



## Zooplankton of Temporary Freshwater Rock Pools of Upeh Guling, Endau Rompin Malaysia

A.U. Gabi<sup>1,2\*</sup> and H.M. Matias-Peralta<sup>2</sup>

<sup>1</sup>Department Biological Science, Ibrahim Badamasi Babangida University, Lapai, Niger State, Nigeria

<sup>2</sup>Department of Technology and Heritage, Faculty of Science, Technology and Human Development, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johor Malaysia

### ABSTRACT

The composition and abundance of zooplankton communities were analyzed from zooplankton samples collected six times within a year in Upeh Guling, Taman Negara Johor Endau Rompin (TNJER), Malaysia. A total of 49 species of zooplankton were recorded with 48 species at rain fed rock pools and 40 species at river fed rock pools. Rotifers contributed the highest number of species with 35 species over others due to their fast growth and development under favourable conditions. Among the rotifers, *Lecane* was most diverse with 11 species in total. For zooplankton communities, the rain fed rock pools recorded higher ( $P < 0.05$ ) variation in total species diversity and density, compared with river fed rock pools. Fewer species composition recorded in river fed rock pools may be attributed to the river water which continually feeding the pools and might carried along some species. High species diversity index in rain fed and river fed rock pools, ranging from  $H' = 3.14$  -  $H' = 3.56$  as a result of long period of the inundation which suggested a healthy (oligotrophic) condition of the ecosystem. The results suggest a healthy state of the environment as it favours the proliferation of diverse species of zooplankton communities.

**Keywords:** zooplankton, freshwater rock pools, diversity, abundance

### INTRODUCTION

Temporary water habitats support specialised assemblages and moderate numbers of rare and endemic species (Bratton, 1990; Baskin, 1994; Kalettka, 1996; King, Simovich & Brusca, 1996) which comprise of bacteria, protoctists, vertebrates, fungi, and an abundance of higher and lower organisms (Williams, 2005). Many aquatic species such as algae, bacteria, fungi and invertebrate organisms transform matter and energy into life. Temporary water species are well represented by micro- and macro forms from major taxonomic groups, namely: Branchiopoda, Ostracoda, Copepoda, Rotifera, Cladocera, Decapoda and Pericardia (Williams, 2005). Similarly the insects are well represented in this type of water bodies, such as the group Hemiptera, Coleoptera, Trichoptera, and Diptera, especially the Chironomidae, Culicidae, and Ceratopogonidae, (Williams, 2005). Aquatic mites (Hydracarina) are also common in temporary waters along with several fish species which migrate in and out of temporary streams, rivers and floodplains (Welcomme, 1979). Similarly, temporary waters

serve as habitat to some rare species of amphibians and also provide important feeding areas for migratory birds (Poiani & Johnson, 1991).

The contributions of temporary waters become even greater with the presence of some biotas like plankton (phytoplankton and zooplankton). Plankton are minute floras or faunas that float, drift or inactively swim against water current. In oligotrophic ecosystem, phytoplankton are the major contributor of biomass and primary productivity (Campbell, 1997). They produce oxygen during photosynthesis, which was estimated on a global scale to be 50% – 60% of all photosynthesis performed (Campbell, 1997). Moreover, they form the base of the food chain in aquatic environments and their diversity and density are generally determined by the existing

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Address Correspondence to:

[usmanalhassan25@gmail.com](mailto:usmanalhassan25@gmail.com)

water quality (Campbell, 1997). The zooplankton in the second level, transform food energy synthesized by the phytoplankton to the higher trophic level (Abujam *et al.*, 2011). Moreover, zooplankton is the most vital biotic components affecting mostly the functional aspects of all aquatic ecosystems, via; food chains, food webs, energy flow/transfer and cycling of matter. Different environmental factors that detect the features of water play an essential role on the growth and abundance of zooplankton (Suresh, Thirumala & Ravind, 2011). As such, water quality influences zooplankton abundance, clustering and biomass.

Freshwater rock pools (a group of all types of depressions that occur on rocky substrate and periodically hold water) which are found all over the world in all major biomes depends mainly on precipitation for filling. The hydro periods ranging from several days to a whole year and interaction between the climate and geology determined the morphology and hydrology of this habitat (Jocque, Vanschoenwinkel, & Brendonck, 2010).

The uncertain nature of the flooding regime requires high durable species with adaptation for surviving the dry phase such as such as dormant eggs, resistance larvae or by active migration and recolonization (Wiggins, Mackay & Smith, (1980); Brendonck & De Meester, 2003).

Taman Negara Johor Endau Rompin (TNJER) is a forest containing rock formations (Upeh Guling) with history traced back to 240 million years. It houses many species of macro and micro flora and fauna that are not found elsewhere. TNJER is a proposed site for Geopark with second oldest and largest park in the whole of Malaysia after Langkawi Geopark (Devapriya *et al.*, 2012). The historically preserved site with temporary freshwater rock pools located in Upeh Guling, has rarely been touched, particularly the records of plankton species that existed there

The objective of this study is to determine the distribution and abundance of zooplankton thriving in temporary rock pools of Upeh Guling, Taman Negara Johor Endau Romping (TNJER). The zooplankton diversity of these areas is underexplored.

## METHODOLOGY

### Sampling location

Field sampling was carried out in Upeh Guling, Taman Negara Johor Endau Romping (TNJER). Two condition temporary rock pools, rain fed rock pools and river fed rock pools were choosing for the study. Rain fed rock pools received water primarily from rainfall and secondarily fed by the river water flow during the rainy seasons (designated as rain-fed rock pools) whereas, River fed rock pools received water mainly from river water and secondarily from rainfall (river fed rock pools).

### Sample collection and proceeding

Samples were collected on a monthly basis for six months (from March to September 2013). Microalgae samples were collected using a Van Dorn water sampler. Triplicate samples were collected, fixed with Lugol's iodine solution after which, were taken to the laboratory for taxonomic identification and enumeration.

Upon arrival in the laboratory, microalgae samples were allowed to settle for at least three days without disturbing. After which, the 500ml water sample were siphoned out until only 50ml of sample remained. The remaining samples were then transferred to labelled 100ml capacity opaque plastic bottle and kept in the dark until further analysis.

### Analyses

Identifications of phytoplankton were done using a compound microscope (ModelYS2-H Nikon Japan) under 40x magnification or higher depending on the size of the species and where the species can be identified comfortably and confidently (McAlice, 1971; Bellinger & Sige, 2010). A Sedgewick-rafter counting chamber was used for species enumeration. Triplicate samples were counted each time. The species found were identified to the lowest possible taxa using phytoplankton identification key (Huber-Pestalozzi, 1938; Huber-Pestalozzi, 1941; Prescott, 1970; Yamagishi & Hirano 1973; Huber-Pestalozzi, 1982; Peerapornpisal, 1996; Yinxin & Minjuan, 2005; Shukla *et al.*, 2008; Stamenković & Cvijan, 2008; Bellinger & Sige, 2010; ITIS, 2010; Sayers *et al.*, 2011; Guiry & Guiry, 2014; Pal & Choudhury, 2014; Parr, *et al.*, 2014). microalgae densities were expressed as cells/ml (Bellinger & Sige, 2010).

The enumerations were done by counting individual cell. In addition, those species of

phytoplankton which have countable filaments (e.g. *Micrasterias*) were counted by individual cell. However, species which have uncountable filaments (e.g. *Oscillatoria* sp) and species that form colony (e.g. *Botryococcus* sp.) were estimated following Findlay & Kling (2001)..

### Field sampling

Samples were collected on a monthly basis for one year. However, due to flash flooding during rainy season, the sampling area was not accessible; hence, sample collection was only possible for a period of six months (March, April, June, July, August and September 2013). The physicochemical parameters (temperature, pH, dissolved oxygen, depth) were measured *in situ*.

### Sample processing

Zooplankton samples were identified and enumerated without prior processing as that of the phytoplankton

### Identification and enumeration

Triplicate samples of zooplankton were counted each time using a zooplankton counting chamber under the compound microscope (Model YS2-H Nikon Japan) with low-power objective (10 x magnifications). The zooplankton were identified to the lowest possible taxon using freshwater zooplankton identification keys (Pennak 1979; Idris 1983; ITIS, 2010; Sayers *et al.*, 2011). Estimation of zooplankton densities expressed as individuals/L (Bellinger & Sigeo 2010), follows the equation of Warren & Horvatin, 2003.

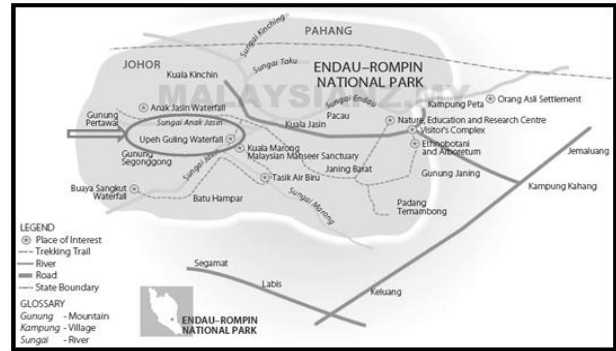
### Data Analysis

The zooplankton densities were used to determine the plankton community structure using statistical software. The community structures were observed by multivariate techniques using a PRIMER Software package (version 6.1.9, PRIMER-E Ltd), (Clarke & Warwive, 2001). Data (species abundance) were  $\log(x+1)$  transformed to balance some rare species that are very few in abundance (Clarke & Warwive, 2001).

Samples were also grouped by sampling stations and on monthly basis, using t-test to determine the significance difference ( $P < 0.05$ ) between two pools but for months (6 months) one way ANOVA was used. The community structure such as species number (s), total number of species (N), the Shannon Wiener diversity were determined

$H' = -\sum p_i \ln p_i$ ,  $H$  = index of diversity,  $\ln$  = the natural logarithm,  $P_i$  = proportion of the  $i$ th species to the total count.

*Margalefs species richness* [ $d = (S-1)/\log(N)$ ] and *Pielou's species evenness* [ $J = H'/\log e(s)$ ] were calculated for each sample to study the impact in community structure. (Heip, *et al.*, 1998).



**Figure 1:** Map showing the location of the study site

## RESULTS

### Zooplankton composition and abundance

The study showed significant variation in zooplankton species density between rain fed rock pools and river fed rock pools (Table 1). A higher ( $P < 0.05$ ) zooplankton species density was recorded in rain fed rock pools (781.38 individuals/ml) than in river fed rock pools (22.56 individuals/ml). A total of 49 species of zooplankton belonging to 20 genera, 12 families, 6 orders, 5 classes and 3 groups were found (Table 2.). Rotifers contributed the highest number of species (35 species); followed by cladocerans (12 species) and copepods (2 species) (Table: 4.5). Among the rotifers, genus *Lecane* was most diverse with 11 species in total (Table: 2).

A total of 48 species from 19 genera, 12 families and 7 orders of zooplankton were present in the rain fed rock pools. Eight species were found only in the rain fed rock pools and these species included *Lecane elasma*, *Lecane hornemanni*, *Lecane mira*, *Lecane subulata*, *Mytilina ventralis*, *Polyarthra remata*, *Trichocerca* sp. 1 and *Chydorus sphaericus*. On the other hand, a

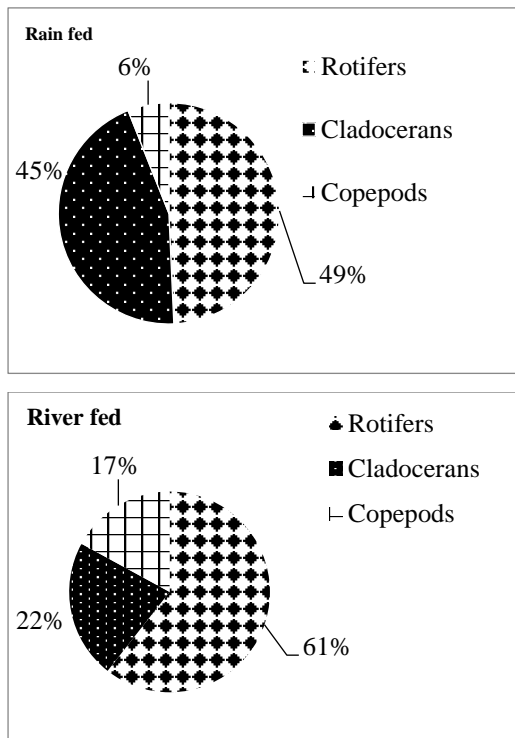
total of 41 species from 19 genera, 11 families and 6 orders were found in the river fed rock pools. Only one species which is the *Brachionus* sp. 1 is found only in the river fed rock pools. Whereas, there were 40 common species of zooplankton recorded in both rock pools (Table 2).

**Table 1:** Average zooplankton density in rain fed rock pools and river fed rock pools

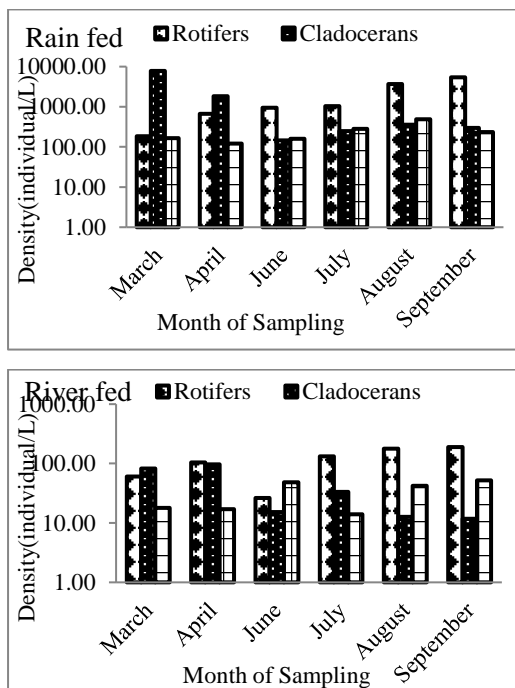
	Rainfed	River fed
Zooplankton Average & S. E	480.74 ±206.25 cells/mL	22.56± 4.0025 cells/mL
Significant level	0.001	
F	12.70	

**Table 2:** List of zooplankton species found in the rare temporary water habitats in Upeh Guling, TNJER, Malaysia

S/N	Group /Species		
	Rotifers	Cladocerans	Copepods
1	<i>Brachionus</i> sp.	<i>Alona</i> sp. 1	<i>Canthocamptus</i> sp.
3	<i>Lecane clara</i>	<i>Alona</i> sp. 2	<i>Mesocyclops</i> sp.
4	<i>Lecane crepida</i>	<i>Alona</i> sp. 3	<i>Copepod nauplii</i>
5	<i>Lecane elasma</i>	<i>Alona</i> sp. 4	
6	<i>Lecane haliclysta</i>	<i>Alona</i> sp. 5	
7	<i>Lecane hornemanni</i>	<i>Alonella excisa</i>	
8	<i>Lecane lunaris</i>	<i>Bosmina longirostris</i>	
9	<i>Lecane mira</i>	<i>Bosminopsis dietersi</i>	
10	<i>Lecane monostyla</i>	<i>Camptocercus</i> sp.	
11	<i>Lecane</i> sp. 1	<i>Ceriodaphnia</i> sp.	
12	<i>Lecane</i> sp. 2	<i>Chydorus</i> sp.	
13	<i>Lecane subulata</i>	<i>Chydorus sphaericus</i>	
14	<i>Lepadella acuminata</i>		
15	<i>Lepadella elongate</i>		
16	<i>Lepadella patella similis</i>		
17	<i>Macrochaetus collinsi</i>		
18	<i>Macrochaetus longipes</i>		
19	<i>Monostyla bulla</i>		
20	<i>Monostyla hamata</i>		
21	<i>Monostyla lunaris</i>		
22	<i>Monostyla</i> sp. 1		
23	<i>Monostyla</i> sp. 2		
24	<i>Monostyla triangle</i>		
25	<i>Mytilina ventralis</i>		
26	<i>Philodina rosela</i>		
27	<i>Platyias quadricornis</i>		
28	<i>Polyarthra major</i>		
29	<i>Polyarthra remata</i>		
30	<i>Polyarthra vulgaris</i>		
31	<i>Trichocerca chattoni</i>		
32	<i>Trichocerca ruttneri</i>		
33	<i>Trichocerca</i> sp.		
34	<i>Trichotria tetractis</i>		
35	<i>Trichotria truncata</i>		



**Figure 2:** Variation in percent abundance (%) of zooplankton groups from the rain fed and river fed rock pools



**Figure 3:** Zooplankton group density (individual/L, in logarithmic scale) variation according to sampling month between two

rock pools (rain-fed rock pools and river fed rock pools

**Table 3:** The monthly zooplankton species abundance significant variation between rain fed rock pools and river fed rock pools. Superscripts with the asterix “\*” are significant while those without the asterix are insignificant

	Rain fed	River fed
March	8.19×103*	0.16×103
April	2.64×103**	0.22×103
June	1.25×103**	0.09×103
July	1.57×103**	0.18×103
August	4.50×103**	0.23×103
September	5.88×103*	0.24×103
Significance: *P< 0.05; **P< 0.01		

**Table 4:** Diversity indices (Mean ± S.E) of zooplankton in the rock pools: Data in row with asterix “\*” denotes significance at p <0.05

Zooplankton		
Species richness (d)	4.66±0.19	7.34±0.41*
Species evenness (J')	0.99±0.00*	0.97±0.00
Diversity index (H')	2.74±0.07	3.37±0.08*

The highest species abundance of zooplankton was contributed by rotifers with 49.00% in the rain fed rock pools (Figure 2). The group cladocerans was the second highest with 45.00% (Figure 2), and the least group was copepods with 6.00%. Similarly, in the river fed rock pools, the highest zooplankton abundance was contributed by rotifers with 61.00% (Figure 2) in river fed rock pool, followed by cladocerans with 22.00% and the copepods contributing 17.00% (Figure 2).

The rotifers of both rain fed and river fed rock pools obtained their maximum densities in the month of September. The cladocerans of rain fed rock pools recorded large abundance in March than other month while copepod was in August. In river fed

rock, cladocerans recorded highest species abundance in the month of April while copepods were in the month of September compared to other months (Figure 2).

In rain fed rock pools, the highest species abundance was recorded in the month of March, followed by September. While, the total least species abundance was recorded in June. Similarly, in river fed rock pools the month of September recorded largest species abundance followed by August and the least species abundance was recorded in the month of June (Table 3). Significant ( $P < 0.05$ ) variation was revealed between rain fed rock pools and river fed rock pools in terms of monthly species abundance (Table 3).

### Diversity indices

Significant values were recorded between rain fed rock pools and river fed rock pools in terms of species diversity index ( $H'$ ) and species richness ( $d$ ) (Table 4). The index value observed for  $H' = 3.56$ ;  $d = 9.33$  (rain fed) and  $H' = 3.14$ ,  $d = 6.13$  (river fed) (Table 4). For the rain fed pools and river fed pools, the observed species diversity index and species richness revealed significant variations. However, there was no significant variation observed in the evenness index values.

Zooplankton species diversity indices on the other hand, recorded significant variations ( $P < 0.05$ ) between rain fed rock pools and river fed rock pools. The values recorded for species diversity index, species richness and species evenness are equivalent to  $H' = 3.37$ ,  $d = 7.34$  and  $J' = 0.97$  (rain fed) and  $H' = 2.74$ ,  $d = 4.66$  and  $J' = 0.99$  (river fed) (Table 4.7).

## DISCUSSION

### Zooplankton composition and abundance

Generally, in many freshwater bodies such as lakes, rivers and temporary waters, rotifers are the most dominant zooplankton group (Table 5.2). This study recorded 35 species of rotifers. Similar observations have been reported by Anusa, (2012) and Thakur *et al.* (2013) who reported 8 and 32

species of rotifers on freshwater temporary rock pools and tropical lakes, respectively. According to Ekpo (2013), rotifers have the advantage over the other zooplankton groups due to its fast growth and development under favourable conditions. In addition, depending on the temperature, their reproductive cycle could fall between 5 days (at 25°C) to 12 days (at 20°C). Perhaps tropical temperature may be an important factor to their reproductive success. The second highest group was the cladocerans with a total of 12 species.

Similar to many lakes and rivers in tropical countries (Table 5.2), cladocerans generally followed in abundance after rotifers (Ekpo, 2013; Thakur *et al.*, 2013). The lowest zooplankton group observed in this study was the copepods with two genera and two species (Table 5.2). The lowest number of copepods recorded in this study may be attributed to their long reproductive cycle (25 to 50 days) which also depended on temperature. In a research conducted by Shah *et al.* (2008) in a freshwater river, only two species of copepods were identified. Copepods nauplii were also observed throughout the duration of this study. This perhaps was an indication of continuous reproduction of copepods in this type of environment. The composition and abundance of zooplankton species in the rain fed rock pools was higher than that of the river fed rock pools. The two pools recorded 40 similar species equivalents to 81.63% despite the fact that sampling was done during the months considered to be dry season in Malaysia. Fewer species composition recorded in river fed rock pools may be attributed to the river water which continually feeding the pools and might carried along some species. Therefore, fewer species composition in river fed rock pools can be attributed unexpected flash flooding caused by unexpected rain fall during the dry season. Occurrence of unexpected rain fall during dry season in tropical rain forest region is a known characteristic which makes the region to be evergreen throughout the year (Grainger,

2013). Rain fed rock pools were observed to be more stable in planktonic community than the river fed rock pools community. This might be attributed to long duration of inundation in habitat due to unexpected rain fall and less flushing out of water when compared to river fed rock pools. Higher community stability observed in rain fed rock pools resulted in higher species diversity when compared to river fed rock pools habitat. Considering the rain fed rock pools with higher abundance may be attributed to long-lived pools caused by unexpected rain fall. This finding is in conformity with what Vanschoenwinkel *et al.* (2009) observed. That large deep pools and pools with very low disturbance and long period of inundation, experience very high species diversity (Vanschoenwinkel *et al.*, 2009). Jocqué *et al.* (2007) reported that pools that are long-lived offer more stable habitat than short-lived and small pools. All the pools during the sampling did not dry up completely. This might be attributed to unexpected rain fall experienced from time to time in tropical rain forest. The sampling was done during the months considered to be dry season in Malaysia. The most diverse zooplankton genus was *Lecane* from the group of rotifers with 11 species, followed by the *Monostyla* with six species. *Lecane* and *Monostyla* species are known to be abundant in small water bodies and can survive well in the presence of carbonates. In addition, they have shown to adapt well to pH in the range of 6.0 to 8.2 and temperature 24.0 to 29.5°C in tropical region (De Manuel Barrabin, 2000; Jocque *et al.*, 2010). These perhaps, could be attributed to their high abundance recorded in this present study. Likewise, *Monostyla bulla* is also known to act as species indicator of fresh and clean water (Abujam *et al.*, 2011). Based on this, the most dominant species of zooplankton (*Lecane* and *Monostyla* species) recorded in this study suggests that the river water and the standing water in both rock pools are oligotrophic. Considering the monthly species composition, rain fed rock pools

recorded the highest total species diversity and density than river fed rock pools. This may be attributed to the partial lentic nature of the ecosystem. The rain fed rock pools primarily receives water from rain and occasionally receives water from river when there is river overflow as a result of heavy rainfall.

The month of August recorded the highest phytoplankton species density with  $52.58 \times 10^3$  cells/mL followed by July with  $52.22 \times 10^3$  cells/mL. The phytoplankton densities on the rain fed rock pools was observed to be highest in July and August. Those months were the peak of dry seasons in Southern Peninsular of Malaysia. The high densities of green algae and diatoms obtained may be due to reduction of water from the pools. Baruah & Kakati (2013) attributed low phytoplankton count in pond to low volume of water. The dominance obtained in green algae and diatoms throughout the sampling months over other groups of algae may be ascribed to their tolerance in different temperature, light and nutrient limitation and similar findings has been observed by some limnologist (Fogg, 1975; Wetzel, 2001).

Rotifers had the highest occurrence in both rock pools. This may be due to their ability to reach reproductive peak level within three and half days under favourable environmental conditions (Allan, 1976; Ekpo, 2013). Likewise, the reason for their relatively higher abundance over others may be due to the fact that they are considered to be passive dispersers which survive the dry periods in rock pools (Wiggins *et al.*, 1980). In addition, their eggs undergo resting stage and resist a lengthy period of drought. Rotifers serve as a good indicator of good water quality and presence of oxygen in the water (Vladimir, 1983). The high abundance of rotifers therefore was perhaps an indication that the rock pools provide an appropriate environmental condition for their reproduction. In fact, the density of rotifers observed in this study, was even higher than those observed in similar studies

(e.g. Mamaril & Fernando, 1978; Mamaril, 1986; Aguigwo, 1998; Abdullahi, Azionu & Ajayi 2007; Ogbeibu & Edutie, 2009; Saidu *et al.*, 2009; Imoobe & Adeyinka, 2010). Thus, the rock pools provide good habitation to the plankton.

September to March was a period considered to be northeast (NE) monsoon in which the major rainy season was obtained in east of Johor and Sarawak (Malaysia Meteorological Department, 2013; Yoshida *et al.*, 2012; Suhaila *et al.*, 2010). On monthly basis, the highest total mean density of zooplankton was recorded with  $8.38 \times 10^3$  and  $6.06 \times 10^3$  individuals/L in March and September, respectively. Similar pattern was also reported by Aguigwo (1998); Kemdirim (2000) and Davies *et al.* (2009). High abundance of rotifers was observed during major rainfall (Aguigwo 1998; Kemdirim, 2000; Davies *et al.*, 2009).

The cladocerans species, *Bosminopsis deitersi* recorded the highest species density in both rock pools which may be attributed to its movement ability to survive environmental changes such as temperature and flood. Similar observation has been recorded by Melão & Rocha, (2004). Melão & Rocha (2004) observed *Bosminopsis deitersi* has a cladocerans which has high movement potential as they can go from the surface of pool to the bottom of the pools during the day when the condition is not favourable. During the months of March and September, which were considered to be end and beginig of wet season in Malaysia, a higher abundance of *Bosminopsis deitersi* was observed in this study. This revealed that *Bosminopsis deitersi* ability to survive current flush of water feature that contributed to their diversity and abundance.

For this present study, potential bioindicator species have been identified. Such species are *Alona* sp *Brachionus* sp, *Chydorus* sp and *Lecane* sp. these species were common to both rock pools except *Brachionus* sp that was only found in river fed rock pools. These species were identified as pollution bioindicators by Thakur *et al.* (2013)

### Diversity indices

High in species diversity reveals absence of pollution in the water (Thakur *et al.*, 2013). Sigeo (2004) stated that biodiversity indices of species diversity are derived from the species count, which can be of three categories: species richness (Margalefs index), species evenness (Simpson index) and a combination of both, (diversity index and Shannon-Wiener index). These three diversity indices accounts for a number of species and their relative abundances which implies the higher the value of the indices the more the oligotrophic state of water bodies (Thakur *et al.*, 2013). For instance, between 0 and 1.0 is the possible range value of species evenness and therefore values near 0 indicated least evenly distributed communities while values near 1.0 indicated most evenly distributed communities (Thakur *et al.*, 2013). Margalef (1958) correlated the number of species to the total number of individuals. In species richness, reduction in values reveal rise in the pollution. When calculating the diversity index, a value above 3.0 indicates clean and oligotrophic water while value below 3 indicates pollution (eutrophication) (Thakur *et al.*, 2013). Relating the data obtained from statistical result of the diversity indices in both rock pools (river fed and rain fed) of this finding; it has been observed that the minimum and maximum values of species evenness (0.79-0.99), species richness (4.66-9.33) and diversity index (2.74-3.56).

The diversity indices values of phytoplankton and zooplankton species obtained in rain fed rock pools of this study was higher species evenness (0.8 - 0.97), species richness (7.34 - 9.33) and diversity index (3.37 - 3.56) when compared with that of river fed rock pools (species evenness (0.79 - 0.99), species richness (4.66 - 6.13) and diversity index (2.74 - 3.14). Lower values of species indices obtained in river fed rock pools may be attributed to lower abundance and number of species of phytoplankton and zooplankton obtained, which may be as a result of frequent in and out of river water that may reduce nutrient



of water, the effect of physico-chemical parameters and flash away of some species by water velocity. The community structural indices values obtained from both rock pools in these findings were considered to be high which account for the healthy status of the water body in the rock pools. Thakur *et al.* (2013) obtained the minimum and maximum values of species evenness (0.153-0.942), species richness (1.398-5.388) and diversity index (1.177-3.310) and similarly Ghosh *et al.* (2012) recorded the minimum and the maximum values of species evenness (0.803-0.914), species richness (1.786-2.814) and diversity index (2.344-2.454). In Thakur *et al.* (2013) findings, station with higher species diversity index of 3 and above were at healthy status, while those stations that recorded less than 3 values of species diversity index were considered to be in polluted status. According to Ghosh *et al.* (2012), the low diversity index value obtained in the study may be as a result of excessive nutrient enrichment (eutrophication). This nutrient increment may be from leaves that accumulate in pools, degraded by bacteria. Phytoplankton and zooplankton communities in both river fed and rain fed varied significantly with high species diversity indices. The zooplankton diversity index on the river fed rock pool was in exception with low value (2.74). This same rock pool recorded the highest value of evenness (0.99).

The diversity index suggested low trophic level of the water body in both rock pools. Despite the fact that some pollution indicator species were found in both rock pools, yet the diversity index revealed healthy status of the pools. Similarly, zooplankton diversity index obtained in rain fed rock pools also showed low trophic status of water. However, low value of the diversity index obtained in the river fed rock pools suggested high trophic level of the water body. This may be attributed to the effect of surrounding forest where wind or rain water can disperse the surrounding dead leaves into the pools and after

decomposition of these leaves by cyanobacteria in-turn naturally influenced the nutrient of the pools

### Conclusion

Forty-nine species of zooplankton were recorded from both rock pools due to stability in the pools. The stability in the plankton community led to diversity and abundance observed in the rock pools which was due to long hydro-period and less disturbances experienced by the pool. Unexpected rain fall was not enough to overflow the pools; instead the additional water had maintained the growth and allowed establishment of diverse species in the rock pools.

High diversity indices values recorded revealed good water quality. Inundation was the primary factor that controls the effectiveness of the parameters which in turn resulted in species diversity and abundance. The environmental parameters of both rock pools were within the favourable range and suitable for organism's conservation.

### REFERENCES

- Abdullahi, H. A.; Azionu, B. C. & Ajayi, O. (2007). Checklist of zooplankton in culture tanks at NIFFRI Green House, New Bussa. Proceedings of the 22nd Annual Conference of Fisheries Society of Nigeria (FISON), Kebbi 12th-16th November,
- Abujam, S. K. S., Dakua, S., Bakalial, B., Saikia, A. K., Biswas, S. P., & Choudhury, P. (2011). Diversity of plankton in Maijanbeel, upper Assam. *Asian J. Exp. Biol. Sci.*, 2 (4), pp 562, 568.
- Aguigwo, J. N. (1998). Studies on the physico-chemical parameters and plankton productivity of a productive stream. *Journal of Aquatic Science*, 13, pp 9-13.
- Allan, J. D. (1976). Life History patterns in zooplankton. *American Naturalist* 110, pp 165-180.

- Anusa, A., Ndagurwa, H. G. T., & Magadza, C. H. D. (2012). The influence of pool size on species diversity and water chemistry in temporary rock pools on Domboshawa Mountain, northern Zimbabwe. *African Journal of Aquatic Science*, 37(1), 89-99.
- Baruah, P. P & Kakati, B. (2013). Water quality and phytoplankton diversity of Gopeswar temple freshwater pond in Assam (India). *Bangladesh Journal of Botany*, 41(2), pp. 181-185.
- Baskin, Y. (1994). California's ephemeral vernal pools may be a good model for speciation. *BioScience* 44, pp 384-385.
- Bellinger, E. G. & Sigeo, D. C. (2010). A key to the more frequently occurring freshwater algae. *Freshwater Algae: Identification and Use as Bioindicators*, pp. 137-244.
- Bratton, J. H. (1990). Seasonal pools: an overlooked invertebrate habitat. *British Wildlife* 2, pp. 22-29.
- Brendonck L., Hamer, M.L., Riddoch, B.J. & Seaman M.T. (2000a). A Branchipodopsis species – specialists of ephemeral rock pools. *African Journal of Aquatic Science*, 25, pp. 98–104.
- Campbell E.M. (1997). Granite landforms. *Journal of the Royal Society of Western Australia*, 80, 101–112.
- Clarke, K. R., & Warwick, R. M. (2001). Change in Marine Communities: An Approach to Statistical Analysis and Interpretation. 2<sup>nd</sup> Edition. (PRIMER-E Ltd: Plymouth, United Kingdom.), pp 1-176
- Davies, O. A.; Abowei, J. F. N. and Otene, B. B. (2009). Seasonal abundance and distribution of plankton of Minichinda stream, Niger Delta, Nigeria. *American Journal of Scientific Research*, 2, pp. 20-30.
- De Manuel Barrabin, J. (2000). The rotifers of Spanish reservoirs: ecological, systematical and zoogeographical remarks. *Limnetica*, 19, pp. 91-167.
- Devapriya C W, Aziman M, Mohd H Z A, Mohamed F T B, Ashida A B A, (2012) Securing Global Geopark Status for Endau-Rompin. Conference paper: Seminar on Scientific Expedition Endau Selai Trans – Map 2012, December 2012, pp. 1-8.
- Ekpo, I. (2013). Effect of physico-chemical parameters on zooplankton species and density of a tropical rainforest river in Niger Delta, Nigeria using Canonical Cluster Analysis. *The International Journal Of Engineering And Science (IJES)* Volume 2 Issue 4 Pages 13-21 2013 ISSN(e): 2319 – 1813 ISSN(p): 2319 – 1805
- Findlay, D. L., & Kling, H. J. (2001). Protocols for measuring biodiversity: phytoplankton in freshwater. Department of Fisheries and Oceans. Freshwater Institute. Winnipeg.
- Fogg, G.E. (1975). *Algal Culture and Phytoplankton Ecology*. Wisconsin University Press, London. Pp 1-50.
- Ghosh, S. B., Sophia K., Jai P. (2012). Diversity and seasonal variation of phytoplankton community in the Santragachi Lake, West Bengal, India
- Grainger, A. (2013). *Controlling Tropical Deforestation*. Routledge. Pp 40-43
- Guiry, M.D. & Guiry, G.M. (2014). *AlgaeBase*. World-wide electronic publication, National University of Ireland, Galway. <http://www.algaebase.org>; searched on (date).
- Heip, C. H., Herman, P. M., & Soetaert, K. E. R. (1998). Indices of diversity and evenness. *Oceanis*, 24.
- Huber-Pestalozzi, G. (1938). *Das Phytoplankton des Süßwassers: Blaualgen Bakterien Pilze 1. Teil E Schweizerbart'sche Verlagsbuchhandlung, Stuttgart, 1-1044pp.*
- Huber-Pestalozzi, G. (1941). *Das Phytoplankton des Süß-wassers Chrysophyceen Farblose Flagellaten Heterokonten 2. Teil E Schweizerbart'sche Verlagsbuchhandlung, Stuttgart. 1044pp.*
- Idris B A G. (1983). *Freshwater zooplankton of Malaysia*. Universiti Pertanian

- Malaysia, Serdang, Selangor, Malaysia, 151 pp.
- Imoobe, T. O. T. and Adeyinka, M. L. (2010): Zooplankton-based assessment of the trophic state of a tropical forest river. *International Journal of Fisheries and Aquaculture*. 2 (2), pp. 64-70.
- Integrated Taxonomic Information System (ITIS), (2010). Integrated taxonomic information system. [https://scholar.google.com.my/scholar?cluster=15399928683461161176&hl=en&as\\_sdt=2005&scioldt=0,5](https://scholar.google.com.my/scholar?cluster=15399928683461161176&hl=en&as_sdt=2005&scioldt=0,5)
- Jocque, M., Graham, T. & Brendonck, L. (2007). Local structuring factors of invertebrate communities in ephemeral freshwater rock pools and the influence of more permanent water bodies in the region. *Hydrobiologia*, 592, pp. 221-280.
- Jocque, M., Vanschoenwinkel, B. & Brendonck, L. (2010). Freshwater rock pools: a review of habitat characteristics, faunal diversity and conservation value. *Freshwater Biology*, 55(8), pp. 1587-1602.
- Kaletka, T. (1996). Die Problematik der Solle (Kleinhohlformen) im Jungmoranengebiet Nordostdeutschlands (translated: The problems of the Solle (small lakes) in the landscape of the last ice age in north-east- Germany). In: Naturschutz und Landschaftspflege in Brandenburg, Sonderheft (special issue), Sölle, pp. 4-12.
- King, J. L., Simovich, M. A. & Brusca, R. C. (1996). Species richness, endemism and ecology of crustacean assemblages in northern California vernal pools. *Hydrobiologia* 328, 85-116.
- Malaysia Meteorological Department (MMD), (2013). [www.weathertogether.org](http://www.weathertogether.org)
- Mamaril Sr, A. C. (1986). Zooplankton guide to Philippine flora and fauna. NRMC and UP Diliman Publ., Quezon City, pp 268
- Margalef, R. (1958). Information theory in ecology. *Gen Syst*, 3, pp. 36-71.
- McAlicee, B. J. (1971). Phytoplankton sampling with the Sedgwick-rafter cell. *Limnology and Oceanography*, 16(1).
- Melão, M. D. G. G., & Rocha, O. (2004). Life history, biomass and production of two planktonic cyclopoid copepods in a shallow subtropical reservoir. *Journal of Plankton Research*, 26(8), pp. 909-923.
- Ogbeibu, A. E. and Edutie, L. O. (2009). Effect of brewery effluent on the water quality and rotifers. *Ecoserve*, 1(1): pp.1-8
- Pal, R., & Choudhury, A. K. (2014). An Introduction to Phytoplanktons: Diversity and Ecology. Springer, ISBN: 978-81-322-1837-1 (Print) 978-81-322-1838-8
- Parr, C. S., N. Wilson, P. Leary, K. S. Schulz, K. Lans, L. Walley, J. A. Hammock, A. Goddard, J. Rice, M. Studer, J. T. G. Holmes, and R. J. Corrigan, Jr. (2014). The Encyclopedia of Life v2: Providing Global Access to Knowledge About Life on Earth. *Biodiversity Data Journal* 2, pp 2-28
- Pennak, R. W. (1979). Freshwater Invertebrates of the United States. 2nd edition. New York, USA: John Wiley & Sons, 803.
- Poiani, K.A. & Johnson, W.C. (1991). Global warming and prairie wetlands. *BioScience*, 41, pp. 611-618.
- Prescott, G.W. (1970). *How to know the freshwater algae*. Brown Company, Iowa, PP 293.
- Saidu, A. K.; Agbelege, O. O.; Ahmed, M. T. and Olanrewaju, A. N. (2009). Some water quality parameters and zooplankton periodicity of the Baga intake channel of Lake Chad. *Proceedings of FISON* 1, pp. 105-107.
- Sayers, E. W., Barrett, T., Benson, D. A., Bolton, E., Bryant, S. H., Canese, K., & Ye, J. (2011). Database resources of the national center for biotechnology information. *Nucleic Acids Research*, 39 (suppl 1), D38-D51.

- Shah A S R M, Ismail S, Mashhor M, et al. 2008. A note on zoo- plankton distributions at two different types of water management systems in the Muda rice agroecosystem [J]. *Journal of Biosains*, 19(1), pp. 81-90.
- Shukla, S. K., Shukla, C. P., Misra, P. K., Cho, S. Y., Ki, J. S., Han, M. S. & Kim, K. Y. (2008). Desmids (Chlorophyceae, Conjugales, Desmidiaceae) from Foothills of Western Himalaya, India. *Algae*, 23(1), pp. 1-14.
- Sigeo, D. C. (2004). Freshwater microbiology: diversity and dynamic interactions of microorganisms in the aquatic environment. Chichester, UK: Wiley, pp 1-71
- Stamenković, M. & Cvijan, M. (2008). Desmid flora (Chlorophyta, Zygnematophyceae) of the Danube in the provinCe of vojvoDina (northern serbia). *Archives of Biological Sciences*, 60(2), pp. 181-199.
- Suhaila, J., Deni, S. M., Zin, W. Z. W., & Jemain, A. A. (2010). Trends in peninsular Malaysia rainfall data during the Southwest Monsoon and Northeast Monsoon Seasons: 1975–2004. *Sains Malaysiana*, 39(4), pp. 533-542.
- Suresh, S.; Thirumala, S. and Ravind, H. (2011). Zooplankton diversity and its relationship with physico-chemical parameters in Kundavada Lake, of Davangere District, Karnataka, India. *Pro-Environment*, 4: 56 – 59.
- Thakur, R. K., Jindal, R., Singh, U. B. & Ahluwalia, A. S. (2013). Plankton diversity and water quality assessment of three freshwater lakes of Mandi (Himachal Pradesh, India) with special reference to planktonic indicators. *Environmental Monitoring and Assessment*, 185(10), pp. 8355-8373.
- Vanschoenwinkel B., Hulsmans A., De Roeck E.R., De Vries C., Seaman M. & Brendonck L. (2009). Community structure in temporary freshwater pools: disentangling effects of habitat size and hydroregime and the impact of dispersal mode. *Freshwater Biology*, 54, pp. 1487–1500.
- Vladimir, S. C. (1983). Rotifers as indicators of water quality. *Hydrobiologia*, 100(1), pp. 169-201.
- Warren, G.J. & Horvatin, P.J. (2003). Great Lakes monitoring results: comparison of probability based and deterministic sampling grids. *Environ Monit Assess*, 81, pp. 63-71.
- Welcomme, R.L. (1979). Fisheries Ecology of Floodplain Rivers. Longman, London, UK. 55pp.
- Wetzel, R.G. (2001). Limnology. 3rd. Edition. Academic Press, California.
- Wiggins, G. B., Mackay R. J. & Smith I. M. (1980). Evolutionary and Ecological strategies of animals in annual temporary ponds, *Arch. Hydrobiology., Suppl.*, 58, pp. 97-206.
- Williams, D.D. (2005). Temporary Forest Pools: Can we see the water for trees? Volume 13, pp. 213-233
- Yamagishi, T. & Hirano, M. (1973). Some freshwater algae from Cambodia. Kyoto University, Kyoto. 24 : 2, 61-78pp
- Yinxin, W. & Minjuan, Y. (2005). New desmids material from Donghu lake, Wuhan, China. *Chinese Journal of Oceanology and Limnology*, 23(2), pp. 210-217.
- Yoshida, T., Matias-Peralta, H., Yusoff, F., Toda, T., & Othman, B. H. (2012). Zooplankton research in Malaysia: Current status and future prospects, pp 205-213.