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Butterfly diversity around an irrigation reservoir in the semi-arid zone of central Gujarat, India: A consideration for conservation management

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Abstract
An appraisal of butterfly species diversity was made around a Nationally Important Wetland - Wadhwana Irrigation Reservoir (WIR) in the semi-arid zone of Central Gujarat as a model geographical area. A checklist of the butterflies observed around the wetland was prepared and monitored for a span of three years (2008-2011). The species recorded were given abundance rating according to their encounter frequency. A total of 42 species were observed around the reservoir dominated by Nymphalidae (38%) over Pieridae (31%), Lycaenidae (21%) and Papilionidae (10%). Three species were rated as abundant while majority of the species were rated either rare or uncommon. The density of the butterflies varied with the seasons and family significantly. It is apparent that the reservoir can sustain diverse butterfly species which includes species requiring conservation efforts. Considering the landscape, steps to enhance the conservation should be adopted to maintain butterfly diversity and sustain the ecosystem services derived from them.

Keywords: Butterfly; Wadhwana irrigation reservoir; Vadodara; conservation management

1. Introduction
Biological diversity is important for the sustenance of ecosystems. Monitoring of species diversity of a region enables estimation of the prospective functional roles of the species [1]. For the ecological study of insects in a landscape, butterflies are ideal subjects [2, 3]. They are mainly studied with reference to biogeography, their role in plant-insect interactions and as environmental bio-indicators. Their indirect role in assessing environmental variations due to their sensitivity to climatic conditions, levels of lightness and proportion of vegetation cover [4, 5] is important. They have always been a subject of interest and are probably next only to the birds in their universal popularity. This can be attributed partially to their great varieties and beauty of their colored patterns, and partially because of their dramatic transformations through their life cycle [6]. They are also regarded as the flagship species and hence one of the most studied and well-known insect group. They are also considered as one of the most appropriate taxonomic group for environmental evaluation as well, and are essential part of any natural ecosystem as they render dual roles of pollinators as well as energy transferors [7].
Several studies have been conducted on butterflies found in forest, urban areas as well as grasslands in central Gujarat [8-12]. However, butterfly fauna present around aquatic ecosystem are meager. The results of this study will augment crucial information on the ecological importance of butterflies in the region and also help in their conservation.
In the semi-arid zone of Central Gujarat in western peninsular India, where rainfall is comparatively low and erratic, large numbers of reservoirs were built over the century to store rain water to ease human needs. Subsequently on the completion of Sardar Sarovar dam in the beginning of the present century, many of these reservoirs are filled with water from Narmada River. Hence even when rains are inadequate in the area the reservoirs get sufficient amount of water. This has facilitated the colonization of various living forms and development of rich aquatic ecosystems. One such reservoir built by the then Ruler of the Baroda State, Shrimant Maharaja Sir Sayajirao Gaekwad III, is Wadhwana Irrigation Reservoir (WIR) constructed in 1909-1910. Most of the studies conducted at this reservoir pertain basically to the water quality, aquatic organisms or the larger organism like birds which are easily observable in water [13-17]. However, the surrounding landscape supporting a great variety of terrestrial organisms is quite often neglected.

Terrestrial birds and insects including butterfly from important components of this comparatively drier ecosystem [9]. The present paper deals with butterfly fauna around this reservoir.

2. Materials and Methods

2.1 Sampling sites

Located in the semi-arid zone of Central Gujarat (22° 10′ N, 73° 29′ E) Wadhwana Irrigation Reservoir (WIR) is a famous wetland for its capacity to support the winged visitors. It is situated about 50 km south-east of Vadodara city at the Wadhwana village of Dabhoi Taluka of Vadodara District (Figure 1). The reservoir spreads in an area of 5.75 square kilometres with an earthen dam (8.2 kilometres) and a periphery of 11.2 kilometres. The reservoir was earlier filled with the water from the Jojwa dam on Orsang River but after the construction of the famous Sardar Sarovar Dam on Narmada River the water from this dam is also diverted to the WIR making it an almost perennial water body. As it irrigates about 8815 hectare land of 25 villages in the surrounding vicinity, a green belt produced remain till end of March and the beginning of April. On the other side of the earthen dam scrub and agricultural lands present support various terrestrial organisms including butterflies. Nonetheless, on the basis of the waterfowl assemblages supported by this wetland, it was declared as a wetland of National Importance by MoEF, Government of India in 2005.

The climate in the area is characteristic hot - dry with the precipitation during south-west monsoon i.e. June to September. The average temperature in the area varies between 20 °C to 35 °C with the hot summers when the temperature is above 40 °C and moderate winters when it drops around 10 °C. The rainfall in the area ranges between 500 mm to 1000 mm, received during the Indian south-west monsoon. The relative humidity ranges from about 40% in the summer to 80-85% in monsoon.

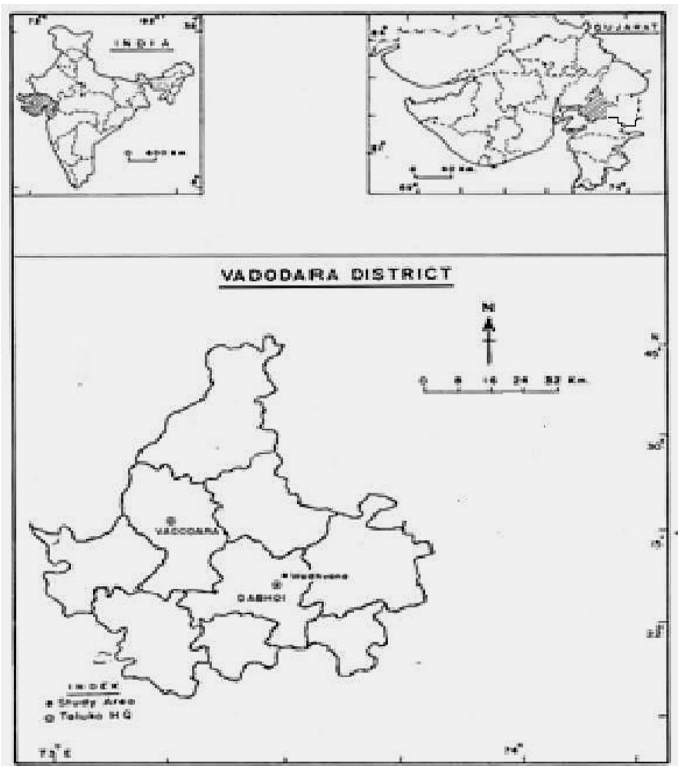

Fig 1: Map showing geographical location of the Wadhwana irrigation reservoir in Vadodara district, Gujarat, India

2.2 Methodology

The study was conducted for a period of three years from March 2008 to February 2011. The reservoir was visited twice in a month over the span of three years and transects were observed from morning (7:00 am) to afternoon (1:00 pm) during good weather periods (no heavy rain and no strong wind). A total of 65 visits were made. The butterflies were recorded directly in the field by "Pollard Walk" method as used by Moore [18], Pollard *et al.* [19] and Walpole and Sheldon [20]. The individuals were counted for one minute in a radius of 10 meters at intervals of 200 meters on each side of the earthen dam while walking on a fixed transect 3.2 kilometers. The butterflies that could be identified in the field were not captured while those that could not be identified were captured by sweep net method and identified using suitable keys [6, 21-23] and released back in the same habitat with least disturbance. The individuals observed were classified into four families as per the classification given by Kehimkar [23].

2.3 Data analysis

The numbers of species present in each of the four families is considered as the species richness. The density (D) is calculated at fixed spots by the formula $D = \frac{n}{\pi r^2}$ where n is number of individuals and r is radius = 10 meters where individuals were counted in a 10 meter radius in one minute. The diversity indices were analyzed separately. Species diversity was calculated using Shannon diversity index ($H' = -\sum Pi \ln Pi$ *where* P*i* = proportion of total sample belonging to i^{th} species, ln is natural log) and Shannon evenness were calculated using the formula; $J = H'/H_{max}$, where, H′ = information content of sample (bits/individual) [24]. The seasonal variations in butterfly abundance were subjected to a three-way factorial analysis of variance (ANOVA) considering species richness, density, diversity and evenness as variables using Prism Version 3.0 (Graph Pad software Inc. CA, USA). For the statistical analysis the data for 3 months is pooled according to the seasons as Summer: March, April, May; Monsoon: June, July, August; Post-monsoon: September, October, November and Winter: December, January, February.

The percentage occurrence for each species as well as family was calculated as the total number of species belonging to a particular family encountered. The species observed were given abundance rating according to the frequency of their occurrence [25]. The species encountered for more than 45 times was rated as abundant, 25-45 times – Common, 15-24 times – Frequent, 5-14 times – Uncommon and Less than 5 times – Rare.

3. Results

Altogether 42 species of butterflies belonging to four families were observed during morning hours around Wadhwana Irrigation Reservoir over the period of three years (Appendix A). Family Nymphalidae was represented by highest 16 species (38%) followed by family Pieridae with 13 species (31%), Lycaenidae with 9 species (21%) and Papilionidae with only 4 species (10%) (Figure 2). The percentage occurrence of the four families indicates that Nymphalidae is the most common family around WIR representing 47.1% of the total butterflies species followed by Pieridae (26.45%) and Lycaenidae (21.65%). Papilionidae was the family with the lowest percentage occurrence of 4.79%.

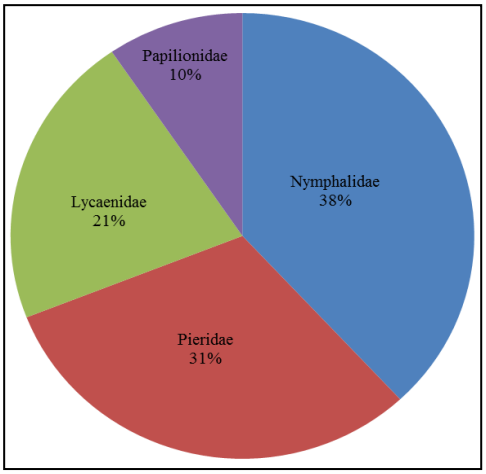

Fig 2: Butterfly families represented according to the number of species observed at Wadhwana Irrigation Reservoir (WIR) during the study period

As per the frequency of occurrence of the butterfly species (Figure 3), 3 species (6.67 %) namely Plain Tiger (*Danaus chrysippus* Linnaeus 1758), Lesser Grass blue (*Zizina otis* Fabricius 1787) and Common Grass yellow (*Eurema hecabe* Linnaeus 1758) were found to be abundant with *D. chrysippus* being the most widespread species. Six species (13.33%) rated as Common include Gram blue (*Euchrysops cnejus* F abricius 1798), Stripped tiger (*Danaus genutia* Cramer 1779), Blue pansy (*Junonia orithya* Linnaeus 1758), Peacock pansy (*Junonia almana* Linnaeus1758), Danaid eggfly (*Hypolimnas misippus* Linnaeus 1764) and Tawny coster (*Acraea violae* Fabricius 1758). Same number of species i.e. six (13.33%) were rated as Frequent which includes Lime butterfly (*Papilio demoleus* Linnaeus 1758), Common Jezbel (*Delias eucharis* Drury 1773), Common emigrant (*Catopsilia Pomona* Fabricius 1775), Mottled emigrant (*Catopsilia pyranthe* Linnaeus1758), Tiny grass blue (*Zizula hylax* Fabricius 1775) and Common crow (*Euploea core* Cramer 1780). Eleven species (24.44%) were Uncommon while maximum 19 species (42.22%) were rare (Figure 3).

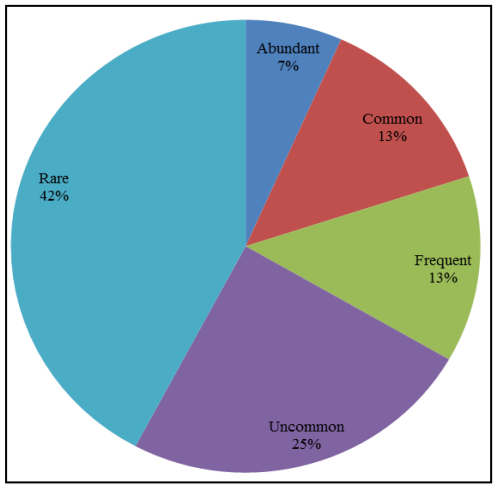

Fig 3: Abundance rating (%) of Butterflies observed at Wadhwana Irrigation Reservoir (WIR)

The seasonal differences in species richness, density and Shannon Weiner diversity index (H′) were significant while the differences in the evenness (E) were non-significant (Table 1).

Table 1: Seasonal variations in the mean Species Richness, Density, Shannon Weiner Diversity Index (H') and Evenness (E) of the butterflies observed at Wadhwana Irrigation Reservoir (WIR)

Indices	Summer	Monsoon	Post monsoon	Winter	Seasonal variation
Mean Species Richness	6.08 ± 1.14	7.91 ± 1.37	13.7 ± 1.03	10.25 ± 0.88	(***) $F_{(3,41)}$ 8.33
Density	0.002± 0.01	0.004 ± 0.0011	0.005 ±0.01	0.011 ± 0.002	(***) $F_{(3,41)}$ 6.57
H’	1.27 ± 0.19	1.54 ± 0.19	2.02 ± 0.08	1.98 ± 0.1	(**) $F_{(3,41)}$ 5.93
E	0.8 ± 0.05	0.8 ± 0.03	0.79 ± 0.02	0.86 ± 0.02	(ns) $F_{(3,41)}$0.93

Appendix A: List of butterflies along with their abundance rating and IWPA status (WPA 1972) observed at Wadhwana Irrigation Reservoir (WIR) during the study period

Sr. No	Common Name (Isaac Kehimkar 2008)	Scientific Name (Isaac Kehimkar 2008)	Abundance Rating at WIR	IWPA status (WPA 1972)
	Order: Lepidoptera			
	Family: Papilionidae			
1	Common Rose	*Atrophaneura aristolochiae (F)*	Uncommon	
2	Lime Butterfly	*Papilio demoleus (L)*	Frequent	
3	Tailed Jay	*Graphium agammemnon (L)*	Rare	
4	Common Mormon	*Papilio polytes (L)*	Rare	
	Family: Pieridae			
5	Psyche	*Leptosia nina (F)*	Uncommon	
6	Common Jezbel	*Delias eucharis (D)*	Frequent	
7	Pioneer	*Belenois aurota (F)*	Uncommon	
8	White Orange tip	*Ixias marianne (C)*	Uncommon	
9	Yellow Orange tip	*Ixias pyrene (L)*	Uncommon	
10	Common Emigrant	*Catopsilia pomona (F)*	Frequent	
11	Mottled Emigrant	*Catopsilia pyranthe (L)*	Frequent	
12	Common Grass Yellow	*Eurema hecaba (L)*	Abundant	
13	Spotless Grass yellow	*Eurema latea (B)*	Uncommon	
14	Common Wanderer	*Pareronia valeria (C)*	Uncommon	
15	Common Gull	*Cepora nerissa (F)*	Rare	Schedule-II
16	Small salmon Arab	*Colotis amata (F)*	Rare	
17	Plain sulfur	*Dercas lycorias*	Rare	

	Family: Lycaenidae			
18	Forget-me-not	*Catochrysops strabo (F)*	Rare	
19	Lesser Grass blue	*Zizina otis(F)*	Abundant	
20				
21	Gram blue	*Euchrysops cnejus(F)*	Common	
22	Common Pierrot	*Castalius rosimon(F)*	Rare	Schedule-I
23	Indian cupid	*Everes lacturnus (G)*	Uncommon	
24	Tiny Grass blue	*Zizula hylax(F)*	Frequent	
25	Grass jewel	*Freyeria trochylus (F)*	Rare	
26	Pea blue	*Lampides boeticus (L)*	Rare	
	Family: Nymphalidae			
27	Plain Tiger	*Danaus chrysippus (L)*	Abundant	
28	Stripped Tiger	*Danaus genutia (C)*	Common	
29	Common Crow	*Euploea core (C)*	Frequent	Schedule-IV
30	Dark Blue tiger	*Tirumala septentrionis(C)*	Rare	
31	Common Evening Brown	*Melanitis leda (L)*	Rare	
32	Joker	*Byblia ilithyia (D)*	Rare	
33	Blue pansy	*Junonia orithya (L)*	Common	
34	Peacock pansy	*Junonia almana(L)*	Common	
35	Lemon pansy	*Junonia lemonias(L)*	Rare	
36	Grey Pansy	*Junonia atilites (L)*	Uncommon	
37	Chocolate pansy	*Junonia iphita (C)*	Rare	
38	Painted Lady	*Vanessa cardui (L)*	Rare	
39	Danaid eggfly	*Hypolimnas missipus(L)*	Common	Schedule I & II
40	Great eggfly	*Hypolimnas bolina(L)*	Rare	
41	Baronet	*Euthalia nais (F)*	Uncommon	
42	Tawny coster	*Acraea violae (F)*	Common	

4. Discussion

The value of butterflies as indicators of environmental conditions is a basis for studying butterfly diversity on a spatio-temporal scale [26]. Observations on the butterfly diversity provide information about the variations in the species richness and the abundance shaped by the vegetation along the landscape [27-30] and the species interactions. Forty two species of butterflies observed around WIR shows the potential of the habitat around the wetlands of semi-arid zone to support this component of the terrestrial biodiversity. WIR is surrounded by scrub on all the sides followed by agricultural matrix and hence both niches could be inhabited frequented by these species of butterflies [23]. Till date 193 species of butterflies have been reported by various authors from Gujarat state [22]. Of these, 87 species have been reported from Central Gujarat mainly Kheda and Panchmahal districts north of Vadodara. Compared to the above report the species recorded at WIR in Vadodara district is small which can be justified as the area surveyed is small compared to the larger districts of the above studies. It is an established fact that larger area supports more species [31, 32]. However, in the neighbouring areas, like the forest of Jambughoda Wildlife Sanctuary (JWLS), 66 species [12] were reported while 43 species were reported from the urban areas of Vadodara city. Both are located at a distance of about 30 kilometers from WIR. 50% species were observed to be common between (JWLS) and WIR which clearly suggest the differences caused due to variations in the habitat; one being a protected forest and another an irrigation reservoir. On the other hand, 55.36% species were common between WIR and Vadodara city again indicating the partial differences of the conditions at a reservoir and urban area with comparatively little vegetation.

WIR provided a variety of microhabitats for the butterflies to explore and hence good species richness was recorded. The results indicate that considerable variations in the diversity of butterflies exist with respect to the season and the families. Significant differences in density, diversity and richness was observed during post-monsoon and winter (Table 1). The results indicate that the best period for butterfly in this semi-arid zone is post-monsoon when rainfall ceases and the land around reservoir flourishes with dense green vegetation. As the winter sets in some species probably become less active decreasing the species richness. Also the humidity and temperature are moderate which justifies higher diversity and density observed during this period.

The family Nymphalidae of brightly coloured butterflies, popularly known as the brush footed butterflies, is the most ecologically diverse group [33]. It is the most dominant family in terms of distribution and numbers of species represented by 16 species around this reservoir. This family was also found to be dominant in different types of environmental conditions i.e. in the Aralam Wildlife Sanctuary, Kerala [7], in the DAE campus, Kalpakkam, Tamil Nadu [34] and in the Arignar Anna Zoological Park, Chennai, Tamil Nadu [35]. Nymphalids are generally found in varied habitats ranging from the scrub land to secondary vegetation, forest edges and gardens [36]. The dominance in the members of Nymphalids has been attributed to their polyphagous habits enabling them to survive in varied habitats [7]. The other reason for the dominance of this family is the recent modification in the phylogenetic classification that brought several other families considered as separate families earlier merged into a single family. These families include Danaids, the Milkweed butterflies, Satyrids, the Browns and Heliconians. Danaids were the most common, conspicuous and well known group among all the butterfly groups represented at WIR. Their presence around WIR may be associated with the presence of milkweeds like *Heliotropium sp.* and *Calotropis sp.* in the scrubland providing the required pyrollizine alkaloids, the precursor of Danaid pheromone [37] that makes these species unpalatable to vertebrate predators [38].

Highest percentage occurrence of Nymphalids was due to the presence of common species like *J. orithya*, *J. almana*, *A. violae*, *D. chrysippus*, *E. core* and *H. missipus*. The latter is listed in the Schedule I and II of the Wildlife Protection Act 1972 [40] and was a common species while *E. core*, a frequently observed species of this family, is categorized

under Schedule IV [25]. *D. chrysippus* was the most common butterfly of the study found on the wings all throughout the year as is also reported by Kehimkar [23]. The overall dominance of *D. chrysippus* is believed to be due to the chemical defense against predators [37]. *D. chrysippus* has greater survival probabilities since it is an unpalatable prey [42]. Further, large aggregation of this species is known to occur in summer and winter when they are known to migrate.

Pieridae (the Whites and the Yellows), the next family with most abundance is represented by 13 species which prefer open spaces, gardens, glades, seashores and watercourses [23]. Scrubland followed by lush green agricultural matrix around WIR favoured the Pierids which frequently explored the earthern dam. *E. hecabe* was the most abundant species with *D. eucharis*, *C. pomona* and *C. pyranthe* as common species recorded from family Pieridae. *E. hecabe* is known to proliferate in all types of habitats due to its polyphagous nature [39, 40]. This species known to be abundant in both disturbed as well as undisturbed habitats [40] is one of the commonest butterflies in the world [41] observed throughout the year. High population of *E. hecabe* occurs during major part of the year except spring and summer [39]. In comparison to other species having single or two broods in a year and disappearing for hibernation in winter *E. hecabe* produces brood all throughout the year [43]. *C. pomona* and *E. hecabe* found to be abundant along streams [44] were common around WIR which is now a perennial water body with inlet and outlet canals probably creating a lotic ecosystem.

Members of the Family Lycaenidae, prefers flying in sunshine, close to the ground. They occur in a wide range of habitats from major biomes from forests to scrublands, grasslands, wetlands, semi-arid regions and desert, as well as waste ground in cities [45] hence their presence at WIR is ubiquitous. The most common Lycaenid around WIR was *Z. otis*. The other species observed frequently were the *E. cnejus* and the *Z. hylax*. Remaining species of Lycaenidae formed the minor component in the habitat with Common Pierrot (*Castalius rosimon* Fabricius 1775), a rare species categorized under Schedule I of the Wildlife Protection Act 1972; and *E. cnejus* and *Lampides boeticus* (Linnaeus 1767) under the Schedule II [25]. According to Kunte [46] species of Grass blues are found in a variety of habitats. Among all the lycaenids the Lesser Grass blue, preferring open habitats with vegetation that resembles the scrub grasses, was one of the abundant species in scrubs around WIR. Many of these Lycaenids are known to appear in late monsoon and reach their peak density by winter [39] as is also observed in the present study.

Family Papilionidae includes swallowtails that are mostly tropical butterflies preferring open areas (fields, vacant plots, meadows, open forest, sides of the streams), forests and sometimes swamps [23]. Mathews and Anto [47] have reported that areas with tall trees providing cool shade mixed with sunlit patches are favourable habitats for several papilionids. As the habitat around the reservoir is surrounded by a few scattered trees on its periphery, members of this family were not frequently observed at WIR. Thus the results of the present study in western India clearly depict that family Nymphalidae and Pieridae exhibited maximum species diversity compared to other families.

5. Conclusion

The present study revealed a total of 42 butterfly species belonging to 4 families and 31 genera during the entire study period. The data recorded during sunrise proves that scrubland and the agricultural matrix present around these reservoirs support several species of butterflies. This research work is a special effort to document and suggest effective ways to increase butterfly diversity of a manmade irrigation reservoir in the rural vicinities of Vadodara district. The present scenario indicates that post-monsoon and winter were found to be most favourable for butterfly activities in the semi-arid zone of Central Gujarat, India where the weather is mild and tolerant for the butterflies. Henceforth, this study was a special effort for knowledge amalgamation of a Nationally important wetland and its habitat restoration to raise butterfly diversity. Additional investigations on this community and their interaction with preferred flora can give us a better understanding regarding their conservation and management around such irrigation reservoirs.

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