CLIMATE CHANGE EFFECTS ON TROPICAL ODONATE COMMUNITY

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ABSTRACT

Climate change, such as increased rainfall variability, has affected Yavatmal district in the last decade. Uncertainty of rainfall affects the inter-annual vegetation growth, and thus biodiversity. A baseline study was carried out in 4 habitats in Waghadi basin of Yavatmal district to analyse Odonates species abundance, richness, and diversity as a prerequisite for the protection and management of these habitats. A total of 1263 individuals of 30 species distributed in 6 families were collected. Libellulidae is most dominant family with 13 species. The influence of vegetation on species richness and diversity was analysed (using normalized difference vegetation index values at buffer zones of 1000 m, 500 m, 100 m and 50 m), with further research into the trends of species diversity for each habitat. There was an increase in species richness and diversity with an increase in the dense vegetation, especially around temporary water bodies. This study indicates the contribution of temporary water bodies to ecosystem function and suggests its conservation by monitoring the impacts of increased rainfall variability and anthropogenic influence using odonates.

Keywords: *climate change, diversity, NDVI-index, odonates, vegetation*

INTRODUCTION

Anthropogenic climate change is a cause of increased weather variability that leads to uneven regional impacts on water resources. Climate change is further predicted to shift the hydrological cycle, which would affect the flow, depth, and existence of fresh water supplies, further affecting drinking, rain-fed agriculture, groundwater recharge, forestry, biodiversity and communities that heavily depend on it [1]. Therefore, the first step towards a sustainable, climate-resilient water supply is to monitor the water flow by building strategies to conserve habitats and resources. A novel and cost-effective approach for monitoring water resources, which provides early warning, detailed evidence, and rapid indication of changes in climate patterns, is through biomonitoring of odonates [2].

There are a total of 7000 species of odonates worldwide, including dragonflies and damselflies [3]. It is estimated that there are about 498 species in India [4], of which 28 % (134 species) are found in Maharashtra [5] with 15 % (72) specific to Vidharbha region [6] and 8 % (38 species) specific to the wetlands of Yavatmal district [7]. Adult odonates breed on water and depend on surrounding terrestrial habitat, primarily of mosaic type in nature. An ideal habitat has scrub, woodland, grassland and bare ground near the water's edge that provides the area for hunting, basking and roosting so that the breeding site is under less competitive pressure. Adult dragonflies need feeding and roosting areas near their breeding places. They and their prey require warmth; therefore, sunny, sheltered places are provided by trees and bushes. Trees and bushes should not be near the water's edge, but ideally a few meters away. Usually, some species will use shelter at some distance from the water. Tall marsh plants provide reasonable shelter along treeless fens and levels. Odonates larvae are ambush predators and use vegetation to find food. When larvae are ready to become a dragonfly or damselfly, they need to find the stalk of an emerging wetland plant to crawl up. Once out of the water, dragonflies and damselflies are very vulnerable to predation. Wetland vegetation provides shelter and camouflage from predators and during bad or windy weather. The distribution of the odonates in the landscape is changing under the influence of climate change, habitat alteration, invasive species, and other factors strongly associated with anthropogenic influence [8]. Because of their sensitivity, they are recognized as a good indicator of terrestrial and aquatic ecosystems as a means of assessing water quality and health, as well as risks to biodiversity.

Rainfall increases water availability, either through forming temporary aquatic habitats or by increasing the depth and flow of water in seasonal and perennial water bodies. This has a direct impact on odonates abundance and diversity. An indirect impact of rainfall on odonates is through availability of food due to an increase in density and distribution of vegetation, which leads to an increase in insect numbers.

The major threats due to rainfall variability in the district were early season, mid-season and terminal drought, unseasonal rainfall, and hailstorms. This led to effects such as limited or delayed release of water from canals, insufficient groundwater recharge, waterlogging, severe damage to crops and assets, and pests and disease outbreak.

The odonates diversity and abundance highly depends on the seasonality and humidity, influenced by variation in rainfall patterns [9]. Increased rainfall variability could affect species migration and breeding, and have a detrimental effect on oviposition due to the temporary habitats drying up before larval development [10].

Waghadi River is one of the important tributes of River Vainganga that flows through the cities of Yavatmal and Kelapur. Waghadi dam, constructed on this river, is a medium type of dam which is used for the purpose of irrigation.

The objective of this research is to create a baseline study to highlight the present status of the species in the project area with the aim of supporting future conservation and management strategies resilient to the impacts of climate change. This study estimates species distribution, richness, and diversity of adult odonates in different habitats. This study also shows the dominant and rare species available in each habitat with their distribution within the different habitats. The species diversity obtained was then correlated with the normalized difference vegetation index (NDVI) values obtained at various buffer zones within Waghadi River basin.

This baseline study will be used to build upon the changes observed in species distribution, diversity, and richness within the same habitats in the following years with a scope of understanding whether it can be directly attributed to the impacts of climate change, bringing a cost-effective approach for monitoring climate variability, conservation measures and anthropogenic influence.

MATERIALS AND METHODS

Characterization of the study area

Yavatmal district falls under agro-climatic zone of Western plateau and hills region under planning commission, which is further categorized as Central Vidharbha Zone under National Agricultural Research Project (NARP). This zone, also known as the zone of moderate rainfall, has an average annual rainfall of 1080 mm in the district, majorly from Southwest monsoon from June to September and partly from Northeast monsoon between October and December. Cultivable area dominates the land use followed by forest area, which accounts for one-sixth of the geographical area of the district. Ninety-five percent of the cultivable area is completely dependent on rainfall and 5 % of the area uses only canals and open wells as a source of irrigation. Long-term rainfall trends were analysed to understand intra-district variability and deficit years.

Characterization of data collection site

Sampling was done on four sites categorized as marshland, pond, river, and seasonal stream.

Marshland: The area primarily consists of agricultural land surrounded by scrub forest with a low vegetation cover, less than 10 % of shaded area, and an open area characterized by mud pits. The area is dominated by grasses of a height of 0.3 m. The disturbance is moderate to high due to presence of the road and activities like cattle grazing and wallowing.

Pond: The pond is primarily surrounded by mosaic kind of habitat mixed with agricultural land, forest, water body, and patches of area dominated either by agriculture or scrub forest. The area has a good vegetation cover with approximately 60 % of shaded area, but has high disturbance due to anthropogenic activities like fishing and cattle grazing. The bottom substrate of the pond has predominantly high leaf litter and marginal aquatic macrophytes.

River: The river is primarily surrounded by agricultural land with moderate vegetation cover, scrub forest with patchy vegetation, and mosaic type of habitat with agriculture and scrub forests. This habitat has approximately 40 % of shaded area, with low to high disturbance due to the presence of human settlements. The bottom substrate of the river is composed of aquatic macrophytes (both submerged and emergent vegetation) and pebbles.

Seasonal Stream: The seasonal stream is primarily surrounded by agricultural land and a patch of forest area with moderate vegetation cover, approximately 50 % of shaded area and moderate to high disturbance due to the presence of human settlements. The bottom substrate of the seasonal stream is composed of aquatic macrophytes (mostly submerged vegetation), moderate leaf litter, low sand patches, and pebbles.

Data collection methodology

The comprehensive study was carried out in September 2019 for 7 days, during which sampling and an active search were carried out for 8 hours, between 8:00 to 16:00 hours, which is the local peak of odonates flight activity at all the biotopes. Line transect method was used during sampling following Moore and Corbet (1990) [11] and Brook (1993) [12] methodology. Observations were made while walking on fixed transect of 500 m length. The species encountered in 5 m breadth on either side were considered and identified following the works of the field guide by Subramanian (2005) [13] and Wildlife of Central India: Photographic Field Guide by David R. & Surya R. (2017) [14]. Systematic arrangement of the species followed the works of Subramanian (2017) [15].

Data analysis

The species abundance, richness and diversity were calculated for all the observed adult odonates from the collection sites in the four identified biotopes. The diversity was calculated using Shannon Wiener index and Simpson's index. The Normalized difference vegetation index (NDVI) values were obtained from Landsat 8 (United States Geological Survey) at buffer zones of 50, 100, 500, and 1000 m from the sampled points. The results estimated the dominant and rare species in each habitat. Using SPSS 20 for Windows through Spearman's rho, the species diversity and species richness were correlated with the mean NDVI values of the above-mentioned buffer zones. This was further analysed by categorizing the NDVI range within each habitat and species diversity into groups (low, medium, and high) to understand the correlation between species diversity and NDVI range at all the above-mentioned buffer zones within each habitat.

RESULTS AND DISCUSSION

Faunal composition

In Yavatmal district within Waghadi basin, a total of 1263 individuals of 30 species distributed in 6 families were collected (Table 1). Libellulidae is most dominant with 13 species, followed by Coenagrionidae with 9 species, and Aeshnidae, Gomphidae, Lestidae and Platycnemididae with 2 species each. The most abundant species were *Pantala flavescens* (Fabricius, 1798), followed by *Brachythemis contaminata* (Fabricius, 1793), and *Pseudagrion microcephalum* (Rambur, 1842) with species abundances of 23.1, 15.2 and 15, respectively. A similar trend was observed in another study conducted in the district, with Libellulidae as the dominant family followed by Coenagrionidae [7].

The species *Pantala flavescens, Diplacodes lefebvrii* (Rambur, 1842), *Brachythemis contaminata*, in family Libellulidae are the most widespread species commonly found in sluggish areas where they dart about and spend most of the time perching in the sun contributing to the species richness of the habitats. Libellulidae are the members of medium-sized dragonflies which participate in active and passive means of thermoregulation, such as frantic feeding, wing whirring and basking, at different locations to increase and decrease the amount of radiation. Due to this, they are found in both open areas and shaded areas. Coenagrionidae are found anywhere along the edges of water streams, including water bodies which are artificial and severely disturbed, making them the second most dominant family in the study area after Libellulidae.

Species richness, abundance, and diversity

a) Marshland

The sampled plots analysed for this habitat showed minimal variation in species richness, ranging from 7 to 8 between the plots, with a total of 12 species in the marshland. The most abundant species in this habitat are *Pantala flavescens* (Libellulidae), followed by *Diplacodes lefebvrii* (Libellulidae), with species abundance of 44 and 15, respectively. The species abundance of all the observed species in the marshland is shown in Figure 1. The species diversity for this habitat calculated through Shannon Wiener index is 1.48 and through Simpson's index is 0.33.

b) Pond

The sampled plots analysed for this habitat showed a large variation in species richness, ranging from 3 to 12 between the plots, with a total of 18 species in the pond. The most abundant species in this habitat are *Diplacodes lefebvrii* (Libellulidae), followed by *Brachythemis contaminata* (Libellulidae) and *Pseudagrion microcephalum* (Coenagrionidae), with species abundance of 19, 18 and 15, respectively. The species abundance of all the observed species in the pond is shown in Figure 2. The species diversity for this habitat calculated through Shannon Wiener index is 2.05 and through Simpson's index is 0.2.

Table 1. List of odonates species observed during the studied period

No.	Common name	Scientific name	Family
1.	Rusty Darner	*Anaciaeschna jaspidea* (Burmeister, 1839)	Aeshnidae
2.	Blue Darner	*Anax immaculifrons* (Rambur, 1842)	Aeshnidae
3.	Pygmy Dartlet	*Agriocnemis pygmaea* (Rambur, 1842)	Coenagrionidae
4.	Coromandel Marsh Dart	*Ceriagrion coromandelianum* (Fabricius, 1798)	Coenagrionidae
5.	Golden Dartlet	*Ischnura aurora* (Brauer, 1865)	Coenagrionidae
6.	Pixie Dartlet	*Ischnura nursei* (Morton, 1907)	Coenagrionidae
7.	Senegal Golden Dartlet	*Ischnura senegalensis* (Rambur, 1842)	Coenagrionidae
8.	Three-lined Dart	*Pseudagrion decorum* (Rambur, 1842)	Coenagrionidae
9.	Violet-striped Blue Dart	*Pseudagrion hypermelas* (Selys, 1876)	Coenagrionidae
10.	Blue Grass Dart	*Pseudagrion microcephalum* (Rambur, 1842)	Coenagrionidae
11.	Saffron-faced Blue Dart	*Pseudagrion rubriceps* (Selys, 1876)	Coenagrionidae
12.	Indian Common Clubtail	*Ictinogomphus rapax* (Rambur, 1842)	Gomphidae
13.	Common Hook-Tail	*Paragomphus lineatus* (Selys, 1850)	Gomphidae
14.	Lestes species	*Lestes* sp.	Lestidae
15.	Brown Spreadwing	*Lestes umbrinus* (Selys, 1891)	Lestidae
16.	Trumpet-Tail	*Acisoma panorpoides* (Rambur, 1842)	Libellulidae
17.	Ditch Jewel	*Brachythemis contaminata* (Fabricius, 1793)	Libellulidae
18.	Granite Ghost	*Bradinopyga geminata* (Rambur, 1842)	Libellulidae
19.	Scarlet Skimmer	*Crocothemis servilia* (Drury, 1770)	Libellulidae
20.	Black Ground Skimmer	*Diplacodes lefebvrii* (Rambur, 1842)	Libellulidae
21.	Blue Ground Skimmer	*Diplacodes trivialis* (Rambur, 1842)	Libellulidae
22.	Green Marsh Hawk	*Orthetrum sabina* (Drury, 1770)	Libellulidae
23.	Wandering Glider	*Pantala flavescens* (Fabricius, 1798)	Libellulidae
24.	Yellow-tailed Ashy Skimmer	*Potamarcha congener* (Rambur, 1842)	Libellulidae
25.	Coral-Tailed Cloudwing	*Tholymis tillarga* (Fabricius, 1798)	Libellulidae
26.	Red Marsh Trotter	*Tramea basilaris* (Palisot de Beauvois, 1805)	Libellulidae
27.	Crimson Marsh Glider	*Trithemis aurora* (Burmeister, 1839)	Libellulidae
28.	Long-Legged Marsh Glider	*Trithemis pallidinervis* (Kirby, 1889)	Libellulidae
29.	Yellow Bush Dart	*Copera marginipes* (Rambur, 1842)	Platycnemididae
30.	Black-winged Bambootail	*Disparoneura quadrimaculata* (Rambur, 1842)	Platycnemididae

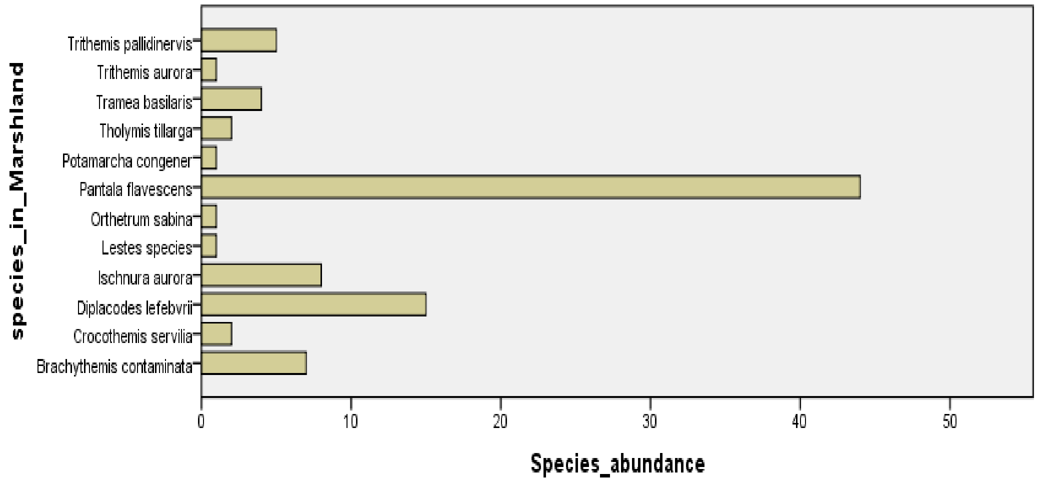

Figure 1. Species abundance in the marshland

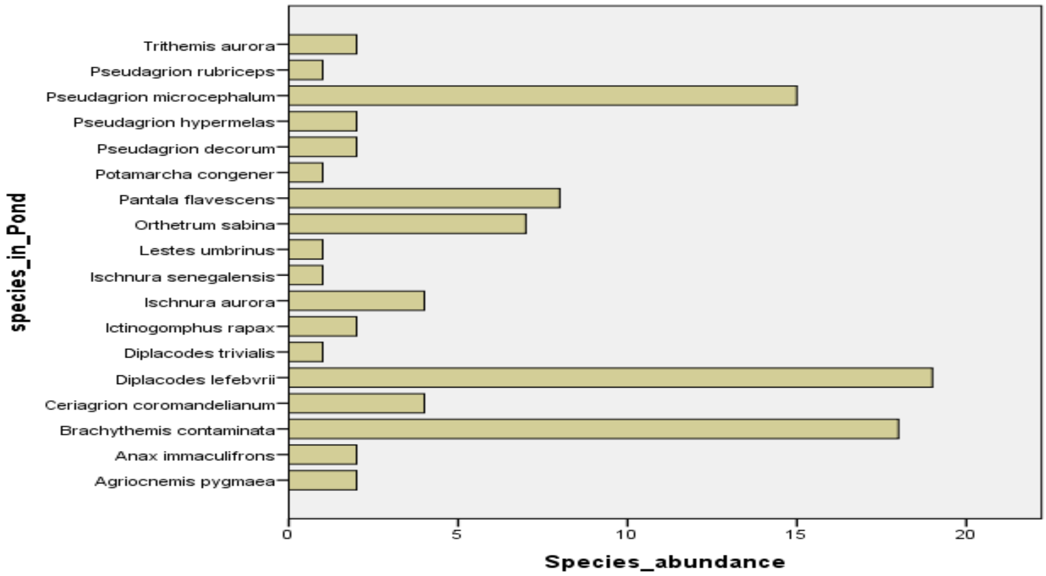

Figure 2. Species abundance in the pond

c) River

The sampled plots analysed for this habitat showed a large variation in species richness, ranging from 5 to 13 between the plots, with a total of 19 species in the river. The most abundant species in this habitat are *Pantala flavescens* (Libellulidae), followed by *Brachythemis contaminata* (Libellulidae), with species abundance of 25 and 23, respectively. The species abundance of all the observed species in the river is shown in Figure 3. The species diversity for this habitat calculated through Shannon Wiener index is 2.05 and through Simpson's index is 0.19.

d) Seasonal steam

The sampled plots analysed for this habitat showed a slight variation in species richness, ranging from 7 to 10 between the plots, with a total of 15 species in the seasonal stream. The most abundant species in this habitat are *Disparoneura quadrimaculata* (Rambur, 1842), followed by *Brachythemis contaminata* and *Pantala flavescens,* with species abundance of 13, 12 and 11, respectively. The species abundance of all the observed species in the seasonal streams is shown in Figure 4. The species diversity for this habitat calculated through Shannon Wiener index is 2.13 and through Simpson's index is 0.14.

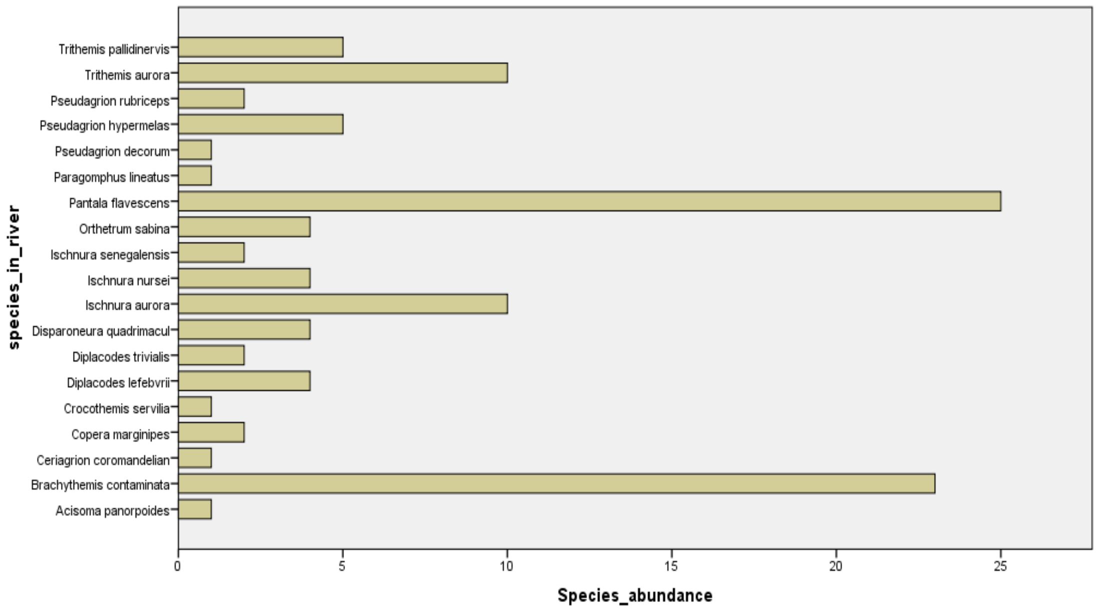

Figure 3. Species abundance in the river

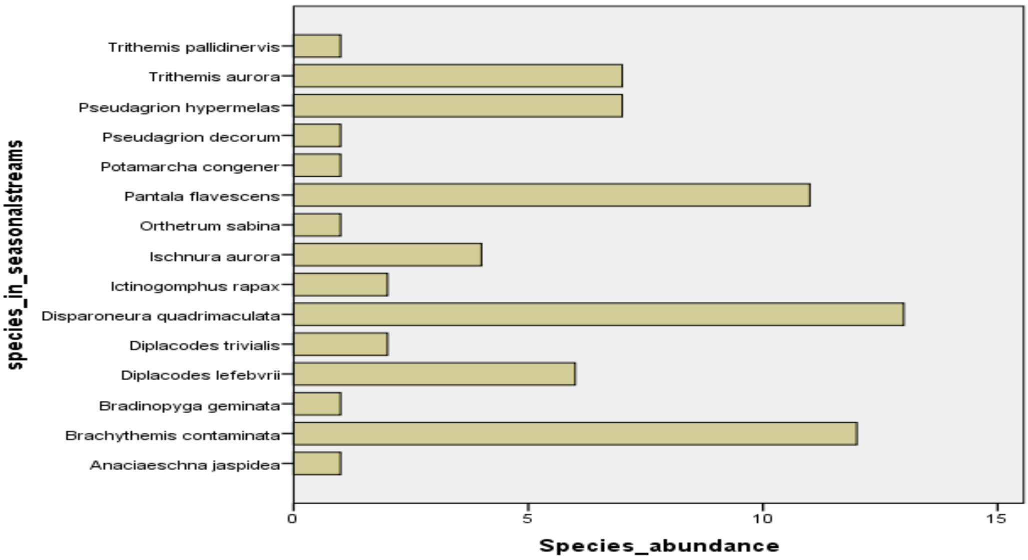

Figure 4. Species abundance in the seasonal streams

It was observed that species diversity is higher in the seasonal stream, the river and the pond, which can be attributed to the tendency of the odonates to be dependent on the aquatic habitat. The main feature that defines the species distribution is the water-body type, categorized as lotic (river and seasonal stream) and lentic (pond and marshland). Lotic and lentic water-body types are further categorized into temporary and perennial water bodies.

The study area can be considered to have both generalist and habitat-specific species. *Brachythemis contaminata*, *Diplacodes lefebvrii*, *Ischnura aurora* (Brauer, 1865), *Pantala flavescens*, *Trithemis aurora* (Burmeister, 1839) and *Orthetrum sabina* (Drury, 1770) were found in lentic and lotic water-body types and in permanent and temporary water bodies. Their high dominance in permanent water bodies makes them migrate towards the temporary water bodies to avoid competition during breeding and egg-laying phase. Due to this behaviour, they may be regarded as highly adaptable and widespread generalist species.

Disparoneura quadrimaculata was the only species found in the lotic water-body type with an ability to migrate towards temporary water body, but not towards a lentic water-body type. Due to this, they can be considered as habitat-specific species [16]. 11 species were unique to a particular habitat, which is why they can also be considered as habitat-specific species.

Ceriagrion coromandelianum (Fabricius, 1798), *Ischnura senegalensis* (Rambur, 1842), and *Agriocnemis pygmaea* (Rambur, 1842) were found only in permanent water bodies of lentic and lotic water-body types. *Pseudagrion decorum* (Rambur, 1842) and *Pseudagrion hypermelas* (Selys, 1876), were found in specific aquatic habitats and can be associated with the presence of shade and aquatic macrophytes.

Dominant species

The dominant species present in all the sampled habitats are *Brachythemis contaminata*, *Diplacodes lefebvrii*, *Ischnura aurora*, *Pantala flavescens*, *Trithemis aurora* and *Orthetrum sabina.* Figure 5 compares the abundance of the dominant species in different habitats.

Pantala flavescens commonly uses temporary ponds, occasionally breeds in permanent water, and was mostly observed in marshland and river habitats. *Diplacodes lefebvrii* requires well-vegetated freshwater habitat and was mostly observed in pond and marshland. *Brachythemis contaminata* inhabits slow-moving streams, is tolerant to disturbance and was mostly observed in the pond, river and seasonal stream. *Trithemis aurora* uses diverse habitats and was mostly observed in lentic water bodies (River and Seasonal Stream). *Orthetrum sabina* prefers still water habitats, has high tolerance to habitat disturbance and was mostly observed in permanent water bodies (river and pond).

Ischnura aurora in family Coenagrionidae was a dominant species mostly observed in the river and the marshland. *Pseudagrion microcephalum* in family Coenagrionidae was a dominant species observed only in the pond habitat. Most of the dominant species were found in lentic water bodies due to their high dispersal capacity resulting in larger ranges and wider ecological preferences and are therefore exposed to lower risk of extinction [17].

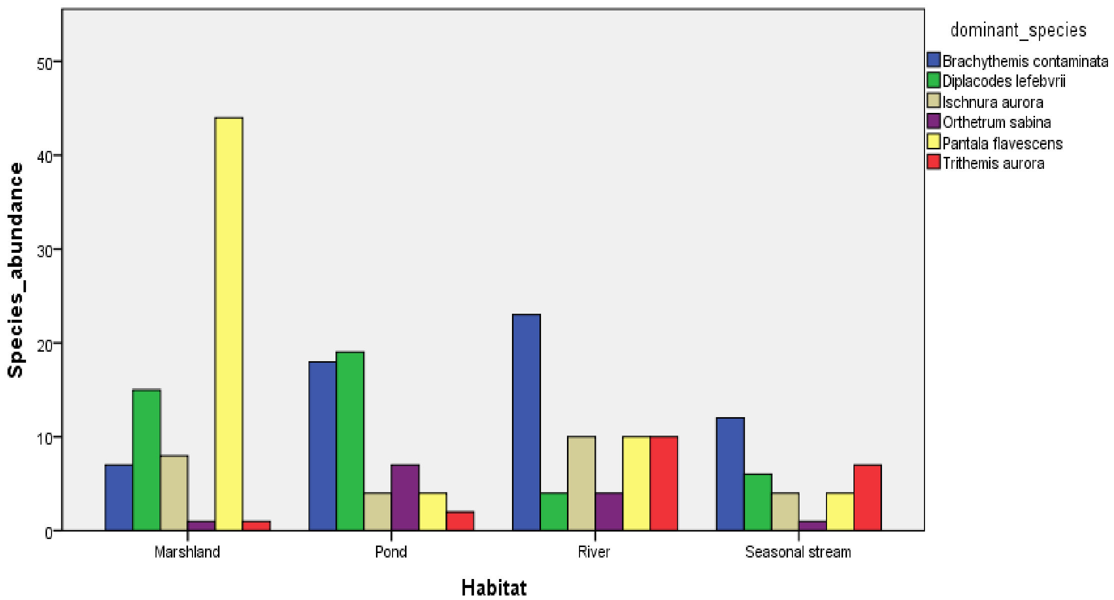

Figure 5. Comparison of dominant species in all habitats

Rare species

Of all species collected for each habitat, there were many species that were represented as singletons (represented by the single individual), doubletons (represented by two individuals), unique (present only in one habitat) and duplicates (present only in two habitats). Table 2 represents the number of these rare species for each habitat.

Table 2. Type of rare species present in each habitat

Place	Marshland	Pond	River	Seasonal stream
Total no. of species	12	18	19	15
Singletons	4	5	5	6
Doubletons	2	6	4	2
Unique	3	4	2	2
Duplicates	1	4	5	2

Having compared the types of rare species in different habitats (Table 2), it can be observed that the temporary water bodies (seasonal stream) had most of the singletons; the ponds had most of the doubletons and unique species, and the river had most of the duplicates.

From a total of 30 species collected combining all the habitats, 6 species were represented by one individual (*Lestes* spp., *Lestes umbrinus* (Selys, 1891), *Acisoma panorpoides* (Rambur, 1842), *Paragomphus lineatus* (Selys, 1850), *Anaciaeschna jaspidea* (Burmeister, 1839), *Bradinopyga geminata* (Rambur, 1842)) and 3 species were represented by two individuals (*Tholymis tillarga* (Fabricius, 1798), *Agriocnemis pygmaea*, and *Anax immaculifrons* (Rambur, 1842)).

A total of 11 species were found only in one of the habitats (*Lestes* spp., *Tramea basilaris* (Palisot de Beauvois, 1805), *Tholymis tillarga* in marshland, *Agriocnemis pygmaea*, *Lestes umbrinus*, *Anax immaculifrons*, *Pseudagrion microcephalum* in pond, *Acisoma panorpoides* and *Paragomphus lineatus* in river, and *Anaciaeschna jaspidea* and *Bradinopyga geminata* in seasonal stream. 5 species were found only in 2 out of 4 habitats (*Ceriagrion coromandelianum*, *Crocothemis servilia* (Drury, 1770), *Disparoneura quadrimaculata*, *Ictinogomphus rapax* (Rambur, 1842) and *Ischnura senegalensis*). Lotic water bodies have majority of unique species which may be at greater risk from greater environmental pressure.

Correlation of the species and vegetation within/between habitats

Species richness and average NDVI at 1000, 500, 100, and 50 m

Regression analyses were made for species richness and mean NDVI at 1000, 500, 100, and 50 m buffer zones. Figure 6 gives the best fit for the observed trends and shows a positive correlation between species richness and mean NDVI.

Using Spearman' rho, the correlation coefficient showed a weak to moderate positive linear relationship between the species richness and mean NDVI value at different buffer zones. Correlation coefficient was the highest at 500 m buffer zone, followed by 50 m, then 100 m and finally at 1000 m (Table 3). The correlation coefficient values at 500 m and 50 m were statistically significant.

Table 3. Correlation coefficient at different buffer zones (species richness)

Species richness and mean NDVI	Correlation coefficient (Spearman's rho)
At 1000 m buffer zone	0.351
At 500 m buffer zone	0.561
At 100 m buffer zone	0.417
At 50 m buffer zone	0.486

Species diversity and average NDVI at 1000, 500, 100, and 50 m

Regression analyses were made for species diversity and mean NDVI at 1000, 500, 100, and 50 m buffer zones. Figure 7 gives the best fit for the observed trends and shows a positive correlation between species diversity and mean NDVI.

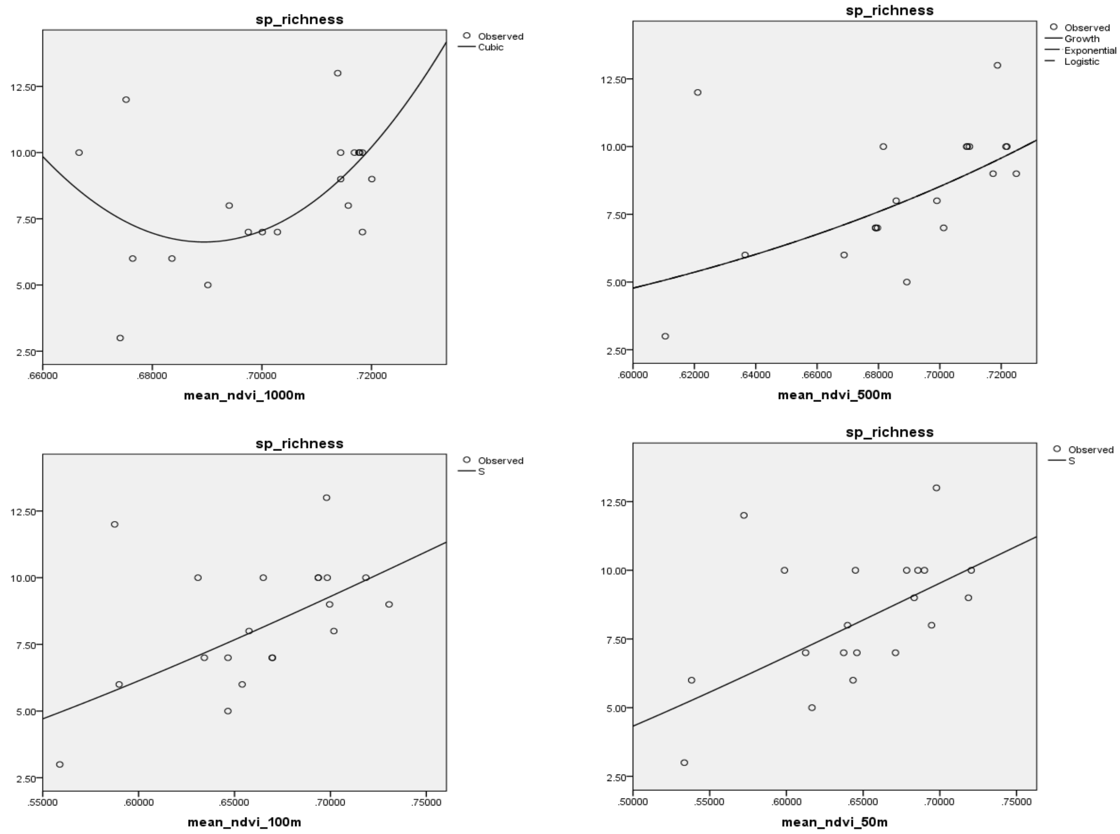

Figure 6. Correlation between species richness and mean NDVI

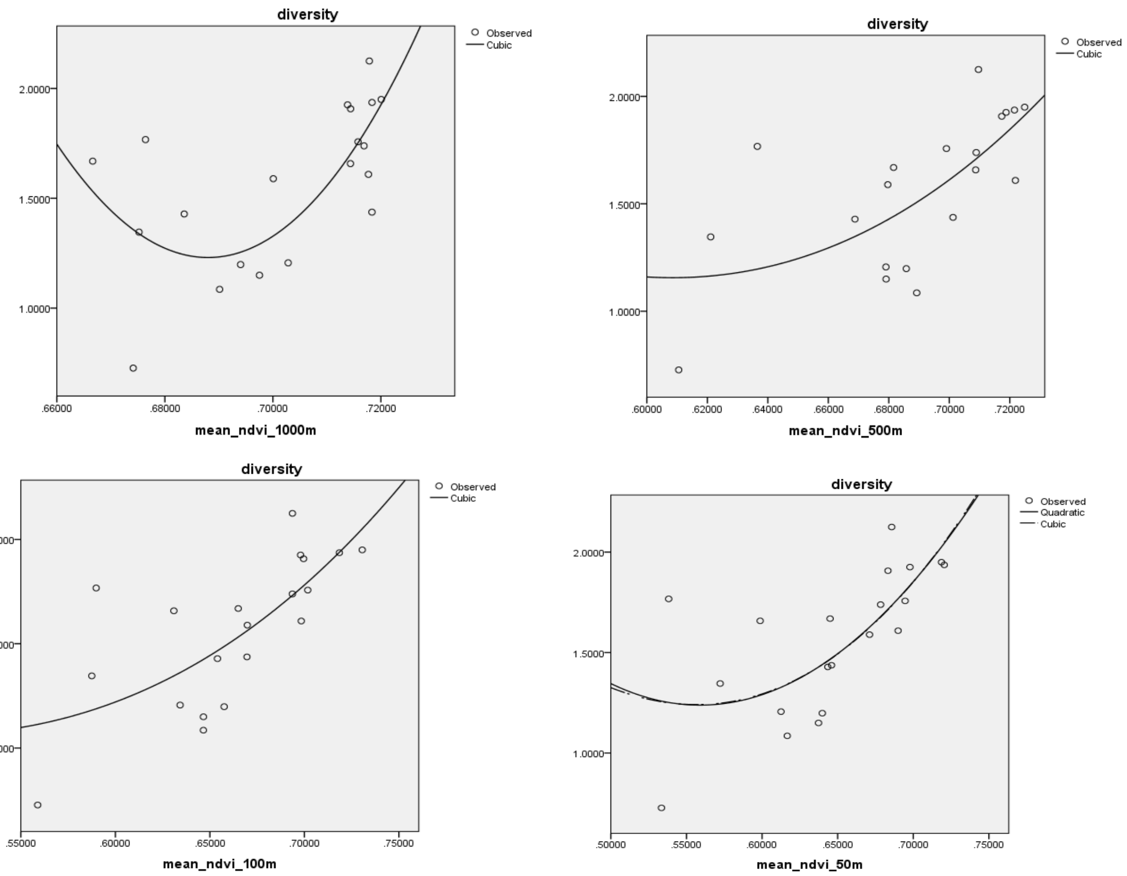

Figure 7. Correlation between species diversity and mean NDVI

Using Spearman' rho, the correlation coefficient had a moderate to strong positive linear relationship between the species diversity and mean NDVI value as the buffer zones decreased. Correlation coefficient was the highest at 50 m buffer zone, followed by 100 m, then 500 m and finally at 1000 m (Table 4). The correlation coefficients were statistically significant at all zones.

Table 4. Correlation coefficient at different buffer zones (species diversity)

Species diversity and mean NDVI	Correlation coefficient (Spearman's rho)
At 1000 m buffer zone	0.603
At 500 m buffer zone	0.681
At 100 m buffer zone	0.711
At 50 m buffer zone	0.714

Species diversity with NDVI range obtained at 1000, 500, 100, and 50 m in each habitat

A cluster box plot analysis was made to analyse the species diversity with the NDVI range for each habitat at different buffer zones. Figure 8 below represents the following: the species diversity is grouped into 3 groups and represented as low, medium, and high diversity group depending on the lowest and highest value for all the sampled plots. This is then analysed with the range of NDVI value at 30 m resolution obtained at different zones from the sampled plot.

Figure 8 presents trends in the mean NDVI that are similar at all buffer zones, showing an increase from low to high diversity group in the marshland, river and seasonal stream and decrease from medium to high diversity group in the pond habitat.

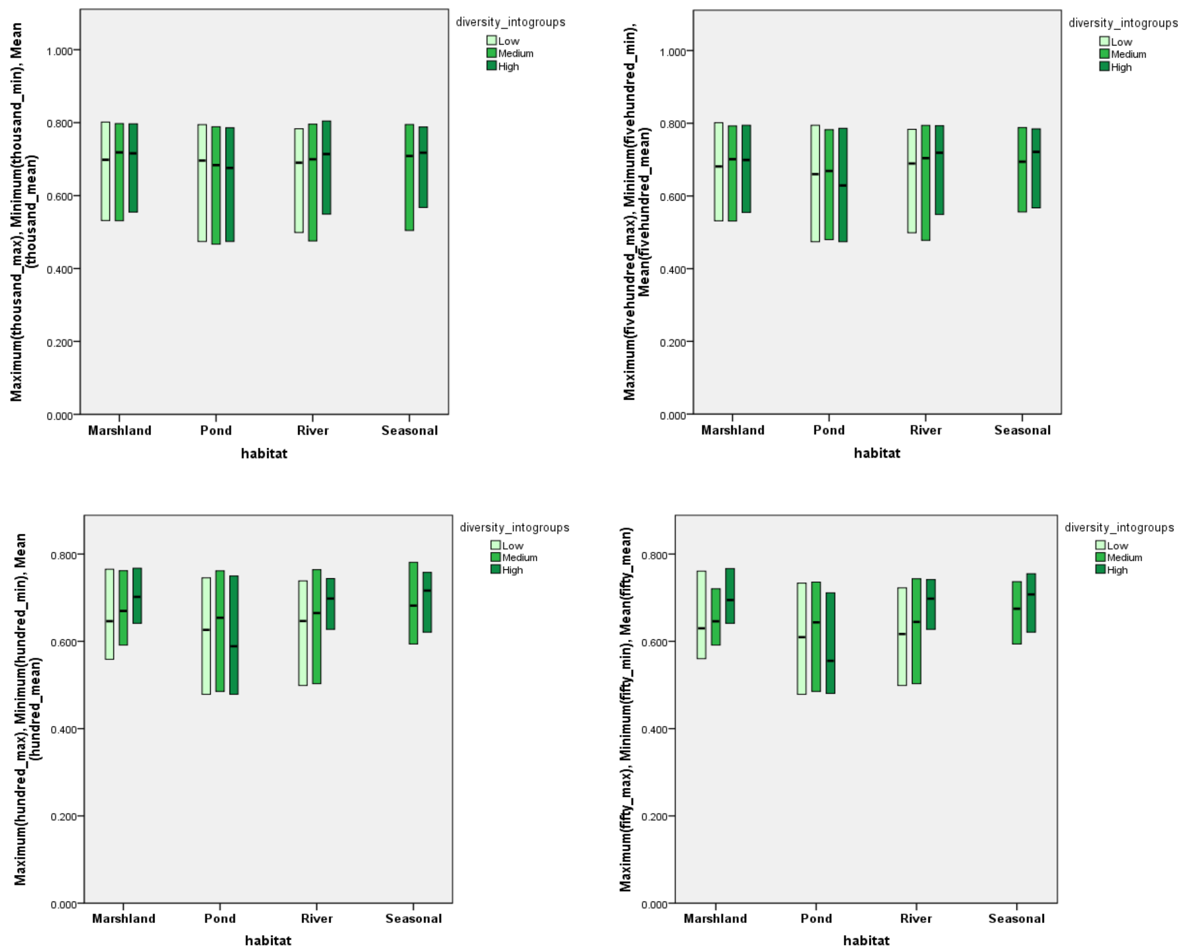

Figure 8. Analysis of NDVI range and the mean observed in different diversity groups for each habitat

Figure 7 illustrates that species diversity has increased with an increase in dense vegetation, showing a significant and stronger correlation as the distance of the buffer zones decreased (Table 5).

The correlation coefficient observed at 1000 m and 500 m can be mainly attributed to the trends observed in the river and seasonal stream habitats followed by the marshland and pond. At 100 and 50 m, strong correlation can be mainly attributed to the marshland and seasonal stream habitats, followed by the river and pond habitats (Figure 8).

Table 5. Trend analysis of distribution of NDVI values in different diversity groups for each habitat

Buffer zone	Marshland	Pond	River	Seasonal stream
At 1000 m	Decrease in variability due to an increase in the minimum NDVI value from medium to high diversity group	Decrease in variability with a slight increase in the minimum value and slight decrease in maximum value from medium to high diversity group	Increase in variability followed by a decrease from low to medium and medium to high respectively	Decrease in variability with an increase in the minimum value and slight decrease in maximum value from medium to high diversity group
At 500 m	Decrease in variability due to an increase in the minimum NDVI value from medium to high diversity group	Decrease in variability followed by an increase from low to medium and medium to high respectively	Increase in variability followed by a decrease from low to medium and medium to high respectively.	Decrease in variability with a slight increase in the minimum NDVI value and slight decrease in maximum NDVI value from medium to high diversity group
At 100 m	Decrease in variability due to an increase in the minimum NDVI value from low to high diversity group	Slight change in variability due to increase in the maximum and minimum NDVI value in medium diversity group followed by a decrease in both	Increase in variability followed by a drastic decrease from low to medium and medium to high respectively. A drastic decrease in variability can be attributed to an increase in the minimum NDVI value	Decrease in variability with an increase in the minimum NDVI value and decrease in maximum NDVI value from medium to high diversity group
At 50 m	Decrease in variability due to increase in the minimum and decrease in the maximum NDVI value in medium diversity group followed by an increase in both values in high diversity group	Slight change in variability due to increase in the maximum and minimum value in medium diversity group followed by a decrease in both	Increase in variability followed by a drastic decrease from low to medium and medium to high respectively. A drastic decrease in variability can be attributed to an increase in the minimum NDVI value	Slight change in variability due to increase in the maximum and minimum NDVI value from medium to high diversity group

CONCLUSION

The baseline study highlights species richness, abundance and diversity across various land-use types categorized as the lentic and lotic water-body type, and further categorized into seasonal and permanent water bodies. It also presents the dominant, rare, and unique species, highlighting their abundance, dispersal capacity and range within the region.

It is evident from this study that there is a strong positive correlation between the vegetation and species diversity within this region. The correlation is statistically significant at all buffer zones, which indicates a strong positive correlation between species diversity and their dependence on vegetation adjacent to aquatic habitats. Also, further analysis of species diversity with NDVI values according to each habitat showed that species diversity was higher in temporary water bodies as the distance of the buffer zones decreased (marshland and seasonal streams). This analysis indicates the importance of temporary water bodies for species diversity. Temporary water bodies are sensitive to rainfall variability, which has been observed to be the highest in the last decade.

Further observations and follow-up studies may build important implications for development of long-term biomonitoring tools that use odonates as surrogates to assess the impact of rainfall variability on local ecosystem. This would also help in building evidence in understanding the impacts of climate change, the impacts of future climate variability and in developing adaptation strategies focussing on wider conservation priorities and ecosystem services.

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