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A study on the diversity of odonate larvae in a permanent pond Melpalai at Melpuram in Kanyakumari district, Tamil Nadu, India

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Abstract
The present study gives an overview of data on the habitat diversity of odonate larvae occurring in a permanent pond Melpalai in Melpuram, Kanyakumari District (Tamil Nadu), India, during August 2013-July 2014. The survey of the permanent pond Melpalai revealed the occurrence of 21 species of Odonata. The family Libellulidae belonging to the sub order Anisoptera and order Odonata dominated all the other families, while the family Coenagrionidae, sub order Zygoptera and order Odonata occupied the second position. The physicochemical parameters (temperature 22-31.5 T ºC; pH 6.8-7.13; Total dissolved solids 110-143 ppm; Dissolved oxygen 4.1- 5.1 ml/l; Electric conductivity 58-105) of this pond were more or less ideal for the abundance and distribution of odonate larvae. Various diversity indices were calculated for premonsoon, monsoon and post monsoon seasons and the results indicated that maximum diversity and distribution were occurred during the monsoon season followed by the postmonsoon season and minimum diversity was recorded during the premonsoon season

Keywords: Odonate larvae, diversity, abiotic factors, environmental warming, bioindicator

1. Introduction
Odonates are the most ancient and beautiful insects that ever roamed on earth with fossil records dating back to the Permian era 230 – 280 million years ago and about 5740 species / subspecies of odonates belonging to 654 genera in 32 families are documented worldwide [1, 2]. India has a unique and exceptionally rich and wide-ranging flora and fauna, known for its distinctive and varied geographical features topography, soil, climate and vegetation, harbours 463 species and subspecies belonging to 140 genera in 19 families [2]. A variety of factors make the odonate an ideal model taxon for the investigation of the impacts of environmental warming and climate change [3].

Immature odonates occupy a great diversity of aquatic habitats but are generally most abundant in lowland streams and ponds [4]. There are many taxonomic studies on larvae and imagoes of odonates, but the ecological studies are relatively scarce, especially for short and long term evaluations on possible changes induced by human activities [5]. Ecological studies on richness and distribution at regional levels are few. It was well known that odonate larvae are dependent on habitat characteristics [6], sensitive to abiotic factors, and play significant roles as predators and prey in the trophic structure of aquatic communities [7]. They possess many desirable bioindicator qualities [8-10, 7, 11], and many species have been used to study a variety of phenomena, such as tolerance to physicochemical factors [12], accumulation of metals in larvae [13], effects of increased water temperature caused by nuclear reactors [14, 15], direct sewage discharge to rivers, pesticide contamination [16], impact from cattle ranching on imago assemblages [17, 18], relationships of assemblages with habitat characteristics, and larvae as indicators of water quality [19]), total richness, and riparian quality [20].

Several studies also have focused on their application in diversity and conservation assessment [21-24]. Both water dissolved oxygen concentration and temperature directly affect the abundance of odonate larvae. The amount of dissolved oxygen in water affects the behaviour, metabolism, and survival of odonate larvae [7, 25]. Variations in oxygen availability in lacustrine (low oxygenation) and lotic (high oxygenation) environments determine the diversity of odonate species [7, 26]). Water temperature also has an effect on the abundance and development of odonate larvae [7]. Sites with high temperatures, such as thermal springs, tend to present low abundance and diversity of odonate species [7].

However, when considering aquatic insects, odonates are characterized by high tolerance to changes of surface water temperature. Odonate larvae are top predators and can feed on a great diversity of macroinvertebrates [7]. This work was aimed to study the diversity and the relationship between the abundance of odonate larvae and the quality of water in a permanent pond Melpalai at Melpuram in Kanyakumari District.

2. Material and Methods

This diversity studies of odonate larvae were carried out in a permanent pond Melpalai at Melpuram in Kanyakumari District, selected based on climatic and geographic features, during the period of August 2013 to July 2014.

Station I: Melpalai

2.1. Site Description

Kanyakumari district was the southernmost district of the state of Tamil Nadu, and the southernmost tip of Peninsular India. It was located between 77° 15' and 77° 36' of east of longitudes and 8° 03' and 8° 35' north of Latitudes. It covers an area of 1,685 sq. km, occupying 1.29% of the area of Tamil Nadu. Melpalai was a permanent pond in Melpuram (latitude of 8°.329' and the longitude of 77°.2'), Kanyakumari District of Tamil Nadu State, India.

2.2. Assessment of the physicochemical parameters of the permanent pond Melpalai

About 5 litre of water sample was collected from the pond separately in plastic containers and brought to the research laboratory and physicochemical parameters such as pH, total dissolved oxygen and electrical conductivity were analysed by water quality analyser (Systronics, 371). The water temperature was noted in the sampling station using thermometer and dissolved oxygen was determined by Winkler's method and the data were tabulated.

Table 1: Physicochemical parameters in Melpalai

S. No	Water parameters	Physicochemical parameters recorded in different months											
		Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
1	T ^{O}C	24	27	25	23	22	26	27	30	31.5	33	22	23
2	pH	7.09 ± 0.33	6.89 ± 0.37	6.81 ± 0.29	7.0 ± 0.39	7.09 ± 0.27	7.01 ± 0.39	6.8 ± 0.27	6.99 ± 0.35	6.98 ± 0.38	6.7 ± 0.29	7.1 ± 0.39	7.13 ± 0.42
3	TDS (ppm)	135 ± 11.1	143 ± 12.3	133 ± 10.4	136 ± 11.3	124 ± 10.8	137 ± 10.4	110 ± 10.9	120 ± 10.8	118 ± 9.28	110 ± 10.8	132 ± 10.4	131 ± 11.2
4	DO (ml/l)	5.1 ± 0.19	5.2 ± 0.18	5.1 ± 0.17	5.1 ± 0.27	5.4 ± 0.18	5.5 ± 0.28	4.1 ± 0.12	4.3 ± 0.14	4.7 ± 0.12	4.29 ± 0.13	4.9 ± 0.11	5.0 ± 0.15
5	EC (µs)	75 ± 4.25	71 ± 4.29	68 ± 3.40	65 ± 3.41	62 ± 3.41	58 ± 3.14	95 ± 9.13	98 ± 8.94	101 ± 9.38	105 ± 9.37	97 ± 6.97	80 ± 6.28

2.2. Field collection of Odonate larvae

Insects were collected from a permanent pond Melpalai at Melpuram in Kanyakumari district. Site selection was based on different environment conditions and levels of disturbance. Insects were collected at monthly intervals from June 2013 to May 2014. Collection was made between 9.00 a.m. to 12 p.m. from selected sites at four corners of the pond. Larvae were collected by sweep sampling method using a standard D-frame net usually used in Limnology with the mesh size of 1.5 mm. The net was swept through the aquatic vegetation at the shore lines and in the bottom sediment down to water depth of approximately 0.5 m. The naiads which were buried in the sediments were sampled by placing the net into the substrate and disturbing the substrate directly upstream for 1 minute. Samples were flushed from the net into stacked 10 mm and 100 mm sieves for collection in order to remove excess substrate. All odonate larvae sighted were placed into labelled jar and brought to the laboratory for further identification and grouping. Diagnosis of each species was based on the examination of the specimen with naked eye or under 10X magnifier and 45X stereomicroscope, with reference to colour photos of living insects, and by using the standard keys (Theischinger 2007).

Table 2: Odonate larvae recorded in Melpalai a permanent pond (August 2013-July 2014)

Insect population	Months 2013 – 2014												Grand total
	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	
Order: Odonata													
Sub Order: Anisoptera													
Family: Aeshnida													38
Anax imperator	2	1	2	-	-	-	1	2	1	2	1	3	15
Anax junius	3	2	1	1	2	-	-	1	2	2	4	5	23
Family: Corduliidae													27
Somatochlora sp.	4	3	2	1	1	-	-	2	2	3	4	5	27

Family: Gomphidae													97
Hagenius brevistylus	15	8	7	5	2	-	-	1	1	3	5	9	56
Megalogomphus sp.	5	3	2	3	1	-	-	-	2	4	4	5	29
Epitheca cynosure	2	1	2	-	-	-	-	2	1	1	2	1	12
Family: Libellulidae													460
Bradynopyga geminata	18	15	9	6	4	3	-	-	-	5	8	12	80
Crocothemis nigrifrons	13	8	5	3	2	1	-	-	3	6	9	15	65
Orthetrum chrysis	5	4	3	2	3	2	1	2	3	4	5	6	40
Plathemis lydia	7	5	4	2	1	-	-	1	1	2	2	3	28
Rhodothemis sp.	14	8	4	3	2	1	-	-	2	1	4	8	47
Rhodothemis rufa	4	2	2	1	2	1	-	-	-	2	3	3	20
Sympetrum corruptum	25	19	11	13	7	3	-	-	8	13	21	29	149
Traemea sp.	4	2	3	5	2	1	-	-	1	2	4	7	31
Family: Macromiidae													18
Macromia sp.	3	2	-	4	2	1	-	-	-	1	3	2	18
Sub order: Zygoptera													
Family: Coenagrionidae`													234
Ceriagrion coromandelianum	13	10	8	11	7	5	-	-	3	8	7	12	84
Enallagma sp.	8	5	6	7	4	2	-	-	3	5	9	5	54
Ischnura sp.	17	13	8	7	3	4	-	-	-	2	5	9	68
Pseudagrion microcephalum	7	4	3	2	1	-	-	-	2	1	3	5	28
Family: Lestidae													29
Lestes sp.	5	7	4	3	2	1	-	-	1	1	3	2	29
Family: Protoneuridae													66
Prodasineura sp.	15	13	11	9	4	1	-	-	-	2	4	7	66
Total	189	135	97	88	52	26	2	11	36	70	110	153	969

2.4. Statistical Analysis

Mean abundance values of odonate larvae for premonsoon (February, March, April and May), monsoon (June, July, August and September) and postmonsoon (October, November, December and January) seasons were calculated from the abundance data of the constituent months. Various univariate diversity indices calculated to find out the Odonate larvae faunal changes found between the months were number of species (S), numerical abundance (N), Margalef index (d) (Margalef, 1958), Pielou's evenness index (j')(Pielou, 1977) and the log2 based Shannon - Weiner species diversity index (H') (Shannon and Wiener, 1949).

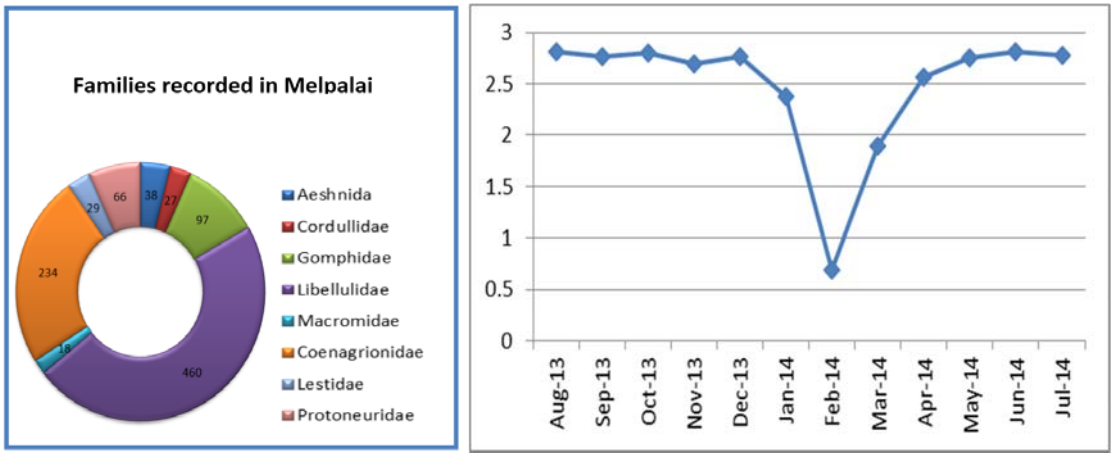

Fig 2: Odonate larvae Index recorded in Melpalai Kanyakumari district (August 2013-July 2014)

Table 3: Diversity indices of Odonate larvae at Melpalai, a permanent pond in three different seasons (August 2013-2014)

S. No.	Diversity indices	Station I		
		Postmonsoon	Premonsoon	Monsoon
1.	S	20.25	18	21
2.	N	136	47	171.25
3.	d	3.98	2.97	4.46
4.	J'	0.96	0.96	0.96
5.	H'	2.87	2.77	2.94
6.	λ	0.92	0.87	0.95

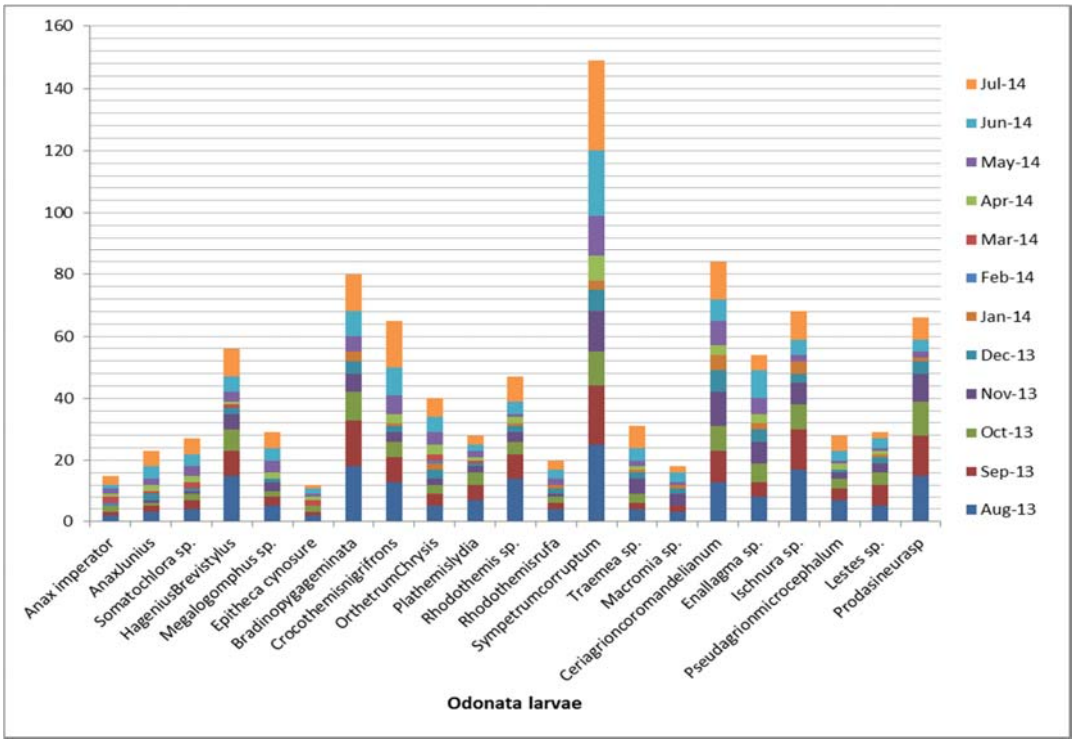

Fig 3: Odonate larvae recorded for Station I in Kanyakumari district (August 2013-July 2014)

3. Result

The results recorded in table 1 showed the physicochemical parameters in the permanent pond Melpalai. In this pond, the maximum temperature (33 ºC) was recorded during the month of May, 2014 and minimum (22 ºC) was recorded during the months of December, 2013 and June, 2014. Maximum pH (7.13) was recorded during the month of July and minimum (6.7) was recorded on May, 2014. During the month of September, 2013 maximum TDS (143 ppm) was recorded and minimum (110 ppm) was in February and May. Maximum DO (5.5 ml/l) was recorded in January, 2014 and minimum (4.1 ml/l) in February, 2014. Maximum EC (105µs) was recorded during the month of May and minimum (62µs) in November, 2013.

Table 2 showed that 21 species of Odonate larvae were common in Kanyakumari district. They come under 19 genera belonging 8 families under two suborders, Zygoptera (Damselflies) and Anisoptera (Dragonflies). Family *Libellulidae* was highly dominant with 7 genera that includes *Bradinopyga, Crocothemis, Orthetrum, Plathemis, Rhodothemis* (two species), *Sympetrum* and *Traemea* with the grant total of 460 individuals in this station. Family *Coenagrionidae* occupies the next position with four genera, *Ceriagrion*, *Enallagma*, *Ischnura* and *Pseudagrion* with the grant total of 234 individuals. Family *Gomphidae* comes to the next place with 3 genera, *Hagenius*, *Megalogomphus*, and *Epitheca* with 97 larvae. This was followed by the family Protoneuridae with 1 genus, *Prodasineura* with the grant total of 66 naiads. Family Aeshnidae with one genus, *Anax* and two species (*Anax imperator* and *Anax junius*) comes to the next position with the total of 38 nymphs. Then comes the Family *Lestidae* with one genus *Lestes*, with the grant total of 29 larvae. This was followed by the family Corduliidae with one genus *Somatochlora* with 27 larvae. The last one was the Family *Macromiidae* with the genus *Macromia* and the number of naiads recorded was 18.

3.1. Distribution pattern of Anisopteran larvae

Anax imperator showed the peak population of 3 individuals during the month of July 2014, and it was absent during the month of November, December 2013 and January 2014. *Anax junius* showed the peak population of 5 individuals during the month of July 2014 and it was absent during the month of January 2014 and February 2014. *Somatochlora* sp. showed the peak population of 5 individuals during the month of July 2014 and it was absent in January and February 2014. *Hagenius brevistylus* showed the peak population of 15 individuals during the month of August and it was absent in January and February 2014. *Megalogomphus* sp. showed the peak population of 5 individuals during the month of July and August 2014, it was absent in January, February and March 2014. *Epitheca cynosure* showed the peak population of 2 individuals during the month of August, October 2013, March and June 2014 and it was absent in November, December 2013, January and February 2014.

Bradynopyga geminata showed the peak population of 18 individuals during the month of August 2014, and it was absent in February, March and April 2014. *Crocothemis nigrifrons* showed the peak population of 15 individuals during the month of July 2014 and it was absent in February and March 2014. *Orthetrum chrysis* showed the peak population of 6 individuals during the month of July 2014 and there was low population in other months. *Plathemis lydia* showed the peak population of 7 individuals during the month of August 2013. It was absent in January and February 2014. *Rhodothemis* sp. showed the peak population of 14 individuals during the month of August 2013 and it was absent in February and March 2014. *Traemea* sp. showed the peak population of 7 individuals during the month of July 2014 and it was absent in February and March 2014. *Macromia* sp. showed the peak population of 4 individuals during the month of November 2013 and it was absent in October 2013, February, March and April 2014.

3.2. Distribution pattern of Zygopteran larvae during the period of July 2013

Ceriagrion coromandelianum showed the peak population of 13 individuals during the month of August 2013 and it was absent in February and March 2014. *Enallagma* sp. showed the peak population of 9 individuals during the month of June 2014 and it was absent in February and March2014. *Ischnura* sp. showed the peak population of 17 individuals during the month of August 2013 and it was absent in February, March and April 2014. *Pseudagrion microcephalum* showed the peak population of 7 individuals during the month of August 2013 and it was absent in January, February and March 2014. *Lestes sp*. showed the peak population of 7 individuals during the month of September 2013 and it was absent in February and March 2014. *Prodasineura sp*. showed the peak population of 15 individuals during the month of August 2013 and it was absent in February, March and April 2014. The above results showed that there are seasonal variation in the distribution of odonate larvae in the selected permanent pond.

3.3. Diversity indices of Odonate larvae at three different stations in three different seasons

Table 3 clearly revealed that, in Melpalai, the species number during the monsoon was 21. It was 20. 25 in the postmonsoon season and 18 for premonsoon season. Numerical abundance (N) was 171.25 during the monsoon season, 136 for postmonsoon season and 47 for premonsoon season. Margalef index (d) was 4.46 at the monsoon season, 3.98 at the postmonsoon season and 2.97 at the premonsoon season. Pielou's evenness index and Shannon - Weiner species diversity index were also shown the same pattern of diversity in all the three seasons where the highest value was recorded during the monsoon season, which was followed by the postmonsoon season and the lowest diversity was recorded during the premonsoon season.

4. Discussion

According to Corbet [7], environmental variables and biotic factors, as predation, had an important effect on Odonate larvae density. A daily modification on environmental factors can occurred in distinct stations and those changes on environmental variables affect the distribution of aquatic insects. More evidences were added showing the effects of environmental variables during the diurnal cycle on Odonate larvae. In aquatic ecosystems, oxygen availability was one of the limiting factors of the survival of insect larvae, such as Odonata [27, 28] and the same findings coincide with our present study in which the permanent pond Melpalai shows high dissolved oxygen (4.1-5.1ml/l) and the diversity of odonate larvae was also high in this station. Although the changes of oxygen availability affected some odonate larvae, many of them are tolerant enough to environmental variations, including of oxygen availability. The amount of dissolved oxygen in water affects the behavior, metabolism, and survival of Odonate larvae [25]. Variations in oxygen availability in lacustrine (low oxygenation) and lotic (high oxygenation) environments determine the diversity of Odonata species [26].

Besides oxygen, the surface water temperature also influenced the distribution of odonate larvae. Only four orders of aquatic insects (Odonata, Hemiptera, Diptera, and Coleoptera) are resistant to significant changes in water temperature [7]. In the present study, only Libellulidae and Coenagrionidae tolerated variations in surface water temperature and are found to be high in number throughout the study period whereas Macromiidae, Gomphidae and Protoneuridae shows less tolerance to temperature and were found to be lesser during the summer time. Some Anisoptera and Zygoptera families are sensitive to variations in water temperature, as was reported for *Acanthagrion*, *Erythemis*, *Telebasis* and *Tauriphila* [7, 29]. Jason [30] confirmed the present results, recorded a raise in the odonatous individuals during July and August. Crowley *et al*., [31] agreed with this result, where they concluded that, the maximum emergence of damselflies was occurred during spring, summer and autumn.In addition to the water dissolved oxygen concentration and surface temperature, other environmental factors, such as electrical conductivity, pH, and depth also had an effect on the abundance of odonate larvae.

Keize and Kalkman [32] reported that Coenagrionidae and Libellulidae are the two largest families of Odonata and dominated the dragonfly fauna of standing water in every continent. Kalkman *et al*., [1] also stated that the two largest families, Coenagrionidae and Libellulidae, are relatively well known, because most species are noticeable and favor open habitats and these reports supported the result of the present study. In the present study also Family Libellulidae occupies the first position in abundance followed by Coenagrionidae. This result also coin side with the report of Cayasan *et al*., [33], which showed that among the 36 species in Zamboanga del Sur, Philippines, 16 are from family Libellulidae and another six species are from Coenagrionidae. Villanueva and Cahilog [37] documented 11 species from Libellulidae and five from Coenagrionidae among 35 species documented. Quisil *et al*., [34] Villanueva and Cahilog [36],and Villanueva [35] found Family Libellulidae to be the most represented while Family Coenagrionidae was the second most represented.

5. Conclusion

The survey of the permanent pond Melpalai revealed the occurrence of 21 species of dragonfly nymphs. Odonate larvae belonging to the sub order Anisoptera, family Libellulidae dominated all the other families, while the Zygopteran family Coenagrionidae occupied the second position. The permanent pond Melpalai, Melpuram showed highest biodiversity because it has a good environmental and climatical conditions and the anthropogenic activity also lesser here. The physicochemical parameters of this pond are also more or less ideal for the abundance and distribution of odonate larvae. Hence if these conditions are maintained in the laboratory, we can maintain a fresh colony of odonate larvae even under laboratory condition for further experiments using dragonfly nymphs.

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