

Odonata (Dragonflies and Damselflies) as Bio Indicators of Water Quality

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ABSTRACT : In order to determine the bioindicator efficiency of odonata, their surveys were conducted and water samples were analysed from thirty ponds of Meenachil taluk at Kottayam district, Kerala. The Water Quality Index, Simpson's Diversity Index and Species abundance values were calculated. The ponds with good water quality showed highest number of odonata species which has been contributed by the abundance of fresh water indicator species like, *Bradinopyga geminata* and *Trithemis festiva*. The odonata species, *Zygomma petiolatum* and *Ceragrion cerinorubellum*, which indicates the polluted water were present abundantly at bad and very bad water quality ponds.

KEYWORDS: Indicator species, water quality, species abundance, odonata, pollution

I. INTRODUCTION

Dragonflies and damselflies are hemimetabolous insects with predominantly aquatic nymphal stage and terrestrial adult. Odonata can be found in a wide array of fresh water systems dependent on biotic and abiotic constraints. They can be seen in both lentic and lotic systems which range from tree holes to large lakes and rivers and they are hospitable for both seasonal and permanent ecosystems. Each type of water body has a characteristic species assemblage of odonata that can typically be found there. Although most species are restricted to fully aquatic environments, a few species around the world can be found as larvae in upland habitats (e.g., a few *Megalagrion* species are found in wet leaf litter) where relative humidity is always high (Polhemus and Asquith, 1996)[1]. Odonates have been widely proposed as indicators of environmental quality in aquatic ecosystems for well-known reasons. By way of reproduction, these insects lay their eggs in or near only freshwater and thus, their high abundance in an area is a good indication of the quality of freshwater (Corbet, 1999)[2]. Odonata (dragonflies and damselflies) are used as bioindicators for wetland quality in Europe, Japan, the USA, Australia (Clausnitzer and Jodicke, 2004)[3] and in South Africa (Stewart and Samways, 1998)[4]. The greatest numbers of species are found at sites that offer a wide variety of microhabitats. Dragonflies tend to be much more sensitive to pollution than damselflies (Ameilia et al., 2006)[5].

The use of odonates as indicators offers several advantages: they are widespread and represent one of the historically most studied insect groups, and so there is a good knowledge of the ecological requirement of a large number of species and their distribution and seasonality; they are relatively easy to observe and identify, and finally they are well dependent on the ecological conditions of the environment (Corbet, 2004)[6]. Using odonata as bioindicators is advantageous than chemical test, because odonata diversity includes a particular period, inexpensive and the negative impacts on the environment is negligible or none. Considering these advantages, experimental analyses were conducted to determine the bioindicator efficiency of odonata. This study will be useful to identify the indicator species of odonata and to analyse quality of pond water by avoiding the chemical tests which will pollute the aquatic ecosystem more.

II. LITERATURE SURVEY

Odonates are characterized as excellent habitat indicators of present and past (long-term) environmental conditions in aquatic habitats (Watson et al., 1982[7]; Clark and Samways, 1996[8]; Samways and Stetler, 1996[9];

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Stewart and Samways, 1998[10]). As habitat quality changes, odonates also exhibit changes in their diversity and distribution due to their sensitivity to structural habitat quality (Clark and Samways, 1996[11]; Samways and Stetler, 1996[12]) and these have made them much easy tools in the monitoring and evaluation of habitat quality. The study conducted by Bulankova (1997) [13] at Danubian region give evidence of good bioindicative qualities of dragonflies and of the need to preserve their biotopes from degradation, which reflects negatively in the changes of the structure of the Odonata fauna. By way of reproduction, dragonflies lay their eggs in or near only freshwater (Corbet, 1999)[14] and thus, their abundance in an area is a good indication of the quality of the habitat. Dissolved oxygen levels are known to affect the behaviour, metabolism, and survival of Odonata larvae at a given temperature and pressure (Corbet, 1999)[15].

Turbidity and conductivity, may have affected adult Odonata in their choice of where to oviposit, since these variables often serve as distant visual cues to adults detecting polarization and reflected light of suitable habitats (Bernath et al., 2002)[16]. The variables likely having a greater impact on Odonata assemblages are conductivity, turbidity, and dissolved oxygen (Amico, et al., 2004[17]; Stewart and Downing, 2008[18]). Conductivity is only known to affect Odonata larvae if it is strong enough to interfere with osmoregulation (Amico, et al., 2004)[19]. The adults are easily sampled animals that are susceptible to human disturbance and recommended for wetlands assessment (Bried, 2005)[20]. Dragonflies can serve as biological indicators of environmental health (Clausnitzer, 2003[21]; Ameilia, et al., 2006[22]).

Adult odonates are conspicuous over water and relatively easy to identify at the species level (Bried, et al., 2012a[23]; Oertli, 2008[24]; Raebel, et al., 2010[25]) and may be especially well suited for broad and integrative assessments of the wetland breeding site and surrounding landscape (Bried and Ervin, 2006[26]; Dolny, et al., 2012[27]; Reece and McIntyre, 2009[28]). Adult odonates are therefore well-suited for rapid assessment methods (Fennessy, et al., 2007[29]) and addressing the increased focus on wetland quality and not just quantity in the United States (Scozzafava, et al., 2011[30]). Odonata are established as focal organisms for freshwater conservation (Samways, 2008[31]) and as good indicators of site value and habitat quality for ponds, lakes, rivers and streams (Primack, et al., 2000[32]; Chovanec, et al., 2002[33]; Flenner and Sahlen, 2008[34]; Raebel, et al., 2010[35]; Silva et al., 2010[36]; Rosset, et al., 2013[37]).

III. MATERIALS AND METHODS

Study area

In order to determine the bioindicator efficiency of odonata, 30 ponds from Meenachil taluk of Kottayam District was selected in a random manner. The locations of the selected ponds are plotted in the Fig.1.

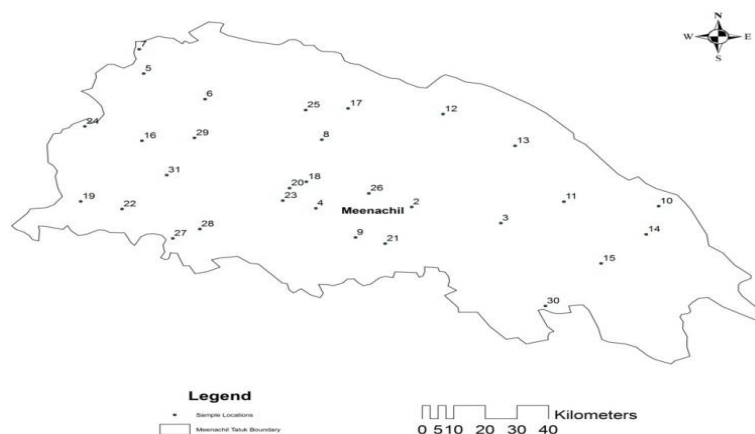


Fig.1 Sampling locations of the selected ponds in Meenachil taluk

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Study was conducted from September 2015 to December 2015. Pocket diary, tally sheet, plankton net, insect net, digital camera, sampling bottles and bucket were used in the field study.

Water Quality Analysis

The water samples of 30 ponds were collected and analyzed for 14 physiochemical parameters by following standard procedures. Temperature, pH, electrical conductivity (EC) and total dissolved solids (TDS) were measured by portable water quality tester and Dissolved Oxygen by Winkler's method. These parameters were monitored at the sampling site itself. Samples were collected in one liter clean polythene bottles and brought to the laboratory for further analysis. The parameters like hardness, acidity, alkalinity, chloride, biological oxygen demand (BOD), chemical oxygen demand (COD), nitrate, phosphate and potassium were analyzed immediately as per the standard procedures of APHA (1998)[38].

Water Quality Index

In order to calculate WQI ten important parameters, such as pH, electrical conductivity (EC), total dissolved solids (TDS), hardness, alkalinity, chloride, dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD) and nitrate were selected. The numerical value obtained from the analysis was multiplied by a weighting factor that is relative to the significance of the test to water quality. The sum of the resulting value were added together to arrive at an overall water quality index (WQI).

$$WQI = \sum W_i \times V_r$$

Where, $W_i \propto 1/V_i$ or $W_i = k/V_i$

k = constant of proportionality

W_i = Unit weight of factor

V_i = maximum permissible limits as recommended by Indian Council of Medical Research / Public health Environmental Engineering Organization.

Value of k is calculated as:

$$k = \frac{1}{\sum 1/V_i}$$

The rating scale was prepared for the range of values of each parameter. The rating varies from 0 to 100 and is divided into five intervals. The rating $V_r = 0$ implies that the parameter present in the water exceeds the standard maximum permissible limits and water is severely polluted. $V_r = 100$ implies that the parameter present in water has the most desirable value. The other ratings fall between these two extremes and are $V_r = 40$, $V_r = 60$ and $V_r = 80$ standing for excessively polluted, moderately polluted and slightly less polluted respectively. This scale is based on the version of rating scale given by Tiwari and Mishra (1985)[39].

The Water Quality Index is the sum of the product of rating (V_r) and unit weight (W_i) of all the factors.

$$\text{i.e. } WQI = W_{i(\text{pH})} \times V_{r(\text{pH})} + W_{i(\text{EC})} \times V_{r(\text{EC})} + W_{i(\text{TDS})} \times V_{r(\text{TDS})} + W_{i(\text{Alkalinity})} \times V_{r(\text{Alkalinity})} + W_{i(\text{Chlorinity})} \times V_{r(\text{Chlorinity})} + W_{i(\text{Hardness})} \times V_{r(\text{Hardness})} + W_{i(\text{DO})} \times V_{r(\text{DO})} + W_{i(\text{BOD})} \times V_{r(\text{BOD})} + W_{i(\text{COD})} \times V_{r(\text{COD})} + W_{i(\text{Nitrate})} \times V_{r(\text{Nitrate})}$$

WQI ranges are given in the table 1.

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Table 1. WQI ranges (Brown et al., 1970)[40]

Value of WQI	Quality of water
90-100	Excellent
70-90	Good
50-70	Medium
25-50	Bad
0-25	Very Bad

Biodiversity of Odonates

Observations were made through naked eyes. Spot observations were followed by photography (Sony-10x) and rarely specimens were collected from the sites using insect net. After taking photos the live dragonflies were released to their environment. The recorded species were identified with the help of a field guide “Dragonflies and Damselflies of Kerala” – Keralathile Thumbikal (Kiran and Raju, 2013)[41]. The species which were not given in the field guide were identified with the help of the members of “Dragonfly group of India”.

The number of species was recorded using tally marking system. Species abundance and Simpson’s Diversity indices were calculate by using the following methods.

Species Abundance

The most and least abundant species in each pond and in the whole area were calculated by using the abundance formula (Thomas, 2011)[42].

$$\text{Abundance} = \frac{\text{Number of individuals of a certain species} * 100}{\text{Total number of individuals}}$$

Simpson’s Diversity Index

Species diversity was computed based on Simpson’s Index (Carlo et al., 1998)[43]. This will done by using the formula,

$$D = \frac{\sum n(n-1)}{N(N-1)}$$

Where, n = the total number of organisms of a particular species

N = the total number of organisms of all species

Simpson’s Diversity Index = 1-D

The value of Simpson’s Diversity Index (1 – D) ranges between 0 and 1, i.e. greater the value, the greater the sample diversity.

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IV. RESULT AND DISCUSSION

Water Quality Index

The diverse parameters for water quality of the ponds and their dimensions are integrated into a single score by using WQI. It was observed that the WQI values ranged from 5.07 (P7) to 91.71 (P20). Based on the water quality index the selected ponds were grouped under excellent, good, medium, bad and very bad status of water quality (Table 2).

Ponds	WQI	Status	Ponds	WQI	Status	Ponds	WQI	Status
P1	59.07	Medium	P11	33.27	Bad	P21	60.62	Medium
P2	6.97	Very Bad	P12	85.27	Good	P22	65.74	Medium
P3	78.72	Good	P13	52.14	Medium	P23	52.91	Medium
P4	71.02	Good	P14	67.16	Medium	P24	72.56	Good
P5	52.18	Medium	P15	84.88	Good	P25	84.61	Good
P6	58.73	Medium	P16	78.34	Good	P26	6.97	Very Bad
P7	5.07	Very Bad	P17	72.06	Good	P27	7.08	Very Bad
P8	77.61	Good	P18	91.43	Excellent	P28	58.69	Medium
P9	32.99	Bad	P19	32.54	Bad	P29	48.02	Bad
P10	6.35	Very Bad	P20	91.71	Excellent	P30	17.7	Very Bad

Statistical analysis of the selected parameters according to water quality status of the pond

The mean and standard deviation values of the selected parameters with respect to the water quality status of the ponds are given in table 3. The highest mean values for the diversity index of odonata nymphs and adults are observed in ponds with good water quality status which are having the highest mean value of temperature and DO, second highest mean value for pH, hardness, alkalinity, phosphate, WQI and sediment pH; lowest mean value for acidity and COD and the second lowest mean value for BOD and nitrate.

Table 3. Mean and SD of selected parameters according to status of the pond

Parameters	Excellent	Good	Medium	Bad	Very bad
Temperature	26.3±0	28.51±1.31	28.27±1.98	26.68±2.99	27.68±1.15
pH	7.43±0.18	7.26±0.53	6.89±0.96	5.84±0.8	5.71±0.72
EC	111±1.41	87.3±36.99	59.16±27.27	69.35±11.57	137.5±64.78
TDS	86.9±16.4	58.82±27.19	41.4±17.97	58.3±14.7	81.65±52.21
Hardness	23±1.41	26.56±21.11	13±12.04	17.75±18.98	29.67±23.18
Acidity	3±1.41	1.42±0.6	2.49±1.47	3±1.15	4.33±0.82

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Alkalinity	60±14.14	46.89±18.68	37.11±19.21	40.5±25.68	60±31.18
Chloride	28.71±0.95	18.6±7.07	15.74±4.46	18.02±10.24	31.29±19.88
DO	10.1±0	7.41±1.82	7.07±3.04	5.3±0.51	1.46±0.65
BOD	0.52±0	1.55±1.07	3.45±3.43	10.03±1.28	8.06±2.08
COD	3760±113.14	1474±979.6	1626.2±985.02	2293±1579	1884±1059
Nitrate	1.15±1.51	1.22±1.84	1.99±2.44	3.17±6.01	3.89±4.47
Phosphate	1.85±0.78	2.75±4.96	3.28±4.89	1.49±1.84	2.71±3.71
Potassium	0.4±0	0.31±0.19	0.27±0.26	0.15±0.13	0.67±.51
WQI	91.57±0.19	78.34±5.67	58.58±5.52	36.71±7.55	8.36±4.64
Diversity index	.77±0.04	0.9±0.04	0.88±0.1	0.87±0.06	0.55±0.46

Biodiversity of odonata

During the study period 67 species of adult odonata, belonging to 11 families were recorded, out of which 28 species were damselflies and 39 were dragonflies. Nine rare species and 13 un-common species were also reported during the survey of odonata adults.

Ponds with 'good' water quality reported more number of odonate species (39) i.e. 31% followed by 'medium' quality 32 (26%). There were only 4 species seen in the excellent quality ponds which are temporary ponds with no vegetation around them. This is a reason for reducing the number of odonate species in these ponds. The ponds with bad and very bad water quality has 23 (18%) and 28 (22%) species respectively. This high number of species is due to the presence of odonata species which are seen only in the polluted area. The percentage of species identified according to the status or water qualities are given in Fig.2.

Based on the number of identified species (Fig.4.27) Libellulidae was the most dominant family (52%) followed by Coenagrionidae(19%); Calopterygidae(5%); Euphaidae and Protoneuridae (4%); Lestidae, Platy Cnemididae, Gomphidae and Aeshnidae(3%) and the lowest numbers of species (2%) were recorded from the family Chlorociphidae and Platystictidae.

Species abundance of odonata according to the status of the ponds

The most abundant odonata species found in the study area was *Bradinopyga geminata* with the abundance value 8.33 and the least abundant species were *Lathrecista asiatica*, *Vestalis gracilis*, *Ceriagrion rubiae*, *Ischnura aurora*, *Lestes umbrinus*, *Caconeura risi*, *Prodasineura verticalis* and *Trithemis pallidinervis* (0.11).

The abundance values of each species in ponds with respect to water quality status are given in table 5 and 6. *Bradinopyga geminata* was the most abundant species in pond having 'excellent' (41.67) and 'good' (16.72) water quality and no damselflies were found in the ponds having excellent water quality. *Pantala flavescens* (16.67) was least abundant species in ponds having excellent status. *Ischnura aurora*, *Lestes umbrinus*, *Ceriagrion rubiae*, *Ceriagrion cerinorubellum*, *Trithemis pallidinervis*, *Lathrecista asiatica* and *Diplacodes trivialis* were the least abundant species

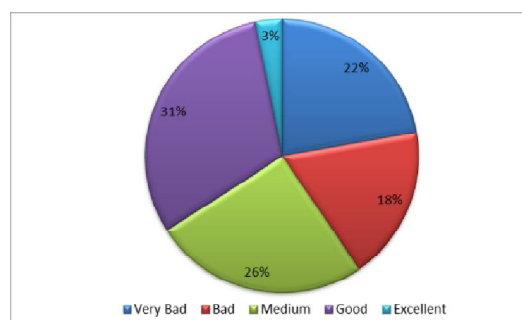


Fig.2. Occurrence of odonata species according to the status of the ponds

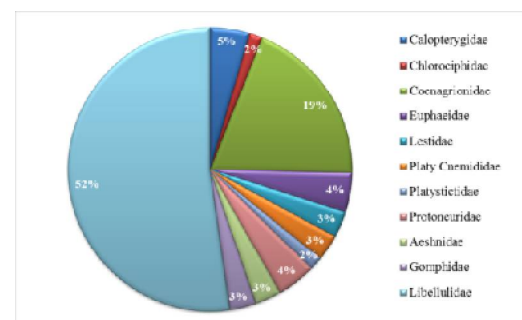


Fig.3. Distribution of adult odonates in different families

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(0.30) in ponds with good water quality. *Agriocnemis pieris* was the most abundant (9.54) and *Gynacantha bayadera* was the least abundant (0.38) species of ponds having 'medium' water quality. *Orthetrum chrysis* and *Ceriagrion cerinorubellum* were the most abundant species (12.63) and *Pseudagrion microcephalum*, *Caconeura risi* and *Acisoma panorpoides* were the least abundant species (1.05) found in the ponds having 'bad' water quality. *Zyxomma petiolatum* and *Ceriagrion cerinorubellum* were the most abundant species and *Vestalis apicalis*, *Trithemis aurora*, *Tetrathemis platyptera*, *Orthetrum taeniolatum*, *Orthetrum glaucum*, *Gynacantha bayadera*, *Gynacantha dravida*, *Brachythemis contaminata* and *Acisoma panorpoides* were the least abundant species (1.25) found in the ponds with 'very bad' water quality.

Table 5. Species abundance of Dragonflies according to water quality status

Dragonflies	Excellent	Good	Medium	Bad	Very Bad
<i>Acisoma panorpoides</i>	-	0.60	-	1.05	1.25
<i>Aethriamanta brevipennis</i>	-	1.49	0.76	2.11	-
<i>Arigomphus furcifer</i>	-	1.19	-	-	-
<i>Brachydiplax chalybea</i>	-	2.69	2.29	5.26	3.75
<i>Brachydiplax denticauda</i>	-	4.18	1.15	-	-
<i>Brachythemis contaminata</i>	-	-	-	-	1.25
<i>Bradinopyga geminata</i>	41.67	16.72	2.67	-	-
<i>Cratilla lineata</i>	-	-	0.76	-	-
<i>Crocothemis servilia</i>	-	2.99	2.29	-	-
<i>Diplacodes lefebvrei</i>	-	0.60	-	-	-
<i>Diplacodes trivialis</i>	-	0.30	0.76	-	1.88
<i>Gynacantha bayadera</i>	-	-	0.38	-	1.25
<i>Gynacantha dravida</i>	-	-	-	-	1.25
<i>Hydrobasileus croceus</i>	-	-	2.29	-	-
<i>Ictinogomphus rapax</i>	-	-	-	-	-
<i>Indothemis carnatica</i>	-	0.90	0.76	-	-
<i>Lathrecista asiatica</i>	-	0.30	-	-	-
<i>Lyriothemis tricolor</i>	-	0.60	-	3.16	-
<i>Macrodiplax cora</i>	-	0.60	-	-	-
<i>Neurothemis fulvia</i>	-	1.79	-	-	3.13
<i>Neurothemis tullia</i>	-	5.97	4.96	2.11	5.00
<i>Orthetrum chrysis</i>	20.83	6.57	6.49	12.63	7.50
<i>Orthetrum glaucum</i>	-	1.79	-	-	1.25
<i>Orthetrum luzonicum</i>	-	5.67	-	2.11	-
<i>Orthetrum pruinosum</i>	-	-	-	-	-
<i>Orthetrum Sabina</i>	-	5.67	3.82	2.11	1.88
<i>Orthetrum taeniolatum</i>	-	-	-	6.32	1.25
<i>Pantala flavescens</i>	16.67	6.57	8.78	10.53	5.63
<i>Rhodothemis rufa</i>	-	1.49	3.82	4.21	2.50
<i>Rhyothemis triangularis</i>	-	1.79	1.91	-	-
<i>Rhyothemis variegata</i>	20.83	6.87	7.25	7.37	5.63
<i>Tetrathemis platyptera</i>	-	-	-	-	1.25
<i>Tholymis tillarga</i>	-	0.60	-	-	-
<i>Tramea limbata</i>	-	1.19	1.53	3.16	-
<i>Trithemis aurora</i>	-	2.39	6.49	-	1.25
<i>Trithemis festiva</i>	-	2.39	6.11	-	-
<i>Trithemis pallidinervis</i>	-	0.30	-	-	-
<i>Urothemis signata</i>	-	1.79	0.76	-	-
<i>Zyxomma petiolatum</i>	-	-	-	6.32	10.63

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Table 6. Species abundance of Damselflies according to water quality status

Damselflies	Excellent	Good	Medium	Bad	Very Bad
Aciagrion hisopa	-	-	-	2.11	-
Aciagrion occidentale	-	-	1.15	-	-
Agriocnemis pieris	-	3.88	9.54	-	-
Agriocnemis pygmaea	-	-	-	8.42	7.50
Archi basisoscillans	-	-	2.67	-	-
Caconeura risi	-	-	-	1.05	-
Ceriagrion cerinorubellum	-	0.30	5.34	12.63	10.63
Ceriagrion coromandelianum	-	-	1.53	4.21	7.50
Ceriagrion olivaceum	-	1.19	-	-	-
Ceriagrion rubiae	-	0.30	-	-	-
Copera marginipes	-	-	1.53	-	-
Copera vittata	-	1.49	1.15	-	-
Esme longistyla	-	-	-	2.11	-
Euphae acardinalis	-	-	1.15	-	-
Euphae adispar	-	-	-	2.11	-
Euphae afraseri	-	-	1.53	-	-
Ischnura aurora	-	0.30	-	-	-
Lestes praemorsus	-	8.66	4.96	-	-
Lestes umbrinus	-	0.30	-	-	-
Libellago lineate	-	-	-	-	3.13
Neurobasis chinensis	-	-	-	-	1.88
Platysticta deccanensis	-	-	-	2.11	-
Prodasineura verticalis	-	-	-	-	4.38
Pseudagrion indicum	-	-	-	-	1.88
Pseudagrion microcephalum	-	2.39	0.76	1.05	2.50
Pseudagrion rubriceps	-	-	-	-	1.88
Vestalis apicalis	-	-	1.15	-	1.25
Vestalis gracilis	-	-	1.53	-	-

Simpson's Diversity Index of odonata

The Simpson's Diversity Index of odonata adults for the study area is 0.99. The index 1 represents infinite diversity and 0 means no diversity. The Simpson's Diversity Index in the study area is so close to one, so in general we can say that the study area Meenachil taluk have rich odonata diversity and it suggests that there are a greater number of successful species and a more stable ecosystem in this area. But when we are considering the Simpson diversity index of individual ponds, there are both stable and unstable ecosystems. The highest Simpson's Diversity Index (0.97) was recorded in P7 which has 'very bad' water quality status. This increase in the diversity index was due to the presence of species which are seen only in the polluted areas, and the pond was near to Meenachil river.

The river dwellers of the adult odonata overlap to the nearby terrestrial ecosystem and thus increase the diversity index. The ponds P3, P4 and P5 with 'medium' and 'good' water quality status have diversity index 0.95. The diversity index was zero for P10 and P30 with 'very bad' water quality i.e., no diversity of adult odonata. The Simpson's Diversity Index of the odonata found in the individual ponds are given in Fig.4.

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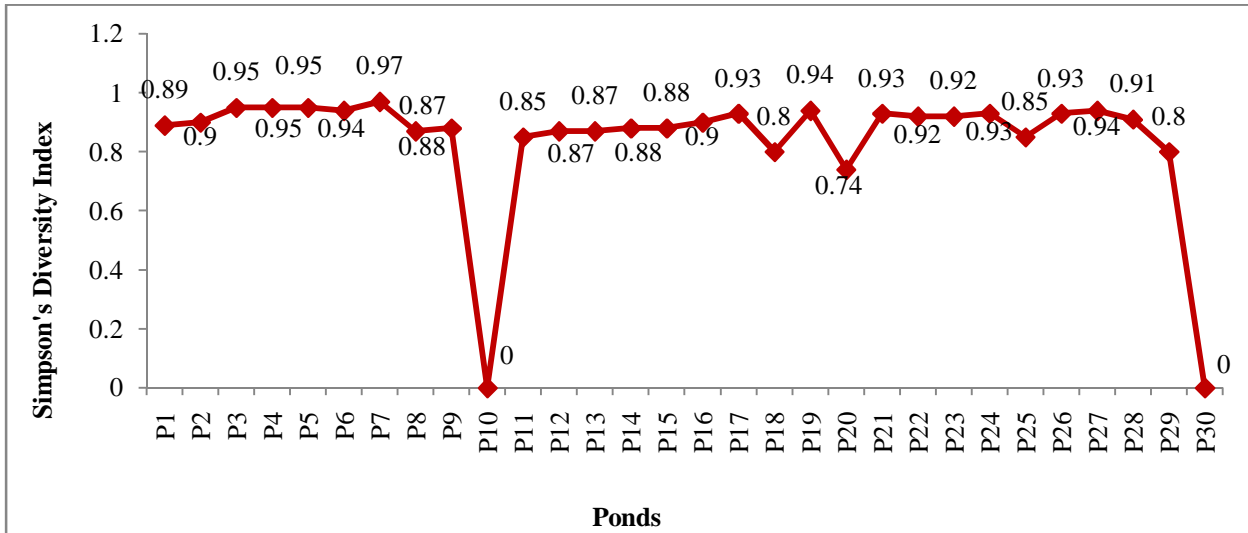


Fig.4 Simpson's Diversity Index of Odonata

Table 7. Simpson's Diversity Index according to WQI

Water Quality	1-D
Very Bad	0.62
Bad	0.87
Medium	0.91
Good	0.90
Excellent	0.77

Based on the water quality index (table 7), the ponds with 'medium' water quality shows the highest Simpson's diversity index (0.91) and diversity index for ponds with 'good' water quality was 0.90. The ponds with 'excellent' water quality has diversity index 0.77, this decrease is mainly due to the absence of vegetation around the ponds and the ponds were temporary. The ponds with 'bad' water quality has diversity index 0.87 and for ponds having 'very bad' water quality status has 0.62.

V. CONCLUSION

The most abundant species for ponds having excellent and good water quality status was *Bradinopyga geminata*; *Trithemis festiva* for ponds with medium status; *Zyxomma petiolatum* for ponds with bad status and *Ceriagrion cerinorubellum* for ponds with very bad water quality status. Simpson's Diversity Index of odonate nymph's in the study area is 0.95, i.e. Meenachil taluk has a rich odonate diversity and it suggests that there are a greater number of successful species indicating generally more or less stable ecosystem in this area. But when we are considering the individual ponds and its surroundings there are both stable and unstable ecosystems. Even though the number of individuals was more in ponds with excellent water quality, the Simpson's Diversity Index was low. These results clearly reveal that we can't make any assumption about the quality of water only by seeing the diversity index of odonata. We should consider the species which are most abundant in that area. Since the odonata diversity of different ponds in Meenachil taluk vary, these populations and the individual species can be monitored, related and used as indicators of the water quality of the pond ecosystem.

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