



Studies on the Diversity and Species Composition of Odonata (Arthropoda: Insecta) from Chandgad Taluk of Kolhapur District, Maharashtra, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: <https://doi.org/10.56557/upjoz/2025/v46i84897>

Open Peer Review History:

This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: <https://prh.mbmph.com/review-history/4754>

Original Research Article

Received: 23/01/2025

Accepted: 28/03/2025

Published: 31/03/2025

ABSTRACT

In present study, a total of 66 odonate species belonging to 41 genera representing 10 families were recorded from Chandgad taluka of Kolhapur district in Northern Western Ghats. Dragonflies (Anisoptera) with 38 species (58%) were dominating the study area followed by 28 species (42%) of Damselflies (Zygoptera). Among the genera, *Orthetrum* were in maximum number (6) of species followed by *Pseudagrion* were of 5 species. Libellulidae family members are recorded in the highest number (30) followed by Coenagrionidae (15). Among the study sites highest numbers of odonates

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were recorded from slow running stream Kitwade with 33 species and weedy pond Tawarewadi with 32 species. The fast-running stream Tilari represents the least number (3) of species. The slow running stream and weedy pond habitat support the odonate diversity compared to fast running stream, semi forest and lake side habitat.

Keywords: Odonate; dragonflies; damselflies; habitat association; similarity in species composition; Jaccard index.

1. INTRODUCTION

Odonates encompassing the dragonflies (Anisoptera) and damselflies (Zygoptera) distributed in a wide range of aquatic habitats. These are sensitive to habitat alterations induced by human activities like industrialization and urbanization (Subramanian et al., 2005; Kulkarni and Subramanian, 2013; Emiliyamma, 2014). Dragonflies have been recognized as ecological indicators to assess the ecosystem health of freshwater wetlands (Suhling et al., 2006; Gómez- Tolosa, et al., 2021). Most of the odonates are highly specific in habitat selection, some of them use natural lentic or lotic water bodies and, some species adapted to manmade water bodies. Habitat selection plays an important role in distribution and ecology of odonates (Andrew et al., 2008). The dragonflies tend to be much more sensitive to pollution than damselflies. The complex habitat and microhabitats offer a large number of odonate species (Subramanian, 2005; Ameilia, et al., 2006; Koli, et al., 2014; Koneri, et al., 2020). The ecological factors like pH, amount and type of aquatic vegetation, temperature and, nature of water bodies (lotic/lentic) affects the distribution pattern of nymphs as well as adult odonate flies. Some generalist species can tolerate a wide range of conditions while some specialist species are very sensitive to their environment (Chovanec and Waringer, 2001; Schindler et al., 2003; Chovanec et al., 2004; Ameilia et al., 2006; Smith and Pontius, 2006; Subramanian et al., 2011). The life history of odonates is closely associated with water bodies and uses a wide range of habitats for their breeding. Globally around 6313 odonate species representing 693 genera (Paulson and Schorr, 2020). Indian subcontinent comprises 488 odonate species and 27 subspecies belong to 154 genera spread across 18 families (Subramanian and Babu, 2017). Subramanian and Babu (2020) documented 196 odonate species from Western Ghats of India. However, so far in Maharashtra 134 odonate species documented by Tiple and Koparde (2015). Recently, it is updated to 144 species by Sawant et al., (2022). Chandgad

taluka in Kolhapur district of southern Maharashtra is a part of Northern Western Ghats and consists of a wide range of diversified temporary and permanent water bodies which are well suited for odonate breeding activity. Aiwale (2016) made a preliminary observation on diversity and morphometry of some odonates in Dharwad (Karnataka) and Tilari of Chandgad taluka and, documented 24 odonate species. Since, there are no published report on diversity of odonates from Chandgad, we made an attempt to assess the diversity, distribution pattern, habitat association and similarity in species composition of odonates in different habitats of Chandgad taluka.

2. MATERIALS AND METHODS

2.1 Study Area

Chandgad being a part of the Northern Western Ghats is rich in biodiversity. It receives 3000mm to 5000mm of annual rainfall from the South-West monsoon and temperatures ranging from 29°C to 36°C during summer and 14°C to 21°C during winter. It consists of several water bodies and irrigation canals. It is also traversed by Ghataprabha, Hiranyakeshi and Tamraparni Rivers connected by several streams and, consists reservoirs like Tilari dam, Ghataprabha dam, Jangamhatti dam, Ambewadi dam etc. The forest area is of moist mixed deciduous and semi-evergreen mixed with acacia plantation, bamboo forest and some cymbopogon type of grasslands.

2.2 Diversity and Habitat Association

We selected ten study sites i.e. Kitwade, Jangmahatti, Nittur, Tilari, Kodali, Tawarewadi, Kamewadi, Ambewadi, Chinchane and Yashwantrao Chavan College (YCC) Campus Halkarni with different habitats viz. Slow Running Stream (SRS), Fast Running Stream (FRS), Lake Side (LS), Weedy Pond (WP), River Side (RS), Marsh Land (ML), Semi Forest (SF) and Semi-Urban (SU) (Table 1). Photo Plate 1 (Images 1 to 10) shows the habitat structure of

study sites selected. Study sites were visited once in a month from June 2018 to July 2022 for the documentation of odonates and to study their diversity, habitat association, species richness. Odonate species were collected using insect net and tried to identify in the field itself using handbooks by Emiliyamma et al., (2005), Subramanian (2005) and Andrew et al., (2008).

Later, the specimens were released in to their natural habitat. Some of the specimens were brought to the laboratory to confirm their identity with the help of literature and biodiversity portals like Odonate of India (Joshi et al., 2020), Bug guide (2020), Encyclopedia Britannica (2020). Nikon D5300, D7200 camera and mobiles are used to capture the images of odonates.



1. Kitwade (SRS)



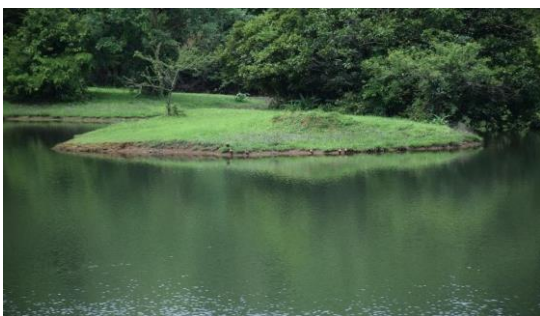
2. Jangamhatti (SRS)



3. Nittur (SRS)



4. Tilari Nagar (FRS)



5. Kodali (LS)



6. Tawarewadi (WP)



7. Kamewadi (RS)



8. Ambewadi (ML)



9. Chinchane (SF)



10. YCC Campus (SU)

Photo Plate 1. habitats of study sites in Chandgad taluka of Kolhapur
Table 1. The study sites, habitat and number of odonate species recorded

Sl. No.	Study site	Latitude	Longitude	Habitat	Number of odonate species recorded
1	Kitwade	16.9101°N	73.946266°E	SRS	33
2	Jangamhatti	17.2142° N	74.55525° E	SRS	18
3	Nittur	15.9873908°N	74.363146° E	SRS	17
4	Tilari Nagar	15.7987° N	74.3433°E	FRS	3
5	Kodali	16.8751807°N	74.1902069° E	LS	9
6	Tawarewadi	15.9200367°N	73.3206208°E	WP	32
7	Kamewadi	16.7101043° N	74.250945799°E	RS	21
8	Ambewadi	16.7158234° N	74.2047176°E	ML	20
9	Chinchane	16.0224N°	74.2525°E	SF	6
10	YCC campus	16.44098°N	73.84388 °E	SU	19

Abbreviations used: SRS - Slow Running Stream, FRS - Fast Running Stream, LS - Lake Side, WP - Weedy Pound, RS - River Side, ML - Marsh Land, SF - Semi Forest, SU - Semi Urban YCC – Yashwantrao Chavan College

2.3 Species Richness and Similarity

Sampling was done by the Visual Encounter Survey (VES) method. VES is used to determine the species richness of an area, to compile a species list (species composition of study site) and to estimate relative abundances of species within an assemblage (Heyer et al., 1994). To examine the similarity in species composition between study-sites, an agglomerative hierarchical cluster analysis were performed using the Unweighted pair-group average (UPGMA) applied to a matrix of Jaccard similarity coefficients between all sites. UPGMA is a cophenetic correlation which showing very less alteration between input and output. It is more efficient than any other method and also more distinct clustering tool (Hale and Dougherty, 1988). Clusters are joined based on the average distance between all members of the group. The algorithm begins the clustering by assigning each observation to a cluster which merges until one large cluster is formed (Struyf et al., 1997). Jaccard similarity coefficient was calculated by Past software Version 3.25 (Hammer, 2019).

3. RESULTS

3.1 Diversity, Habitat Association and Species Richness

A total of 66 odonate species belonging to 41 genera representing 10 families were recorded from the study sites (Table 2). Photo Plate 2 (Images 1 to 20) shows some of the odonate species recorded in different habitats of study area. The dragonflies dominated the study area with 38 (58%) species belonging to 4 families whereas, the damselflies comprised 28 (42%) species belonging to 6 families of odonates recorded (Table 2, Fig. 1) in study area. Out of ten study-sites Kitwade and Tawarewadi represented more number (18% - each of the study sites) of odonate species whereas, Tilari contributed hardly 2% of odonate species (Figs. 2 and 3) recorded. Among the genera *Orthetrum* represent maximum number (6) of species followed by *Pseudagrion* representing 5 species (Table 3). Members of Libellulidae are most common representative of Anisoptera with 30 (45%) species followed by Coenagrionidae

representing Zygoptera with 15 (23%) species (Fig. 4). In Gomphidae family we identified one odonate upto genus *Bumagomphaus* (Table 2). Platynemididae and Aeshnidae represent 5 and 4 species respectively; Gomphidae contribute 3 species; Calopterygidae, Chlorocyphidae, Euphaeidae and Lestidae represents 2 species each; Synthemistidae represent single species (Table 2, Fig. 4). The slow running stream - Kitwade and weedy pond - Tawarewadi recorded highest number (33 and 32 respectively) of species

followed by River side - Kamewadi (21) and Marsh land - Ambewadi (20). Slow running stream – Nittur, Jangamhatti and Semi-urban - Yashawantrao Chavan College Campus study- sites represent almost equal number of species (17, 18 and 19 respectively); Lakeside - Kodali and Semi forest area - Chinchane represent 9 and 6 species respectively. The fast-running stream – Tiları recorded the least number (3) of odonate species (Table 1). Dragonflies are dominating almost all the study sites (Fig. 2).



1. *Neurothemis tullia* (Male)



2. *Brachydiplax sobrina*



3. *Trithemis aurora* (Male)



4. *Neurothemis fulvia* (Male)



5. *Gynacantha dravida*



6. *Macromidia donaldi*



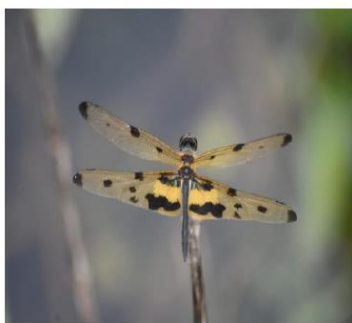
7. *Orthetrum luzonicum* (Female)



8. *Orthetrum luzonicum* (Male)



9. *Urothemis signata*



10. *Rhyothemis variegata*



11. *Orthetrum pruinosum* (Female)



12. *Zygonyx iris*



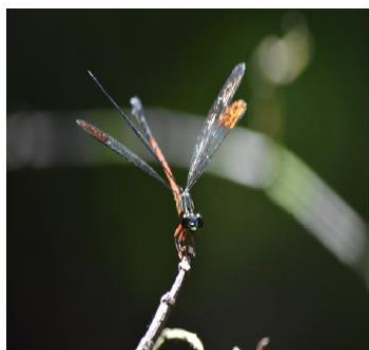
13. *Crocothemis servilia*



14. *Vestalis apicalis*



15. *Brachythemis contaminata*



16. *Euphaea fraseri*



17. *Palpopleura sexmaculata*



18. *Neurobasis chinensis*



19. *Pseudagrion malabaricum*



20. *Pseudagrion rubriceps*

Photo Plate 2. some of the Odonate species recorded in the study area Chandgad taluka of Kolhapur, Maharashtra

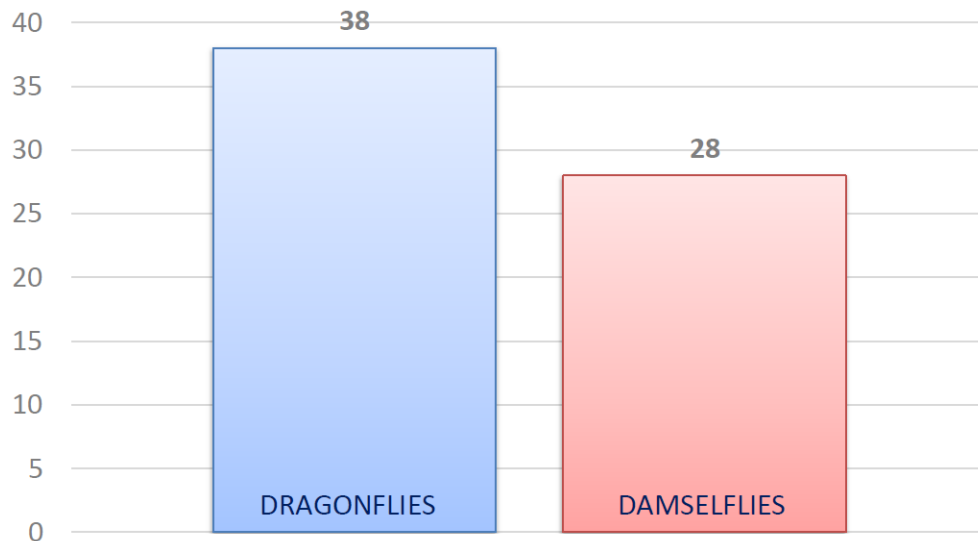


Fig. 1. Shows number of Dragonfly and Damselfly species recorded in study area

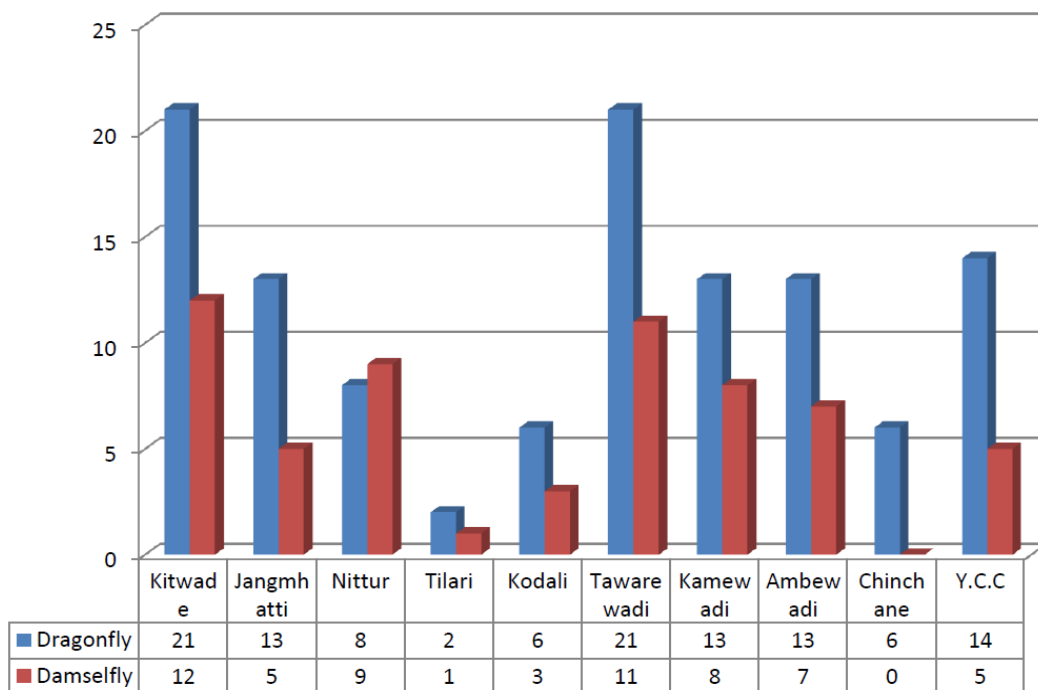


Fig. 2. Showing number of dragonfly and damselfly species recorded in different study sites

Among the recorded species *Neurothemis fulvia*, *Neurothemis tullia*, *Orthetrum internum*, *Urothemis signata*, *Ischnura rubilio*, *Ischnura nursei* and *Agriocnemis pieris* are the most dominant species in Marshland (Ambewadi) and Weedy pond (Tawarewadi) characterized by stagnant water covered with heterogeneous vegetation. Some of the species like *Brachythemis contaminata*, *Bradinopyga geminata*, *Diplacodes trivialis*, *Orthetrum sabina*,

Pantala flavescens and *Potamarcha congener* preferred open habitat. The other species like *Acisoma panorpoides*, *Trithemis aurora*, *Crocothemis servilia*, *Neurobasis chinensis*, *Vestalis apicalis*, *Pseudagrion decorum*, *Euphaea fraseri* and *Euphaea thosegharensis* were associated with rocky slow running stream shaded with heterogeneous vegetation and dense forest canopy habitat. These species also prefer paddy field. *Pseudagrion rubriceps*,

Paracercion malayanum found very close to water bodies.

3.2 Similarity in Species Composition

The dendrogram (Fig. 5) illustrates more or less similar influence on species composition. Overall pattern shows two are larger groups which

contain Tawarewadi, Kamewadi, Ambewadi, Jangmahatti and Kitwade as a first group and Nittur, Chinchane and Y.C.C as a second group. Kodali and Tilari study sites not showing much similarity with other study sites so they form different clades as third and fourth groups. Kamewadi and Ambewadi share highest similarity (60%) among them.

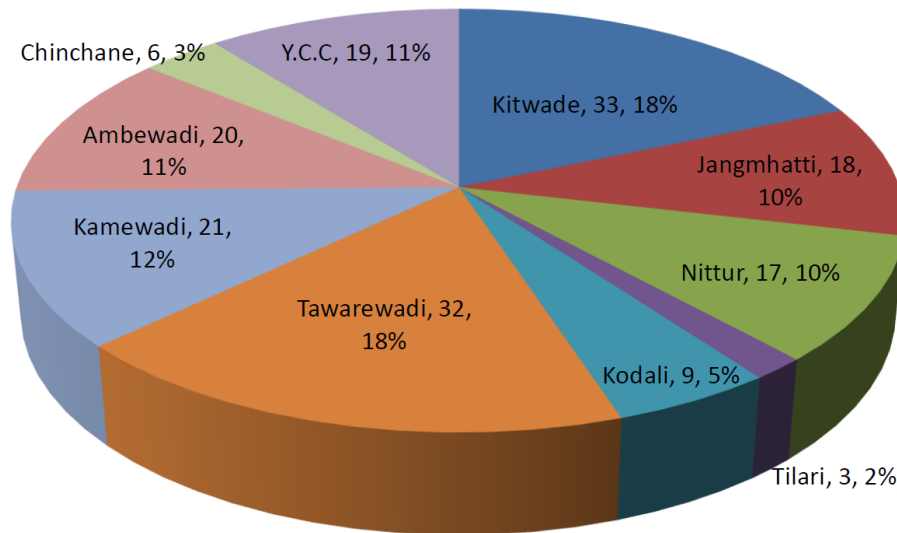


Fig. 3. Showing number and percentage of odonates species recorded in different study sites

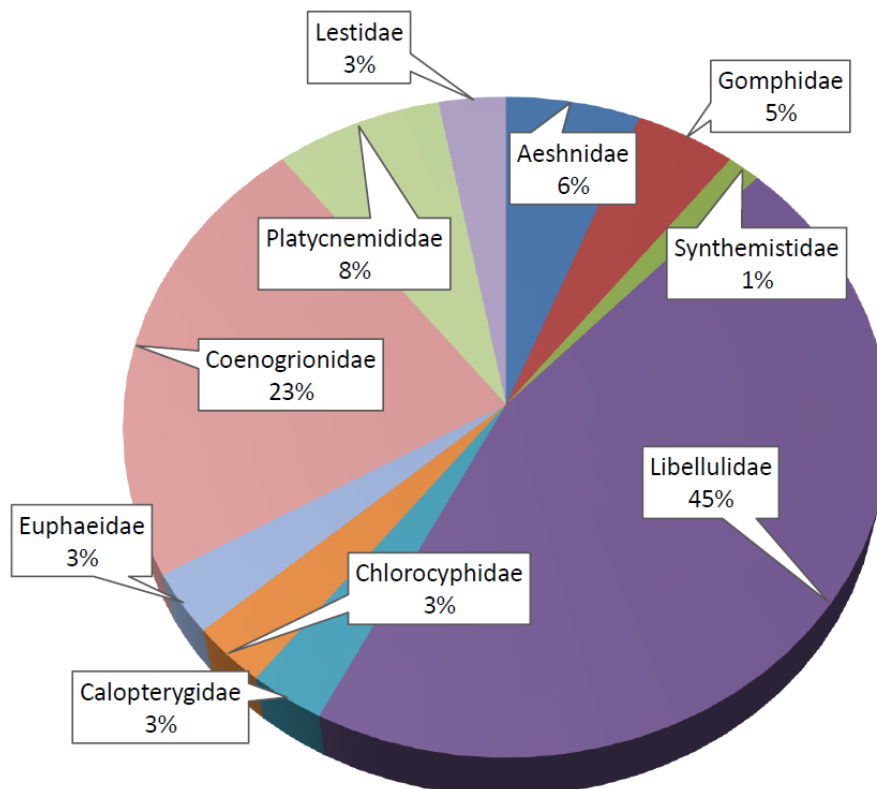
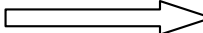
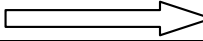
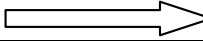


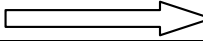
Fig. 4. Showing family wise percentage of odonate species recorded in study area

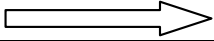
Table 2. Odonate species Recorded in Different Study Sites in Chandgad Taluka of Kolhapur district, Maharashtra

Sl. No.	Species Name	Name of the Study Site and their Habitat										Frequency
		Kitawade (A)	Jangmhatti (B)	Nittur (C)	Tilari (D)	Kodali (E)	Tawarewadi (F)	Kamewadi (G)	Ambewadi (H)	Chinchane (I)	Y.C.C (J)	
	Habitat 	SRS	SRS	SRS	FRS	LS	WP	RS	ML	SF	SU	
I. Suborder : Anisoptera												
A. Superfamily : Aeshnoidea												
1. Family : Aeshnidae												
1	<i>Anax guttatus</i> (Burmeister, 1839)	-	-	-	-	-	*	-	-	-	-	1
2	<i>Anax immaculifrons</i> (Rambur, 1842)	-	-	-	-	-	-	-	-	-	*	1
3	<i>Anax indicus</i> (Lieftinck, 1942)	-	-	-	-	*	-	-	-	-	-	1
4	<i>Gynacantha dravida</i> (Lieftinck, 1960)	-	-	-	-	-	-	-	-	-	*	1
B. Superfamily: Gomphoidea												
2. Family : Gomphidae												
5	<i>Burmagomphus</i>	*	-	-	-	-	-	-	-	-	-	1
6	<i>Ictinogomphus rapax</i> (Rambur, 1842)	*	-	-	-	*	*	-	-	-	-	3
7	<i>Merogomphus longistigma</i> (Fraser, 1922)	*	-	-	-	-	-	-	-	-	*	2
C. Superfamily : Libelluloide												
3. Family : Synthemistidae												
8	<i>Macromidia donaldi</i> (Fraser, 1924)	*	-	-	-	-	-	-	-	-	-	1
4. Family : Libellulidae												
9	<i>Acisoma panorpoides</i> (Rambur, 1842)	*	*	*	-	-	*	*	*	-	-	6
10	<i>Brachythemis contaminata</i> (Fabricius, 1793)	*	-	*	-	*	-	-	-	-	*	4
11	<i>Bradinopyga geminata</i> (Rambur, 1842)	-	-	-	-	-	-	-	-	*	*	2
12	<i>Brachydiplax sobrina</i> (Rambur, 1842)	-	*	-	-	-	-	-	-	-	-	1
13	<i>Crocothemis servilia</i>	*	*	-	-	-	*	-	*	-	-	4

Sl. No.	Species Name	Name of the Study Site and their Habitat										Frequency
		Kitawade (A)	Jangmhatti (B)	Nittur (C)	Tilari (D)	Kodali (E)	Tawarewadi (F)	Kamewadi (G)	Ambewadi (H)	Chinchane (I)	Y.C.C (J)	
	Habitat 	SRS	SRS	SRS	FRS	LS	WP	RS	ML	SF	SU	
	(Drury, 1770)											
14	<i>Diplacodes lefebvrii</i> (Rambur, 1842)	–	–	–	*	–	*	–	–	–	–	2
15	<i>Diplacodes trivialis</i> (Rambur, 1842)	*	–	–	–	–	*	*	–	*	*	5
16	<i>Hylaeothemis apicalis</i> (Fraser, 1924)	*	*	–	–	–	–	–	–	–	–	2
17	<i>Indothemis carnatica</i> (Fabricius, 1798)	–	*	–	–	–	–	–	–	–	–	1
18	<i>Indothemis limbata</i> (Selys, 1891)	*	*	–	–	–	*	–	–	–	–	3
19	<i>Neurothemis fulvia</i> (Drury, 1773)	–	–	–	–	*	*	–	*	–	*	4
20	<i>Neurothemis intermedia</i> (Rambur, 1842)	–	–	–	–	–	*	*	*	–	–	3
21	<i>Neurothemis tullia</i> (Drury, 1773)	–	–	–	–	–	*	*	*	–	–	3
22	<i>Orthetrum chrysis</i> (Selys, 1891)	–	*	–	–	–	–	–	*	–	–	2
23	<i>Orthetrum glaucum</i> (Brauer, 1865)	*	*	–	–	*	*	–	–	–	–	4
24	<i>Orthetrum luzonicum</i> (Brauer, 1868)	*	–	–	–	–	–	*	*	–	–	3
25	<i>Orthetrum pruinsum</i> (Burmeister, 1839)	*	*	*	–	–	*	*	*	*	*	8
26	<i>Orthetrum sabina</i> (Drury, 1770)	*	–	*	–	*	*	*	*	*	*	8
27	<i>Orthetrum taeniolatum</i> (Schneider, 1845)	*	*	–	–	–	–	*	*	–	–	4
28	<i>Palpopleura sexmaculata</i> (Fabricius, 1787)	*	–	–	–	–	*	–	–	–	*	3
29	<i>Pantala flavescens</i> (Fabricius, 1798)	*	*	*	–	–	*	*	*	*	*	8
30	<i>Potamarcha congener</i>	–	–	–	–	–	–	–	–	*	–	1

Sl. No.	Species Name	Name of the Study Site and their Habitat										Frequency
		Kitawade (A)	Jangmhatti (B)	Nittur (C)	Tilari (D)	Kodali (E)	Tawarewadi (F)	Kamewadi (G)	Ambewadi (H)	Chinchane (I)	Y.C.C (J)	
	Habitat 	SRS	SRS	SRS	FRS	LS	WP	RS	ML	SF	SU	
	(Rambur, 1842)											
31	<i>Rhyothemis variegata</i> (Linnaeus, 1763)	–	–	*	–	–	*	*	*	–	–	4
32	<i>Tholymis tillarga</i> (Fabricius, 1798)	*	–	–	–	–	–	–	–	–	*	2
33	<i>Tramea limbata</i> (Desjardins, 1832)	*	–	–	–	–	*	–	–	–	*	3
34	<i>Trithemis aurora</i> (Burmeister, 1839)	*	*	*	–	–	*	*	–	–	–	5
35	<i>Trithemis festiva</i> (Rambur, 1842)	*	*	*	–	–	*	*	–	–	*	6
36	<i>Trithemis kirbyi</i> (Selys, 1891)	–	–	–	–	–	*	*	–	–	–	2
37	<i>Urothemis signata</i> (Rambur, 1842)	–	–	–	–	–	*	–	*	–	–	2
38	<i>Zygonyx iris</i> (Selys, 1869)	–	–	–	*	–	–	–	–	–	–	1
II. Suborder : Zygoptera												
D. Superfamily: Calopterygoidea												
5. Family : Calopterygidae												
39	<i>Neurobasis chinensis</i> (Linnaeus, 1758)	*	–	–	–	–	–	–	–	–	–	1
40	<i>Vestalis apicalis</i> (Selys, 1873)	*	–	*	–	–	–	–	–	–	*	3
6. Family : Chlorocyphidae												
41	<i>Heliocypha bisignata</i> (Hagen in Selys, 1853)	*	–	–	*	–	–	–	–	–	–	2
42	<i>Libellago indica</i> (Fraser, 1928)	*	–	–	–	–	–	*	–	–	–	2
7. Family : Euphaeidae												
43	<i>Euphaea fraseri</i> (Laidlaw, 1920)	*	*	–	–	–	–	–	–	–	–	2
44	<i>Euphaea thosegharensis</i> (Sadasivan & Bhakare,	*	–	–	–	–	–	–	–	–	–	1

Sl. No.	Species Name	Name of the Study Site and their Habitat										Frequency
		Kitawade (A)	Jangmhatti (B)	Nittur (C)	Tilari (D)	Kodali (E)	Tawarewadi (F)	Kamewadi (G)	Ambewadi (H)	Chinchane (I)	Y.C.C (J)	
	Habitat 	SRS	SRS	SRS	FRS	LS	WP	RS	ML	SF	SU	
	2021)											
	E. Superfamily : Coenagrionoidea											
	8. Family : Coenagrionidae											
45	<i>Aciagrion approximans</i> (Selys, 1876)	*	–	–	–	–	–	*	*	–	–	3
46	<i>Agriocnemis pieris</i> (Laidlaw, 1919)	–	–	–	–	–	–	–	*	–	–	1
47	<i>Agriocnemis pygmaea</i> (Rambur, 1842)	–	–	–	–	–	*	–	–	–	*	2
48	<i>Agriocnemis splendissima</i> (Laidlaw, 1919)	*	*	–	–	–	*	–	*	–	–	4
49	<i>Ceriagrion coromandelianum</i> (Fabricius, 1798)	–	–	*	–	–	*	–	*	–	*	4
50	<i>Ceriagrion olivaceum</i> (Laidlaw, 1914)	–	–	–	–	*	*	–	–	–	–	2
51	<i>Ceriagrion rubiae</i> (Laidlaw, 1916)	–	–	*	–	*	*	–	–	–	*	4
52	<i>Ischnura rubilio</i> (Selys, 1876)	–	*	*	–	–	*	*	*	–	*	6
53	<i>Ischnura nursei</i> (Morton, 1907)	–	–	–	–	–	–	–	*	–	–	1
54	<i>Paracercion malayanum</i> (Selys, 1876)	–	–	–	–	–	*	–	–	–	–	1
55	<i>Pseudagrion indicum</i> (Fraser, 1924)	–	–	–	–	–	–	–	*	–	–	1
56	<i>Pseudagrion malabaricum</i> (Fraser, 1924)	*	–	–	–	–	*	–	–	–	–	2
57	<i>Pseudagrion microcephalum</i> (Rambur, 1842)	*	–	–	–	*	*	–	–	–	–	3
58	<i>Pseudagrion rubriceps</i> (Selys, 1876)	–	*	–	–	–	*	*	–	–	–	3
59	<i>Pseudagrion decorum</i> (Rambur, 1842)	*	–	–	–	–	–	*	–	–	–	2

Sl. No.	Species Name	Name of the Study Site and their Habitat										Frequency
		Kitawade (A)	Jangmhatti (B)	Nittur (C)	Tilari (D)	Kodali (E)	Tawarewadi (F)	Kamewadi (G)	Ambewadi (H)	Chinchane (I)	Y.C.C (J)	
	Habitat 	SRS	SRS	SRS	FRS	LS	WP	RS	ML	SF	SU	
9. Family : Platycnemididae												
60	<i>Caconeura ramburi</i> (Fraser, 1922)	*	-	-	-	-	-	-	-	-	-	1
61	<i>Copera vittata</i> (Selys, 1863)	-	-	*	-	-	-	*	-	-	-	2
62	<i>Copera marginipes</i> (Rambur, 1842)	-	-	*	-	-	-	-	-	-	-	1
63	<i>Disparoneura quadrimaculata</i> (Rambur, 1842)	-	-	*	-	-	-	-	-	-	-	1
64	<i>Prodaineura verticalis</i> (Selys, 1860)	-	-	-	-	-	*	-	-	-	-	1
Superfamily : Lestoidea												
10. Family : Lestidae												
65	<i>Lestes elatus</i> (Hagen in Selys, 1862)	-	*	*	-	-	-	*	-	-	-	3
66	<i>Lestes viridulus</i> (Rambur, 1842)	-	-	*	-	-	-	*	-	-	-	2

Note: (.) - indicate species recorded, (-) - indicate species not recorded

Table 3. genera wise number of odonate species recorded in study area

Sl. No.	Name of the Genera	Number of species recorded	Sl. No.	Name of the Genera	Number of species recorded
1	<i>Gynacantha</i>	1	22	<i>Libellago</i>	1
2	<i>Burmagomphus</i>	1	23	<i>Heliocypha</i>	1
3	<i>Ictinogomphus</i>	1	24	<i>Aciagrio</i>	1
4	<i>Merogomphus</i>	1	25	<i>Paracercion</i>	1
5	<i>Macromidia</i>	1	26	<i>Caconeura</i>	1
6	<i>Acisoma</i>	1	27	<i>Disparoneura</i>	1
7	<i>Brachythemis</i>	1	28	<i>Prodasineura</i>	1
8	<i>Bradinopyga</i>	1	29	<i>Diplacodes</i>	2
9	<i>Brachydiplax</i>	1	30	<i>Indothemis</i>	2
10	<i>Crocothemis</i>	1	31	<i>Euphaea</i>	2
11	<i>Hylaeothemis</i>	1	32	<i>Ischnura</i>	2
12	<i>Palpopleura</i>	1	33	<i>Copera</i>	2
13	<i>Pantala</i>	1	34	<i>Lestes</i>	2
14	<i>Potamarcha</i>	1	35	<i>Anax</i>	3
15	<i>Rhyothemis</i>	1	36	<i>Neurothemis</i>	3
16	<i>Tholymis</i>	1	37	<i>Trithemis</i>	3
17	<i>Tramea</i>	1	38	<i>Agriocnemis</i>	3
18	<i>Urothemis</i>	1	39	<i>Ceriagrion</i>	3
19	<i>Zygonyx</i>	1	40	<i>Pseudagrion</i>	5
20	<i>Neurobasis</i>	1	41	<i>Orthetrum</i>	6
21	<i>Vestalis</i>	1	Total		66

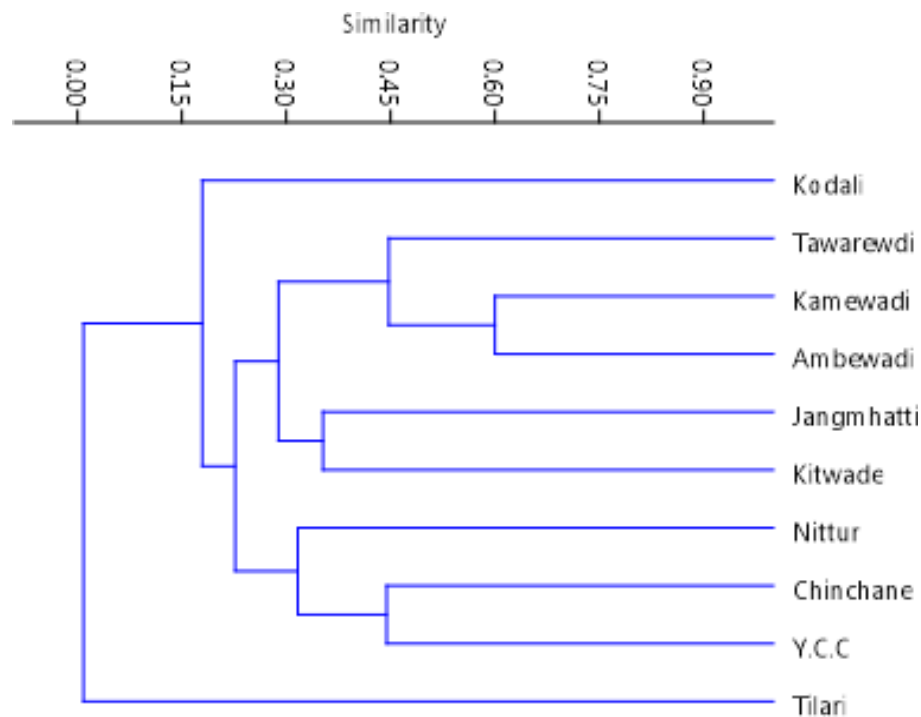


Fig. 5. A dendrogram show the similarity in species composition between different habitat types

4. DISCUSSION

Chandgad taluka is rich in odonate diversity representing 14% of odonate species recorded in Indian subcontinent, 34% of species documented in the Western Ghats and 46% of species reported from Maharashtra. The weedy pond and rocky slow running streams shaded with riparian vegetation and dense forest canopy habitat supporting more number of odonate species than fast running stream, semi forest and open lake side (without vegetation cover) habitat. The variety of wetland biomass present on the water body supports the life cycle and breeding activity of odonates. Our findings also corroborates the results of Kulkarni & Subramanian (2013) that, the species composition depends upon landscape structure and vegetation cover. We noticed that, among the array of species in all the habitats, in specific habitats - specific dragonflies/damselflies show their abundance. It also depends upon the season and type of riparian vegetation present. Specific season and riparian vegetation play an important role in species diversity and abundance.

There is a seasonal pattern of odonate distribution. Some species are dominating in the rainy season (June to September) and some species are dominating in summer (December to

April). Gomphidae and Coenagrionidae species predominantly found in June to August. Whereas, Aeshnidae species found in summer season. Likewise, *Brachydiplax sobrina*, *Ictinogomphus rapax*, *Neurothemis fulvia*, *Neurothemis tullia*, *Orthetrum internum*, *Rhyothemis variegata*, *Urothemis signata*, *Vestalis apicalis*, and *Euphaea fraseri* species abundantly found only in June to September. *Acisoma panorpoides*, *Crocothemis servilia*, *Pseudagrion rubriceps* and *Trithemis* species recorded in present study are (Table 2) abundantly found during October to April. Some more studies are needed in this direction to analyze the seasonal distribution of odonates.

The dendrogram illustrate two large groups Tawarewadi, Kamewadi, Ambewadi, Jangmhatti Kitwade and Nittur, Chinchane, Y.C.C shows more or less similar type of species composition and vegetation cover (Fig. 5). The dragonflies were abundantly present in almost all the study sites (Fig. 2). The study sites characterized with rocky habitat with riparian vegetation contribute more number of odonate species. The study sites Chinchane and Y.C.C had open habitat with a canopy cover of the deciduous forest without natural water reservoir. The odonate species of these sites are adapted for man-made water resources such as cement cisterns, small pits

and mining ditches. The common thing in these habitats is anthropogenic activity like industrialization, mining and urbanization. Therefore very few generalist species were recorded from these habitats. Tilari study site is of fast running stream habitat lacks vegetation cover and not supporting wetland vegetation. On the other hand Kodali study site is also lacks vegetation cover and pH ranges from 6.2 to 6.7. Hence, in these habitats very few odonate species were recorded (Fig. 2) and formed different clade in dendrogram (Fig. 5).

Odonates are highly responsive to environmental changes including anthropogenic activity (Emiliyamma et al., 2005). We noticed that, there is a decrease in number of odonate species and their abundance after reopening of Daulat Sugar Factory in Halkarni nearer to YCC campus. After reopening of the said factory due to heavy dumping of factory waste, ash dusting on all over the plantation there is a tremendous change in habitat structure. This type of anthropogenic activity causes loss of habitat quality and local extinctions of dragonflies, especially the habitat of specialists (Harabis and Dolny, 2011).

The dragonflies are considered as more sensitive to habitat disturbance and their presence in any water body confirms its synthetic pollution-free status (Zia et al., 2009; Zia, 2010). The agricultural habitat supports the effective number of odonate species. Many odonate species complete their life cycle in paddy or sugarcane field (Seidu et al., 2017). Tawarewadi weedy pond appear to be good habitat for odonate diversity situated in densely populated area along the roadside surrounded by sugar cane and paddy field. Several larval and adult odonates feed on many insects such as mosquitoes (Culicidae), deer flies (Tabanidae), blackflies (Simuliidae) and other dipterans that are pest of humans and domestic animals. *Crocothemis servilia* species effectively used to control the paddy jassid *Nilaparvata* sp., paddy borer *Chilo suppressalis* (Walker) and jowar stem borer *Chilo partellus* (Bhusnar and Sathe, 2017). Therefore, we need to conserve natural habitats and consider odonates as biocontrol agent as well as ecological indicators. Among the present study sites, Chinchane and YCC campus are under threat due to intensive anthropogenic activities like mining and industrialization. Some conservation measures are needed to be taken up to conserve these habitats to protect

odonates and other insects which maintain ecological health in nature.

5. CONCLUSION

Chandgad taluk of Kolhapur district in Maharashtra is very rich in odonate diversity. Dragonfly species were recorded in maximum number compared to damselfly species. Libellulidae family members were dominating and are most common species recorded. Odonates prefer the slow running stream habitats and stagnant water bodies rather than fast moving stream habitats. It is also observed that, odonates show seasonal distribution.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

ACKNOWLEDGEMENTS

Author wish to acknowledge forest department officials CF Kolhapur, DFO Kolhapur, RFO Patne Phata, RFO Chandgad for access to the forest area. Author also thank the Principal, Yashwantrao Chavan Mahavidyalaya Halkarni for providing facilities.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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