



E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2016; 4(4): 40-47
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Received: 06-03-2016
Accepted: 07-04-2016

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Odonate diversity along different habitats of Koraput district, Odisha, India

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Abstract

Odonates are considered to be indicator of ecological balance. An inventory was carried out to document the over looked odonate diversity in four habitat types (hill stream, river, reservoir and pond) of Koraput district, southern Odisha, India. The study recorded 64 species representing 45 genera under 9 families. Family Libellulidae was the dominant group representing 32 species. Maximum species (n=58, 90.6%) were recorded along hill streams. Forty-one species were recorded from single habitat type, of which 37 species were confined to hill streams. A decreasing trend in species diversity was observed from the water bodies in the forested areas to human dominated landscapes indicating human impact on odonate species diversity. Ditch Jewel (*Brachythemis contaminata*) was most frequently sighted in the water bodies near human habitations, indicating highly polluted water not suitable for human consumption, whereas species like Common Clubtail (*Ictinogomphus rapax*) and Common Hooktail (*Paragomphus lineatus*) were only recorded along hill streams, indicating unpolluted water.

Keywords: Odonate diversity, bioindicator, water bodies, hill stream, human dominated landscape, Koraput

1. Introduction

The Odonates are a group of freshwater invertebrates, closely linked to specific freshwater habitat conditions and are widely used as ecological indicators of habitat quality and the integrity of freshwater ecosystems [1-7]. Evolved around 250 million years ago [8], these magnificent groups of flying insects are sharing a long cultural relationship with humans as well as an important species in the ecosystem, being key indicator of water quality and fluvial ecosystem disturbance [9]. The greatest numbers of species are found at places that provide a wide variety of microhabitats, though dragonflies tend to be much more sensitive to pollution than damselflies [10]. They are also important and widespread components of freshwater ecosystems, being top predators [11]. Extant Odonates of the World are broadly divided into three suborders the Zygoptera or damselflies, Anisozygoptera and the Anisoptera or dragonflies. The Anisozygoptera with four relict species was earlier recognized as a third suborder of Odonata. However, recent studies groups Anisozygoptera with Anisoptera [12, 13]. About 6,000 species of Odonata and subspecies belonging to 677 genera have been documented world-wide [14], of which India is represented by 474 species in 142 genera under 18 families [15].

Odisha is one of the biodiversity rich regions of Eastern India because of its unique biogeographic amalgamations and home to diverse flora and fauna. Odonate research in Odisha dates back to early 1900s documenting the diversity of Chilika Lake and its adjoining areas [16, 17]. This was followed by reporting of 58 species of Odonate fauna by the Zoological Survey of India as part of faunal exploration [18]. Subsequently, various workers [19-26] surveyed the Odonate diversity along different geographic regions of Odisha and a total of 110 species of odonates representing 60 genera and 9 families have been documented from the state. Nair [24] for the first time added 36 new species of Odonates in Odisha. Occurrence of Lesser Blue Wing (*Rhythemis triangularis*) was reported from the Kotgarh Wildlife Sanctuary, Odisha [27], which was earlier reported from Assam, Karnataka, Kerala, and Tamil Nadu in India.

Perusal of the above literature shows that, studies on the Odonate diversity of southern Odisha is meagre and few attempts have been made to bridge the information gap. Thus, the present study was carried out for an inventory of Odonate diversity and their distribution pattern in Koraput district of southern Odisha, India.

2. Materials and Methods

2.1 Study Area

The study was conducted in Koraput district, one of the hilly regions of southern Odisha, India (Figure-1). It lies between 18°14' to 19°14' N and 82° 05' and 83°25' E covering an area of 8807 sq km along the Eastern Ghats hill ranges in Odisha. The district is bordered by the neighbouring state of Andhra Pradesh in south-east and Chhattisgarh in the western side. Forest cover of Koraput is broadly characterized by tropical moist deciduous forest and tropical dry deciduous forests [28, 29]. The altitude varies from 500 m near western side to 1600 m on eastern side with mountain peaks and ridges. The highest

mountain peak of Odisha, Deomali (1672 m) is found in this district. Three distinct seasons i.e. summer (April - June), monsoon (July - October) and winter (November - March) are experienced in the region. However, monsoon is the most dominating season as a result of topographic and climatic variations. The temperature varies from a minimum of 12 °C during winter to a maximum of 38 °C during summer with an average annual rainfall of 1500 mm. The predominant soil type is sandy and clay. The topography of the area is undulating with discontinuous mountains interspersed with rivers, water reservoirs and a number of waterfalls, which provide suitable habitats for odonates.

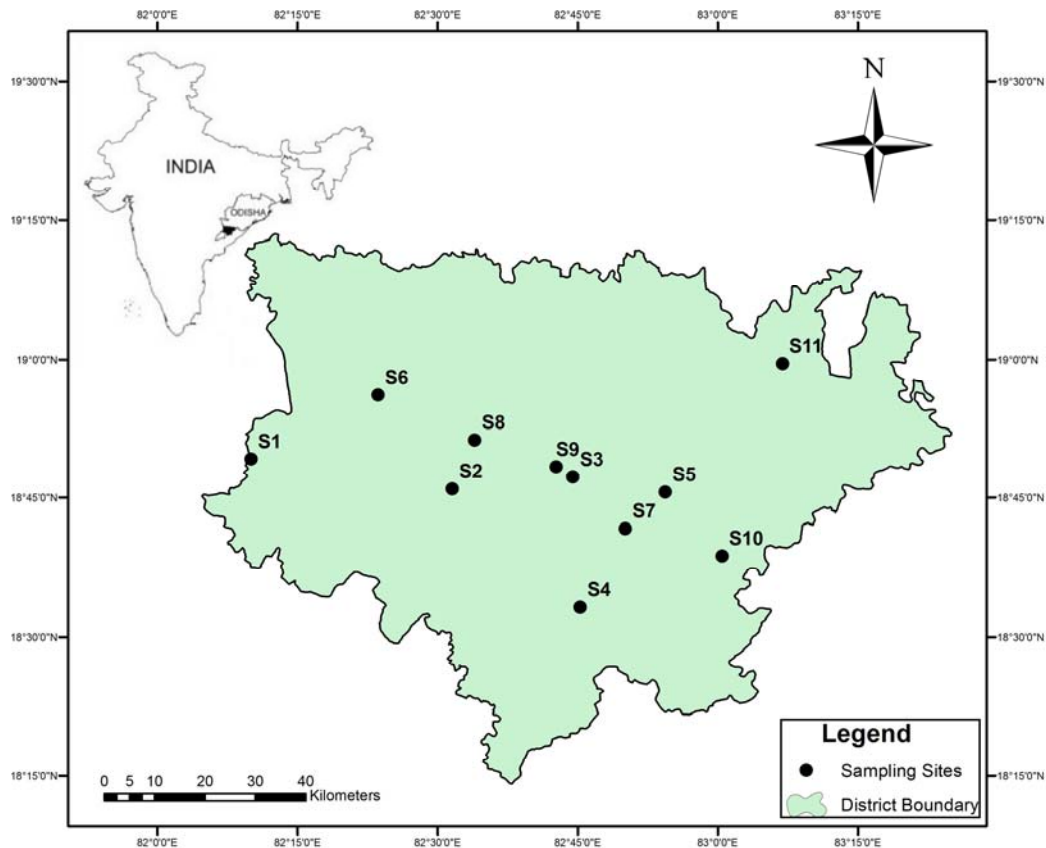


Fig 1: Map showing Odonate sampling sites in Koraput district, Odisha, India (S₁- Gupteswar hill stream, S₂- Kota hill stream, S₃-Amtiguda hill stream, S₄- Rani Duduma hill stream, S₅- Deomali hill stream, S₆- Kundra, S₇- Janiguda reservoir, S₈-Jeypore Pond, S₉- Koraput Pond, S₁₀-Damanjodi Pond, S₁₁- Laxmipur Pond)

2.2 Methods of data collection

The survey was conducted in and around eleven water bodies (hill streams, rivers, reservoirs and ponds) of Koraput district during August 2014 to April 2015 (Figure-1). The study sites include hill streams at Gupteswar (S₁), Kota (S₂), Amtiguda (S₃), Rani Duduma (S₄) and Deomali (S₅); river at Kundra (S₆) and reservoir at Janiguda (S₇) and ponds at Jeypore (S₈), Koraput (S₉), Damanjodi (S₁₀) and Laxmipur (S₁₁). While the study sites of hill streams are located inside reserve forests (S₁ - S₅), the river at Kundra (S₆) is flowing close to Kundra reserve forest, the reservoir (S₇) and ponds (S₈- S₁₁) are located in human dominated landscapes. While the hill streams are placed at elevation between 450 to 1234 m, the elevation of reservoir is at 876 m and ponds between 588 to 888 m (Table-2). The geographic location and elevation of each survey site were recorded using a hand held Garmin etrex10 GPS. Field survey was carried out between 0900 to 1200 hours in each survey day as odonates are most active during this period. Visual encounter survey [30] was used to survey the Odonates. A number of trails were randomly made near the survey sites

and all encountered species were photographed using Canon EOS 600D digital camera with 55-250 mm zoom lens and Canon EOSM with 18-55 mm zoom lens. The species were identified using the appropriate field keys [31-33, 24]. Doubtful species were captured using an entomological net for confirmation of identification in the laboratory. The scientific names are adopted from the revised nomenclature given by Subramanian [15]. All the sampling sites were broadly categorized into four habitat types i.e. River, Water reservoir, Hill stream and Pond. Species diversity from all these habitats was recorded and the significant difference of species diversity among the four types of water bodies was studied by χ^2 -test. The Bray-Curtis Coefficient of Similarity was measured and a dendrogram based on similarity coefficients generated. Clusters are formed of sites that are similar in species composition, as measured by a chosen ecological distance. Cluster analysis provides a summary of the similarity in species composition of various sites. The Similarity index was calculated by using Past 3.0 software.

3. Results

The name of the odonate species along with their families, and their presence and absence in the habitats studied are shown in Table 1. IUCN categories are also mentioned against each species. A total number of 64 species of Odonates representing 45 genera under 9 families were recorded from the study sites (Table-1). The sub-order Anisoptera was found to be the most diverse group representing 38 species under 28 genera. The family Libellulidae was the dominant group representing 32 species under 23 genera, followed by Gomphidae (3 species

under 3 genera) and Aeshnidae (3 species under 2 genera). The genus *Orthetrum* under family Libellulidae was the most diverse with six species. The sub order Zygoptera is represented by 26 species under 6 families with Coenagrionidae as the dominant family (13 species under 6 genera), followed by Platycnemididae (5 species under 4 genera), Chlorocyphidae (3 species under 3 genera), Calopterygidae (2 species under 2 genera), Lestidae (2 species under 1 genus each) and Euphaeidae (1 species) (Table-1, Figure-2).

Table 1: Checklist of Odonates recorded from different water bodies of Koraput district, Southern Odisha, India (+ and - denotes presence and absence respectively)

Sl No	Scientific Name	Sampling sites*											
		HS					R	RV	P				
		S ₁	S ₂	S ₃	S ₄	S ₅	S ₆	S ₇	S ₈	S ₉	S ₁₀	S ₁₁	
Sub order: Anisoptera Selys, 1854													
Family: Gomphidae Rambur, 1842													
1	<i>Ictinogomphus rapax</i> (Rambur, 1842) LC	+	-	-	-	-	-	-	-	-	-	-	
2	<i>Gomphidia t-nigrum</i> Selys, 1854 LC	-	-	-	+	-	-	-	-	-	-	-	
3	<i>Paragomphus lineatus</i> (Selys, 1850) LC	-	-	+	+	-	-	-	-	-	-	-	
Family: Aeshnidae Leach, 1815													
4	<i>Anax guttatus</i> (Burmeister, 1839) LC	-	-	-	+	-	-	-	-	-	-	-	
5	<i>Anax immaculifrons</i> Rambur, 1842 LC	+	-	+	+	+	+	-	-	-	-	-	
6	<i>Gynacantha bayadera</i> Selys, 1891 LC	-	-	-	-	+	-	-	-	-	-	-	
Family: Libellulidae Leach, 1815													
7	<i>Acisoma panorpoides</i> Rambur, 1842 LC	+	-	-	-	-	-	-	-	-	-	-	
8	<i>Brachydiplax farinosa</i> Krüger, 1902 LC	+	-	+	-	-	-	-	-	-	-	-	
9	<i>Brachythemis contaminata</i> (Fabricius, 1793) LC	-	-	-	-	-	+	-	+	+	-	-	
10	<i>Bradynopyga geminate</i> (Rambur, 1842) NA	+	-	-	+	-	-	-	-	-	-	-	
11	<i>Camacina gigantea</i> (Brauer, 1867) LC	-	-	-	-	+	-	-	-	-	-	-	
12	<i>Crocothemis servilia</i> (Drury, 1770) LC	+	-	-	-	+	-	-	-	-	-	+	
13	<i>Diplacodes nebulosa</i> (Fabricius, 1793) LC	-	-	-	-	-	-	-	+	-	-	-	
14	<i>Diplacodes trivialis</i> (Rambur, 1842) LC	+	+	+	+	+	+	+	+	+	+	+	
15	<i>Indothemis carnatica</i> (Fabricius, 1798) NT	+	-	-	-	-	-	-	-	-	-	-	
16	<i>Lathrecista asiatica</i> (Fabricius, 1798) LC	-	-	-	-	+	-	-	-	-	-	-	
17	<i>Neurothemis fulvia</i> (Drury, 1773) LC	+	+	+	+	+	+	-	-	-	-	-	
18	<i>Neurothemis intermedia</i> (Rambur, 1842) LC	+	-	+	+	+	+	-	-	-	+	-	
19	<i>Onychothemis testacea</i> Laidlaw, 1902 LC	-	-	-	+	-	-	-	-	-	-	-	
20	<i>Orthetrum triangulare</i> (Selys, 1878) LC	+	-	+	-	-	-	-	-	-	-	-	
21	<i>Orthetrum glaucum</i> (Brauer, 1865) LC	+	-	-	-	+	-	-	-	-	-	-	
22	<i>Orthetrum luzonicum</i> (Brauer, 1868) LC	+	-	-	-	-	-	-	-	-	-	-	
23	<i>Orthetrum pruinosum</i> (Burmeister, 1839) LC	+	+	+	+	+	+	+	+	-	+	-	
24	<i>Orthetrum sabina</i> (Drury, 1770) LC	+	-	-	+	-	+	-	-	-	-	-	
25	<i>Orthetrum taeniolatum</i> (Schneider, 1845) LC	-	-	-	-	+	-	-	-	-	-	-	
26	<i>Palpopleura sexmaculata</i> (Fabricius, 1787) LC	-	-	+	+	-	-	-	-	-	-	-	
27	<i>Pantala flavescens</i> (Fabricius, 1798) LC	+	-	+	+	+	+	+	-	-	+	+	
28	<i>Potamarcha congener</i> (Rambur, 1842) LC	-	-	-	-	+	-	-	-	-	-	-	
29	<i>Rhodothemis rufa</i> (Rambur, 1842) LC	+	-	-	-	-	-	-	-	-	-	-	
30	<i>Rhyothemis variegata</i> (Linnaeus, 1763) LC	+	-	-	-	-	-	-	-	-	-	-	
31	<i>Tetrathemis platyptera</i> Selys, 1878 LC	+	-	-	-	-	-	-	-	-	-	-	
32	<i>Tholymis tillarga</i> (Fabricius, 1798) LC	-	-	-	-	-	-	-	-	+	-	-	
33	<i>Tramea basilaris</i> (Palisot de Beauvois, 1805) LC	+	-	+	-	-	-	-	-	-	-	+	
34	<i>Trithemis aurora</i> (Burmeister, 1839) LC	+	-	-	+	-	-	-	-	-	-	-	
35	<i>Trithemis festiva</i> (Rambur, 1842) LC	+	+	+	+	+	+	+	+	+	+	+	
36	<i>Urothemis signata</i> (Rambur, 1842) LC	+	-	-	-	-	-	+	-	-	-	-	
37	<i>Zygonyx iris</i> Selys, 1869 LC	-	-	-	+	+	-	-	-	-	-	-	
38	<i>Zygonyx torrida</i> (Kirby, 1889) LC	-	-	-	-	+	-	-	-	-	-	-	
Sub order: Zygoptera Selys, 1854													
Family: Calopterygidae Selys, 1850													
39	<i>Neurobasis chinensis</i> (Linnaeus, 1758) LC	-	-	+	+	-	-	-	-	-	-	-	
40	<i>Vestalis gracilis</i> (Rambur, 1842) LC	+	+	+	+	+	+	-	-	-	-	-	
Family: Chlorocyphidae Cowley, 1937													
41	<i>Aristocypha quadrimaculata</i> Selys, 1853 LC	-	-	+	-	-	-	-	-	-	-	-	
42	<i>Heliocypha bisignata</i> Hagen in Selys, 1853 LC	-	+	+	+	+	-	-	-	-	-	-	
43	<i>Libellago lineate</i> (Burmeister, 1839) NA	+	-	+	+	+	-	-	-	-	-	+	
Family: Coenagrionidae Kirby, 1890													
44	<i>Aciagrion pallidum</i> Selys, 1891 LC	+	-	-	-	+	-	-	-	-	-	-	

45	<i>Agriocnemis pygmaea</i> (Rambur, 1842) LC	+	-	-	-	-	-	+	-	-	-	-
46	<i>Agriocnemis splendidissima</i> Laidlaw, 1919 NA	+	+	-	-	-	-	-	-	-	-	-
47	<i>Ceriagrion rubiae</i> Laidlaw, 1916 NA	-	-	+	-	-	-	-	-	-	-	-
48	<i>Ceriagrion cerinorubellum</i> Brauer, 1865 LC	-	-	-	+	-	-	-	-	-	-	-
49	<i>Ceriagrion coromandelium</i> Fabricius, 1798 NA	+	-	-	+	-	+	-	+	+	-	+
50	<i>Enallagma parvum</i> Selys, 1876 LC	+	-	-	+	-	-	-	-	-	-	-
51	<i>Ischnura aurora</i> (Brauer, 1865) LC	+	-	+	-	+	+	+	-	+	+	-
52	<i>Ischnura nursei</i> (Morton, 1907) LC	-	-	+	-	-	-	+	-	-	-	-
53	<i>Ischnura senegalensis</i> (Rambur, 1842) LC	-	-	-	-	-	-	-	+	-	+	+
54	<i>Pseudagrion decorum</i> (Rambur, 1842) LC	-	-	-	-	-	+	-	-	-	-	-
55	<i>Pseudagrion microcephalum</i> (Rambur, 1842) LC	-	-	-	-	-	-	+	-	-	+	-
56	<i>Pseudagrion rubriceps</i> Selys, 1876 LC	+	+	-	+	-	-	-	-	-	-	-
Family: Euphaeidae Yakobson & Bainchi, 1905												
57	<i>Dysphagia ethela</i> Fraser, 1924 DD	+	-	-	-	-	-	-	-	-	-	-
Family: Lestidae Calvert, 1901												
58	<i>Lestes umbrinus</i> Selys, 1891 DD	+	-	-	-	-	-	-	-	-	-	-
59	<i>Lestes viridulus</i> Rambur, 1842 LC	+	-	-	-	-	+	-	-	+	-	-
Family: Platynemididae Yakobson & Bainchi, 1905												
60	<i>Copera marginipes</i> (Rambur, 1842) LC	+	+	+	+	-	+	-	-	-	-	+
61	<i>Copera vittata</i> Selys, 1863 LC	-	-	+	-	-	+	-	-	-	-	-
62	<i>Caconeura ramburi</i> (Fraser, 1922) DD	-	+	-	-	-	-	-	-	-	-	-
63	<i>Prodasineura verticalis</i> (Selys, 1860) LC	-	-	+	+	-	-	-	-	-	-	-
64	<i>Disparoneura quadrimaculata</i> (Rambur, 1842) NA	+	-	-	-	-	+	-	-	-	-	-

NB: *HS- Hill Stream, R- River, RV- Reservoir, P- Pond, S₁- Gupteswar hill stream, S₂- Kota hill stream, S₃- Amtiguda hill stream, S₄- Rani Duduma hill stream, S₅- Deomali hill stream, S₆- Kundra, S₇- Janiguda reservoir, S₈-Jeypore Pond, S₉- Koraput Pond, S₁₀-Damanjodi Pond, S₁₁- Laxmipur Pond, LC-Least Concern, NA- Not Assessed, DD-Data Deficient, NT- Near Threatened

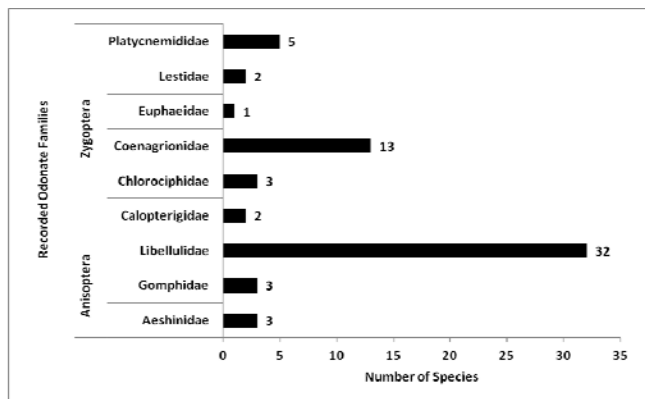


Fig 2: Odonate diversity in Koraput district, Odisha: Family wise record of species

Of all the surveyed habitats, majority of the species (n=58, 90.6%) were recorded along the hill streams followed by river and ponds (n=17, 26.6% each) and least in water reservoirs

(n=9, 14.1%). Of the entire hill streams most of the species (n=37, 63.8%) were recorded near hill streams of Gupteswar forest followed by hill streams of Rani Duduma (26 species), Amtiguda hill stream (23 species) and Deomali hill streams (21 species) (Table-2). Considering the habitat specificity of all the recorded odonates, 41 species were restricted to single habitat type (hill streams or rivers or ponds) and thus are exclusive. Among these, majority of the species (n=37, 90.2%) were confined to hill streams (Table-2). Black-tipped Ground Skimmer (*Diplacodes nebulosa*), Coral-tailed Cloud Wing (*Tholymis tillarga*) and Senegal Golden Dartlet (*Ischnura senegalensis*) were recorded near ponds whereas Three Lined Dart (*Pseudagrion decorum*) was recorded along rivers. Rest of the species were habitat generalists and recorded from multiple habitat types (Table 1). Only five species (*Diplocodes trivialis*, *Orthetrum pruinosum*, *Pantala flavescens*, *Trithemis festiva* and *Ischnura aurora*) were common to all sites owing to their distribution throughout the habitat types.

Table 2: Habitat type and odonate species diversity in the sampling sites

Sl No	Place	Geographic location		Elevation (in mtr)	Type of Water body	Type of habitat	Recorded species (no.)
		Latitude	Longitude				
1	Gupteswar (S ₁)	18°49'10.75"	82°10'01.01"	450	HS	RF	37
2	Kota (S ₂)	18°45'54.76"	82°31'33.06"	590	HS	RF	10
3	Amtiguda (S ₃)	18°47'13.41"	82°44'28.80"	845	HS	RF	23
4	Rani Duduma (S ₄)	18°33'08.53"	82°45'16.07"	920	HS	RF	26
5	Deomali (S ₅)	18°45'35.41"	82°54'22.80"	1234	HS	RF	21
6	Kundra (S ₆)	18°56'08.33"	82°23'36.19"	560	R	RF	17
7	Janiguda (S ₇)	18°41'38.89"	82°50'05.97"	876	RV	HDLS	9
8	Jeypore (S ₈)	18°51'13.19"	82°33'57.85"	588	P	HDLS	7
9	Koraput (S ₉)	18°48'19.47"	82°42'40.43"	873	P	HDLS	7
10	Damanjodi (S ₁₀)	18°38'41.66"	83°00'27.69"	888	P	HDLS	8
11	Laxmipur (S ₁₁)	18°59'34.40"	83°06'55.51"	917	P	HDLS	9

HS- Hill Stream, R- River, RV- Reservoir, P- Pond; RF- Reserve Forest, HDLS- Human Dominated landscape

Ditch Jewel *Brachythemis contaminata*, which is an indicator of water pollution, have been recorded from three sampling sites, one at Kundra (S₆) and other two are ponds at Jeypore (S₈) and Koraput (S₉). Though, S₆ is a river close to Reserve

Forest, water is mostly polluted due to human activities and other two sites (S₁₀ and S₁₁) are ponds in urban areas amidst human dominated landscapes. The water reservoir at Janiguda (S₇) is also close to human habitation.

The survey areas included the undisturbed and unpolluted hill streams in the Reserve forests to the highly polluted water bodies within human habitations (Table-2) and a significant difference in species diversity was found along survey sites ($\chi^2= 61.67, df=10, p<0.001$). The decreasing trend in species diversity was observed from the water bodies in the forested areas to human dominated landscapes (Figure-3).

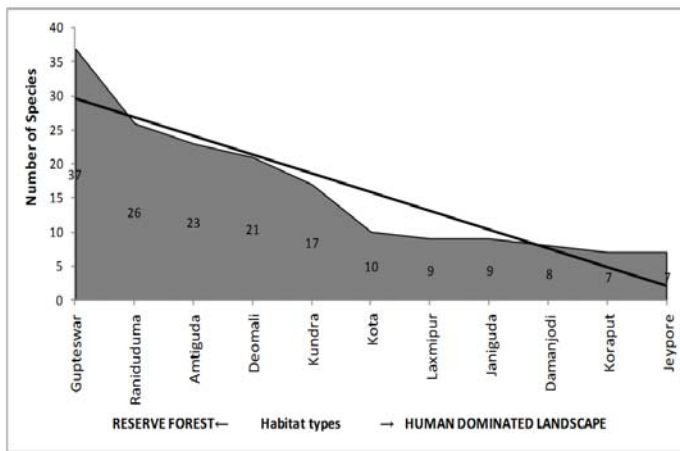


Fig 3: Trend in Odonate diversity along different sampling sites

The diversity of odonates depends upon various factors like presence or absence of water bodies, size of the water bodies, natural habitat, and level of human disturbances, shade cover and degree of pollution. The similarity of diversity of odonates among different sampling sites was measured by drawing a dendrogram (Figure-4). The sampling sites are grouped into two super-clusters, the hill stream sites (S₁, S₂, S₃, S₄, S₅) and river (S₆) are in one super-cluster and reservoir (S₇) and ponds in the human dominated landscape (S₈, S₉, S₁₀, S₁₁) in another super-cluster. Coefficient of similarity indicated a maximum 71% similarity in species composition between Janiguda reservoir and Damanjodi Pond and 58% similarity between ponds of Jeypore and Koraput. Both of these showed strong affinity to the pond at Laxmipur. In other supercluster, there is 62 % similarity of species composition between hill streams of Amtiguda and Rani Duduma and they show strong affinity with river at Kundra (S₆) and hill streams of Gupteswar (S₁), Deomali (S₅) and Kota (S₂) respectively (Figure-4).

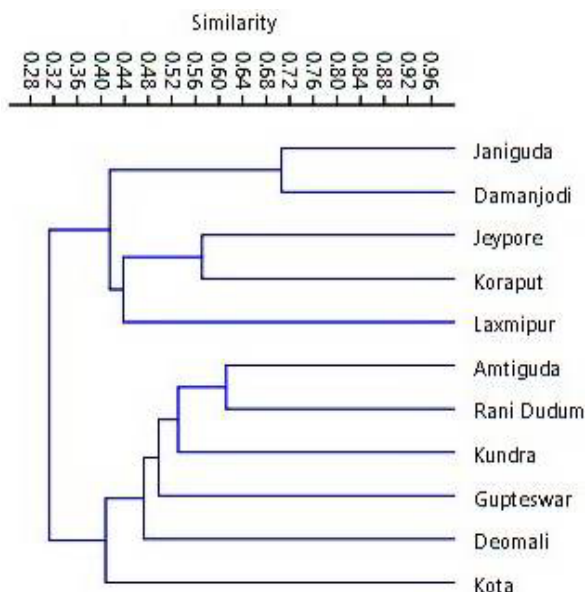


Fig 4: Dendrogram showing Bay-Curtis similarity in Odonate diversity for 11 sampling sites of Koraput district, Odisha

The IUCN threat status of the inventoried odonates indicate that one species (*Indothemis carnatica*) is Near Threatened (NT), three species (*Dysphagia ethela*, *Copera marginipes*, *Caconeura ramburi*) are Data Deficient (DD), five species (*Bradynopyga geminate*, *Libellago lineate*, *Agriocnemis splendidissima*, *Ceragrion coromandelium* and *Disparoneura quadrimaculata*) have not been assessed (NA) and rest 55 species are under Least Concern (LC). The Near Threatened species *Indothemis carnatica* has been recorded from only one site e.g. Gupteswar (S₁).

4. Discussion

Odonates survive in a wide range of aquatic habitats and are susceptible to anthropogenic habitat modifications. Dragonflies have been proposed as indicators for assessing the ecosystem health of freshwater wetlands [34]. In biodiversity conservation, Odonates serve as an umbrella species [35, 36] and represent specific biotic wetland assemblages.

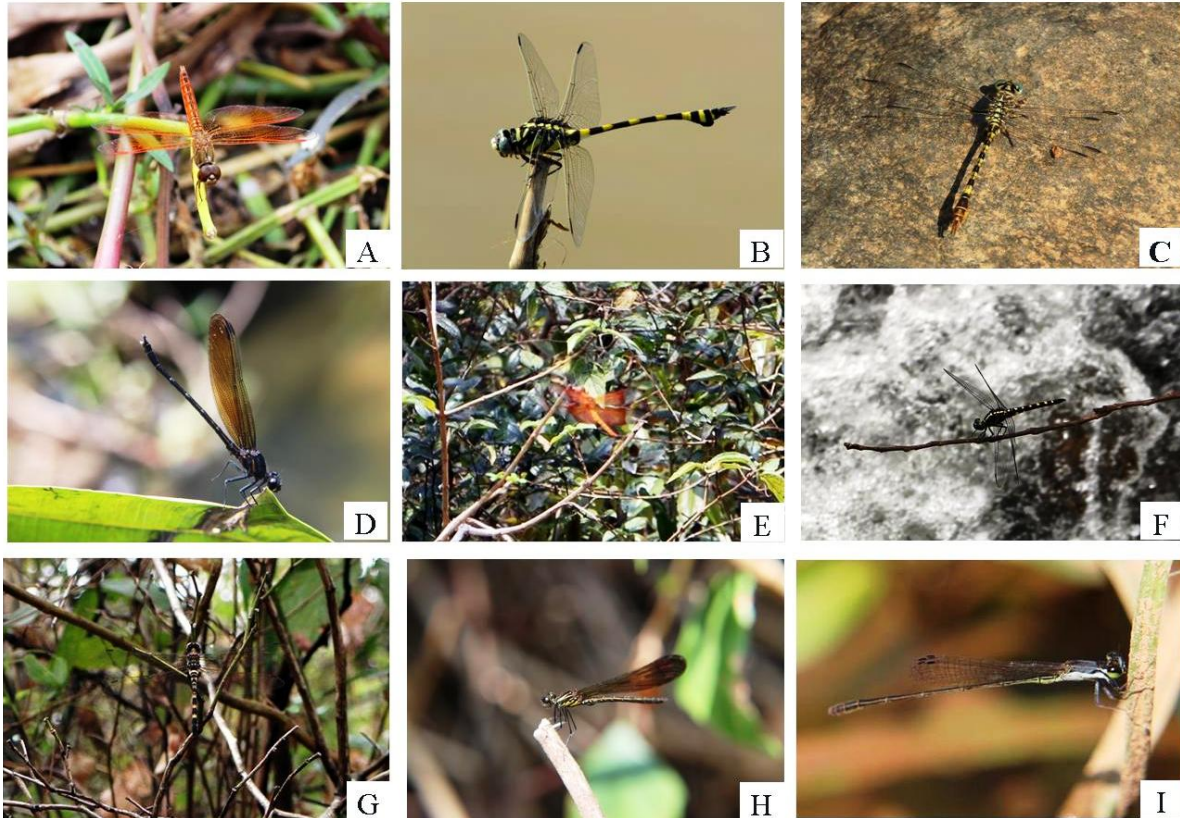
A wide range of functional and structural features of a particular habitat are required for survival and reproduction of Odonates [37]. Habitat heterogeneity especially the quality and quantity of aquatic and semi-aquatic plant communities, shoreline structures, hydrological features and sunlight are the most important variables determining the appearance of odonate species or associations [38-40]. On the other hand habitat alterations and climate change have threatened odonate survival.

The reported species (n=64) represent 58% of the total odonate species documented from Odisha (n=110). Libellulidae was the dominant family in the study area represented by 32 species and 23 genera, of which genus *Orthetrum* was the most diverse with six species. Similar reports have been documented from Odisha [21-23, 25, 26]. Among all habitats, highest number of species assemblage was recorded from the hill streams. In Koraput district, majority of the hill streams are away from human activities and are less disturbed which may be the reason for high species richness of odonates in these habitats and low diversity in river and reservoir may be due to degradation of water quality. A similar trend in the diversity of odonates was reported [23] in the Similipal Tiger Reserve, where a decreasing trend in species diversity was marked from core area to the outer buffer area with high anthropogenic activities.

Ditch Jewel (*Brachythemis contaminata*) (Plate 1, A) was frequently sighted in the polluted water bodies near human habitations, which is an indicator species of highly polluted water not suitable for human consumption [24]. Koraput being an underdeveloped region of the state, majority of the tribal communities depend on these water sources for their daily use. In contrast, Common Clubtail (*Ictinogomphus rapax*) (Plate 1, B) and Common Hooktail (*Paragomphus lineatus*) (Plate 1, C) were only observed along the hill streams, which were unpolluted. Presence or absence of certain groups of species can be looked as a proxy for habitat variables or to assess quality of freshwater habitats [41, 42]. The present study not only documented the diversity, but also confirmed the geographic range extension of many species of odonates in Odisha. Black Torrent Dart (*Dysphagia ethela*) (Plate 1, D) is an indicator species of good forest cover and it was reported from the Palpala River in Similipal Tiger Reserve [24]. In the present study, this species was reported from Gupteswar area, indicating it as one of the good forest habitats in Koraput district. Besides, Giant Forest Skimmer (*Camacinia gigantea*) (Plate 1, E) and Stellate River Hawk (*Onychothemis testacea*) (Plate 1, F) were earlier reported from Similipal [24] only.

These two species were also recorded from Deomali and Rani Duduma hill streams during the present survey. Torrent Glider (*Zygonyx torrida*) (Plate 1, G), a dragonfly was earlier reported from two localities of Keonjhar district ^[24], is now recorded from Deomali hill streams. The Black Emperor (*Rhinocypha quadrimaculata*) (Plate 1, H), a damselfly is found in Himalayas and NE India, was reported by Zoological Survey of India by a single record from Kotgarh Wildlife Sanctuary

and Nair ^[24] mentions that its confirmation is desirable. The record of this species now from Amtiguda hill stream confirms its presence in the southernmost region of Odisha. Nair ^[24] also stated that the report of Orange marsh dart (*Ceriagrion rubiae*) (Plate 1, I) from Koraput by the Zoological Survey of India needs confirmation. However, this species is now also reported from the Amtiguda hill stream of Koraput, confirming its occurrence in Odisha.



A: *Brachythemis contaminata* (Fabricius, 1793), **B:** *Ictinogomphus rapax* (Rambur, 1842), **C:** *Paragomphus lineatus* (Selys, 1850), **D:** *Dysphagia ethela* Fraser, 1924, **E:** *Camacinia gigantea* (Brauer, 1867), **F:** *Onychothemis testacea* Laidlaw, 1902, **G:** *Zygonyx torrida* (Kirby, 1889), **H:** *Aristocypha quadrimaculata* Selys, 1853, **I:** *Ceriagrion rubiae* Laidlaw, 1916

Plate 1

Among the 64 recorded species, only 5 species are distributed throughout the study area and 41 species were exclusive as they are restricted to either one or two localities. The exclusiveness of such large number of species indicates that alteration of their respective habitats will not only make them disappear but also affect the existence of other species.

The Bay-Curtis similarity indicated that, sites that are grouped into the same cluster are more similar in species composition than sites that are grouped into different clusters. The species composition in undisturbed habitats away from human dominated landscape (hill streams and river in Reserve Forest area) are high in species richness in comparison to sites in human dominated landscape. Findings of the study indicate that, among the surveyed sites, Gupteswar forest was the most preferable habitat for odonates with occurrence of not only maximum number of species but this site also supports the range extension of many odonate species in Odisha (*Dysphagia ethela*, *Camacinia gigantea*, *Onychothemis testacea*, *Zygonyx torrida*, *Rhinocypha quadrimaculata* and *Ceriagrion rubiae*). Further, recording of Near Threatened species *Indothemis carnatica* from this site indicates that the population of this species can be maintained provided the habitat of Gupteswar remains intact. The species diversity trend is gradually increasing from human dominated habitats

to forested areas which are comparatively less disturbed. The water bodies of human occupied landscapes are dominated by species which are indicator of water pollution. This implies, water being one of the crucial natural resource for life forms is now gradually losing its quality in the human dominated landscapes as a result of increasing anthropogenic activities and unsustainable use.

5. Conclusion

Odonates are the flagship insect communities which are bioindicators of the aquatic ecosystems. Understanding the odonate-habitat association provides essential information for characterising the response of odonates to changes in the habitat. The rich faunal and floral biodiversity of Koraput is under tremendous anthropogenic pressure, due to industrialisation and other developmental projects in the last five decades. The higher odonate species richness in hill streams away from human dominated landscapes indicates the poor state of water bodies in populated urban or sub-urban habitats. The present inventory has served as the baseline information on Odonate diversity and distribution in the water bodies of Koraput as well as it contributed to the biodiversity database of the state. Documentation of the biodiversity of this biogeographically important region in the Eastern Ghats is an

urgent need. However, further studies are required to be undertaken for a longer period to understand the community structure, behaviour and impact of urbanization and habitat modification on odonate diversity and distribution.

6. Acknowledgement

The authors are thankful to the Divisional Forest Officers of Koraput and Jeypore Forest Divisions for permission to carry out the survey along different Reserve forests. Authors are also thankful to Dr. Malaya Kumar Misra, Senior Academic Consultant, Department of Biodiversity and Conservation of Nature, Central University of Orissa and Dr. L.A.K. Singh, Senior Scientist (Retd.), Department of Environment and Forest, Govt. of Odisha for critically reviewing the manuscript.

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