



Research Article

Diversity of Odonata (Insecta) in protected areas of Gujarat, India

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ABSTRACT: The species of Odonata are highly predacious on invertebrates, especially the immature stages, which are generalist predators. The Odonate diversity of protected areas of Gujarat state, India was studied from August, 2014 to July, 2017. Fifteen protected areas of Gujarat were surveyed. A total of 60 species (41 species of Anisoptera and 19 species of Zygoptera) belonging to 40 genera under 8 families and two suborders were recorded. Maximum species (54) were recorded from Purna Wildlife Sanctuary of Dang district followed by Vansda National Park (44 species) of Navsari district. Amongst the protected wetlands, maximum species (47) were recorded from Nalsarovar Bird Sanctuary.

KEY WORDS: Damselfly, Dragonfly, Inventory, Nalsarovar Bird Sanctuary, Protected area, Purna Wildlife Sanctuary

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INTRODUCTION

Odonates as predators, both during their adult and larval stages play a crucial role in ecosystem functioning and serve to keep other insects including those harmful to humans (like mosquitos, blood-sucking flies, etc.) under control. Though not quantified precisely, the number of crop pests like aphids, plant hoppers etc., which are predated upon by odonates must be enormous. Thus odonates play a valuable role in the biological control of agricultural pests (Nair, 2011). Most of the Odonate inventories are either state specific or area specific. Inventory of some protected areas of India have been separately studied recently (Sethy and Siddiqi, 2007; Sahoo *et al.*, 2013; Das *et al.*, 2012, Das *et al.*, 2013; Debata *et al.*, 2013; Varghese *et al.*, 2014; Boruah *et al.*, 2015, Tiple and Koparde, 2015; Kannagi *et al.*, 2016; Singh *et al.*, 2017). In Gujarat state, information about the odonate fauna of only six protected areas is available to some extent; the available information refers to Blackbuck National Park, Velavadar and Thol Bird Sanctuary (Mokaria, 2015); Vansda National Park and Purna Wildlife Sanctuary (Rathod *et al.* 2016); Khijadiya Bird Sanctuary (Mokaria *et al.*, 2017); Nalsarovar Bird Sanctuary (Rathod and Parasharya, 2018, Mokaria and Jethva, 2018). As the Gujarat state is having

diverse biogeographic zones (Singh, 1998), the diversity of odonata is also likely to be high, particularly in the protected areas. With this assumption, the present investigations were made to generate a primary database of the odonates of the protected areas and add to our knowledge about the diversity and distribution of the odonates of Gujarat state in Western India and as a documentation of beneficial fauna in the area.

STUDY AREA

Surveyed Protected Areas

Gujarat state (Western India), has twenty five protected areas, four of which are National Parks and twenty one of which Wildlife Sanctuaries. In the present study, fifteen protected areas including three National Parks and twelve Wildlife Sanctuaries were surveyed during August, 2014 to July, 2017. Of the 19,178.89 sq. km of forest area, 17,972.41 sq. km has been declared as protected area and of which 7506.22 sq. km is occupied by Kachchh Desert Wildlife Sanctuary alone. Salient features of the protected areas under this study given in Table 1 are adopted from Singh (1998) and Forest/habitat classification from Champion and Seth (1968). Protected areas under study are shown on Map1.

In southern Gujarat, the climate in the Dang district, as well as the eastern parts of Valsad and Navsari districts, is similar to that of the other northern Western Ghats Mountains. Forest area of Dang district and eastern part of Valsad and Navsari districts of South Gujarat has similar climate as other northern Western Ghats Mountain. Hence, Vansda National Park and Purna Wildlife Sanctuary of Dang forest in South Gujarat are part of the Western Ghat biogeographic zone. Western parts of Valsad and Navsari districts as well as Tapi and Surat districts are extensions of Malabar plains of Western Ghats. The Deccan Plateau is another important part of the peninsular plateau of India. The Deccan Plateau starts near the border of Gujarat and Maharashtra, covering eastern edge of Narmada, Tapi and Dang districts and runs approximately 1600 km through Maharashtra, Goa, Karnataka, Kerala, and Tamilnadu and ends at Swamithoppe, near Kanyakumari (Rodgers and Panwar, 1988).

A semi-arid climate is the climate of a region that receives precipitation below potential evapotranspiration, but not extremely. Most of the region of Gujarat comes under a semi-arid zone. All other protected areas fall in the semi-arid zone with annual precipitation varying from 1200 mm (Shoolpaneshwar Wildlife Sanctuary) to 600 mm (Porbandar and Khijadyia Bird Sanctuary). North Gujarat, Central Gujarat, Saurashtra and some parts of South Gujarat fall under semi arid zone. Kachchh Desert Sanctuary, Wild Ass Sanctuary and Chhari Dhandh Community reserve in the extreme north-western area of the state are part of the Arid zone (Map 1). Average annual rainfall is 250 to 450 mm.

The coastline of Gujarat, overlooking the Arabian Sea, stretches for a length of about 1600 km is very important coastal wetland zone. There are some important sites declared as National Parks and Sanctuaries located in the coastal zone indicating its rich biodiversity. These include the marine sanctuary and National Park in the Gulf of Kachchh, Porbandar Bird Sanctuary and Velavadar Blackbuck National Park. Kachchh coast line stretches for about 300 km and has an arid climate with low rainfall of 250-400 mm. The East-West trending inner segment that lies inside the Gulf of Kachchh is sandy and silt with narrow beaches and merges into the Little Rann of Kachchh to the east. Saurashtra coast stretches from Navlakhi to Bhavnagar for about 800 km. Entire Gulf of Khambhat and coastal area of South Gujarat is muddy with extensive intertidal zone, creeks and estuaries.

Sampling area and method

This study was carried out in Gujarat state during August, 2014 to July, 2017 with necessary permissions for research from the Gujarat State Biodiversity Board and the State Forest Department, Gandhinagar. Permission letter No. GBB/Form-I/T-3b/2885/2016-17 on dated 24.08.2016 by

Gujarat Biodiversity Board and Permit No.: 18/2016-2017 on dated 28.07.2016 by Forest and Environment Department, Gujarat. Fifteen protected areas including, three National Parks and twelve Wildlife sanctuaries were surveyed at least once during the study period. Four Protected areas *i.e.* Gir National Park, Gir Wildlife Sanctuary, Khijadiya Bird Sanctuary, Porbandar Bird Sanctuary and Jessore Sloth Bear Sanctuary were surveyed only once. However, other ten protected areas *i.e.*, Vansda National Park, Purna Wildlife Sanctuary, Shoolpaneshwar Wildlife Sanctuary, Jambughoda Wildlife Sanctuary, Ratanmahal Sloth bear Sanctuary, Nalsarovar Bird Sanctuary, Thol Wildlife Sanctuary, Blackbuck National Park, Wild Ass Sanctuary and Kachchh Desert Wildlife Sanctuary were surveyed more than once. Surveys were carried out during monsoon (June to September) and post monsoon season (October-November) during the study period. Dragonflies and damselflies were observed on wetlands with the aid of binocular (7X35). Photographs of the observed species were also taken for later identification and confirmation.

Only those specimens were collected whose identification needed further confirmation. Preserved specimens and their photographs were used for the identification of the species from the taxonomic key given by Fraser (1933, 1934 and 1936); Subramanian (2009); Nair (2011); Kiran and Raju (2013). Identification of the species was confirmed by a taxonomist Dr. Talmale of Zoological Survey of India (Jabalpur, Madhya Pradesh). The scientific names are adopted from the revised nomenclature by Subramanian and Babu (2017).

RESULTS

A total of 60 species belonging to two suborders and 40 genera, under eight families were collected from all fifteen protected areas of Gujarat (Table 2). Total nineteen species of Zygoptera (damselflies) and 41 species of Anisoptera (dragonflies) were recorded. In this study, Zygoptera and Anisoptera both were represented by four families each (Table 2). Representative species are shown in Fig. 1.

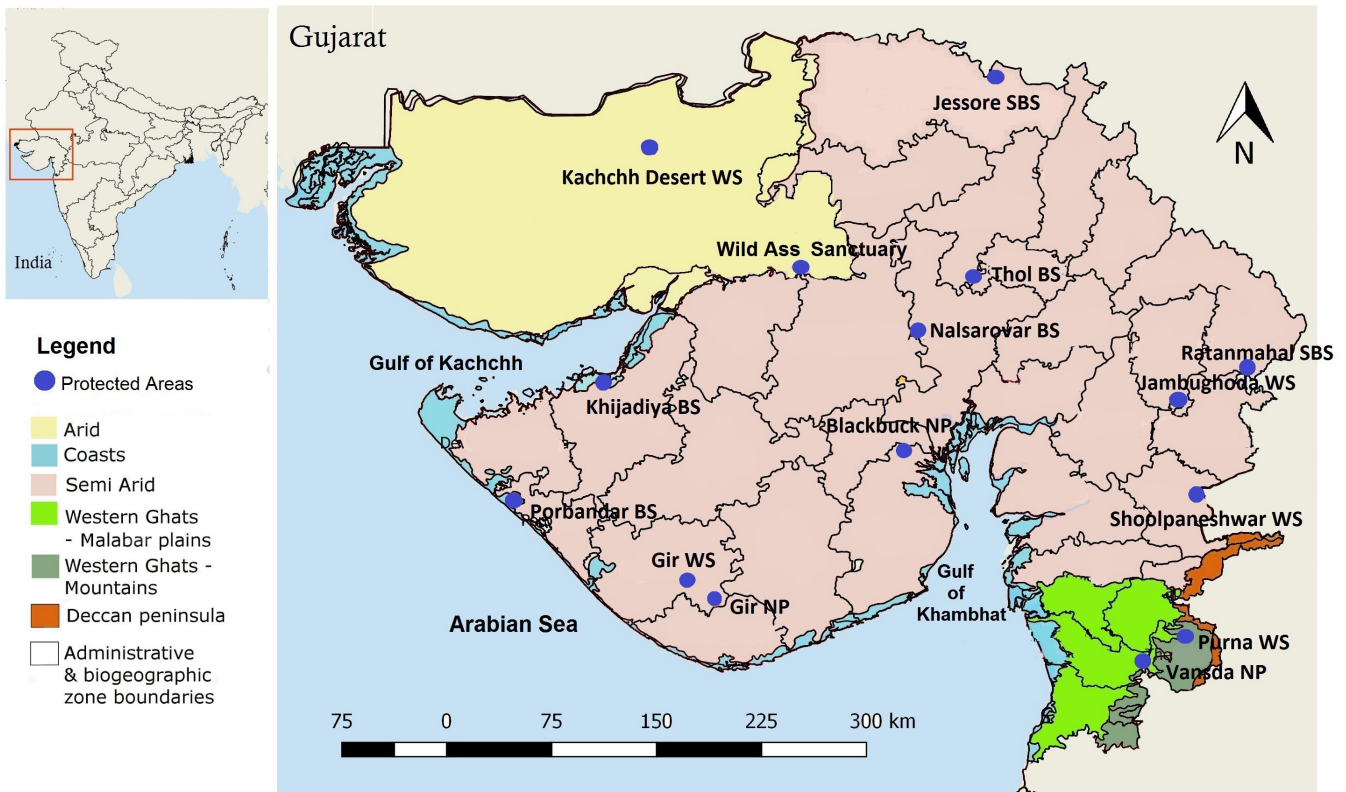
The highest number of odonate species (54 species) was recorded from the Purna Wildlife Sanctuary (38 species of Anisoptera and 16 species of Zygoptera). Nalsarovar Bird Sanctuary ranked second with 47 species (32 species of Anisoptera and 15 species of Zygoptera). Vansda National Park ranked third with 44 species (30 species of Anisoptera and 14 species of Zygoptera). More number of species are recorded from Purna Wildlife sanctuary as compared to Vansda National Park may be because of Purna Wildlife sanctuary covered much more area than Vansda National Park. Gir National Park and Gir Wildlife Sanctuary had 43 species and 41 species, respectively. Species richness

Table 1. Salient features of the protected areas

Protected areas/ Important wetlands	Area (sq. km)	Coordinates		Forest/wetland type	Water Source River/ others
		Latitude	Longitude		
Vansda National Park	23.99	20°51'16"- 21°21'22"	73°20'30"- 73°31'20"	3B/C-South Indian tropical moist forest: 3B/C _{1c} - Moist teak, 3B/C _{1b} -Slightly moist teak forest, 3B/C ₂ -Moist deciduous mixed forests and 5/E ₉ bamboo break	Ambika
Purna Wildlife Sanctuary	160.8	20° 51'- 21° 21'	73° 32' – 73° 48'	3B/C ₂ -Southern moist mixed deciduous forest: 3B/C _{1c} - Moist teak, 3B/C _{1b} -Slightly moist teak forest, 3B/2S ₁ -Southern secondary moist deciduous and 5/E ₉ bamboo break	Purna, Gira
Shoolpaneshwar Wildlife Sanctuary	607.7	21° 03' – 21° 59'	73° 05'- 74° 10'	3B/C _{1c} - Moist teak forest, 3B/C _{1b} - Slightly moist teak forest, 3B/C ₂ - Southern moist mixed deciduous forest, 5/DS ₁ -Dry deciduous scrub, 5/E ₉ - Dry bamboo brakes, and 5/1S ₁ - Southern dry tropical riverine forest	Narmada, Devanadi, Talav, Karjan
Jambughoda Wildlife Sanctuary	130.3	22° 22' – 22° 28'	73° 38' – 73° 44'	5A/C _{1b} - Dry teak forest, 5A/C ₃ - Southern dry mixed deciduous forest 5/DS ₁ -Dry deciduous scrub, 5/E ₅ - <i>Butea</i> forest, 5/1S ₁ - Southern dry tropical riverine forest and 5/2S ₁ - Secondary dry deciduous forest	Rain water stored in Kada dam
Ratanmahal Sloth Bear Sanctuary	55.65	22° 32'- 22° 53'	74° 03'- 74° 11'	5A/C ₃ - Southern dry mixed deciduous forest, 3B/C ₂ -Southern moist mixed deciduous forest:, 5A/C _{1b} -Dry teak forest at foothills, 5/E ₉ - Dry bamboo brakes and 'Timru' forest	Panam and Orsang
Jessore Sloth Bear Sanctuary	180.66	24°24'58.69"	72°29'57.74"	5A/C ₃ -Southern dry mixed deciduous, 6B/DS ₁ - <i>Zizyphus</i> forest, 6/E ₁ -Dhav forest, 5/DS ₁ - dry deciduous scrub 'Khair', 5/2S ₂ - secondary dry deciduous and 6/E ₃ - <i>Prosopis juliflora</i> forest	Banas
Nalsarovar Bird Sanctuary	120.8	22°78'- 22° 96'	71° 92'- 72° 64'	Natural shallow lake	Rain water, natural drainage/ Narmada Canal
Thol Bird Sanctuary	7.00	23° 22.50'	72° 37.50'	Man- made wetland	Rain water/ Narmada canal
Blackbuck National Park	34.08	22° 02'00"	72° 03'00"	Grassland dense, saline land, <i>Prosopis</i> shrubland	Rain water, natural drainage
Gir National Park and Gir Wildlife Sanctuary	258.7- NP 1153.4 WS	20° 40' - 21° 50'	70° 50' – 71° 50'	5A/C _{1a} -Dry deciduous teak forest, 5/DS ₁ - Dry deciduous thorn and 5/DS ₂ - Dry savannah forest	Hiran, Shetrunji, Machhundri, Godavari and Raval
Khijidiya Bird Sanctuary	6.05	22°31 '27"	70° 07' 17"	Inland wetland, marsh vegetation, saline land	Rain water, natural drainage

Protected areas/ Important wetlands	Area (sq. km)	Coordinates		Forest/wetland type	Water Source River/ others
		Latitude	Longitude		
Porbandar Bird Sanctuary	0.099	21°38'11.96"	69°37'5.28"	Freshwater lake	Domestic sewage
Wild Ass Sanctuary	4954	23° 9'3.78"	71°23'43.73"	5/E ₈ - Saline-alkaline scrub desert, 6/E ₃ - Rann saline thorn forest or <i>prosopis</i> shrubland, marsh vegetation and saline grassland	Rain water, natural drainage
Kachchh Desert Wildlife Sanctuary	7506.2	23°54'16.96"	70°26'34.85"	Saline desert, Saline-alkaline scrub, desert thorn scrub forest, <i>prosopis</i> shrubland, marsh vegetation	Rain water, natural drainage

Note: NP - National Park, WS - Wildlife Sanctuary



Map 1. Study area showing collection/observation sites of protected areas

was comparatively low in the remaining protected areas: Ratanmahal Sloth Bear Sanctuary (36), Shoolpaneshwar Wildlife Sanctuary (35), Thol Wildlife Sanctuary (35), Jambughoda Wildlife Sanctuary (34), Blackbuck National Park (31), Jessore Sloth Bear Sanctuary (30), Khijadiya Bird Sanctuary (29), Kachchh Desert Wildlife Sanctuary (29 species), Wild Ass Sanctuary (27) and Porbandar Bird Sanctuary (26) (Table 3).

Highest number of odonates recorded belonged to the family Libellulidae (29 species), followed by Coenagrionidae (12 species), Gomphidae (six species), Aeshnidae (five

species), Lestidae and Platycnemididae (three species each), Macromiidae and Chlorocyphidae (one species each) (Table 2).

Fourteen species were most widely distributed and common as they were recorded in all fifteen protected areas. Five species were recorded in fourteen protected areas. Three species were recorded in thirteen protected areas. Two species recorded in twelve protected areas. The absence of these species in one or two protected areas may be due to comparatively less survey efforts since these species are otherwise widely distributed in India and hence likely to be widespread in the entire Gujarat state (Table 2).









	
<p><i>Lestes viridulus</i></p>	<p><i>Libellago lineata</i></p>
	
<p><i>Agriocnemis splendidissima</i></p>	<p><i>Gynacantha bayadera</i></p>
	
<p><i>Cyclogomphus ypsilon</i></p>	<p><i>Macrogomphus annulatus</i></p>
	
<p><i>Cratilla lineata</i></p>	<p><i>Lathrecista asiatica</i></p>

Fig. 1. Certain odonate species representative of specific protected areas

Table 2. Odonate diversity in protected areas of Gujarat

Taxon	IUCN status	Protected areas														
		Vansda NP	Purna WLS	Shoolpaneshwar WLS	Jambughoda WLS	Ratanmahal SBS	Jessore SBS	Nalsarovar BS	Thol WLS	Blackbuck NP	Gir NP	Gir WLS	Khijadiya BS	Porbandar BS	Wild Ass Sanctuary	Kachehh Desert WLS
Suborder: Zygoptera																
Superfamily : Lestoidea																
Family : Lestidae																
1. <i>Lestes thoracicus</i> Laidlaw, 1920	LC	+	+			+		+	+	+			+	+	+	+
2. <i>Lestes umbrinus</i> Selys, 1891	DD	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
3. <i>Lestes viridulus</i> Rambur, 1842	LC		+													
Superfamily: Calopterygoidea																
Family: Chlorocyphidae																
4. <i>Libellago lineata</i> (Burmeister, 1839)	LC										+					
Superfamily: Coenagrionoidea																
Family: Platycnemididae																
5. <i>Copera marginipes</i> (Rambur, 1842)	LC	+	+	+	+	+		+			+	+				
6. <i>Disparoneura quadrimaculata</i> (Rambur, 1842)	LC	+	+	+	+	+		+			+	+				
7. <i>Elatoneura nigerrima</i> (Laidlaw, 1917)	DD	+	+		+			+		+	+	+				
Family: Coenagrionidae																
8. <i>Agriocnemis pygmaea</i> (Rambur, 1842)	LC	+	+	+	+	+	+	+#	+	+	+	+	+	+	+	+
9. <i>Agriocnemis splendidissima</i> Laidlaw, 1919	LC	+														
10. <i>Ceriagrion coromandelianum</i> (Fabricius, 1798)	LC	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
11. <i>Enallagma cyathigerum</i> (Charpentier, 1840)	LC							#								
12. <i>Enallagma parvum</i> Selys, 1876	LC									+						+
13. <i>Ischnura aurora</i> (Brauer, 1865)	LC		+	+	+	+		+	+	+	+	+			+	+
14. <i>Ischnura nursei</i> (Morton, 1907)	LC	+	+	+			+	+#	+	+	+	+			+	+
15. <i>Ischnura senegalensis</i> (Rambur, 1842)	LC	+	+	+	+	+	+	+#	+	+	+	+	+	+	+	+
16. <i>Paracercion malayanum</i> (Selys, 1876)	LC	+	+		+			+	+	+		+	+	+	+	+
17. <i>Pseudagrion decorum</i> (Rambur, 1842)	LC	+	+	+	+	+	+	+#	+	+	+	+	+	+	+	+

18. <i>Pseudagrion hypermelas</i> Selys, 1876	LC		+						+		+	+	+				
19. <i>Pseudagrion microcephalum</i> (Rambur, 1842)	LC	+	+	+					+	+		+	+				
20. <i>Pseudagrion rubriceps</i> Selys, 1876	LC	+	+	+	+	+			+			+	+				
Suborder: Anisoptera																	
Super family: Aeshnoidea																	
Family: Aeshnidae																	
21. <i>Anax ephippiger</i> (Burmeister, 1839)	LC	+	+	+	+	+			+	+	+	+	+	+	+	+	+
22. <i>Anax guttatus</i> (Burmeister, 1839)	LC		+			+	+		+	+	+					+	+
23. <i>Anax immaculifrons</i> Rambur, 1842	LC	+	+	+		+	+		+	+		+	+	+			+
24. <i>Anax parthenope</i> (Selys, 1839)	LC								+	+	+			+	+	+	+
25. <i>Gynacantha bayadera</i> Selys, 1891	LC					+											
Superfamily: Gomphoidea																	
Family: Gomphidae																	
26. <i>Burmagomphus laidlawi</i> Fraser, 1924	DD		+														
27. <i>Ictinogomphus rapax</i> (Rambur, 1842)	LC	+	+	+	+	+			+	+	+	+	+	+	+	+	+
28. <i>Cyclogomphus ypsilon</i> Selys, 1854	NA		+														
29. <i>Macrogomphus annulatus</i> (Selys, 1854)	DD		+														
30. <i>Onychogomphus acinaces</i> (Laidlaw, 1922)	DD		+														
31. <i>Paragomphus lineatus</i> (Selys, 1850)	LC	+	+	+		+	+		+	+		+	+				
Superfamily: Libelluloidea																	
Family: Macromiidae																	
32. <i>Epophthalmia vittata</i> Burmeister, 1839	LC		+			+											
Family: Libellulidae																	
33. <i>Acisoma panorpoides</i> (Rambur, 1842)	LC	+	+	+	+	+	+	+#	+	+	+	+	+	+	+	+	
34. <i>Brachydiplax sobrina</i> (Rambur, 1842)	LC	+	+	+		+	+		+	+		+	+				
35. <i>Brachythemis contaminata</i> (Fabricius, 1793)	LC	+	+	+	+	+	+		+	+	+	+	+	+	+	+	+
36. <i>Bradinopyga geminata</i> (Rambur, 1842)	LC	+	+	+	+	+	+		+	+	+	+	+	+	+	+	+
37. <i>Cratilla lineata</i> Foerster, 1903	LC		+														
38. <i>Crocothemis servilia</i> (Drury, 1770)	LC	+	+	+	+	+	+		+	+	+	+	+	+	+	+	+
39. <i>Diaplocodes lefebvrui</i> (Rambur, 1842)	LC	+	+		+	+	+		+	+	+	+	+	+	+	+	+

Diversity of Odonata (Insecta) in protected areas of Gujarat, India

40. <i>Diplacodes nebulosa</i> (Fabricius, 1793)	LC	+	+		+			+			+					
41. <i>Diplacodes trivialis</i> (Rambur, 1842)	LC	+	+	+	+	+	+	+	+	+	+#	+	+	+	+	+
42. <i>Indothemis carnatica</i> (Fabricius, 1798)	LC		+		+			+								
43. <i>Lathrecista asiatica</i> (Fabricius, 1798)	LC		+													
44. <i>Neurothemis tullia</i> (Drury, 1773)	LC	+	+	+	+			+	+	+	+	+				
45. <i>Orthetrum luzonicum</i> (Brauer, 1868)	LC	+	+	+	+	+	+	+	+	+	+	+	+	+		
46. <i>Orthetrum pruinosum</i> (Burmeister, 1839)	LC	+	+	+	+	+	+	+	+		+	+				
47. <i>Orthetrum sabina</i> (Drury, 1770)	LC	+	+#	+	+	+	+	+#	+	+	+	+	+	+	+	+
48. <i>Orthetrum taeniolatum</i> (Schneider, 1845)	LC	+	+	+	+	+	+	+	+		+	+	+	+		+
49. <i>Pantala flavescens</i> (Fabricius, 1798)	LC	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
50. <i>Potamarcha congener</i> (Rambur, 1842)	LC	+	+				+	+	+		+	+				
51. <i>Rhodothemis rufa</i> (Rambur, 1842)	LC	+														+
52. <i>Rhyothemis variegata</i> (Linnaeus, 1763)	LC	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
53. <i>Tholymis tillarga</i> (Fabricius, 1798)	LC	+	+	+			+	+			+	+	+	+	+	+
54. <i>Tramea basilaris</i> (Palisot de Beauvois, 1805)	LC	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
55. <i>Tramea limbata</i> (Desjardins, 1832)	LC	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
56. <i>Trithemis aurora</i> (Burmeister, 1839)	LC	+	+	+	+	+	+	+	+		+	+	+	+	+	
57. <i>Trithemis festiva</i> (Rambur, 1842)	LC	+	+	+	+	+	+	+	+		+	+				
58. <i>Trithemis pallidinervis</i> (Kirby, 1889)	LC	+	+	+	+	+	+	+	+	+	+	+	+	+	+	
59. <i>Trithemis kirbyi</i> Selys, 1891	LC	+	+	+		+	+	+		+	+	+				+
60. <i>Urothemis signata</i> (Rambur, 1842)	LC	+	+		+			+								
61. <i>Zyxomma petiolatum</i> Rambur, 1842	LC	+	+					+			+	+				

Table 3. Species richness of dragonflies and damselflies of protected areas

Sr. No.	Protected areas	No. of species		Total
		Dragonfly	Damselfly	
1.	Vansda National Park	30	14	44 (74%)
2.	Purna Wildlife Sanctuary	38	16	54 (89%)
3.	Shoolpaneshwar Wildlife Sanctuary	24	11	35 (59%)
4.	Jambughoda Wildlife Sanctuary	23	11	34 (57%)
5.	Ratanmahal Sloth Bear Sanctuary	26	10	36 (61%)
6.	Jessore Sloth Bear Sanctuary	24	06	30 (51%)
7.	Nalsarovar Bird Sanctuary	32	15	47 (79%)
8.	Thol Wildlife Sanctuary	25	10	35 (59%)
9.	Blackbuck National Park	19	12	31 (52%)
10.	Gir National Park	29	14	43 (72%)
11.	Gir Wildlife Sanctuary	28	13	41 (69%)
12.	Khijadiya Bird Sanctuary	20	09	29 (49%)
13.	Porbandar Bird Sanctuary	19	07	26 (44%)
14.	Wild Ass Sanctuary	18	09	27 (46%)
15.	Kutch Desert Wildlife Sanctuary	19	10	29 (49%)
	Total	41	19	60* (100%)

Purna Wildlife Sanctuary is a part of Western Ghat in Dang district. Record of fifty four species is the highest number amongst the protected areas surveyed in Gujarat. At least seven species *i.e.*, *Lestes viridulus* Rambur, 1842, *Burmagomphus laidlawi* Fraser, 1924, *Cyclogomphus ypsilon* Selys, 1854, *Macrogomphus annulatus* (Selys, 1854), *Onychogomphus acinaces* (Laidlaw, 1922), *Cratilla lineata* Foerster, 1903 and *Lathrecista asiatica* (Fabricius, 1798) were exclusively recorded from Purna Wildlife Sanctuary. For the Gomphidae family, Purna Wildlife Sanctuary was the most suitable habitat as out of six species of the family, four of them were exclusively recorded from Purna WS. *Agriocnemis splendidissima* Laidlaw, 1919 was recorded only from Vansda National Park. *Libellago lineata* (Burmeister, 1839) was recorded only from Gir National Park; several specimens were observed on Hiran River near Sasan. *Enallagma parvum* was recorded only from two protected area *i.e.*, Kachchh Desert Sanctuary and Blackbuck National Park.

At least five species are listed under 'Data Deficient' species (IUCN 2017). The Data Deficient species recorded from protected areas are as follows: *Lestes umbrinus*,

Elatoneura nigerrima, *Burmagomphus laidlawi*, *Macrogomphus annulatus* and *Onychogomphus acinaces*. Fifty four species of odonates from present study are listed under 'Least concern' species. One species *i.e.* *Cyclogomphus ypsilon* Selys, 1854 is not available on IUCN Red list (Table 2). Hence, current records may help to undertake threat analysis. Two species *i.e.* *Burmagomphus laidlawi* and *Onychogomphus acinaces* are showing range extension. The record of *Burmagomphus laidlawi* in Dang forest is an extension of 450–500 km north. *Onychogomphus acinaces* also shows an extension of its range of distribution from Karnataka to Dang in southern Gujarat (Rathod *et al.*, 2016).

DISCUSSION

In Gujarat, all records of odonates from Protected Area (PA) were part of the general collection of fauna by the scientists of Zoological Survey of India (ZSI) as hardly a few species has been reported so far from any of the Protected area (Prasad 2004). ZSI took up general faunal studies of PAs in the early nineties. However, a specific survey of any protected area for specific lower taxa (invertebrates) was taken up in the country recent years. First such paper appeared in Zoo's

Print Journal (Patel, 2003). Odonate survey of the protected area of Gujarat was done by Rathod *et al.*, (2016, 2018) and Mokaria (2015), Mokaria *et al.*, (2017, 2018).

In the country, odonate diversity of only two or three PAs are available in a given state. But the present study involved fifteen PAs, which is first of its kind. Though some of the PAs could be visited only once during monsoon, it has provided baseline information about the diversity and distribution. Repeated surveys may result in exploration of some more species.

Rathod *et al.* (2016) recorded 47 species of odonates from Dang district and 35 species of odonates from Navsari district. In the present study, Purna WS and Vansda NP were surveyed intensively which are part of Dang and Navsari districts respectively. Total 54 species are recorded from Purna WS and 44 species from Vansda NP which are higher than total species recorded from whole Dang (47) and Navsari (35) district (Rathod *et al.*, 2016).

Mokaria (2015) recorded 21 species of odonates from Blackbuck National Park and 15 species from Thol Bird Sanctuary. In present study, 31 species were recorded from Blackbuck National Park and 35 species from Thol Bird Sanctuary. Thus, ten species in Blackbuck National Park and 20 species from Thol Bird Sanctuary are additions to the earlier list. Moreover, in Mokaria (2015), at least three species were wrongly identified which may be due to labelling mistakes or identification error.

Kumar (2013) made an inventory of the fauna of Khijadiya Bird Sanctuary; however, nothing was mentioned about odonates. Recently, Mokaria *et al.*, (2017) reported ten species of Odonates from Khijadiya Bird Sanctuary. Though we could make only one survey of Khijadiya Bird Sanctuary in October 2016, at least twenty nine species of odonates could be listed. It seems that Odonates were neglected in all previous studies.

Rathod and Parasharya (2018) recorded 46 species of odonates from Nalsarovar Bird Sanctuary. In present study, we have added one more species to this list which is *Disparoneura quadrimaculata* (Rambur, 1842). Hence, the total list of Nalsarovar Bird Sanctuary is now 47. Prasad (2004) recorded only seven species from the same area.

Kumar (2009) made an inventory of the fauna of Nalsarovar Bird Sanctuary; however, nothing is mentioned about the odonates in the book. Mokaria and Jethwa (2018) reported thirty species of Odonates from Nalsarovar Bird Sanctuary during three year's study. We have come across at

least twenty eight species out of thirty listed by Mokaria and Jethwa (2018) from Nalsarovar Bird Sanctuary. *Enallagma cyathigerum* and *Macrodiplax cora* listed by them were not encountered by us. One wonders why the collected specimens were photographed and released back! As the specimens were not retained for future verification, the same is reflected in the label of some of the photographs in the same paper. Earlier, Common blue damselfly *Enallagma cyathigerum* was reported by Prasad (2004) from Nalsarovar and some other areas of Gujarat. During three years of study in the entire state, we have never come across *Enallagma cyathigerum*. As *E. cyathigerum* is a European species, its occurrence in arid/semi-arid regions of India is doubtful. Occurrence of this species in Gujarat is questioned by us (Rathod and Parasharya 2018).

Considering distribution of the protected areas in various biogeographic zones, it appears that the diversity was highest (88%) in the Western Ghat area with very high annual precipitation (2500mm) followed by Semi-arid zone (78% species with 500 to 840mm annual precipitation) and Arid Zone (48% species with 250 to 450mm annual precipitation). Protected areas are least disturbed areas and hence support high diversity (Gray *et al.*, 2016). Wetlands with high anthropogenic pressure have low odonate diversity (Subramanian, 2010; Balaraman, 2008; Kulkarni and Subramanian, 2013). According to the checklist of Rathod (2017), total species of Odonata of Gujarat accounts to 81. In present study, 60 species of odonates were recorded, which covered 74% odonate of the total (81) species in entire Gujarat.

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