 2005; Kotov and Štifter, 2006; Van Damme and Dumont, 2008; Kotov, 2009; Van Damme *et al.*, 2011).

Data analyses

Species occurrence data (presence/absence) for Cladocera were recorded for all 12 localities. Relative frequencies of occurrence for all cladoceran families were calculated and expressed as percentages. Jaccard's index for β diversity (C_J) was calculated to evaluate similarities between localities using the method given by Magurran (2004). Statistical significance of the similarities of this index was determined using tables given by Real (1999).

Results

Faunal composition

Six families including 22 species were recorded from 12 localities. Chydoridae was the most species-rich family with 12 species followed by Daphniidae with five species; Sididae was the rarest group with one species (Table 2). The average number of species for all localities was 5.5 (ranging from 2 to 12). Twenty-seven percent of the species were reported only from a single locality while about 9% were observed in more than seven localities (Table 2). Congeneric species like *Ceriodaphnia cornuta* Sars, 1885 s. lat. and *Ceriodaphnia quadrangula* (O. F. Müller, 1785) s. lat. and *Macrothrix spinosa* King, 1853 and *Macrothrix odiosa* Gurney, 1916 were observed in the same locality, but did not co-occur in the same pool. Five most commonly occurring species viz. *Leydigia* (*Neoleydigia*) *ciliata* Gauthier, 1939, *Macrothrix spinosa*, *Simocephalus* (Simocephalus) *mixtus* Sars, 1903, *Ilyocryptus spinifer* Herrick, 1882 and *Karualona* cf. *karua* (King, 1853) were relatively more frequent in pools with no aquatic vegetation with *I. spinifer* being the highest (90%) followed by *M. spinosa* (76%) and *L.* (*N.*) *ciliata* (62.5%).

S. mixtus was the most commonly occurring daphniid seen in the study (Fig. 4). The two species of *Daphnia* (*Ctenodaphnia*) did not co-occur in the same locality (Fig. 3). *Daphnia* (*Ctenodaphnia*) *similoides* Hudec, 1991 was observed mainly in pools with no submerged or emergent aquatic vegetation in large densities while *Daphnia* (*Ctenodaphnia*) *carinata* King, 1853 s. lat. showed

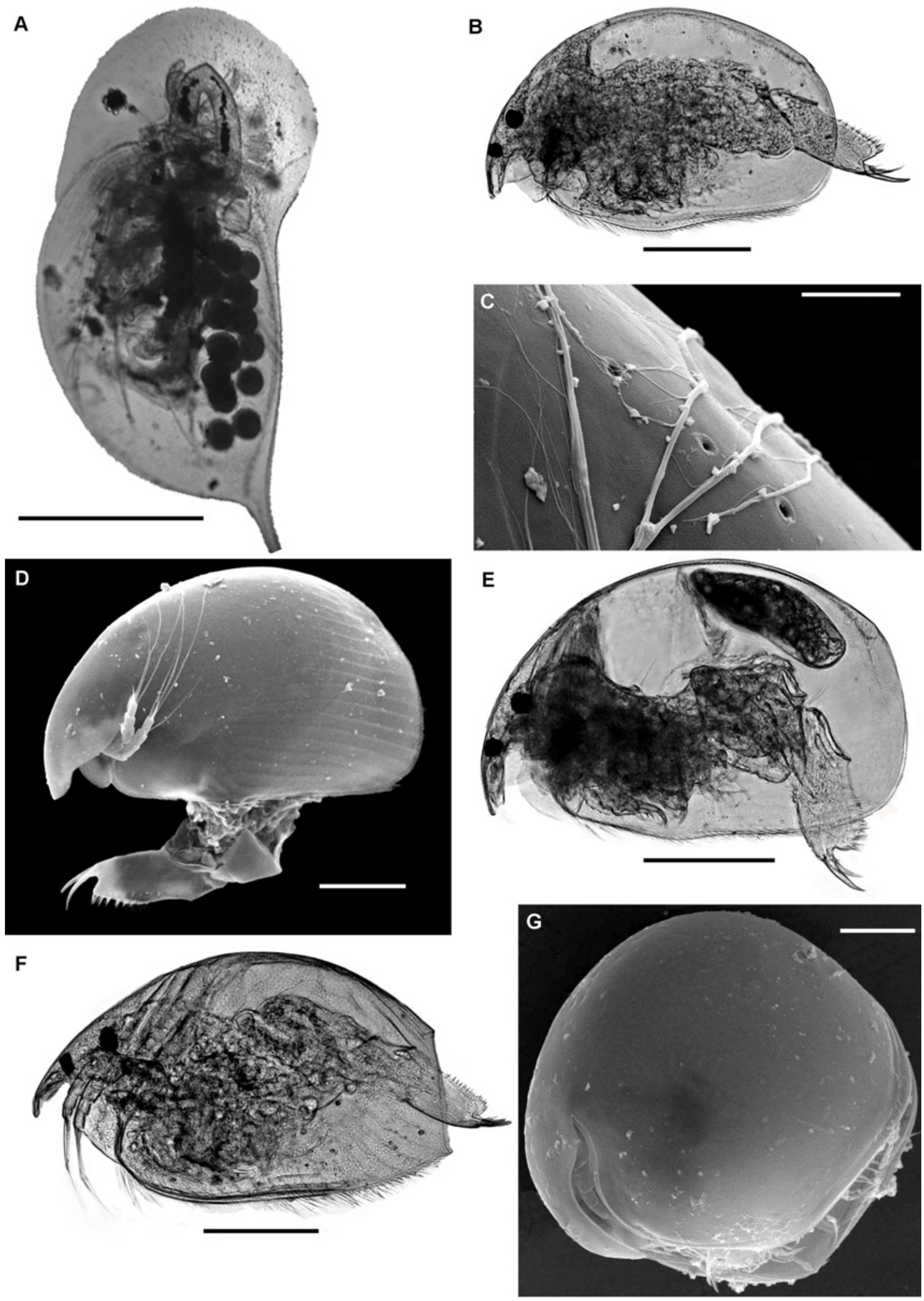

Fig. 2. Some Cladocera seen in the study. A: *Daphnia* (*Ctenodaphnia*) *carinata* (Cephalate form); B: *Alona cambouei* (habitus); C: head pores of *Alona cambouei*; D: *Alona cheni*; E: *Anthalona harti harti*; F: *Alonella* cf. *excisa*; G: *Chydorus parvus*. (Scale bars: A – 500 µm; B, D, E and F – 100 µm; C – 10 µm).

no such preference, but occurred in pools with a relatively bigger surface area. Only daphniid species seen south of Ta locality was *D*. (*C*.) *carinata*. Cephalate forms of *D*. (*C*.) *carinata* were observed in one habitat from Tableland locality (Ta) in 2012, but were not subsequently seen in the 2013 collections (Fig. 2A). *M*. *spinosa* and *M*. *odiosa* were seen in high numbers at the bottom of the pools in the detritus, though the latter was observed only in one locality while the former, more widespread, was found in eight localities (Fig. 3).

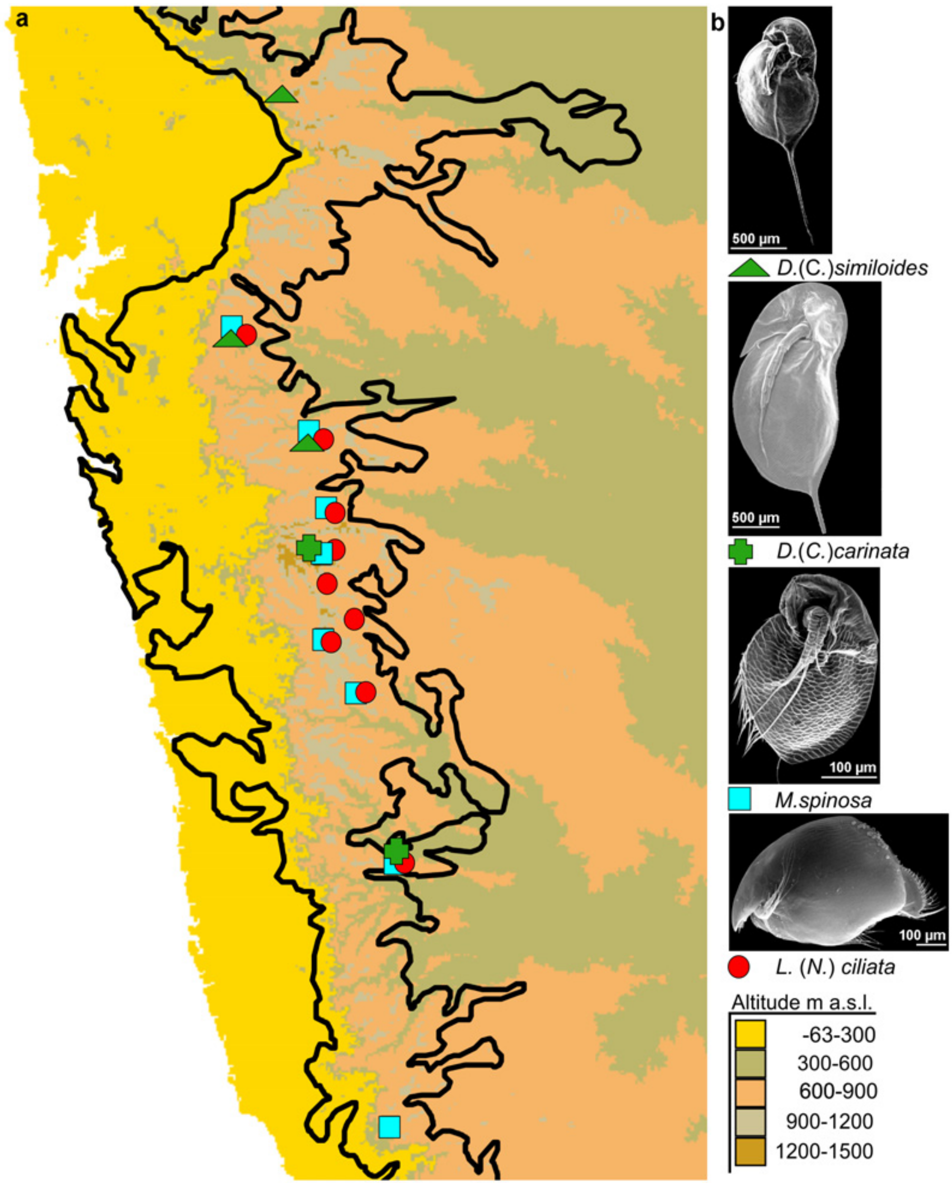

Fig. 3. Distribution of a few common species across the study area. a: Distribution map; b: species images and corresponding symbols used in the map.

Representatives of the genus *Alona* were found only in seven samples from five localities. In contrast, species of *Leydigia* (Fig. 3) and *Karualona* (Fig. 4) were quite common in occurrence. *L.* (*N.*) *ciliata* was the most common chydorid seen in large numbers in some pools having no submerged aquatic vegetation (Table 1; Fig. 3b). *Chydorus* was the most species-rich genus amongst the Chydorinae with three species. *Chydorus eurynotus* Sars, 1901 s. lat. (Fig. 4b) was the most common and widespread species mostly seen in pools without submerged aquatic vegetation. *Chydorus ventricosus* Daday, 1898 was observed commonly in the pools of a single lateritic outcrop locality Tableland (Ta). Only a few specimens of *Chydorus parvus* Daday, 1898 (Fig. 2G) were observed in samples from two localities (Visapur (Vi), Madangad (Md)).

Faunal similarities

Table 3 shows the faunal similarities calculated using the Jaccard's index of similarity (C_J). This index has tables for statistically significant similarities ranging from $P < 0.05$ to $P < 0.001$ (Real, 1999). The numbers of significant C_J values were 26. The similarity did not correspond to the geography of the localities except for a few exceptions. Locality Yavteshwar (Ya) which is close to Ta and Medha-Panchgani (Mp) showed significant similarity with both (Table 3). Locality Rohida (Ro) was significantly similar to Alang (Al) and Md; Jagmin (Ja) showed five significant similarities to Vi, Ro, Ta, Mp and Ya while Mhavshi (Mh) also showed five significant similarities to Sinhagad (Si), Ro, Mp, Ya and Ja. The locality Masai (Ms) was similar to Mp and Ja.

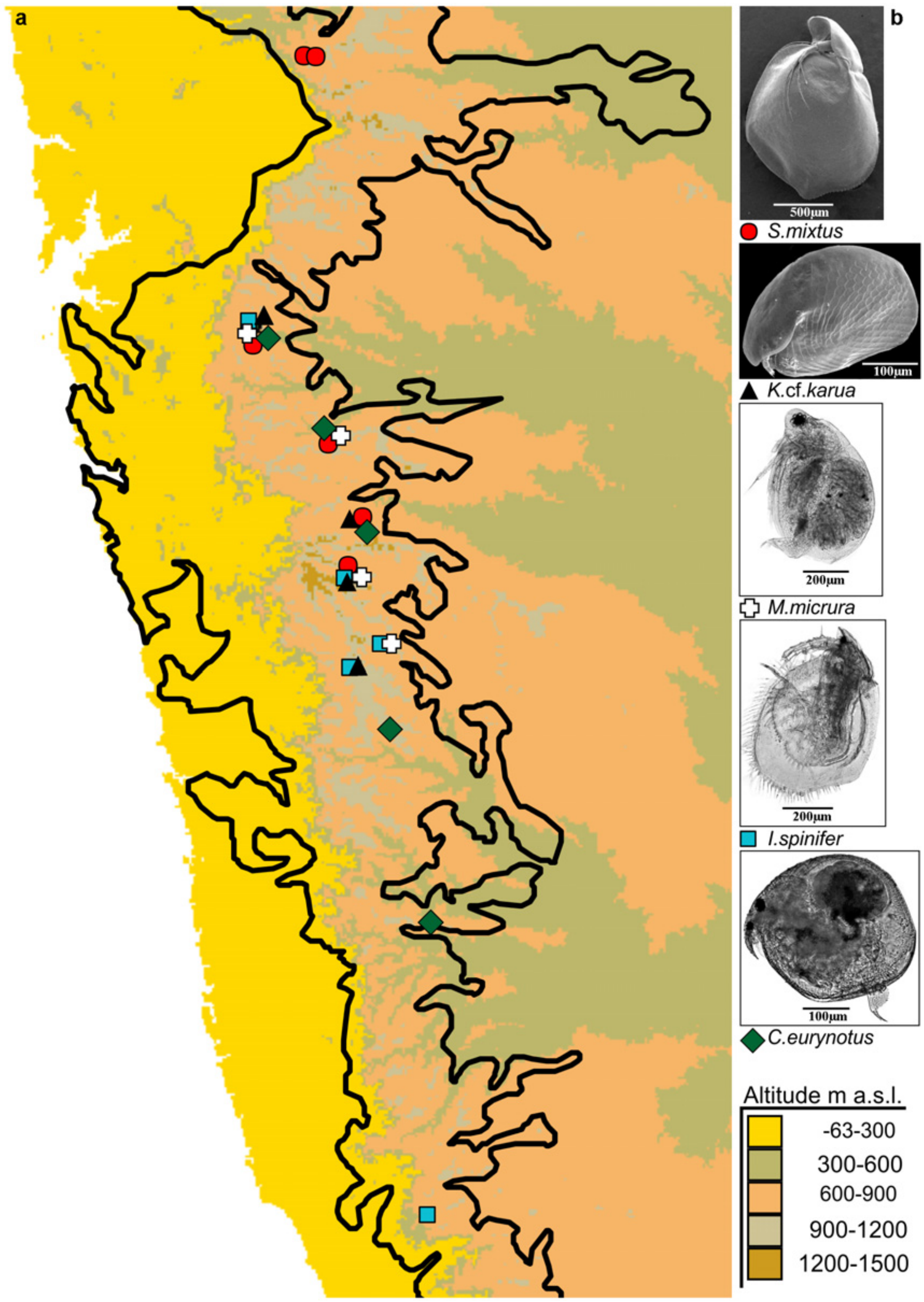

Fig. 4. Distribution of a few common species across the study area. a: Distribution map; b: species images and corresponding symbols used in the map.

The southernmost locality Amboli (Am) showed two significant similarities with Ya and Ja.

Discussion

There are no reports specifically detailing the cladoceran diversity of rock pools in the Oriental region thus making a comparative analysis difficult (Jocque *et al.*, 2010). Without considering the area of the geographical region and the possible differences in sampling methods, the species number reported in this study (22) is similar to that reported by Coronel *et al.* (2007) in Bolivia (21) and by Frisch *et al.* (2006) in Spain (21). It is however, much higher than that recorded by Eitam *et al.* (2004) in Israel (6) and Jocque *et al.* (2006) in South Africa (1). The overall

Table 3. Faunal similarities of localities using Jaccard's C_J index (*-denotes cut-off values for significant similarity).

	Al	Md	Vi	Si	Ro	Ta	Mp	Ya	Ja	Mh	Ms	Am
Al												
Md	0.67*											
Vi	0.834	0.833										
Si	0.8	0.909	0.533									
Ro	0.833*	0.857*	0.615*	0.545*								
Ta	0.909	0.909	0.625*	0.571*	0.667*							
Mp	1	1	0.923	0.9	0.857	0.909						
Ya	1	1	0.667	0.818	0.875	0.7*	0.75*					
Ja	1	1	0.667*	0.833	0.571*	0.727*	0.8*	0.833*				
Mh	1	1	0.769	0.727*	0.571*	0.833	0.8*	0.833*	0.667*			
Ms	1	1	0.714	0.769	0.667*	0.727	0.857*	0.875	0.75*	0.875		
Am	1	1	0.786	0.929	0.9	0.929	1	0.857*	0.714*	0.875	0.9	

family-wise occurrence of cladoceran species in the rock pools of this study is similar to those reported for many other temporary water bodies around the world with Chydoridae having the most species followed by Daphniidae (Coronel *et al.*, 2007).

All species recorded in this study area are known to occur in a wide range of habitat types in the surrounding regions of the area (Padhye, personal observation; Padhye and Dumont, 2015). Since Cladocera are capable of short range passive dispersal (De Meester *et al.*, 2002; Cáceres and Soluk, 2002), their presence in the studied rock pools is not surprising. What is significant here is the absence of species like *Diaphanosoma excisum* Sars, 1885, *Bosmina* (*Bosmina*) *longirostris* (O. F. Muller, 1776) s. lat. and *Indialona ganapati* Petkovski, 1966 which were commonly observed in the limnetic zones of permanent water bodies on the slopes of the Western Ghats (Rane, 2002, 2005a, 2005b; Padhye and Dumont, 2015). Gross physical differences such as the size of pools and the presence or absence of aquatic vegetation also seem to have an influence on species distribution (Eitam *et al.*, 2004; Sakuma *et al.*, 2004).

More similarities and lack of distinct grouping among all localities as shown by Jaccard's C_J seem acceptable since this study was conducted in a relatively small geographic area at similar altitudes.

This study on Cladocera complements those conducted on large branchiopods and Ostracoda (Shinde *et al.*, 2014; Rogers and Padhye, 2014; Padhye *et al.*, 2015). Temporary freshwater rock pools are ideal microcosms for studying ecological processes especially relating to biodiversity, species distributions, resilience to widely fluctuating environmental conditions and resource sharing. Temporary habitats in general are being destroyed at an alarming rate due to various anthropogenic activities (Witham *et al.*, 1998; Williams, 2002) with no data available on the rate of loss in developing countries (Brendonck *et al.*, 2008). Such destruction is a threat to ecosystem integrity and their conservation should receive attention.

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