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ORIGINAL ARTICLE

Insect Diversity and its co-relation with Ecological Parameters in and around Wadhwana-- a Wetland in Central Gujarat

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ABSTRACT
A preliminary study of the insect diversity in and around Wadhwana Irrigation Reservoir (WIR), a wetland of national importance in the semi arid zone of central Gujarat, was carried out fortnightly for a period of one year from January to December 2008. To compare the variability in insect density and diversity during different seasons, the period of study was divided into three seasons, Summer (March to June), Monsoon (July to October) and Winter (November to February). A total of 115 insect species belonging to 11 orders were recorded. Lepidoptera was the most prominent order with 38 species followed by Odonata and Hymenoptera with 32 and 15 species respectively. Lepidoptera and Odonata exhibited highest diversity in monsoon while Hymenoptera exhibited highest density in summer. The highest species richness and density of total insects corresponded to monsoon while the diversity index and Evenness were highest during summer. All the four measures were low during winter. A positive correlation was observed for insect density and species richness with relative humidity.
Key words: *Wadhwana Irrigation Reservoir, Lepidoptera, Odonata, Hymenoptera, Species richness, Density.*

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INTRODUCTION

In any landscape, wetlands are essential ecological features. They support a large variety of sub mergent and emergent vegetation which in turn support various fauna in and around the wetlands. The area surrounding the wetlands harbors a large number of terrestrial species which are significant contributors to the food chain. It ranks the second most productive ecosystem next to the tropical rain forests [1] with a significant and sensitive ecological role in terms of the bio-geo-chemical cycle [2]. It also serves as a good sink for the disposal of various biodegradations and is therefore aptly designated as the "Kidneys of the landscapes" [3].

The major groups of organisms found in and around the wetland ecosystem are Planktons, Molluscs, Insects, Fishes and Aves which form an intimate part of the food web. At many instances, lower strata and waterfowl diversity in wetland ecosystem are documented but the terrestrial fauna surrounding the wetlands remains unexplored. Although insects dominate terrestrial ecosystem in terms of species density and diversity[4,5,6], they are often overlooked in biological inventories as preference is given to more charismatic and familiar groups like birds and mammals[7]. However in the recent past there has been a change in this trend. Many reports have shown that insects are ideal subjects for monitoring landscapes for biological conservation [8,9,10] as they are good bio-indicators [11,12]. Seasonality is a common phenomenon exhibited by insect populations [13,14]. Abiotic factors like variations in temperature, humidity and solar radiations have substantial influence on the activity of different insects [15]. Their population dynamics are generally influenced by environmental factors like temperature, humidity, rainfall, photoperiod, variations in the availability of food resources and plants for larval and adult stages [16,17,18]. There is an increasing interest in conserving and managing insects as their diversity and density are diminishing very rapidly with increasing pollution, reduced water quality, habitat degradation, urbanization and decreased plant diversity [18,19]. The concept of creating

Biodiversity Registers has taken momentum and hence the documentation of each and every existing organism has to be taken care of .

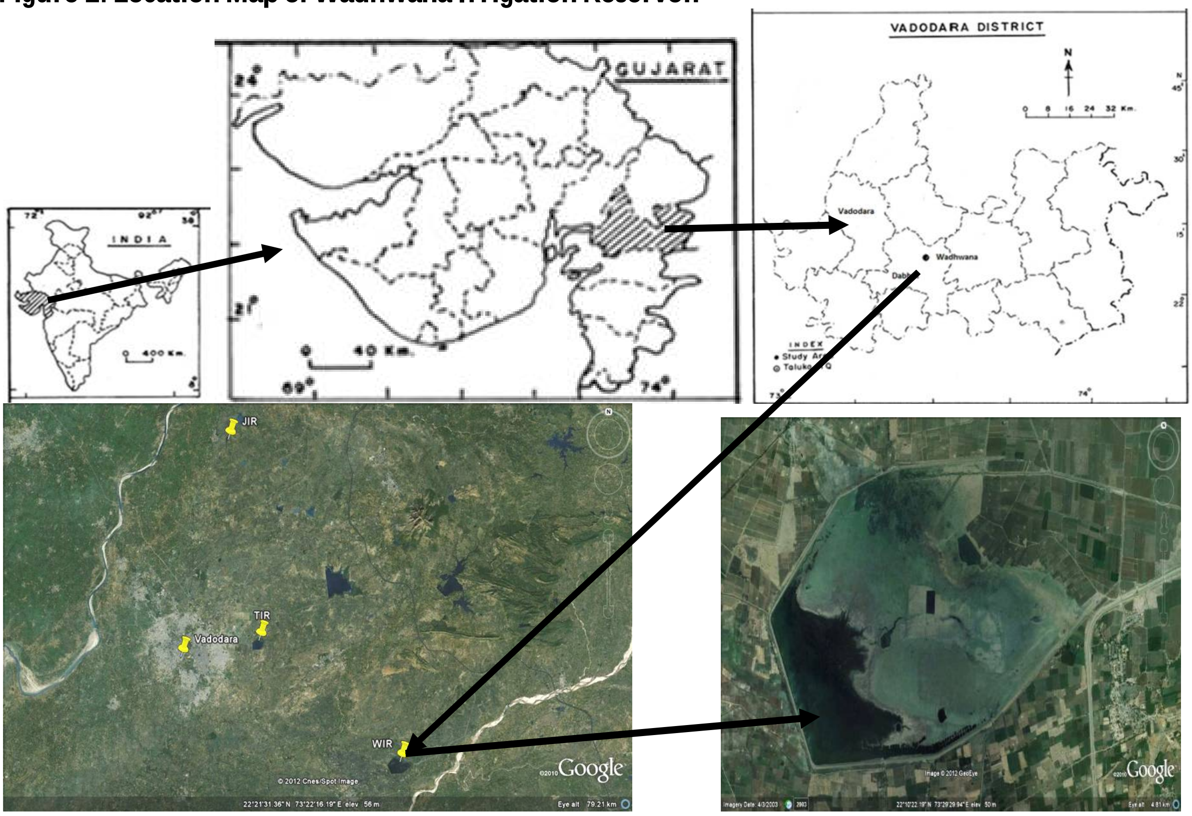
In India there are about Ninety-four wetlands identified for conservation and management under the National Programme for Conservation and Management of Wetlands. In Gujarat, eight wetlands are listed under this and Wadhwana Irrigation Reservoir (WIR) is one among them. The State Forest department has also taken an initiative to develop this reservoir into a major wetland for migratory birds[20]. However, the area remains to be explored for biodiversity aspects. Earlier studies of aquatic fauna and its co-relation with the physico-chemical parameters have shown a good density and diversity of the planktons and water birds at this reservoir[21] Recent report on physico-chemical aspects of the water showed that the lake was slightly eutrophic with high concentrations of alkalinity during summer [20]. No report of terrestrial fauna, especially insect diversity, is available so far from this region. Hence, the present study was initiated to get an overall insight into the terrestrial insect diversity during different seasons of the year.

MATERIALS AND METHODS

Study Area

Gujarat falls in the arid and semi arid zone of India, where the water requirements of the habitants is fulfilled by the irrigation reservoirs which had been constructed in the past. One such reservoir is the Wadhwana Irrigation Reservoir in Dabhoi taluka of Vadodara District.

Figure 1: Location Map of Wadhwana Irrigation Reservoir



Wadhwana Irrigation Reservoir (WIR)

Wadhwana Irrigation Reservoir (22^{o} 10′ N, 73^{o} 30′ 'E) is situated about 50 kms south- east of Vadodara city in Central Gujarat (Fig.1). This reservoir was constructed about 100 years ago in the year 1909-1910 by His Highness Shrimant Maharaja Sir Sayajirao Gaekwad III of erstwhile State of Baroda at the Wadhwana village, with a view to make the farmer's independent of rain water. The dam is mainly an earthen dam of 8.2 kilometers having a periphery of 11.2 kms. In recent years, the reservoir has been regularly receiving water from the famous Sardar Sarovar Dam on Narmada River. The reservoir is surrounded by agricultural matrix and scrubland that supports a variety of terrestrial birds and large group of insects. On the basis of waterfowls assemblage supported by this wetland, it was declared as a

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wetland of National Importance in 2005[21]. The climate of the region is characterized by a hot summer and general dryness.

Methodology

The present study was conducted for a period of 12 months from January 2008 to December 2008. The area was visited fortnightly in the morning hours between 8: 00 a.m to 11: 00 a.m. The insects encountered on the earthen dam were recorded using transect method known as "Pollard Walk" [22,23], transect length being 1.2 kms and width 0.01 km. The insects present on both sides of the earthen dam were recorded and majority of them were identified in the field itself while some species that could not be identified on spot collected, identified and released to the same spot within a short time. Some of them were identified after taking photographs. Standard books were followed for identifying the fauna upto species level [24]. Insect density [25], Species Richness and diversity indices like Shannon Wiener diversity index ($H^{/}$) and Evenness (E) [26,27]were calculated for the whole class Insecta as well as for some predominant orders of the class.

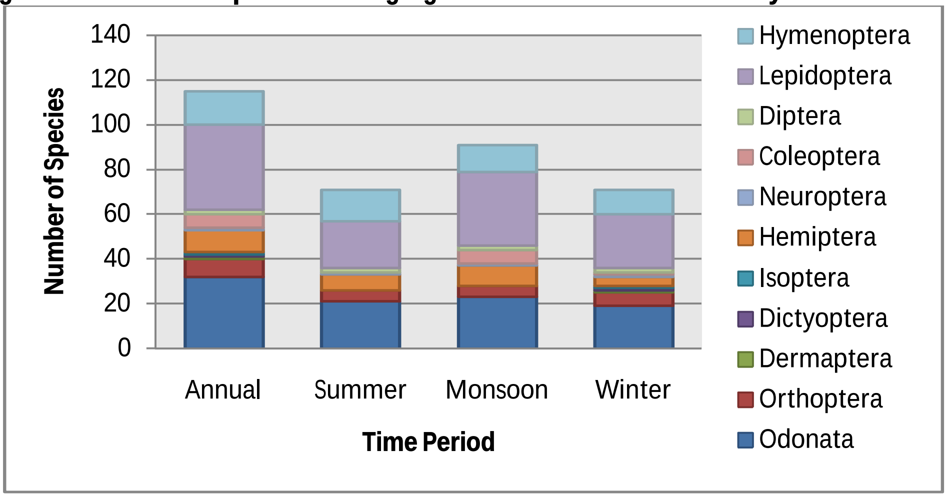
Data Analysis

The Density was expressed as no. of insects/10m^2. The species richness is the total number of species encountered during particular visit while Shannon Wiener Species Diversity Index and Evenness were expressed as an index defining the community structure . They were expressed as Mean ± S.E. The seasonal differences in the assessed parameters were statistically analyzed by ANOVA using Prism 3 software while the influence of the ecological parameters on the above mentioned parameters was evaluated by Pearson correlation using software SPSS 7.5.

RESULTS

Insect Diversity: A total of 10339 insects of 115 species belonging to 11 orders of insects were recorded from WIR during the study period. Among them, Lepidoptera was the most prominent order with 38 species followed by Odonata and Hymenoptera with 32 and 15 species respectively. Hemiptera, Orthoptera and Coleoptera were represented by 10, 8 and 6 species, while Diptera had 2 species. Dermaptera, Dicytoptera, Isoptera and Neuroptera were the least represented orders with a single species in each (Figure 2). Lepidoptera exhibited the highest diversity in monsoon with 33 species followed by Odonata with 23 species. Their number declined to 24 and 19 in winter while 21 species of each order were recorded in summer. Other order with moderate species abundance was Hymenoptera having 14 species in summer declining to 12 and 11 species in monsoon and winter respectively (Figure 2).

Figure2: Number of species belonging to different orders annually and seasonally



Seasonal variations in community structure:

Significant results were obtained when the data were subjected to ANOVA for the seasonal variations in total species richness ($F_{(2.22)}$ 27.03 ; $P \leq 0.0001$), density ($F_{(2.22)}$ 11.06 ; $P \leq 0.0001$), Shanon Weiner diversity index (H ') ($F_{(2.22)}$ 10.83; $P \leq 0.0001$) and Evenness (E) ($F_{(2.22)}$ 5.85; $P \leq 0.05$) during different seasons of the year (Figure 3). The highest species richness and density, corresponded to monsoon while diversity and evenness was highest during summer (Figure3). All were recorded lowest during the winter. Species richness was high for Lepidoptera, Hymenoptera and Hemiptera (Figure 4a) while for other orders like Dermaptera, Dicytoptera, Isoptera, Neuroptera, Coleoptera and Diptera was comparatively low and the differences among the orders was highly significant ($F_{(10,242)}$ 90.19, $P < 0.0001$). Similarly when insect density was considered, it was the highest for Hymenoptera followed by Hemiptera, Odonata, Lepidoptera and Diptera. Rest of the orders had very low density. Highly significant differences ($F_{(10,242)}$ 57.11 and $P < 0.0001$) were noted among different orders (Figure 4b). For the orders with single species H'was immaterial. Of the remaining orders, H' was the highest for Lepidoptera followed by Odonata, Hymenoptera, Hemiptera, Orthoptera, Coleoptera and Diptera ($F_{(10,242)}$ 91.67, $P < 0.0001$). (Figure 4c). Evenness (E) was maximum for Lepidoptera followed by Odonata and Hymenoptera. The Evenness of Orthoptera, Hemiptera, Coleoptera and Diptera was comparatively low and the differences among different orders was highly significant ($F_{(10,242)}$ 37.06 and $P < 0.0001$; Figure 4d).

Figure 3: Seasonal Variations in Community pattern

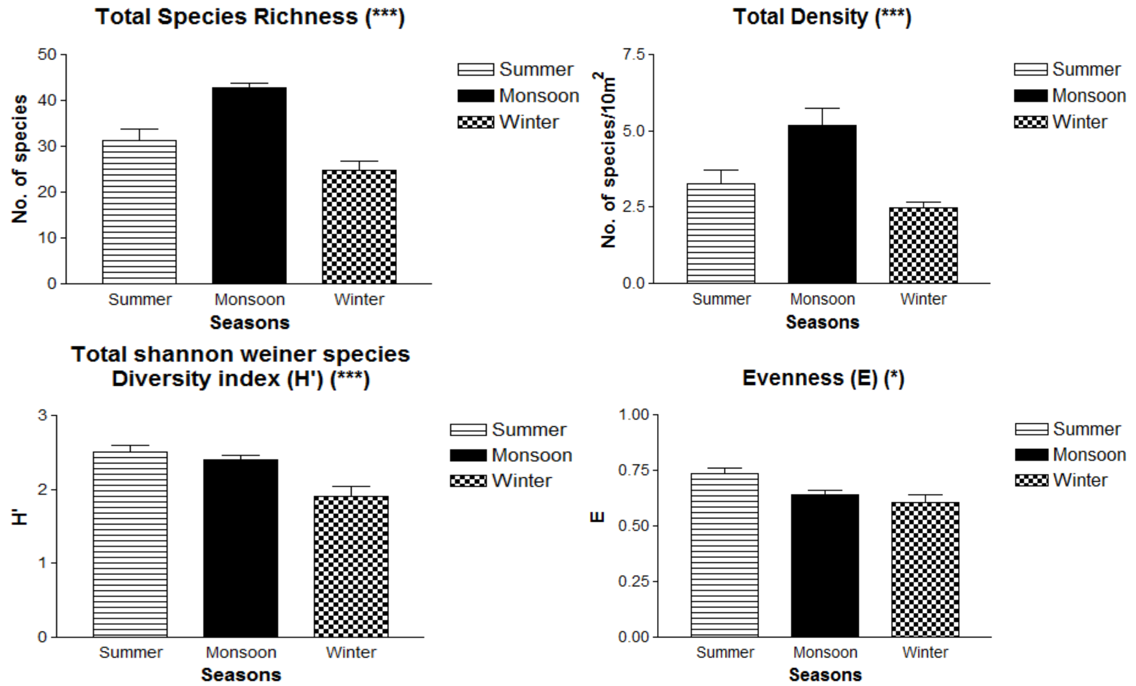


Figure 4: Annual Variations in the community pattern of different insect orders.

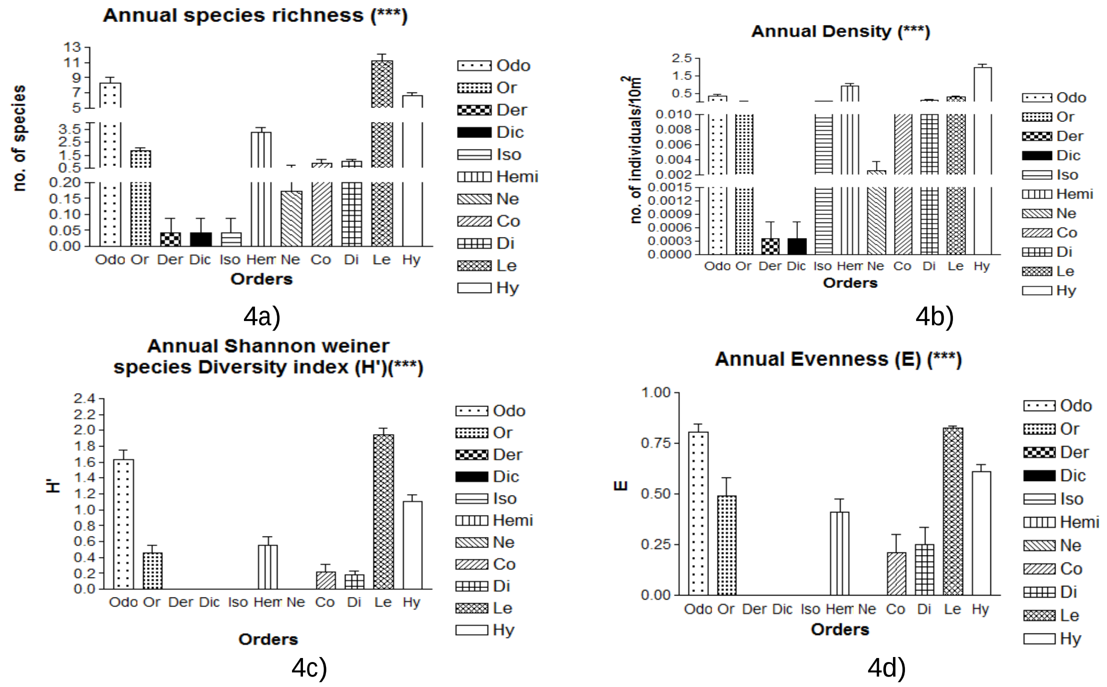


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Table 1: Annual and Seasonal Pearson Correlation of density, Species Richness, H' and Evenness with different environmental parameters

	TID	**TISR**	**TIH'**	**TIE**	OD	OSR	OH'	OE	LD	LSR	LH'	LE	HD	HSR	HH'	HE
	ANNUAL															
MiT	**.288**	**.438***	**.637****	**.470***	.238	.324	.374	.3077	.341	.225	.085	-.372	.427*	-.015	.417*	.073
MaT	**-.261**	**-.009**	**.528****	**.623****	-.212	-.076	.041	.26	.116	-.096	-.187	-.44*	.582**	-.43*	.67**	.285
RH	**.770****	**.686****	**.083**	**-.339**	.713**	.666**	.543**	.078	.431*	.557**	.486**	.181	-.320	.628**	-.53**	-.45*
RF	**.246**	**.257**	**.160**	**-.010**	-.267	.219	.192	.023	.244	.240	.204	.005	-.106	.184	-.093	-.088
	SUMMER															
MiT	**.322**	**-.016**	**.069**	**.096**	.524	.276	.308	-.374	.028	-.372	-.080	.498	-.152	-.549	-.366	.168
MaT	**-.340**	**-.079**	**.535**	**.612**	-.445	-.475	-.349	-.517	.271	.271	.160	.039	.003	.370	.145	-.226
RH	**.594**	**.037**	**-.448**	**-.478**	.901**	.688	.602	.133	-.229	-.497	-.209	.433	-.156	-.866*	-.480	.371
RF	**-**	**-**	**-**	**-**	-	-	-	-	-	-	-	-	-	-	-	-
	MONSOON															
MiT	**.510**	**-.180**	**-.425**	**-.352**	-.637	-.193	.094	.396	-.87**	-.664	-.598	-.265	.361	.191	.141	.122
MaT	**-.637**	**-.027**	**.395**	**.368**	.575	-.060	.191	-.083	.772*	.3 93	.374	.199	-.476	-.105	-.190	-.252
RH	**.637**	**.018**	**-.401**	**-.372**	-.570	.056	-.176	.093	- .774*	-.412	-.398	-.221	.476	.097	.178	.242
RF	**-.095**	**-.482**	**.092**	**.191**	-.110	-.063	.135	.159	-.002	-.223	-.173	-.062	-.099	-.137	.311	.339
	WINTER															
MiT	**-.335**	**.420**	**-.262**	**-.620**	.598	.790*	.839*	.512	.842*	.332	.508	.606	-.108	-.014	-.504	- .814*
MaT	**-.504**	**.709**	**.015**	**-.444**	.647	.790*	.750	.368	.807*	.560	.659	.566	-.360	.218	-.312	-.85*
RH	**.133**	**-.096**	**-.589**	**-.689**	.520	.672	.779*	.579	.505	-.189	-.011	.273	.216	-.511	-.747	-.46
RF	**-**	**-**	**-**	**-**	-	-	-	-	-	-	-	-	-	-	-	-

Mi T- Minimum Temperature, Ma T- Maximum Temperature, RH – Relative Humidity, RF- Rainfall
TID –Total Insect Density, TISR – Total Insect Species Richness, TIH' – Total Insect H', TIE – Total Insect Evenness
OD – Odonata Density, OSR – Odonata Species Richness, OH' – Odonata H', OE – Odonata Evenness
LD – Lepidoptera Density, LSR- Lepidoptera Species Richness, LH' – Lepidoptera H', LE – Lepidoptera Evenness
HD – Hymenoptera Density, HSR – Hymenoptera Species Richness, HH' – Hymenoptera H', HE – Hymenoptera Evenness.

Correlation with Ecological parameters Correlation with ecological parameters like temperature, relative humidity and rainfall are exhibited in Table 1. The first four columns represent the data related to total insect species while the remaining columns represent that for three major orders.

Total Insects

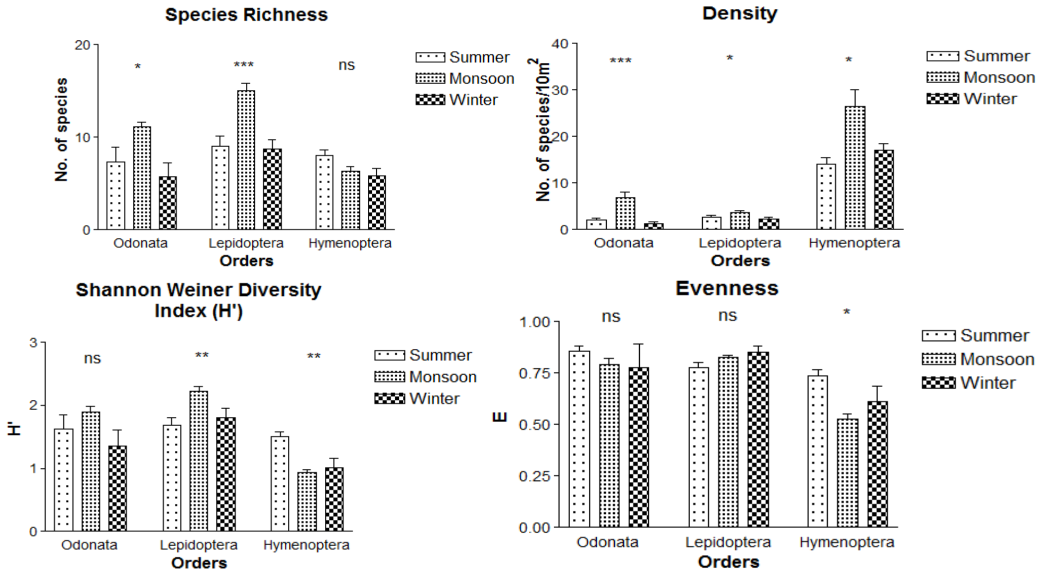
When the annual data was correlated with ecological parameters, a significant positive correlation was obtained for total insect species richness and density with relative humidity and for total insect species richness with minimum temperature. Similarly positive correlation was obtained for total insect H' and evenness with temperature. However, the seasonal data of total insects failed to show any correlation with any of the ecological parameters (Table 1).

Three major orders

A positive correlation was observed for Hymenopteran density and H' with temperature while the maximum annual temperature affected the Hymenopteran species richness and Lepidopteran evenness negatively. Relative humidity was positively correlated with the density, species richness and H' of Odonata and Lepidoptera and with the species richness and evenness of Hymenoptera. Hymenopteran evenness was negatively correlated with the relative humidity.. During summer, only density of Odonata showed a positive correlation with relative humidity while it was negative for species richness of Hymenoptera. In Monsoon, density of Lepidoptera was negatively correlated with minimum temperature and relative humidity while positively correlated with maximum temperature. However, during winter a positive correlation was observed for the species richness and H' of Odonata and the density of Lepidoptera with temperature and also between H' of Odonata and relative humidity. On the other hand, a negative correlation was observed between the Hymenopteran evenness and temperature.

When these three orders were seasonally analyzed it was clear that the density and species richness were the highest during monsoon followed by summer and winter except for Hymenoptera which showed predominance in summer. H' and Evenness were maximum during monsoon for Odonata and Lepidoptera while it was so for Hymenoptera during summer. Diversity and Evenness decreased further in summer and monsoon for the former two orders while the latter showed a decline in monsoon followed by an increase in winter (Fig.5).

Figure 5: Seasonal differences in Species Richness, Density, Shannon weiner species Diversity index (H') and Evenness (E) in Odonata, Lepidoptera and Hymenoptera



As rainfall is relatively low in this region, it did not exhibit any direct impact on the insect population and diversity at WIR but contributed indirectly by increasing the rejuvenation of feeding plants of the larval and adult insects.

DISCUSSION

Daily variations in temperature, solar radiation, wind and humidity are reported to influence the activity of insects [15] mainly due to their surface area to mass ratio [28]. A period of high air temperature and sunlight are potentially lethal while low temperatures result in inefficient breeding activities [29].

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Occurrence and abundance of insects are influenced by many of these environmental factors. Light acts as a token stimulus to indicate whether the season is favorable or not. In some cases stimulus is provided by a gradient in light intensity. The diurnal rhythm in intensity of light and quality of light is associated with the rhythm in temperature, moisture, food etc., [30] and any change in light intensity may lead them to a place where there is surplus food. In other cases stimulus can be provided by length of the day, which acts as a clock indicating the seasonal changes in temperature, moisture, food etc. In India, many reports show that monsoon governs the distribution of insects especially butterfly diversity to a large extent and they flourish post monsoon [17, 31, 32, 33, 34].

Considering the community pattern in WIR, the Species Richness and Density of total insects were highest during monsoon when more number of insects in large populations were found. In the Indian climatic condition monsoon represents the wet period of the year which is considered to be favorable for most of the insect species [16] and is reflected by their high density and species richness. A similar report [35] have shown a high association of insects with sugarcane during monsoon. The Diversity index H' and Evenness were more during summer when less number of insects were present and hence uniformly distributed.

In the present study, a number of insects belonging to different orders were recorded from WIR. Though the present study was concentrated mainly during day time, it becomes clear that the site supports sufficient diversity of insects throughout the year. Had it been extended to night time, the data would have been enormous owing to the occurrence of large number of insects at night time. Despite this limitation, the study provides a baseline data to compare with different seasons and time periods in future years to come.

Butterflies being the easily assessable and observable group, maximum number of species observed from WIR were of Lepidoptera. They have important ecosystem roles as they form an important part of food web and act as good pollinators and bio indicators[11,12], in addition to enhancing the aesthetic value of our environment[36]. They are considered as ideal subjects for ecological evaluation in landscapes [37] as they are very sensitive to environmental changes [38]. They are also known to colonize in a wide variety of environments and are considered the best group of insects for examining the patterns and the distribution of terrestrial biotic diversity[39] Hence, inventory and monitoring of butterflies has proven useful in the evaluation of terrestrial landscapes for biological conservation [9]. Among different species of butterflies recorded around WIR, family Pieridae and Nymphalidae dominated the site. They increased in number from July, flourished during the months of August, September, and October and declined considerably during November and December. Their increase can be directly correlated with an increase in vegetation and larval host plants in the area after the rainfall as reported by others [29,40]**.** They were abundant when the flower density was high as they could maximize the net rate of energy intake per unit time [41]. Hence a direct correlation was observed for the abundance of these butterflies with floral density and intensity of light and larval host plants [14,40,42,43,44]. The decline during November and December could be owing to a decrease in food availability, photoperiod and temperature with the approaching winter [29].

Odonates are known to colonize in a wide range of aquatic habitats as it is the site for their egg laying and are considered as a priority for inventory [45]. They are also upper level predators in invertebrate food chain and good indicators of ecosystem health [46,47,48.49]. In the present study they were found in considerable numbers in WIR compared to other orders. As Odonates link the terrestrial and aquatic food web and also function as opportunistic predators and prey items from the wetland fauna[50], they serve as indicators of species richness and health of fresh water wetlands [51]. Among them, Anisopterans (Dragon flies) were more common compared to Zygopterans (Damsel flies) and were abundant during monsoon season. Their high density and species richness in WIR is a good indication of health of this fresh water habitat.

Hymenoptera also had reasonable representation comprising ants, wasps and bees. Their abundance was directly correlated with abundance of the plant species *Proscobis* which supported a large number of ants mainly *Camponotus* species accompanied by Treehoppers (Hemiptera). Honey bees (*Apis dorsata)* were observed during summer while bumble bees (*Bombus pysthrus*) and Capenter bees (*Xylocopa aestuens*) were observed all throughout the year. However, the seasonal analysis showed a predominance of Hymenoptera during summer and winter. Summer is considered to be favourable season for most of these hymenopterans as the dry habitat encourages the nest building [52,53]. Although winter is considered to be unfavorable season due to low temperature for many insects, higher density of hymenopterans was observed at WIR in this season. Hymenopteran density depends upon the plant composition and the vegetation cover [53] which is still dense during winter with compact or tightened

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soil. When compared to other predominant groups like Lepidoptera and Odonata they thrive well in dry seasons.

Though the diversity index (H') and Evenness of Odonata and Lepidoptera were high, their density was low because more species were encountered but in lower numbers.. Hymenoptera also had good H' and Evenness. The seasonal evenness varied for different orders. Odonates were uniformly distributed only in summer while in winter and monsoon the Lepidopterans were more evenly distributed.

All other orders of insects did not show much abundance in this area except for a few of the following and they together contributed only a less percentage (around 26%). Among Orthoptera, Short horned Grasshoppers were the main representative. Coleoptera was represented by Ground Beetles while Diptera by Housefly (*Musca domestica*) and Blue bottle flies (Calliphora vomitaria). However, a noticeable thing was a single species of white flies (Hemiptera) dominated throughout the study period, except in monsoon. This was not included in the present data as it was a mono dominant species affecting all the diversity indices.

From the present study it can be concluded that the region surrounding WIR supports a good density and diversity of insect population. This is associated with the ideal ecological conditions and availability of food plant species around WIR. A similar approach for the assessment of aquatic insects and an overall evaluation for a period of five years is under progress. This will definitely give an insight into the present status of WIR and can be utilized for the conservation strategies and management of this wetland region. This gains significance as the state forest department has taken measures to develop this reservoir into a major wetland for migratory birds.

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