# CHAPTER 6.

# STUDY OF ODONATES

## INTRODUCTION

Though the invertebrates form major part of animal biomass on earth on which many of the higher forms depend, they have not been given much importance in global biodiversity assessment programmes. However, currently Odonata is the only insect group for which a representative global assessment of conservation status has been completed and analyzed. This assessment succeeds in providing an indication of the level of global threat across freshwater invertebrate groups but it also identifies a high level of data deficiency. This elucidates non availability of sufficient information to assess their status. Clausnitzer *et al*., (2009) used a combined expertise of a large international network of odonata specialist to assess Odonates of the world using the Red List categories and criteria of IUCN (2001). These authors have put more than half of Odonate species as Least Concerned while 35 % of Data Deficient and one out of 10 as Threatened. Many of these Threatened species are clustered in tropical areas, especially in Indo-Malayan Realm where 47.31 % are data deficient.

The species inhabiting lotic waters are at greater risk than those in the lentic waters probably because these habitats are less predictable in space and time. Species in lentic system tend to be more generalized and have a higher dispersal capacity (Corbet, 1999) resulting in larger ranges and wider ecological preferences and therefore are at lower extinction risk (Clausnitzer and Jodicke, 2004). Higher environmental pressure on lotic waters may also be responsible for the increased risk to species in these habitats. This holds especially true for most forests in tropical areas too. The data gap in tropical countries is a taxa-wide problem and does not apply only to odonata (Collen *et al*., 2008).

Destruction of tropical forest is probably the most important threat to global odonate diversity potentially resulting in the extinction of numerous species. Unfortunately these species are often poorly known, making it difficult to say whether a species is genuinely rare or merely overlooked. Examples of data deficiency are more common from oriental region (Orr, 2004). Hence, more field-work has been proposed to establish the true ranges of these species and to determine area of endemism within larger tropical forest areas.

Diversity of tropical odonates is partly explained by the high diversity of aquatic habitats in tropical forests (Orr, 2006), especially in mountainous regions (Oppel, 2005). Mountains not only provide greater contemporary diversity of habitats, but also a greater potential for survival in regional refugia particularly for the groups like odonates having specialist lifestyle.

Approximately 6000 species and subspecies of odonates belonging to 630 genera of 28 families are known to occur over the world (Tsuda, 2000). Though the taxonomy of adult odonata is well documented from India (Fraser, 1933; 1934; 1936; Prasad and Varshney, 1995, Subramanian, 2009), majority of odonate diversity of India falls in Data deficient category. Important initiatives taken in 2005 for their conservation at Global level are the update of the IUCN Red List and the 'Pan-African Freshwater Biodiversity Assessement' started by the IUCN (Darwall *et al*., 2005), that include odonates among other taxa and the 'Global Odonates Assessment'. This requires inputs from various parts of India. Hence while studying ecology and biodiversity of Toranmal area density and diversity of Odonates of the area are also considered.

Based on morphology, the order odonata are divided into three sub-orders – Zygoptera, Anisozygoptera and Anisoptera. The suborder Anisozygoptera is a living fossil with two species where as Zygoptera includes damselflies and Anisoptera includes dragonflies.

The life history of odonates is closely linked with water bodies. They use a wide range of flowing and stagnant water bodies. Many species have small distributional ranges and are habitat specialists, inhabiting alpine mountain bogs, seepage areas in tropical rain forests or waterfalls. All lay their eggs in a wide range of aquatic habitats. The larva is a sophisticated predator preying on all kinds of small organisms up to the size of tadpoles and small fishes. Larvae take a few weeks to develop. Emergence takes place above water on plants or on the shore, after which most species leave the water edges as mature adults. Males return to the water in search of females and to establish territories, while females often return only to mate and oviposit. Some species in the tropics and warm temperate regions often complete one or more generation per year.

Among insects with life histories crossing the aquatic – terrestrial boundary, odonate biomass often exceeds that of any other taxa (Bried, 2005), underscoring the ecological importance of this group as predator and prey in both wetland and terrestrial ecosystem. Odonates are also valuable as ‘biological indicators of the integrity of freshwater system (Corbet, 1993; Stewart and Samways, 1998). They exhibit complex life histories requiring use of both aquatic habitat as larvae and littoral, riparian and upland areas as adults for maturation, foraging and mating (Corbet, 1999). Diverse and habitat-specific odonate assemblages with varied tolerance for aquatic pollution and water shed degradation are common (Corbet, 1993).

Habitat degradation and pollution impose great pressure on the species that are confined to a small area. Odonate has been considered as an excellent easy– to–use indicator group to understand the status of biodiversity in freshwater ecosystem (Suhling *et al*., 2006; Clausnitzer, 2003).

Though the Indian odonate fauna is well known taxonomically, the natural history and ecology has been documented only for few species (Subramanian, 2005). No data on odonates is available from the dry deciduous forest of Toranmal area. The issues on biodiversity and conservation have been instrumental in motivating the present study of odonates. Though the study is preliminary, it is expected to provide baseline data on assemblage structure, spatial and temporal variations, flight period and ecological preferences of Odonates in wetlands and forested tracts of Toranmal area with a major knowledge gap at local scale. The major thrust of the study is to determine occupancy patterns and test the influence of physical environmental gradients on adult distribution. Last but not least to develop wider conservation priorities for odonata and to assess the suitability of adult odonata as biological indicators of environmental quality at local scale.

# MATERIAL AND METHODS

## STUDY AREA

Four transects (Biotope) within 10 Km radius of Toranmal Village were selected for the present study. Their characteristics are as follows:

### 1) Sitakhai Stream (SS)

Located 21˚53’ 28” N and 74˚ 28’ 05” E at 868 AMSL it runs parallel to the Sitakhai stream which is located north to Toranmal. The stream is slow flowing with many turns and deposited soil because of abundant leaves and gravel as well as pebble. It is perennial at some places. Mixed riparian vegetation or larger trees around the stream form open-closed cover over the stream. Patches of herbs, shrubs and emergent littoral vegetation are present in moderate density around the transect. Some agricultural plots are present on the northwest side of the stream and this area faces low anthropogenic pressure.

### 2) Kalapani Stream (KS)

Located at 21˚51’ 03” N and 74˚ 28’ 06” E at 822 AMSL, this biotope is 10 Km east of Toranmal. The stream passes over hilly area having more slope. The stream flows from June to January and then dries up. The stream is characterized with low heterogeneity. The speed of water and little roughness limit the presence of gravel, pebbles and other substrates in larger quantity. Moderate grazing pressure in riparian area is observed around this stream. It is a forested area with tall trees dominated by *Tectona grandis* (Teak). Among the tall trees few gaps are occupied by herbs and shrubs. The wild weeds include *Achyranthes aspera, Cassia tora, Vernonia cinerea, Tridax procumbens, Andropogon spp, etc.* (Annexture-I) in the riparian zone.

### 3) Lotus Lake (LL):

Located at 21˚53’ 16” N and 74˚ 27 47” E at 900 AMSL on north side of Toranmal village, the lake has 1.17 Km perimeter and spreads in about 3.5 Hectare area. It is a shallow water body with small check dam towards its north outlet. The vegetation around the lake includes few tall trees dominated by herbaceous vegetation and shrubs. The dominant herb in littoral zone was *Polygonum barbatum* and emergent vegetation *Nymphaea pubescens*.

### 4) Yashwant Lake (YL)

Located at 21˚52’ 50” N and 74˚ 27 21” E at 1000 AMSL, Yashwant Lake has a perimeter of 2.75 Km and it spreads in 39 hectares with spill way on the Northeast side. It is a perennial water body. The western bank is muddy with few large trees, among which patches of herbs and shrubs are present in the littoral zone. Little emergent and floating vegetation are present.

### Methods:

To study adult odonates, monthly surveys were conducted during December 2006 to November 2008 for a period of two years at Toranmal area in four identified biotopes. Each survey was conducted between 900 to 1600 hours, the local peak of odonate flight activity at all the biotopes. Line transect method was used for study of odonates (Moore and Corbet, 1990; Brook, 1993). Observations were made while walking on fixed transect of 500 m length. The species encountered in 5m breadth on either side were considered and their density and species richness were recorded for each biotope. Double counts were probably infrequent because most species were perchers and relatively motionless. Species which could not be identified in the field were collected and stored in 70% ethyl alcohol and carried to the laboratory for identification. All species were identified following Fraser (1933; 1934; 1936) and field guide by Subramanian (2005). Systematic arrangement of the species follows Subramanian (2009).

### Statistical Analysis

The data of the two year study (from December-2006 to November-2008) was pooled for three months and four seasons and analyzed for seasonal variations, with respect to winter (December, January, February), Summer (March, April, May), Monsoon (June, July, August) and Post monsoon (September, October, November). Further, the Mean, Standard Error of Mean (SEM) were calculated for each season and One-Way ANOVA with No post test for various parameters for four seasons was performed using Graph Pad Prism version 3.00 for Windows (Graph Pad Software, San Diego California USA). The correlation between the abiotic factors and the odonates was calculated. The Pearson correlation was calculated by keeping odonates as dependent variable and other abiotic and biotic factors as independent variables with the help of SPSS 7.5 for Windows.

# RESULTS

## Community comparison of odonate fauna of Toranmal Area.

Odonate fauna of Toranmal is rich with total 24 species (Annexture V) recorded in the present study over two year period. The suborder Anisoptera appeared dominant quantitatively as well as qualitatively in all biotopes (SS, KS, LL and YL) and formed 68.4 % and 68.2% components respectively.

Seventeen species of Anisoptera (Dragonflies) were recorded from Toranmal area which includes three families: Gomphidae, Aeshnidae and Libellulidae, with Libellulidae as dominant family with 80 % of total dragonflies richness with nine genera and fourteen species. This family includes most common species such as *Brachythemis contaminate, Bradinopyga geminaata, Crocothemis servilia, etc*. (Annexure V). The second dominant family was Aeshnidae with 13.3 % of total Anisoptera having one genus and two species; *Anax guttatus* and *A. immaculifrons.* The third family Gomphidae was represented with only single genus and species (6.6 %), *Ictinogomphus rapax*, but this species is wide spread and appeared in all the four biotopes.

Seven species of Zygoptera (Damselflies) recorded around Toranmal area also include three families. Of these Coenagrionidae appeared dominant family with 71.4% of the total Zygopterans recorded. This family includes four genera and five species. The common species for four biotopes studied were *Agriocnemis pygmea*, *Ceriagrian coromandelianum* and *Ischnura aurora,* while *Ischnura senegalensis* and *Pseudagrion microcephalum* were recorded from LL and YL. Other two families were represented by one genus and one species each. The family Protoneuridae was represented by *Disparoneura quadrimaculata* which was rarely observed in the study area and was recorded from SS and KS biotope while Family Lestidae represented by species *Lestes umbrinus* was very common and was observed at both the streams.

### 1) Sitakhai Stream (SS)

Total density of odonates (Anisoptera - Dragonflies and Zygoptera - damselflies) at this biotope (Table 6.1, Fig 6.1a) showed significant seasonal variations ($F_{3\ 20}$ 19.58) with maximum density recorded in post-monsoon (207.2 ± 14.6/hectare) and minimum in summer (54.8 ± 4.4 /hectare) while it was 104.7 ± 16 /hectare and 119 ± 18 /hectare in winter and monsoon respectively.

Anisoptera dominated Zygoptera in both density as well as species richness. Maximum density of Anisoptera (Table 6.1, 6.2, Fig 6.1a,b) was recorded in post-monsoon (129.3 ± 10.8 /hectare) and minimum in summer (39.7 /hectare), while it was 63.5 ± 6.8 /hectare and 77.3 ± 12.3 /hectare in winter and post-monsoon respectively ($F_{3\ 20}$ 17.7). Maximum density of Zygoptera was recorded in post-monsoon (77.8 ± 8.5 /hectare) and minimum in summer (15.2 ± 1.2 /hectare), while it was 41.2 ± 9.6 /hectare and 41.6 ± 6.1 /hectare in winter and monsoon respectively. ($F_{3\ 20}$ 13.04).

Total species richness showed same trend as density with significant seasonal variations ($F_{3\ 20}$ 25.16). Maximum species richness (Table 6.2, Fig 6.1b) was recorded in post-monsoon (15.3 ± 0.42) and minimum in summer (7 ± 0.0), while it was 10.7 ± 0.9 and 11.7 ± 0.9 in winter and monsoon respectively. The species richness of dragonflies was maximum in post-monsoon (10.7 ± 0.2) and minimum in summer (5 ± 0.0), while it was 7.7 ± 0.6 and 8.7 ± 0.4 in winter and monsoon respectively with significant seasonal variation ($F_{3\ 20}$ 33.3). The damselflies also varied significantly across the seasons ($F_{3\ 20}$ 15.71) with maximum species noted in post-monsoon 4.7 ± 0.2 and minimum in summer 2.0 ± 0, while it was 3 ± 0.3 and 3 ± 0.5 in winter and monsoon respectively.

**2) Kalapani Stream (KS)**

The seasonal variations in the density and species richness of Odonates at KS showed similar trends as those recorded for SS. Total density of odonates at KS showed significant seasonal variations ($F_{3\ 20}$ 23.04) (Table 6.1, Fig 6.2a) with maximum density recorded in post-monsoon ( 178.5 ± 13.3 /hectare) and minimum in summer (8.3 ± 2.9 /hectare). The density of dragonflies were maximum 106.8 ± 10.7 /hectare in post-monsoon and minimum 7.5 ± 2.5 /hectare in summer while that of damselflies was highest (71.7 ± 6.4 /hectare) and lowest in post-monsoon and summer (0.8 ± 0.5 /hectare) respectively. The F value for dragonflies and damselflies were ($F_{3\ 20}$ 22.77) and ($F_{3\ 20}$ 16.53) respectively.

Maximum species richness (15 ± 0.4) of total odonates at KS was recorded in post-monsoon and minimum in summer 4.2 ± 0.9 (Table 6.2, Fig 6.2b). The Dragonfly species richness was also maximum in post-monsoon (10.5 ± 0.2) and minimum in summer (3.3 ± 0.6) with the damselfly richness of 4.3 ± 0.2 and 0.8 ± 0.4 respectively in post-monsoon and summer.

### 3) Lotus Lake (LL)

This biotope also showed significant seasonal variations in total odonate density ($F_{3\ 20}$ 30.11) with maximum density (Table 6.1, Fig 6.3a) recorded in post-monsoon (189.8 ± 14.6 /hectare) and minimum in summer (34.6 ± 2.1 /hectare) while it was 97.8 ± 10.3 /hectare and 106.3 ± 14.6 /hectare in winter and monsoon respectively. The densities of dragonflies and damselflies (Table 6.1, Fig 6.3a) were maximum in post-monsoon (137.3 ± 12.3 /hectare) and (52.5 ± 3.3 /hectare respectively) while minimum in summer ( 26 ± 1.4 /hectare and 8.7 ± 0.8 /hectare respectively) ($F_{3\ 20}$ 24.6; $F_{3\ 20}$ 34.51 respectively).

At LL, maximum species richness of total odonates (Table 6.2, Fig 6.3b) was recorded in post-monsoon (16.5 ± 0.2) and minimum in summer (7.5 ± 0.0), while it was 10.8 ± 0.5 and 13.1 ± 1.2 in winter and monsoon respectively. When two groups are considered separately, the richness of dragonflies and damselflies (Table 6.2, Fig 6.3b) were maximum in post monsoon (12 ± 0.0 and 4.2 ± 0.2 respectively), while minimum in summer (5.5 ± 0.0 and 2 ± 0.0 respectively).

The species richness of total odonates; Anisoptera and Zygoptera at LL showed significant seasonal variations with F value 32.97, 44.35 and 18.19 respectively.

### 4) Yashwant Lake (YL)

Total odonate density at this biotope (YL) showed significant seasonal variations ($F_{3\ 20}$ 29.4) with maximum density during post-monsoon (220.2 ± 13.4 /hectare) and minimum in summer (39 ± 2.5 /hectare) (Table 6.1, Fig 6.4a). Maximum density of dragonflies at this biotope (YL) was observed in post-monsoon 162.7 ± 12.5 /hectare and minimum 29.3 ± 1.9 /hectare in summer, while it was 84 ± 10.8 /hectare and 91.7 ± 13.3 /hectare in winter and monsoon respectively. The density of damselflies was maximum in post-monsoon 57.5 ± 7.5 /hectare and minimum in summer.

Maximum species richness of total odonates (Table 6.4b, Fig 6.4b) at YL was recorded in post-monsoon (16.8 ± 0.5) and minimum in summer (7.7 ± 0.2), while it was 11.7 ± 0.6 and 13.2 ± 1.2 in winter and monsoon respectively. Total species richness at YL showed significant seasonal variations ($F_{3\ 20}$ 29.6). The richness of dragonflies and damselflies (Table 6.2, Fig 6.4b) were maximum in post-monsoon 12.7 ± 0.2 and 4.1 ± 0.3 while minimum in summer 5.7 ± 0.2 and 2 ± 0.0 respectively.

To summarize the above results, among the four biotope maximum density and species richness of total odonate were recorded at Yashwant Lake (YL) while minimum at Kalapani Stream (KS). Anisoptera followed same trend as total odonate with maximum density and species richness (Dragonflies) recorded at Yashwant Lake (YL) and minimum at Kalapani Stream (KS). However, maximum density and species richness of Zygoptera (Damselflies) were recorded at Sitakhai Stream (SS) while lower densities and species richness were recorded both at lotus Lake (LL) and Yashwant Lake (YL).

**Status of Odonates (Table 6.3)**

Of the total 24 odonate species recorded in the present study, 12 species, 8 Anisopterans and 4 Zygopterans were found to be very common, while 8 species comprising 7 dragonflies and one damselflies were common and 4 species, 2 of each Anisoptera and Zygoptera were rare. None of the species encountered was frequent or very rare.

When correlation of total density and Total species richness with various environmental parameters is considered a positive significant correlation is obtained only with humidity at the level of 0.05 (two tailed). Atmospheric temperature and wind showed negative and rainfall showed positive non-significant correlation with odonate density and species richness (Table 6.4).

**Table: 6.1 Seasonal Variations in density (no./hectare) of Odonates at Sitakhai Stream (SS), Kalapani stream (KS), Lotus Lake (LL) and Yashwant Lake (YL) during December 2006 to November 2008**

| Parameters | Sites | F value | Winter | Summer | Monsoon | Postmonsoon |
|---|---|---|---|---|---|---|
| Total density | **SS** | $F_{3\ 20}$ 19.58 | 104.7 ± 16 | 54.8 ± 4.4 | 119 ± 18.13 | 207.2 ± 14.6 |
| | **KS** | $F_{3\ 20}$ 23.04 | 74.7 ± 16.6 | 8.3 ± 3 | 102 ± 19.9 | 178.5 ± 13.3 |
| | **LL** | $F_{3\ 20}$ 30.11 | 97.8 ± 10.3 | 34.6 ± 2.1 | 106.3 ± 14.6 | 189.8 ± 14.6 |
| | **YL** | $F_{3\ 20}$ 29.40 | 121.3 ± 15.5 | 39 ± 2.5 | 127.3 ± 17.9 | 220.2 ± 13.4 |
| | | | | | | |
| Dragonfly density | **SS** | $F_{3\ 20}$ 17.71 | 63.5 ± 6.8 | 39.7 ± 3.3 | 77.3 ± 12.3 | 129.3 ± 10.8 |
| | **KS** | $F_{3\ 20}$ 22.77 | 48 ± 7.3 | 7.5 ± 2.5 | 67.7 ± 11.3 | 106.8 ± 10.7 |
| | **LL** | $F_{3\ 20}$ 24.60 | 68.8 ± 7.7 | 26 ± 1.4 | 81.8 ± 11.4 | 137.3 ± 12.3 |
| | **YL** | $F_{3\ 20}$ 26.52 | 84 ± 10.8 | 29.3 ± 1.9 | 91.7 ± 13.3 | 162.7 ± 12.5 |
| | | | | | | |
| Damselfly density | **SS** | $F_{3\ 20}$ 13.04 | 41.2 ± 9.6 | 15.2 ± 1.2 | 41.6 ± 6.1 | 77.8 ± 8.5 |
| | **KS** | $F_{3\ 20}$ 16.53 | 26.7 ± 9.4 | 0.83 ± 0.5 | 34.3 ± 8.7 | 71.7 ± 6.4 |
| | **LL** | $F_{3\ 20}$ 34.51 | 29 ± 3.9 | 8.7 ± 0.8 | 24.5 ± 3.4 | 52.5 ± 3.3 |
| | **YL** | $F_{3\ 20}$ 14.68 | 37.3 ± 4.9 | 9.7 ± 1 | 35.7 ± 4.7 | 57.5 ± 7.5 |

**Table: 6.2 Seasonal Variations in species richness (No. of Species) of Odonates at Sitakhai Stream (SS), Kalapani stream (KS), Lotus Lake (LL) and Yashwant Lake (YL) during December 2006 to November 2008**

| Parameters | Sites | F value | Winter | Summer | Monsoon | Postmonsoon |
|---|---|---|---|---|---|---|
| Total species richness | SS | $F_{3\ 20}$ 25.16 | 10.7 ± 0.9 | 7 ± 0.0 | 11.7 ± 0.9 | 15.3 ± 0.4 |
| | KS | $F_{3\ 20}$ 34.16 | 10 ± 0.7 | 4.2 ± 0.9 | 11.7 ± 0.9 | 15 ± 0.4 |
| | LL | $F_{3\ 20}$ 32.97 | 10.8 ± 0.5 | 7.5 ± 0.0 | 13.1 ± 1.2 | 16.5 ± 0.2 |
| | YL | $F_{3\ 20}$ 29.60 | 11.7 ± 0.6 | 7.7 ± 0.2 | 13.2 ± 1.2 | 16.8 ± 0.5 |
| | | | | | | |
| Dragonfly species richness | SS | $F_{3\ 20}$ 33.33 | 7.7 ± 0.6 | 5 ± 0.0 | 8.7 ± 0.4 | 10.7 ± 0.2 |
| | KS | $F_{3\ 20}$ 44.57 | 7 ± 0.4 | 3.3 ± 0.6 | 8.7 ± 0.5 | 10.5 ± 0.2 |
| | LL | $F_{3\ 20}$ 44.35 | 7.2 ± 0.3 | 5.5 ± 0.0 | 9.8 ± 0.7 | 12.3 ± 0.0 |
| | YL | $F_{3\ 20}$ 44.67 | 8 ± 0.4 | 5.7 ± 0.2 | 9.8 ± 0.7 | 12.7 ± 0.2 |
| | | | | | | |
| Damselfly density | SS | $F_{3\ 20}$ 15.71 | 3.0 ± 0.3 | 2.0 ± 0.0 | 3 ± 0.5 | 4.7 ± 0.2 |
| | KS | $F_{3\ 20}$ 17.78 | 3.0 ± 0.3 | 0.8 ± 0.4 | 3 ± 0.4 | 4.3 ± 0.2 |
| | LL | $F_{3\ 20}$ 18.19 | 3.7 ± 0.2 | 2.0 ± 0.0 | 3.3 ± 0.4 | 4.2 ± 0.2 |
| | YL | $F_{3\ 20}$ 10.85 | 3.7 ± 0.2 | 2.0 ± 0.0 | 3.3 ± 0.4 | 4.1 ± 0.3 |

**Table:6.3: Status of Odonates at Yashwant Lake**

| Status | Total Odonates | Anisoptera | Zygoptera |
|---|---|---|---|
| VC | 12 | 8 | 4 |
| C | 8 | 7 | 1 |
| R | 4 | 2 | 2 |

VC – very common, C common, R-Rare

**Table 6.4: Pearson Correlations: Odonate density and species richness with Abiotic parameter in Toranmal region during December 2006 to November 2008**

**Pearson Correlations of Odonates**

| | | TDEN | AT | HUMI | RF | TSPR | WIND |
|---|---|---|---|---|---|---|---|
| | TDEN | 1.000 | | | | | |
| | AT | -.344 | 1.000 | | | | |
| | HUMI | .580* | .193 | 1.000 | | | |
| | RF | .356 | .279 | .909** | 1.000 | | |
| | TSPR | .953** | -.372 | .656* | .423 | 1.000 | |
| | WIND | -.430 | .729** | .321 | .518 | -.392 | 1.000 |

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

**Fig.: 6.1a Seasonal Variations in density (/hectare) of Total Odonates, with dragonfly and damselfly densities at Sitakhai Stream (SS) during December 2006 to November 2008**

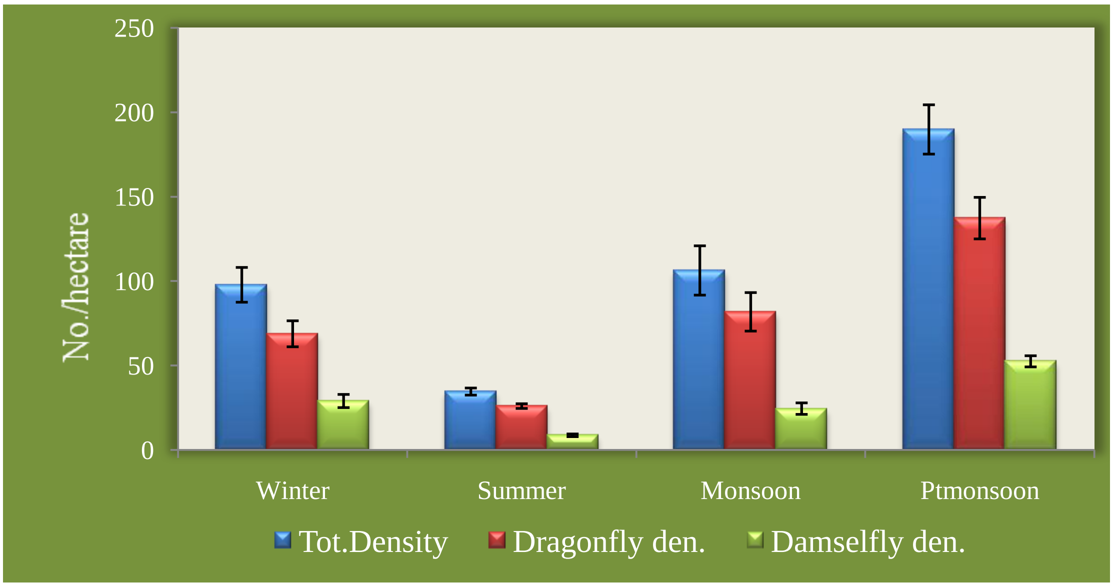



**Fig.: 6.1b Seasonal Variations in species richness (No. of species) of total Odonates, with dragonfly and damselfly species richness at Sitakhai Stream (SS) during December 2006 to November 2008**

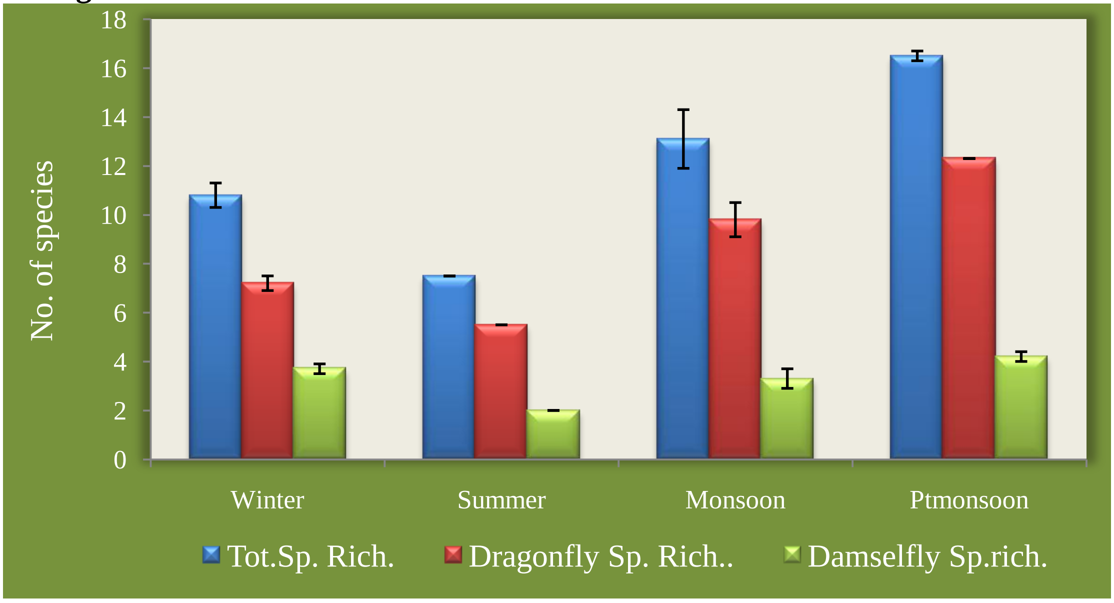


**Fig.: 6.2a Seasonal Variations in density (/hectare) of total Odonates, with dragonfly and damselfly densities at Kalapani Stream (KS) during December 2006 to November 2008**

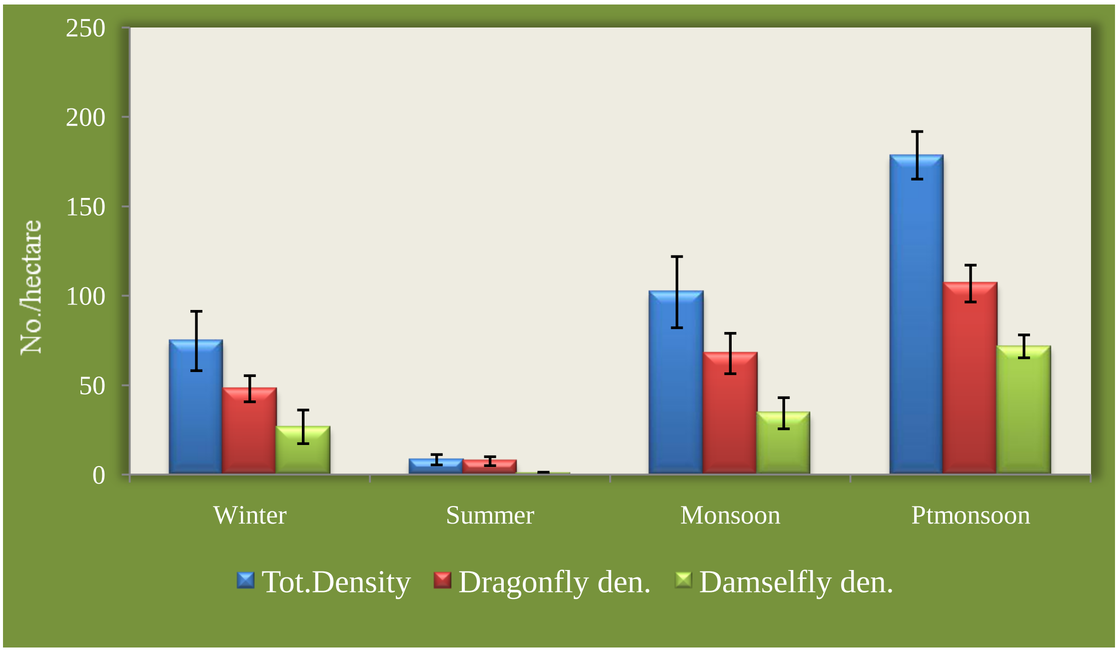



**Fig.: 6.2b Seasonal Variations in species richness of total Odonates, with dragonfly and damselfly species richness at Kalapani Stream (KS) during December 2006 to November 2008**

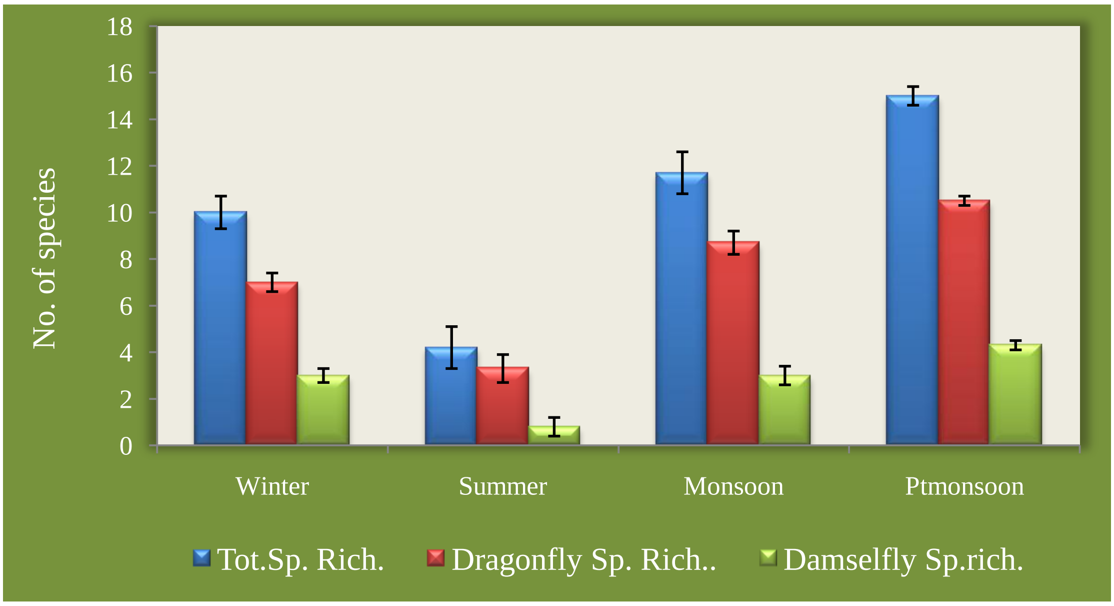


**Fig.: 6.3a Seasonal Variations in density (/hectare) of total Odonates, with dragonfly and damselfly densities at Lotus Lake (LL) during December 2006 to November 2008**

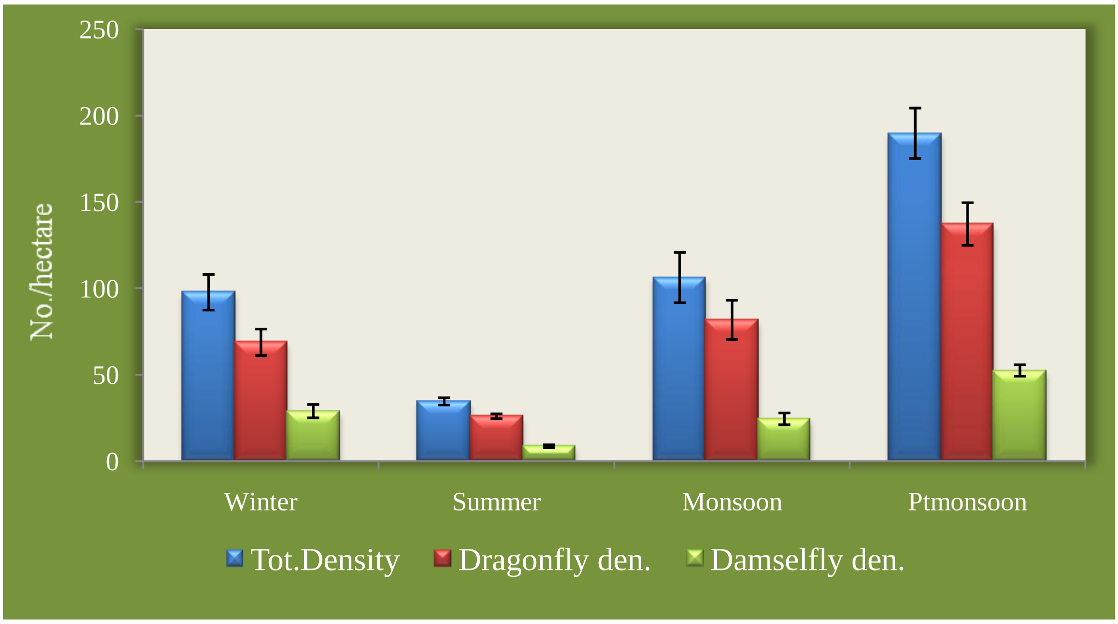



**Fig.: 6.3b Seasonal Variations in species richness of total Odonates, with dragonfly and damselfly species richness at Lotus Lake (LL) during December 2006 to November 2008**

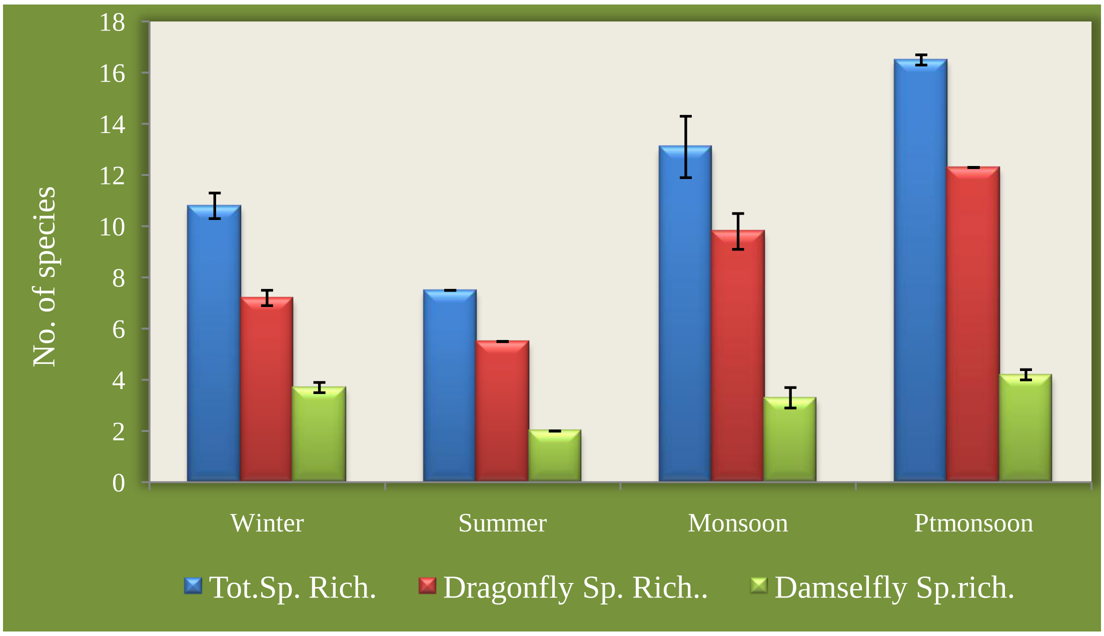


**Fig.: 6.4a Seasonal Variations in density (/hectare) of total Odonates, with dragonfly and damselfly densities at Yashwant Lake (YL) during December 2006 to November 2008**

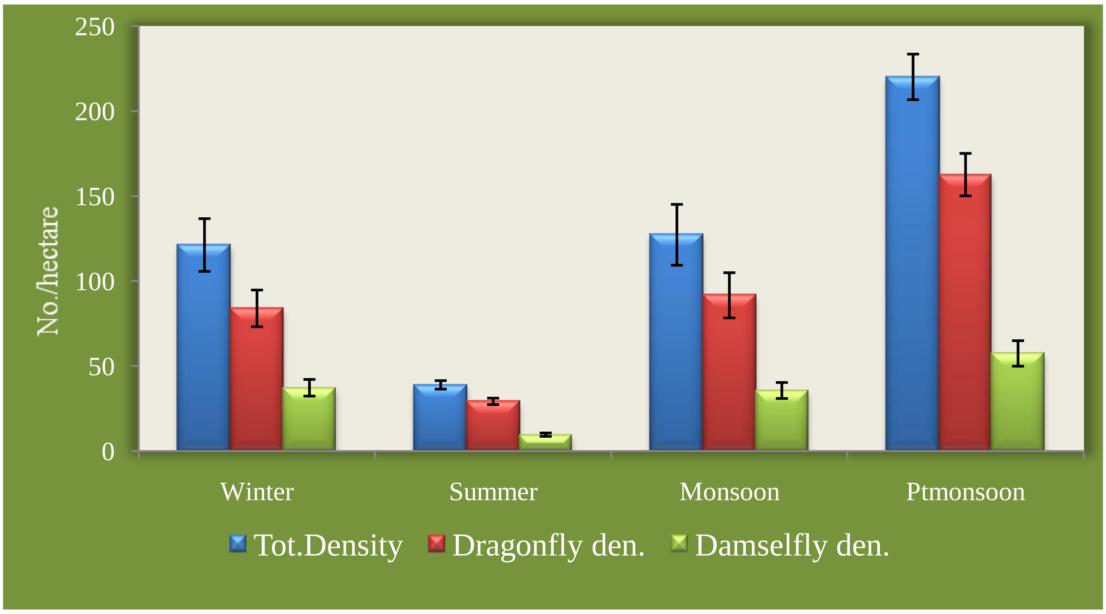
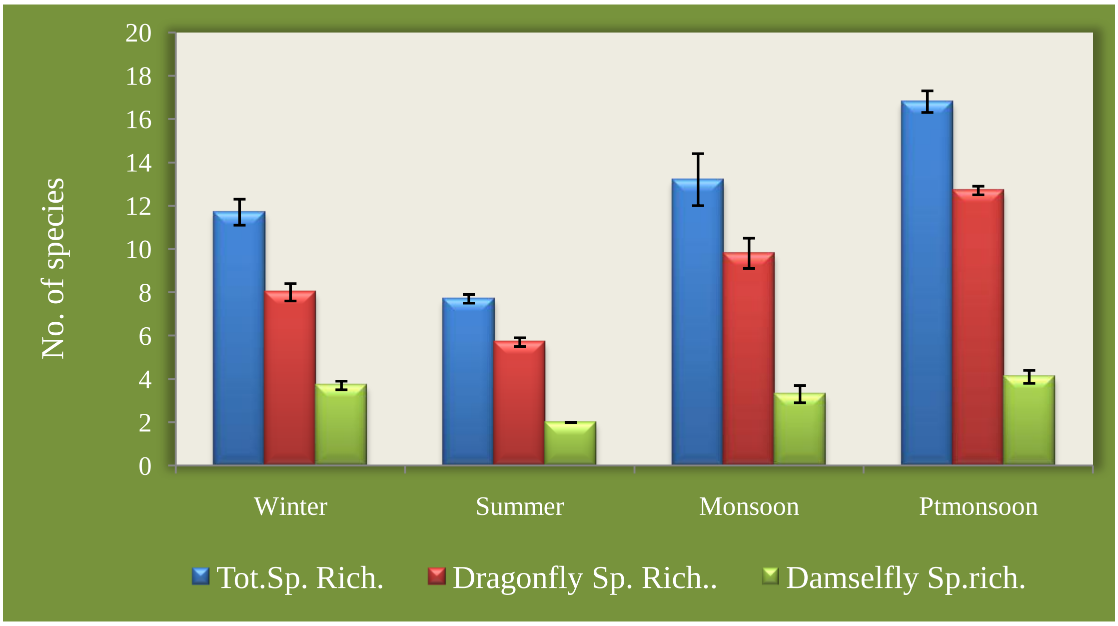



**Fig.: 6.4b Seasonal Variations in species richness of total Odonates, with dragonfly and damselfly species richness at Yashwant Lake (YL) during December 2006 to November 2008**



## DISCUSION

The diversity of species in a habitat is considered as an emergent property of any ecological system (Begon *et al*., 1995). It is relevant in ecology to understand the distribution pattern of the organisms and the pressures that determines them (Apodaca and Chapman, 2004). The habitat is an important element to predict the occurrence of certain species. Among various habitats ponds or streams are the environments where community of odonates can be detected.

Seasonality is a common phenomenon in insect populations which was noted in the present study of odonates at Toranmal area with significant seasonal variations in all the biotopes (transects). Odonates abundance and species richness increased from the onset of monsoon till early winter when weather conditions were warm and moderate and declined from late winter up to the end of summer when the climate started becoming hostile. Variation in rainfall patterns has been reported to be the most important factor affecting the seasonality of tropical insects (Hill *et al*., 2003a

In present study humidity was positively correlated with odonate density and species richness, while rainfall was nonsignificantly correlated. As discussed in earlier chapter, for odonate density and species richness also, the probable explanation lies in the energy in the ecosystem as explained by Srivastava and Lawton (1998). At Toranmal the main driving component of primary productivity is mainly governed by the southwest monsoon which adds humidity in the atmosphere. The monsoon being the major factor in density and distribution of plants leads to increase is abundance of herbivorous insects, the prey for odonates. Thus, influence of water (rainfall) in the form of humidity on density and diversity in environment is likely to be an indirect effect operating via effects on food availability.

According to the hypothesis proposed by Currie *et al*., (2004), about species richness the patterns of richness are typically strongly correlated with climatic variables related to productivity or energy balance. The hypothesis is consistent with most of the predictions of the energy richness hypothesis, and the most cited explanation of richness climate correlation (Wright, 1983; Currie, 1991). Thus, the energy availability in monsoon and post-monsoon at Toranmal may be attributed to increase in odonate density and species richness in the same season.

Temperature acts directly on survival and development of insects and indirectly through food, humidity, rainfall, wind, *etc*. In the present study of Odonates the temperature was positively but non-significantly correlated with total density and species richness of odonates. Hence, the moderate temperature of Toranmal area may benefit the density and species richness of odonates. The observed moderate temperature and humidity may be preferendum for odonates in this area of Toranmal. Further, the summer is dry and hot (minimum humidity and maximum temperature) with a severe draught like conditions as the dry deciduous forest of the Toranmal area dries of limits the growth of most plants. Summer drought has a predictably adverse effect on insect on which odonates feed. Hence, comparatively higher temperature in summer may lead to decreased abundance and species richness of total odonates. Obviously, the relationships among vegetation and weather (temperature, rainfall, humidity) are complex and further study of their interaction and main effects on adult odonates are needed.

**Odonates diversity and habitat**

Numbers of factors influencing larval odonate diversity and assemblage composition including intra and interspecific competition have been identified (Crowley and Johnson, 1992). These factors are habitat structure and complexity (Schridde and Suhling, 1994) predation (McPeek, 1998), pollution and water chemistry (Worthen, 2002). The relationship of adult odonate assemblage composition to habitat constraints associated with hunting, mating, roosting/sheltering and oviposition behavior is less understood (Corbet, 1999).

In the forested area of Toranmal the variations recorded were similar at all four biotopes. However, among these, maximum density and species richness of total odonates (Table 6.1, 6.2) were recorded at Yashwant Lake transect (YL) and minimum at Kalapani Stream (KS) with variations in the density and species richness of both Anisoptera (dragonflies) and Zygoptera (damselflies). This reflects the heterogeneity of habitats associated with vegetation (Buchwald, 1992; Corbet, 1999). At Toranmal, riparian forest of Kalapani stream and surrounding littoral aquatic vegetation of Yashwant lake exhibit heterogeneity of habitats.

**Community Comparison**

In the current study high density and species richness of odonates were due to the presence of species of family Libellulidae (Anisoptera ) with14 species which have wide spread distribution. High species richness of this family has been attributed to its tolerance to wide range of habitats (Samways, 1989), shorter life cycle and wide geographic spread especially around lentic habitats, which are widely available (Subramanian *et al*., 2008; Rodolfo and Jose, 2009). At Toranmal, the two lentic habitats (YL and LL) probably increase species richness and potentially encourage colonization of widespread generalists species of odonates such as Libellulids. The members of Libellulids were also recorded from lotic habitat (SS and KS) but their density and species richness were lower compared to lentic habitats. Most Anisoptera species are known to breed in lentic waters and such habitats are rare in streams (Brooks, 1999). Further, most dragonflies prefer sunny areas with low woody vegetation (Clark and Samways, 1996) hence at Kalapani Stream (KS) where maximum riparian vegetation (Tall trees) is present species richness and density of dragonflies were low. In addition, it is mountainous, mostly shaded, less perturbed, narrow and non-perennial stream. The closed canopy habitat can be less diverse than those containing mosaic of sun shade and open-closed area (Kinving and Samways, 2000; Smith *et al*., 2007). The Kalapani stream is a minor order streams ($1^{st}$ and $2^{nd}$ order) and characterized by having bottoms with low heterogeneity resulted due to volcanic activity. The speed of water and little roughness of floor as noted Kalapani Stream limit the presence of gravel, pebbles and other substrates that are necessary for establishment of higher population of larvae (*e.g*. Rosi-marshall and Wallace, 2002). Thus, emergence rate of nymphs is lower decreasing the abundance and species richness at this biotope.

Among the two suborders, Density and richness of Anisoptera (dragonfly) were recorded maximum compared to Zygoptera (damselflies) in all the four biotopes. This might be due to their high dispersal ability (Lawler, 2001; Kadoya *et al*., 2004) and their adaptability to wide range of habitats (Suhling *et al*., 2004, 2005). Among four biotopes studied maximum abundance and species richness of Anisoptera were recorded from Yashwant Lake (YL), where preferred open sunny area with less tall trees (Clark and Samways, 1996) are available. Light interception by trees affects conditions for thermoregulation and visibility (Thery, 2001). Illumination can also play an important role in habitat selection (Valentine *et al*., 2007) because insects that fly during day, orient themselves almost entirely based on visual cues (Olberg *et al*., 2005). The shoreline of Yashwant Lake has created an open habitat that attracts more Anisopterans. Further, Odonate species in the 'percher behavioural guild' may also require riparian understory vegetation because the adults guard breeding territories, thermoregulate and watch for prey from plant perches (Corbet, 1999). The shoreline of Yashwant Lake have herbs and shrubs (*Polygonum barbatum, Ipomoea carnea, Typha domingensis, Cyperus exaltatus, Achyranthes aspera etc*.) that can serve as perches which may further favour the Anisoptera in this biotope (YL). The density and richness of Anisoptera were moderate at Lotus Lake and Sitakhai Stream where the mixed litoral vegetation support the Anisoptera as well as Zygoptera.

Seven species of Zygoptera (Damselflies) were recorded in the study area in which family Coenagrionidae appeared dominant with five species (Annexure-V). In general like Libellulidae (Anisoptera) family Coenagrionidae is also most common family (Arulprakash and Gunathilagaraj, 2010; Norma Rashid *et al*., 2001) on the basis of its abundance and richness due to shorter life cycle, widespread distribution and tolerant to wide range of habitats (Gentry *et al*. 1975). However, it has been reported that their dispersal movements from natural ponds and lakes are limited both in terms of numbers of individuals and distance traveled (Conrad *et al*., 1999; Purse *et al*., 2003). The present study reveals that the damselflies may have limited dispersal as even though the LL, YL and SS biotopes have corridor for migration, the species *Ischnura senegalensis* was not recorded from SS while, *Disparonura quadrimaculata* and *Lestes umbrinus* were not recorded from LL and YL. The above said species therefore have a strong association between larval habitat and local abundance of breeding adults.

Rich damselfly assemblages are associated with relatively long, narrow and diverse littoral and lacustrine zones (Butler and Philip, 2008). The floating and emergent macrophytes of these habitat provide an important biotic structure for several key activities like foraging, roosting/ sheltering, predator avoidance, oviposition, *etc*. Damselflies have especially been considered as valuable biological indicators of freshwater ecosystem integrity because they are obligate endophytic ovipositors (Westfall and May, 1996). They lay eggs in a wide range of floating and emergent macrophytes, often involving structure-specific and species specific plant associations (Corbet, 1999; Gibbons *et al*., 2002).

The SS was most preferred habitat by the damselflies. It may be attributed to its specific vegetation. The lacustrine zone have moderate number of tall trees. The moderate number of trees are also observed at Lotus Lake (LL), few at Yashwant Lake (YL), while maximum at Kalapani Stream (KS). It has been documented that more zygopteran species than Anisopterans occur in dense forests (O' Neill and Paulson, 2001) or along shaded stretches of streams (Brooks and Jakson, 2001). The dominance of zygoptera under shaded conditions may also have a physiological explanation. Given their small size, relative to Anisopteran they qualify as thermal conformers (May, 1976), showing high conductance with body temperature varying with environmental temperature (De Macro and Resende, 2002). In the present study the SS, having moderate number of trees is preferred over KS that is having maximum number of trees. This may be attributed to the stream characteristic. The KS starts drying by winter and is totally dry in summer. The unavailability of water negatively affects the lacustrine understory vegetation which may cause unfavorable conditions for damselflies, (indirectly via lower population of plant dependent prey) and affects their density and richness. The understory vegetation of lacustrine zone of Sitakhai Stream (SS) includes many herbs and shrubs. As the stream is perennial it supports this vegetation throughout the year in turn supporting more zygopteran population. Overall lower density and species richness of damselflies at LL and YL may be correlated to few large trees providing less shade which act as hiding places for larvae and alteration of macrophytes of littoral zone due to anthropogenic activities.

Odonate assemblage composition in South Africa was related to variation in macrophyte cover, water temperature and shade, which in turn are impacted by shoreline alteration (Steytler and Samways, 1995). Similarly, negative effects on odonate diversity in altitudinal ponds of Italy have been attributed to livestock trampling and grazing of riparian and aquatic vegetation (Carchini *et al*., 2005). As Toranmal is a hill station, the shoreline development and recreational activities are common at Yashwant Lake and Lotus Lake. These activities also disturb vertical macrophyte such as *Polygonum barbatum* whose stems provide important emergence sites for final instar larvae and copulation sites for adults. The marginally low density and species richness of damselflies at these two Lakes as compared to both the streams may indicate that the watersheds of these biotopes are still intact and have not yet passed land use conversion thresholds that may impact littoral habitat at the local scale. The diversity of damselflies at Lotus Lake (LL) may be affected due to use of resources by local tribals. It is observed that the tribal children collect the lotus flowers (*Nymphaea pubescens*) regularly from the Lake and hence disturb the vegetations. On the basis of behavioural observations it has been reported that some damselfly species prefer ovipositing on the underside of floating plants (Gibbons *et al*., 2002), while others prefer emergent plant stems or roots (Corbet, 1999). Given our limited knowledge of specific aquatic plant-damselfly relationships for most regional and local faunas, it is important to recognize the potential role of both structural and compositional elements of aquatic macrophytes in the life history of lacustrine and littoral odonates.

Presence of total 24 odonates with 17 Anisoptera and 7 Zygoptera indicates that various biotopes of Toranmal support good odonate diversity. Of the four seasons, post-monsoon is the preferred season for odonates while summer is least preferred season at Toranmal area.

In this study, adult odonata (dragonfly and damselfly) were investigated. However, conflicting opinions have been expressed regarding the use of larval versus adult odonata as indicators. Samways (1994) reports the advantages of using adult odonata in investigating their relationships to environmental characteristic. However, one needs to bear in mind that biological indicators also have a number of limitations (Grillas, 1996). Even changes in a particularly well known species or species assemblages cannot tell the mechanism by which habitat disturbance has occurred. Hence, they cannot be used to determine whether the disturbance is single or interactive, direct or indirect or whether it is natural or anthropogenic. In other words, Stewart and Samways, (1998) put it as- “it is difficult to use indicator species to pinpoint a specific type of effect or disturbance”. More importantly, indicator species should be chosen or used by criteria that are clearly defined (Landres *et al*., 1988). Firmly established baseline information; showing spatial and temporal abundance, richness and distribution based on long term observations is critical. Though, the current limited basic information restricts the use of odonata as biological indicator in Toranmal area at this stage the results of present study provide insight into some critical elements of habitat integrity for conservation of lacustrine odonates associated with littoral zone habitat. From conservation point of view these elements should be considered, as these elements are adversely affected due to shoreline development to encourage ecotourism. The present study suggest that the recent wave of public interest in odonates (damselflies and dragonflies) as colourful and conspicuous members of insect fauna (Dunkle, 2000; Subramanian, 2005) may provide a timely opportunity for sensitizing watershed councils, government officials and the general public to the importance of maintaining and restoring diverse macrophyte bed in lacustrine and littoral zone and quality of water for the conservation of aquatic biodiversity.