Protosticta sanguinostigma

REPORT OF SURVEY ON ODONATES IN MUNNAR LANDSCAPE TARGETING THE CONSERVATION OF FRESH WATER HABITAT & THREATENED SPECIES

Conducted as part of
"Protection of Freshwater Ecosystems for the Conservation of Threatened Species in Munnar, Western Ghats, India"
Project Code: 2023A-41

Funded by:
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REPORT ON THREATENED ODONATE SPECIES OF MUNNAR, IDUKKI, KERALA

Implemented as part of the project: Protection of Fresh water Ecosystems for the Conservation of Threatened Species in Munnar, Western Ghats, India.
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Implemented by : Tropical Institute of Ecological Sciences (TIES)

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Disclaimer: The findings and conclusions presented are generalized insights derived from the collective responses of the community members who participated in the survey. The information is used solely for the purpose of understanding and improving community conditions and should not be construed as reflecting the views or conditions of any specific individual or group.

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Indosticta deccanensis

Introduction

Munnar, located in the Western Ghats of Kerala, is a biodiversity hotspot, known for its lush landscapes, rich flora, and fauna. Among its diverse wildlife, the odonates; dragonflies and damselflies, are crucial indicators of the health of aquatic ecosystems and are an essential part of the region's ecological balance. The Western Ghats, a UNESCO World Heritage Site, is home to several endemic and rare species of odonates, making it a focal point for ecological studies.

To monitor and document the diversity of odonate species in Munnar, a year-long survey was undertaken. The study involved identifying key transects across various habitats and conducting phase-wise surveys from January to December. These surveys aimed to record species presence, observe behavior, and assess population trends.

This project aims to protect three vulnerable odonate species in Munnar: two damselflies, Indosticta deccanensis and ***Protosticta sanguinostigma,*** and a dragonfly, ***Chlorogomphus xanthoptera.*** Previously documented in the region, these species are at risk due to habitat degradation and other environmental threats.

The surveys focuses on studying their populations, understanding their habitat requirements, and identifying key threats such as climate change and pollution. The goal is to develop targeted conservation strategies to protect these species, which serve as important indicators of ecosystem health. By doing so, the project seeks to ensure their survival and contribute to the overall biodiversity conservation of the region.

Background

The project titled "Protection of Freshwater Ecosystems for the Conservation of Threatened Species in Munnar, Western Ghats, India" is dedicated to the conservation of three vulnerable odonate species in Munnar: two damselflies, Indosticta deccanensis and Protosticta sanguinostigma, and a dragonfly, Chlorogomphus xanthoptera. These species are endemic to the Western Ghats and are considered vital indicators of the health of freshwater ecosystems. Due to their specific habitat requirements and sensitivity to environmental changes, they are increasingly threatened by habitat degradation, pollution, and climate change.

The primary aim of this project is to identify key habitats where these species are found, assess their ecological needs, and evaluate the environmental pressures affecting them. Special attention will be given to monitoring the specific threats these species face, including habitat destruction, water pollution, and the impacts of climate change. Through detailed surveys and data collection, the project will strive to better understand the distribution and status of these odonates in Munnar and develop targeted conserva-

tion strategies to safeguard their future. A key component of the project is the sustainable protection of the freshwater ecosystems that these species rely on, ensuring their long-term viability.

In addition to the scientific and conservation goals, the project aims to raise awareness about the importance of these threatened species among local communities in Munnar. By engaging with residents and stakeholders, the project will highlight the significance of these odonates as indicators of ecosystem health and the need for collective action in their conservation. Spreading awareness will help foster a sense of responsibility and community involvement in protecting the biodiversity of Munnar's unique freshwater habitats.

Indosticta deccanensis

Indosticta deccanensis is an endemic damselfly species of the Western Ghats, typically found in fast-flowing streams and rivers with clear, cool water, often in higher altitude regions of the Ghats. The male of the species is easily identified by its striking blue coloration and black markings, while the female has a more subdued greenish or yellowish body with pale markings. This damselfly species prefers shaded, riparian habitats rich in vegetation along the water's edge. Due to its specialized habitat preferences, I. deccanensis is vulnerable to habitat degradation, particularly from pollution, deforestation, and other anthropogenic disturbances that compromise the quality of freshwater ecosystems.

Protosticta sanguinostigma

Protosticta sanguinostigma is another damselfly endemic to the Western Ghats. This medium-sized species is found in forested streams and small rivers, favoring clean, well-vegetated waters with minimal human disturbance. Males exhibit a distinctive reddish coloration on their thorax and abdomen, contrasting with the darker body of the female. Like ***I. deccanensis, P. sanguinostigma*** is highly vulnerable due to its specific habitat needs and sensitivity to environmental changes. Habitat destruction, water pollution, and the impacts of climate change are significant threats to its survival, necessitating immediate conservation efforts to protect its natural habitats.

Chlorogomphus xanthoptera

Chlorogomphus xanthoptera, a dragonfly species known for its striking yellow markings on the wings, is typically found in fast-flowing rivers and streams with rocky substrates, especially in forested or semi-forested areas. The species' bright yellow-winged appearance gives it its name, "xanthoptera" meaning "yellow wings." As with many other odonates, ***C. xanthoptera*** is highly sensitive to changes in water quality and habitat disruptions. Its presence is often used as an indicator of the health of freshwater ecosystems, and its decline may signal significant ecological changes. Due to its specific habitat requirements, ***C. xanthoptera*** faces increasing threats from habitat degradation and water pollution, raising concerns about its long-term viability in the region.

Neurobasis chinensis

Methodology

In the odonate surveys in Munnar, a robust methodology is designed to thoroughly assess dragonfly and damselfly populations across a range of freshwater ecosystems. The study focuses on key sites along the Nallathanni, Muthirapuzha, and Kundala rivers, as well as their tributaries (which are finally reaches Periyar), representing diverse habitats that are critical for odonate species.

About 29 locations were selected for the survey. One km. long transects were laid in each location and thoroughly explored by 2-3 field researchers, with three seasonal replications. Field investigators recorded species richness, abundance and collected environmental data. This includes key habitat variables such as water quality and other ecological factors. The surveys prioritize careful species identification, behavioural observations, and photographic documentation to ensure the accuracy and reliability of our findings.

Each survey session is meticulously planned, with records of the date, time, and weather conditions at the site. Additional environmental details, including vegetation type, water quality, and temperature readings, are carefully noted. GPS coordinates are logged to precisely locate the survey points, allowing for accurate spatial mapping of odonate distributions. This detailed approach enables us to correlate species data with environmental factors, offering critical insights into the health and diversity of Munnar's odonate populations.

By analyzing the collected data, it aims to generate valuable information that will inform conservation strategies, odonate data and enhance our understanding of the dynamics shaping these freshwater ecosystems.

Figure 1. Field visit at Ambazhachal

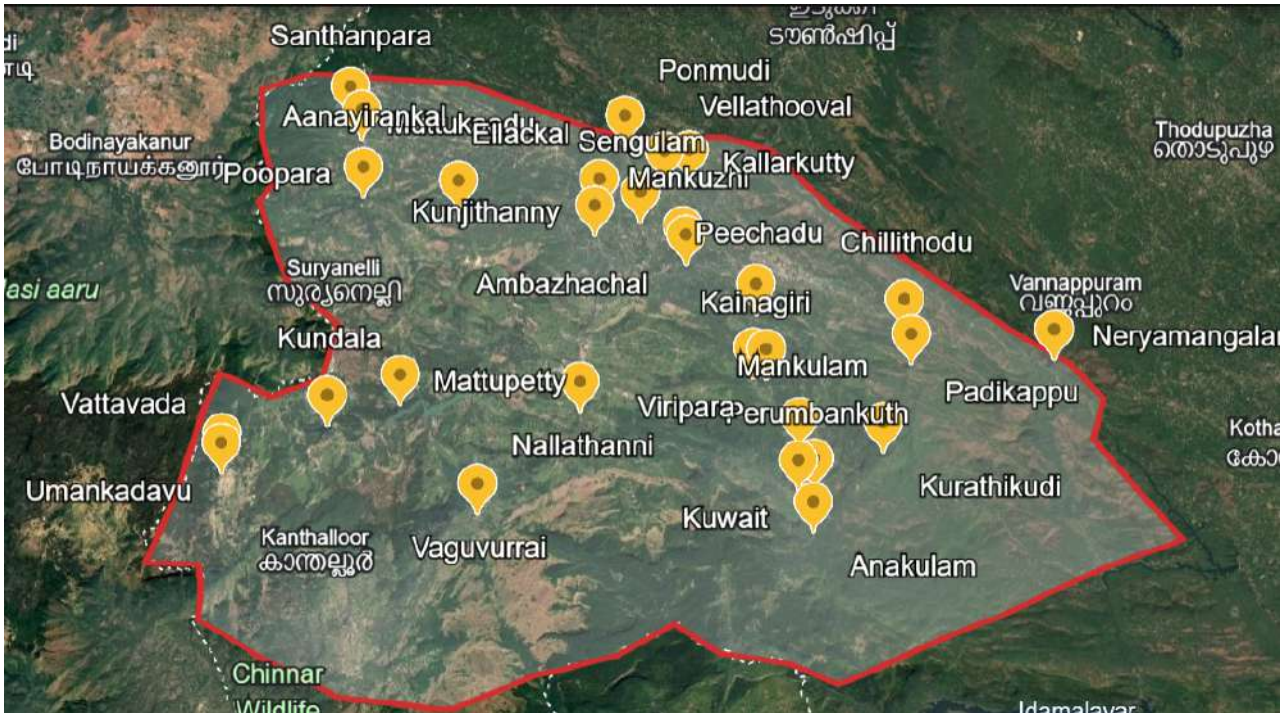


Figure 2. Map showing transect locations

Transect Details

SL. NO.	LOCATION NAME	MSL	START COORDINATES	END COORDINATES
1	PADIKAPPU STREAM	601m	10°03'23"N 76°52'18"E	10°03'34"N 76°52'24"E
2	CHILLITHODU STREAM	612m	10°02'14"N 76°52'44"E	10°02'09"N 76°52'47"E
3	AMBAZHACHAL RIVER	712m	10°00'59"N 77°00'49"E	10°01'09"N 77°00'53"E
4	MUTTUKADU PADDY FIELD	970m	10°00'42"N 77°08'48"E	10°00'42"N 77°08'40"E
5	KUWAIT CITY	363m	10°08'19"N 76°55'28"E	10°08'27"N 76°55'22"E
6	MANKULAM RIVER	701m	10.113549, 76.929851	10.115958, 76.928474
7	PEECHAD RIVER	990m	10°02'32"N 76°57'57"E	10°02'29"N 76°58'14"E
8	POOPARA STREAM	1104m	9°58'51"N 77°12'30"E	9°58'39"N 77°12'23"E
9	KUNJITHANNY	771m	10°00'47"N 77°03'58"E	10°00'40"N 77°03'58"E
10	ELLACKAL BRIDGE	723m	10°00'00"N 77°04'02"E	9°59'51"N 77°03'57"E
11	MANKUZHI WATERFALLS	720m	10°01'13"N 77°00'42"E	10°01'13"N 77°00'48"E
12	AANAKULAM	330m	10°09'39"N 76°54'43"E	10°09'35"N 76°54'40"E
13	KALLARKUTTY RESERVOIR	473m	9°58'22"N 77°01'01"E	9°58'41"N 77°00'23"E
14	PONMUDI RESERVOIR	720m	9°57'33"N 77°03'27"E	9°57'33"N 77°03'28"E
15	ANAYIRANKAL RESERVOIR	1207m	10°00'47"N 77°12'07"E	10°00'50.0"N 77°12'13.1"E
16	SENGULAM RESERVOIR	853m	10°00'04"N 77°02'28"E	10°00'41"N 77°01'57"E
17	MATTUPETTY RESERVOIR (ECHO POINT)	1602m	10°07'33.7"N 77°09'38.8"E	10°07'30.6"N 77°09'30.7"E
18	SANTHANPARA	1049m	9°58'07"N 77°13'03"E	9°58'07"N 77°13'08"E

19	VAGUVURRAI STREAM	1361m	10°10'49"N 77°06'24"E	10°10'41"N 77°06'27"E
20	NALLATHANNY RIVER (PERIYAVURRAI)	1505m	10°06'48"N 77°03'27"E	10°06'30"N 77°03'29"E
21	VATTAVADA TRANSECT 1	1637m	10°10'51"N 77°15'23"E	10°10'50"N 77°15'18"E
22	VATTAVADA TRANSECT 2 (UMANKADAVU)	1632m	10°10'31"N 77°15'25"E	10°10'46"N 77°15'23"E
23	KAINAGIRI WATERFALLS, VIRIPARA	1165m	10°04'42.5"N 76°57'42.8"E	10°04'43.7"N 76°57'45.2"E
24	KUNDALA RESERVOIR	1750m	10°08'36.7"N 77°11'55.4"E	10°08'43.2"N 77°12'04.6"E
25	PERUMBANKUTH	460m	10°08'18"N 76°54'52"E	10°08'16"N 76°54'53"E
26	VIRIPARA	1043m	10°04'41"N 76°57'15"E	10°04'39"N 76°57'16"E
27	VELLATHOOVAL	495m	9°58'32"N 77°01'52"E	9°58'32"N 77°01'41"E
28	KUTHUPARA (NERYAMANGALAM)	111m	10°02'25"N 76°47'19"E	10°02'37"N 76°47'03"E
29	KURATHIKUDI	424m	10°06'33"N 76°52'45"E	10°05'55"N 76°52'15"E

Table 1. Transect locations in Munnar landscape

1. Padikappu

The transect at Padikappu lies in Adimali Panchayath, close to the Muthuvan tribal settlement, serving as a vital link between Mamalakandam and Munnar. The riparian zone consists of wetland and paddy fields, surrounded by hills. The stream originates from Mudippara, flowing through Padikappu before merging with the Karinthiri River and eventually joining the Periyar River. Agriculture, particularly paddy cultivation, thrives here, with local tribes relying on the stream for drinking water and other daily needs.

Figure 3. Padikappu

Figure 4. A rivulet at Chillithodu

2. Chillithodu

This transect features a medium-sized stream sourced from Kattamudi, Mudippara, and Chillithodu waterfalls, flowing towards Irumbupalam and continuing through Totti Aaru to merge with the Periyar River. The riparian habitat supports a diverse population of odonates, especially damselflies, thanks to the rocky terrain. Water levels fluctuate, with droughts in summer and surges during the rainy season. Agriculture, particularly cardamom plantations, is prominent, though pollution from nearby households threatens water quality in the riparian zone.

3. Ambazhachal

Ambazhachal is marked by a river that feeds into the Kallarkutty Dam, eventually flowing into the Periyar River. A small town lies nearby, with point pollution from homes and shops along the riparian zone. The river enjoys a steady flow throughout the year and is characterized by a healthy water column. Cardamom plantations near the riparian zone further alter the ecosystem, though it remains relatively intact.

Figure 5. Ambazhachal

5. Muttukadu Paddy Field

Situated at an elevation of 970 meters between Chokramudi and Bison Valley, the Muttukad paddy field holds the distinction of being the highest paddy field in Kerala. The fields are irrigated through strategic bunds designed to store water, as water scarcity is common during summer months. Crop rotation practices include vegetables and sunflowers. However, the area is threatened by tourism, with plastic pollution from passing visitors further compromising the ecological balance.

Figure 6. Muttukadu Paddy Field

5. Kuwait City

Located between Anakulum and Mankulam, the transect is traversed by the Karinthiri River, characterized by a fast-flowing, sandy riverbed with pebbles. It receives water from nearby Rajamalai Hills, Kadalar, and Muppathi Moonu waterfalls. Sand mining is prevalent in the area, and open defecation contributes to water contamination. A bridge, damaged during the 2018 floods, remains visible in the transect, highlighting the area's vulnerability to natural disasters.

Figure 7. Kuwait City

6. Mankulam River

Receiving water from the Letchmi Hills and Chinnarkuthu, the Mankulam River flows toward the Karinthiri River. The riverbed is rocky and supports grassy vegetation. While the riparian zone offers rich habitats for aquatic species, pollution from plastic waste dumped by tourists and locals poses a significant threat. A dam currently under construction will likely alter the flow and ecosystem of the river, potentially exacerbating these issues.

Figure 8. Mankulam River

7. Peechad River

Peechadu Aaru, located in Kurisupara within Pallivasal Grama Panchayat, flows alongside the Kallar-Mankulam road. The stream faces considerable pressure from greywater discharge and habitat encroachment. Originating from the Letchmi Estate and smaller streams in Kallar Valley, it joins the Kallar Stream and Ambazhachal before merging with the Periyar River. The river is a vital resource for local communities, but increasing human activity is straining its ecosystem.

Figure 9. Peechad River

8. Poopara Stream

Poopara receives water from the Anayirangal Dam, flowing into the Panniyar River and ultimately reaching the Periyar River. The stream's waters come from pristine shola forests, though pollution from nearby towns is rampant. The high water column during dam releases is offset by the poor sanitary conditions in Poopara town, where untreated waste pipes discharge directly into the stream. Plastic pollution is pervasive, and the surrounding riparian zone is dominated by plantations.

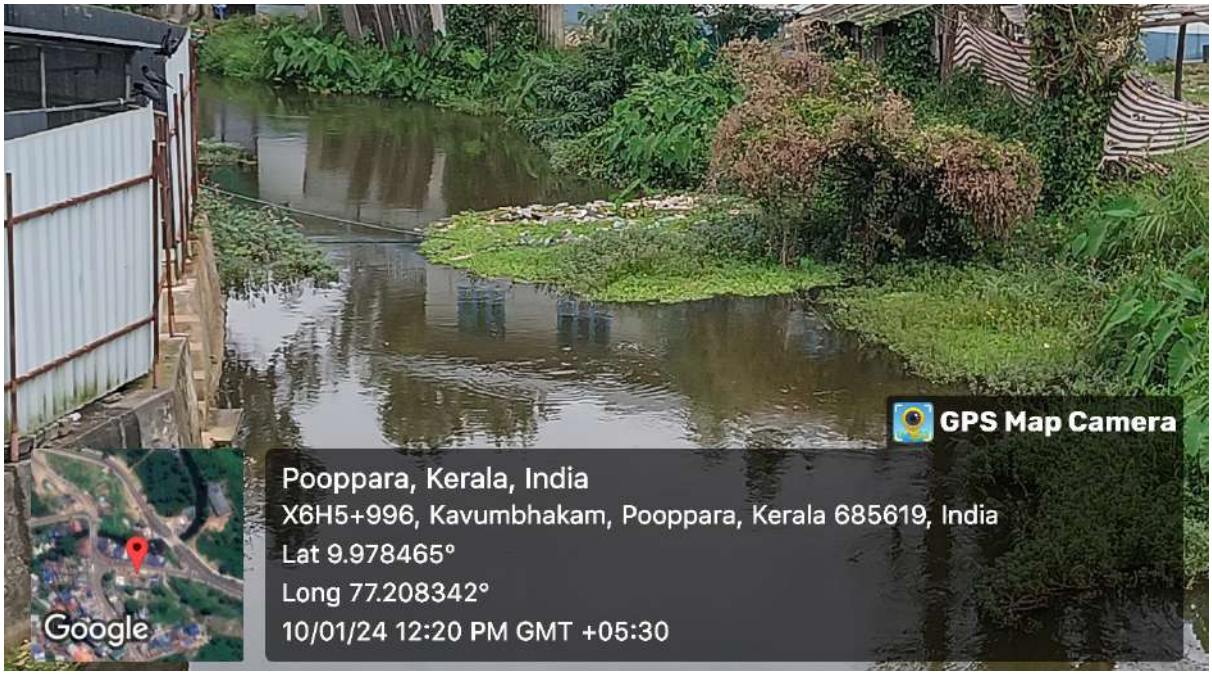


Figure 10. A view of a rivulet at Pooppara

9. Kunjithanny

Kunjithanny's transect passes through the town, flowing through cardamom estates, and includes water from the Muthirapuzha River. Water levels surge during the rainy season, though riparian areas are limited, with both sandy and rocky riverbed terrains. Pollution from factories and nearby households adds to the ecological stress of the region.

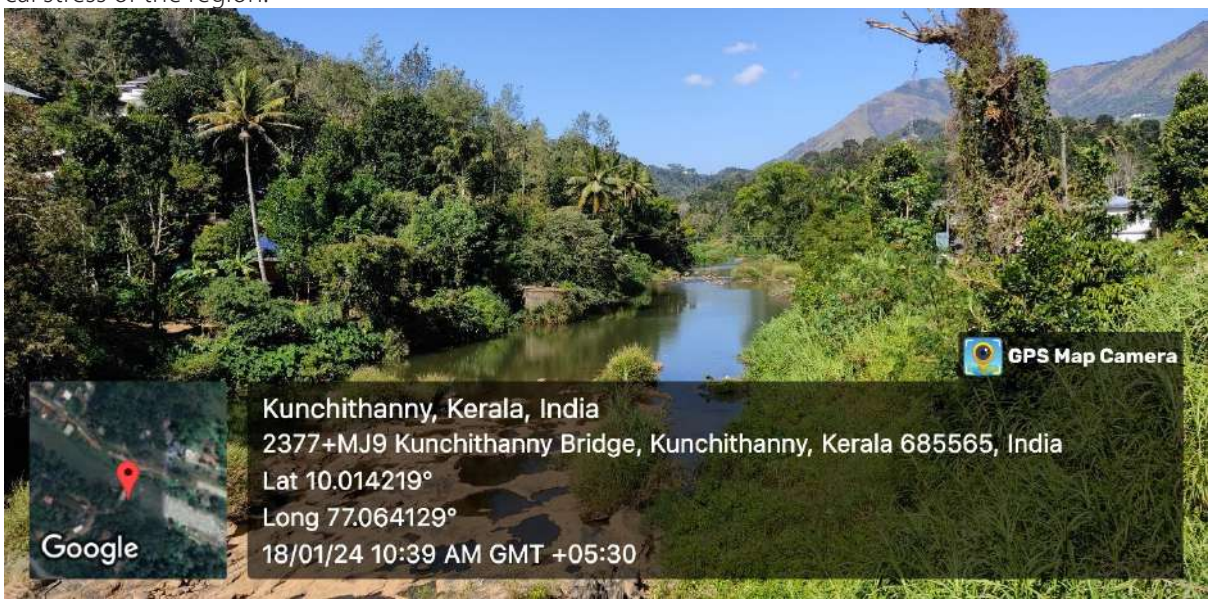


Figure 11. Kunjithanny

10. Ellackal Bridge

The lower extension of the Kunjithanny transect, where the Muthirapuzha River is characterized by both sandy and rocky riverbeds. One side of the river features a moderately healthy riparian zone, while the other has been altered due to human activity. Low water flow is common here, with a considerable presence of homestays along the riparian zone, further contributing to pollution.

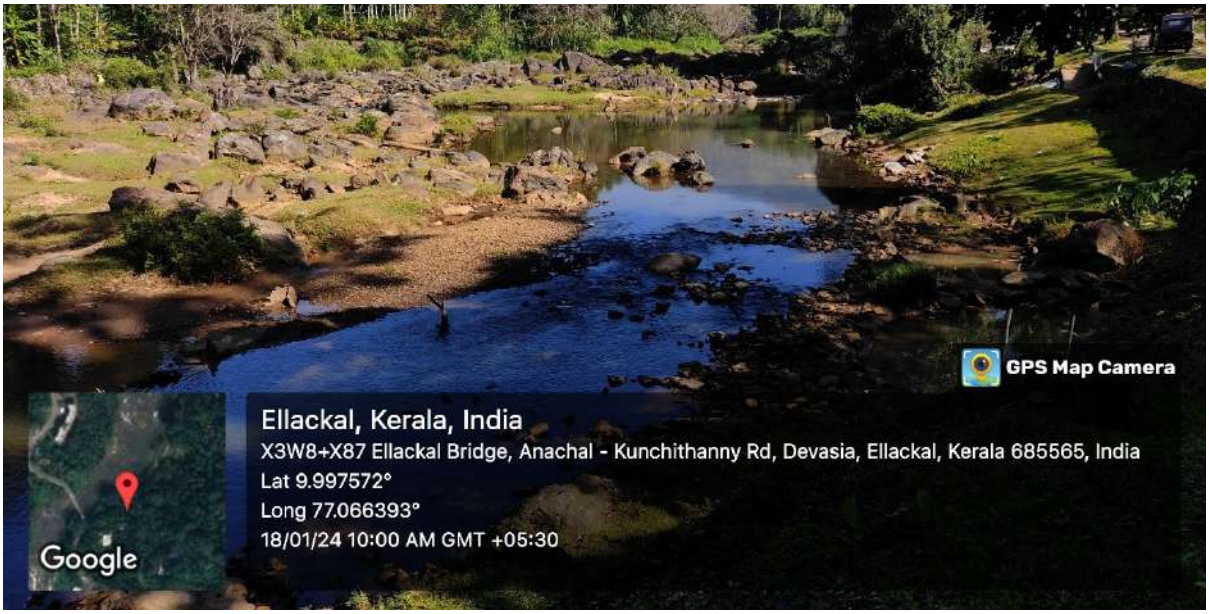


Figure 12. Ellackal Bridge

11. Mankuzhi Waterfalls

Located within a pristine forested riparian zone, the Mankuzhi Waterfalls offers significant biodiversity. However, upstream areas are dominated by cardamom plantations. Public waste disposal, particularly plastic beverage bottles, is a notable problem in the riparian areas, which threaten the ecological balance. The riverbed is rocky, and the surrounding area is a crucial habitat for local flora and fauna.

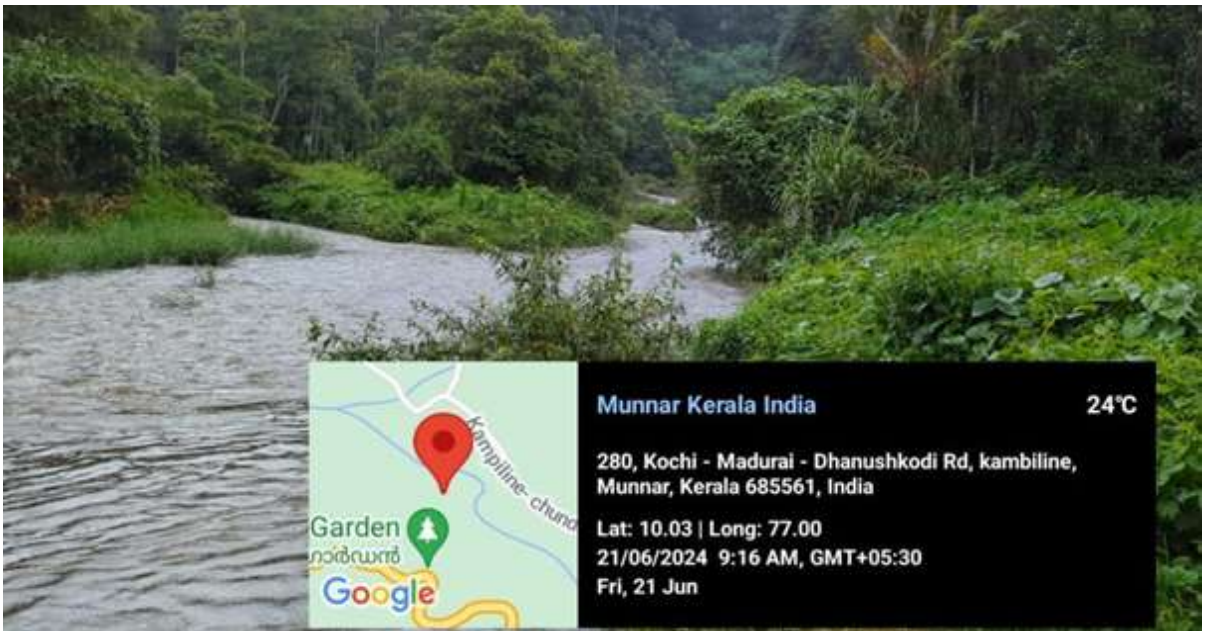


Figure 13. Mankuzhi Waterfalls

12. Aanakulam

Aanakulam, situated amidst wild elephant habitats, features mineral-rich springs seeping through rocks, enriching the local water bodies. The area's streams, including those from Edamalakudi and Kozhiyilakudi, support a variety of fish species. The transect is located in the Malayattoor and Mankulam Forest Divisions, home to indigenous tribal communities. This region is ecologically significant, as the streams here maintain the delicate balance of local ecosystems and wildlife.

Figure 14. Aanakulam

13. Kallarkutty Reservoir

The Kallarkutty Reservoir collects water from Muthirapuzha, Panniyar, and Ambazhachal rivers before flowing into the Periyar River. Hydro-electric projects affect the river's ecosystem, but the reservoir typically maintains a good water column throughout the year. Plastic waste, particularly beverage bottles, is a persistent issue along the riparian zone. The banks feature grasslands with a limited presence of trees, yet the riparian forests are generally in good condition.

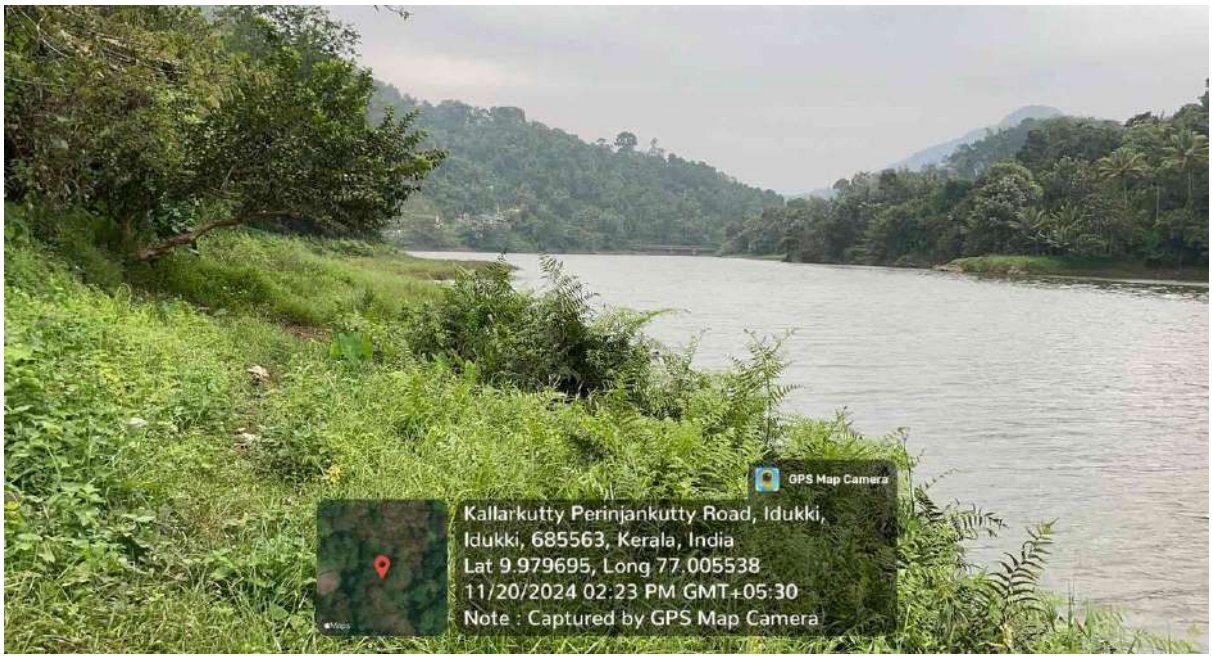


Figure 15. Kallarkutty Reservoir

14. Ponmudi Reservoir

Ponmudy receives water from Panniyar, Rajakkad, Konnathady, and Chemmanar regions. The water levels decrease during summer, and boating activities are common. The reservoir is surrounded by teak forests, but biodiversity here is limited. The area was the site of a catastrophic incident in 2007, where a penstock valve burst, leading to the loss of lives, homes, and crops, highlighting the risks associated with such projects.

Figure 16. Ponmudi Reservoir

15. Anayirankal Reservoir

Located near the Munnar-Kumily road, Anayirankal Reservoir is bordered by forests on one side and Tata Tea plantations on the other. The dam's water flows to Kuthungal and Ponmudi dams through the Panniyar River. Exotic fish species thrive here, though water levels are low during the summer months. Boating activities are common, and the water serves as an essential drinking source for elephants in the Panniyar region.

Figure 17.Anayirankal Reservoir

16. Sengulam Reservoir

Sengulam Reservoir, located on the Muthirapuzha River in Vellathooval Panchayat, collects water that is funneled to the Sengulam Powerhouse. One side of the riparian zone is a natural forest, while the other is dominated by eucalyptus plantations. The ongoing construction of a power house in the area is likely to affect the region's biodiversity. Sewage runoff reaches the dam, further compounding the environmental pressures on this water body.

Figure 18. Sengulam Reservoir

17. Mattupetty Reservoir (Echo Point)

Surrounded by eucalyptus forests and tea plantations, the Mattupetty Reservoir, fed by water from Kundala, faces significant environmental degradation. As a major tourist attraction, the area suffers from plastic and food waste accumulation in the riparian zone. Noise pollution from vehicles and buses further disrupts the area's biodiversity. The riparian zone is poor, with little natural forest remaining.

Figure 19. Mattupetty Reservoir (Echo Point)

18. Santhanpara

Santhanpara includes the Panniyar River, a tributary of the Periyar River. Fed by streams like Uchilkuthipuzha, Mathikettan Puzha, Chemmannar, and Nander Puzha from Mathikettan National Park, the river flows through Ponmudi and Kallarkutty Dams, eventually joining the Periyar River. This region, situated at 1049 meters above sea level, is largely surrounded by cardamom plantations, which contribute to chemical runoff. The area faces algal blooms, plastic pollution, and habitat degradation, posing a threat to its aquatic ecosystems.

Figure 20. Santhanpara

19. Vaguvurrai Stream

Originating in the Eravikulam National Park at around 2000 meters above sea level, the Vaguvurrai Stream is a vital tributary to the Pambar River. Passing through steep terrain near the Gundumalai Hills, the stream is surrounded by forests and tea plantations. However, pollution from tourists, vendors, and a nearby tea factory is increasingly compromising the water quality, affecting the health of the Pambar River, which eventually merges with the Chinnar River in Tamil Nadu.

Figure 21. Vaguvurrai Stream

20. Nallathanni River (Periyavurrai)

At an altitude of 1505 meters, the Nallathanni River flows from the Anamudi Hills towards the Muthirapuzha River, joining the Periyar River. Flanked by grasslands and with minimal forest cover, the river's flow is wide and slow. Local factories and nearby settlements contribute to pollution. The river's ecosystem was severely impacted by the 2018 floods, which caused lasting alterations to its environment.

Figure 22.Nallathanni River (Periyavurrai)

21. Vattavada Transect 1

Vattavada town is heavily polluted, with greywater from households and hotels flowing into the nearby streams, which have become de facto sewage drains. The riparian zone is in poor condition, and water contamination is high due to agricultural runoff and other pollutants. The region is also highly prone to landslides, further exacerbating environmental challenges.

Figure 23. Vattavada Transect 1

22. Vattavada Transect 2 (Umankadavu)

This third-order stream originates from Pampadum Shola and flows through Vattavada town before joining the Amaravathi River. The stream, once pristine, now suffers from high levels of sewage and drainage contamination. At 1632 meters above sea level, the stream supports limited aquatic life and faces additional stress from agricultural runoff.

Figure 24. Vattavada Transect 2 (Umankadavu)

23. Kainagiri Waterfalls

Located near the Letchmi Tea Estate, Kainagiri Waterfalls flows through a small but significant forested riparian zone, supporting high biodiversity in a restricted area. The riverbed is rocky, and water levels drop during summer. Chemical runoff from nearby plantations poses a threat to the local ecosystem. The stream eventually feeds into Peechadu, Kallar, and Ambazhachal rivers.

Figure 25. Kainagiri Waterfalls

24. Kundala Reservoir

Kundala Reservoir, the highest dam in Munnar, is built on the Muthirapuzha River. Its water is released through the Palar River to the Mattupetty Dam. Surrounded by tea plantations and eucalyptus forests, the reservoir faces environmental degradation due to altered riparian zones. While boating is a popular activity, the ecological balance is compromised by the lack of natural forests in the surrounding area.

Figure 26. Kundala Reservoir

25. Perumbankuthu

Perumbankuthu, at around 460 meters above sea level, collects water from Letchmi Hills and Nakshatra-kuthu, flowing into Karinthiri Aaru and joining the Periyar River. This transect features a steep waterfall and is bordered by a mix of reserve forest and plantations. While biodiversity is rich, agricultural runoff and plastic waste are significant threats to the area's ecological health.

Figure 27. Perumbankuthu

26. Viripara

Located in the Viripara Forest Area at 1043 meters above sea level, the Viripara stream flows from the Letchmi Hills into the Mankulam Aaru, merging with the Karinthiri Aaru. Surrounded by well-preserved riparian forests, it is ecologically significant. However, chemical runoff from nearby plantations threatens the biodiversity of the river and its surrounding habitat.

Figure 28. Viripara

27. Vellathooval

This transect near the powerhouse generation area has poor riparian conditions and high contamination. Although odonates were observed during field visits, the region's ecological integrity is compromised by pollution. The area connects Ponmudi and Kallarkutty rivers, but its environmental value has been diminished due to human activity.

Figure 29. Vellathooval Small Hydro Electric Plant

28. Kuthupara (Neryamangalam)

Situated in Neryamangalam, within the reserve forests, Kuthupara is a small-order stream flowing into the Periyar River. It features a rich riparian forest with natural trees and significant biodiversity. Despite this, open defecation and significant plastic waste pollution threaten the region's environmental health. The Idukki Neryamangalam Road bisects the transect, contributing to the degradation of this ecologically important area.

Figure 30.Kuthupara (Neryamangalam)

29. Kurathikudi

Located within the Adimali forest range, Kurathikudi's water reaches the Periyar River via the Karinthiri. The area boasts a healthy forested riparian zone, home to wild elephants and indigenous wildlife. The region remains minimally impacted by human activity, with rocky terrain and a steady water column supporting diverse flora and fauna. The natural forest ecosystem is well-preserved, contributing to the area's rich biodiversity.

Figure 31. Kurathikudi

Vestalis apicalis

First Odonate Survey

The Odonate Survey, conducted in three phases from January to June 2024, provided valuable insights into species diversity, population trends, and the environmental factors influencing odonate populations. The survey spanned the Summer, Pre-monsoon, and Monsoon periods, documenting a wide range of odonate species across various habitats. This comprehensive survey was carried out by a team of experts from TIES, including Dr. Abraham Samuel, Dr. Punnen Kurien, Dr. Nelson P. Abraham, Mr. Ajayakumar, Mr. Sarath Babu N.B., Mr. Nihal Hussain T.P., Mr. Praful V. Panicker, and Mr. Bechu Punnen Abraham.

During this phase, two individuals of ***Protosticta sanguinostigma*** were observed in Mankuzhy in April. Photographs were taken for identification and later verified with the assistance of odonate experts.

Sl No	Transect Locations	Odonate Survey Periods (First Survey)		
		Phase 1	Phase 2	Phase 3
1	Anayirangal Dam	06-02-2024	22-04-2024	23-06-2024
2	Poopara	06-02-2024	22-04-2024	23-06-2024
3	Padikappu	23-01-2024	17-04-2024	-
4	Chillithodu	23-01-2024	17-04-2024	-
5	Ponmudi Dam	23-01-2024	24-04-2024	23-06-2024
6	Kallarkutty Dam	05-02-2024	24-04-2024	21-06-2024
7	Peechadu	24-01-2024	16-04-2024	-
8	Sengulam Dam	06-02-2024	20-04-2024	23-06-2024
9	Mattupetty Echo Point	23-04-2024	14-06-2024	-
10	Muttukadu	06-02-2024	20-04-2024	-
11	Mankuzhy	24-01-2024	16-04-2024	21-06-2024
12	Ambazhachal	16-04-2024	21-06-2024	-
13	Mankulam	07-02-2024	15-04-2024	20-06-2024
14	Anakulam	23-01-2024	15-04-2024	22-06-2024
15	Kuwait City	24-01-2024, 07-02-2024	15-04-2024	22-06-2024

16	Kunjithanny	20-04-2024	-	-
17	Ellackal	20-04-2024	21-06-2024	-
18	Kundala	23-04-2024	14-06-2024	-
19	Santhanpara	22-04-2024	23-06-2024	-
20	Kainagiri Waterfalls	25-04-2024	21-06-2024	-
21	Vaguvurrai	16-05-2024	-	-
22	Perumbankuth	24-01-2024	-	-
23	Vellathooval	05-02-2024	-	-
24	Nallathanni	05.02.2024	19-06-2024	-
25	Vattavada 1	03-02-2024	-	-
26	Vattavada 2	03-02-2024	-	-

Table 2. Odonate Survey first phase details

Summer Phase

During the peak Summer phase, notable observations included ***Brachythemis contaminata*** predominantly inhabiting reservoirs, highlighting its preference for environments characterized by stagnant or polluted water conditions. Conversely, species like ***Heliocypha bisignata*** and ***Neurobasis chinensis*** exhibited lower presence during Summer but showed increased abundance in the Post-monsoon and Monsoon phases. This seasonal variation suggests a dynamic response to environmental factors such as rainfall and water availability, reflecting their sensitivity to freshwater habitat conditions. Understanding these patterns is crucial for assessing the ecological dynamics and conservation implications of odonates across diverse habitats surveyed during the study period.

During the transition from the summer phase to the pre-monsoon phase survey, conducted across various transects including waterfalls, a concerning trend of widespread water drying was observed. Locations such as Chillithodu and Kainagiri Waterfalls documented significant reductions in water levels, impacting local ecosystems profoundly. This drying trend not only diminishes the natural beauty of these areas but also poses serious ecological challenges, potentially disrupting biodiversity, causing habitat loss for aquatic species, and altering ecosystem dynamics. Understanding these impacts is crucial for implementing effective conservation measures to mitigate the adverse effects of climate variability and ensure the resilience of freshwater ecosystems in the face of changing environmental conditions.

In April 2024, surveys conducted at Ponmudi Dam, Kallarkutty Dam, and Anayirangal Dam revealed significant fluctuations in odonate populations, reflecting seasonal changes and local environmental conditions. While some areas showed stable or increasing densities of odonates, indicating relatively healthy habitats, others experienced declines likely influenced by factors such as habitat degradation and human activities. Notably, Ponmudi Dam and Kallarkutty Dam saw a marked increase in Brachythemis contaminata during the summer surveys, potentially linked to pollution from tourism activities. The composition of odonate species like ***Pseudagrion rubriceps*** and ***Trithemis aurora*** also varied, underscoring their sensitivity to changing habitat conditions, including fluctuations in reservoir levels.

Anayirangal Dam faced severe environmental degradation during the 2024 monsoon phase, evidenced by the complete drying up of the reservoir. This catastrophic event resulted in the death of fish species and the accumulation of plastic and waste, highlighting significant environmental pressures in the area. These findings underscore the urgent need for effective environmental management strategies to protect freshwater ecosystems from deterioration and ensure the conservation of biodiversity in the face of escalating human impacts.

Pre-Monsoon Phase

During the pre-monsoon phase, favorable conditions supported the rejuvenation of reservoirs and streams, benefiting both odonates and overall water levels. This period typically marks the buildup of moisture preceding the monsoon rains, playing a crucial role in replenishing water resources after the dry season. Reservoirs and streams, including those in Mankuzhy, Peechadu, and Ellackal, experienced gradual replenishment, providing essential habitats for odonates

to thrive. The increased water availability during this phase not only sustains aquatic ecosystems but also supports the life cycles of odonates, contributing to their population health and ecological diversity. This natural replenishment underscores the importance of seasonal dynamics in maintaining the resilience of freshwater habitats and emphasizes the critical role of pre-monsoon conditions in preparing ecosystems for the challenges and opportunities brought by the monsoon season.

Monsoon Phase

During the monsoon phase survey, contrasting conditions were observed across different habitats, with sufficient water levels noted in waterfalls and low-lying reservoirs. This period typically sees ample rainfall replenishing water resources, particularly evident in waterfalls such as Chillithodu and low-lying reservoirs like those in Sengulam and Mattupetty. These areas benefited from increased water availability, crucial for sustaining local ecosystems and supporting diverse aquatic species. The presence of sufficient water during the monsoon underscores their resilience to seasonal fluctuations and highlights the importance of these areas as refuges for biodiversity amidst broader environmental changes.

As part of the monsoon phase, dams in higher altitudes, including Kundala and Ponmudi, adopted proactive measures by opening their shutters to manage water levels and prevent sudden discharges that could potentially lead to flooding, similar to the events of 2018 and 2019. This strategy aims to regulate water flow downstream, ensuring controlled releases that minimize the risk of flooding in surrounding areas. By carefully managing water discharge during the monsoon, these dams not only mitigate immediate flood hazards but also contribute to the sustainable management of water resources, balancing ecological needs with the safety of local communities and infrastructure.

Dams like Kundala, Mattupetty, Anayirangal, Kallarkutty and Ponmudi still remain below their normal water levels due to the early opening of shutters as a precautionary measure during the monsoon phase. This proactive approach is intended to regulate water flow and prevent the accumulation of excessive water that could potentially lead to downstream flooding. Despite these measures aimed at preventing sudden discharge and flooding risks, these dams continue to experience lower water levels compared to typical conditions, reflecting the ongoing challenges in managing water resources effectively during the monsoon season.

Checklist

Odonates in First Survey		
Sl. No.	Scientific Name	Family
1	*Neurobasis chinensis*	Calopterygidae
2	*Vestalis apicalis*	Calopterygidae
3	*Heliocypha bisignata*	Chlorocyphidae
4	*Libellago indica*	Chlorocyphidae
5	*Aciagrion approximans krishna*	Coenagrionidae
6	*Aciagrion occidentale*	Coenagrionidae
7	*Agriocnemis keralensis*	Coenagrionidae
8	*Agriocnemis pieris*	Coenagrionidae
9	*Agriocnemis pygmaea*	Coenagrionidae
10	*Ceriagrion coromandelianum*	Coenagrionidae
11	*Pseudagrion indicum*	Coenagrionidae
12	*Ischnura rubilio*	Coenagrionidae
13	*Ischnura senegalensis*	Coenagrionidae
14	*Pseudagrion malabaricum*	Coenagrionidae
15	*Pseudagrion microcephalum*	Coenagrionidae
16	*Pseudagrion rubriceps*	Coenagrionidae

17	*Euphaea cardinalis*	Euphaeidae
18	*Euphaea fraseri*	Euphaeidae
19	*Dysphaea ethela*	Euphaeidae
20	*Caconeura risi*	Chlorocyphidae
21	*Copera marginipes*	Chlorocyphidae
22	*Copera vittata*	Chlorocyphidae
23	*Esme mudiensis*	Chlorocyphidae
24	*Prodasineura verticalis*	Platycnemididae
25	*Protosticta gravelyi*	Platystictidae
26	*Protosticta sanguinostigma*	Platystictidae
27	*Anax immaculifrons*	Aeshnidae
28	*Gynacantha dravida*	Aeshnidae
29	*Hemicordulia asiatica*	Corduliidae
30	*Ictinogomphus rapax*	Gomphidae
31	*Paragomphus lineatus*	Gomphidae
32	*Acisoma panorpoides*	Gomphidae
33	*Aethriamanta brevipennis*	Libellulidae
34	*Brachydiplax chalybea*	Libellulidae
35	*Brachydiplax sobrina*	Libellulidae
36	*Brachythemis contaminata*	Libellulidae
37	*Bradinopyga geminata*	Libellulidae
38	*Crocothemis servilia*	Libellulidae
39	*Diplacodes trivalis*	Libellulidae
40	*Lathrecista asiatica*	Libellulidae
41	*Lyriothemis acigastra*	Libellulidae
42	*Neurothemis tullia*	Libellulidae
43	*Onychothemis testacea*	Libellulidae
44	*Orthetrum chrysis*	Libellulidae
45	*Orthetrum glaucum*	Libellulidae
46	*Orthetrum luzonicum*	Libellulidae
47	*Orthetrum pruinosum*	Libellulidae
48	*Orthetrum sabina*	Libellulidae
49	*Palpopleura sexmaculata*	Libellulidae
50	*Pantala flavescens*	Libellulidae
51	*Rhyothemis variegata*	Libellulidae
52	*Tholymis tillarga*	Libellulidae
53	*Trithemis aurora*	Libellulidae
54	*Trithemis festiva*	Libellulidae
55	*Trithemis pallidinervis*	Libellulidae
56	*Urothemis signata*	Libellulidae
57	*Zygonyx iris*	Libellulidae

Table 3. Checklist of Odonates of First Survey

Based on our survey so far we have compiled an extensive odonate checklist encompassing 56 species across various families. This checklist includes species such as ***Aciagrion approximans krishna, Acisoma panorpoides, Agriocnemis keralensis, and Orthetrum sabina,*** among others. Each species has been meticulously documented to contribute to our understanding of dragonfly and damselfly diversity in Munnar. This systematic approach is important for assessing the ecological health of freshwater ecosystems in the region and informing conservation strategies.

The odonates surveyed in Munnar represent diverse families such as Coenagrionidae, Libellulidae, and Platycnemididae. Each family plays a unique ecological role: Coenagrionids indicate water quality around dams and riversides, Libellulidae are adaptable predators found in various habitats, and Platycnemidids thrive in shaded streams. Monitoring these families provides insights crucial for conserving Munnar's freshwater ecosystems and their biodiversity.

Dysphaea ethela

Second Odonate Survey

The second survey, covering phases 4, 5, and 6 from July to December, included the Monsoon, Post-Monsoon, and Winter phases. The survey was conducted by the same expert team as the first survey. Periodic visits were made to specific locations in suitable months. During this phase, we successfully spotted two vulnerable species: ***Protosticta sanguinostigma*** at Viripara, Perumbankuthu, and Kurathikudi, and Indosticta deccanensis at Kuthupara, Neryamangalam.

Sl. No.	Transect Locations	Odonate Survey Periods (Second Survey)		
		Phase 4	Phase 5	Phase 6
1	Peechadu	03-07-2024, 12.30 PM	25-09-2024, 10.00 AM	23-11-2024, 11.30 AM
2	Kunjithanny	03-07-2024, 03.30 PM	27-11-2024, 02.20 PM	-
3	Kainagiri Waterfalls	07-07-2024, 04.00 PM	25-09-2024, 12.30 PM	-
4	Perumbankuthu	04-07-2024, 2.30 PM	16-08-2024, 25-09-2024	08-12-2024, 12.30 PM
5	Viripara	08-07-2024, 10.00 AM	25-09-2024, 10.30 AM	23-11-2024, 12.15 PM
6	Mankulam	16-08-2024, 01.30 PM	23-11-2024, 01.15 PM	-

7	Kurathikudi	20-09-2024, 02.30 PM	21-09-2024, 11.30 AM	26-09-2024, 11.30 AM
8	Padikappu	15-11-2024, 02.30 PM	-	-
9	Chillithodu	15-11-2024, 03.30 PM	-	-
10	Vattavada 1	14-11-2024, 10.00 AM	-	-
11	Vattavada 2 Umankadavu	14-11-2024, 11.00 AM	-	-
12	Kuthupara, Neryamangalam	07-11-2024, 09.30 AM	-	-
13	Ponmudi Dam	20-11-2024, 03.00 PM	-	-
14	Kallarkutty Dam	20-11-2024, 02.00 PM	-	-
15	Mankuzhy	20-11-2024, 12.30 PM	-	-
16	Ambazhachal	20-11-2024, 01.30 PM	-	-
17	Mattupetty Echo Point	22-11-2024, 02.30 PM	-	-
18	Anakulam	21-11-2024, 04.00 PM	-	-
19	Kuwait City	21-11-2024, 03.00 PM	-	-
20	Kundala Dam	22-11-2024, 01.45 PM	-	-
21	Ellackal	27-11-2024, 01.10 PM	-	-
22	Anayirangal Dam	07-12-2024, 05.00 PM	-	-
23	Poopara	07-12-2024, 04.00 PM	-	-
24	Santhanpara	07-12-2024, 03.00 PM	-	-

Table 4. Odonate Survey second phase details

Monsoon Phase

The continuation of the survey during the rainy (monsoon) season took place in the remaining transects throughout July and August. During this phase, ***Protosticta sanguinostigma*** was again spotted at two distinct locations: Perumbankuthu and Viripara. Interestingly, Viripara lies at an altitude above 1000 meters MSL, while Perumbankuthu is situated at a much lower elevation of approximately 450 meters MSL. This observation highlighted a significant aspect of the species' distribution, revealing that ***Protosticta sanguinostigma*** appears to be extending its range into middle-altitude regions. This shift suggests potential adaptations to varying environmental factors, such as changes in altitude, temperature, and other ecological variables. During previous visits to Perumbankuthu, human activities, including boating and recreational pursuits, were prevalent in the transect. However, with the onset of the monsoon, these activities came to a halt, providing an opportunity to observe the vulnerable species in the area. Without the usual human interference, the species were able to freely explore and utilize their habitat, offering a unique glimpse into their natural behaviors in the absence of disturbances.

While a notable population of ***Protosticta sanguinostigma*** was observed in Perumbankuthu, it remained limited in Viripara. These findings underscore the potential flexibility of the species in adapting to different terrain types. During this phase, other transects such as Peechadu, Kunjithanny, and Kainagiri Waterfalls also demonstrated varying odonate densities and distributions, further enriching our understanding of the seasonal shifts in odonate populations. The data gathered during this period continues to provide valuable insights into the ecological dynamics and habitat preferences of these species.

Post- Monsoon Phase

During September and October, Peechadu, Kainagiri Waterfalls, Perumbankuthu, Viripara, and Kurathikudi were visited for further surveying. Overall, a comparatively lower odonate population was observed in many of these locations. In an effort to expand the survey and discover new species, Kurathikudi, a forest area within the Adimali Range, was selected as a potential new transect. With the assistance of local forest guides, a two-day pilot study was conducted, which revealed a higher odonate density, with around 20 species recorded.

Following this initial survey, a subsequent visit was made with the expert team, and once again, ***Protosticta sanguinostigma*** was spotted within the forest area. Interestingly, the altitude at which the species was found was lower than previously expected. In addition to ***Protosticta sanguinostigma***, several key and abundant species were recorded, including ***Vestalis apicalis, Euphaea cardinalis,*** and ***Caconeura ramburi.*** These findings further underscored the ecological significance of the area and its potential for supporting a rich diversity of odonate species.

A large population of ***Pantala flavescens*** was observed flying in unison at higher altitudes, with a noticeable increase in their numbers. As the monsoon season came to an end, these dragonflies began their migration towards nearby continents. This migratory phenomenon was also recorded during this phase, marking a significant natural event.

Winter Phase

The water levels during November and December were significantly lower compared to the previous phases, resulting in a noticeable increase in the population of various odonate species. As the monsoon season ended, many species became more visible, with Pantala flavescens continuing to show a high population density. These dragonflies were observed migrating, but their numbers remained abundant across several transects.

The following locations were revisited during this phase: Padikappu, Anayirangal Dam, Chillithodu, Poopara, Vattavada 1, Santhanpara, Vattavada 2, Perumbankuthu, Kuthupara (Neryamangalam), Ponmudi Dam, Kallarkutty Dam, Mankuzhy, Ambazhachal, Peechadu, Mattupetty Echo Point, Mankulam, Anakulam, Kuwait City, Kundala, Viripara, and Kunjithanny. In these locations, a considerable number of odonates were recorded, with sites like Mankulam, Kuwait, Chillithodu and Mankuzhy showing particularly strong odonate populations. Vattavada also yielded some interesting findings, though the population was somewhat lower compared to other sites. In the case of the reservoirs, only a limited number of odonates were spotted. However, the overall population across the transects was promising, highlighting the importance of diverse habitats for supporting these species during the later months of the year.

During a visit to Kuthupara in Neryamangalam in November, ***Indosticta deccanensis*** was successfully spotted, marking a significant observation for this location, as it had been identified during the pilot study. Nine individuals were recorded, indicating a healthy population in this region. The transect boasts a rich forest riparian zone, which undoubtedly supports such species. However, it is concerning to note the large amounts of waste being dumped near the roadsides, which have begun to affect the water quality and the overall health of the habitat. This pollution poses a threat to the biodiversity in the area, especially to sensitive species like Indosticta deccanensis.

Another surprising finding was the location's relatively low altitude, at only 100-150 meters MSL, which contrasts sharply with older studies that placed the species at higher elevations, typically above 700 meters MSL. This shift in distribution could be linked to various factors, including climate change, changes in the species' adaptive behaviors, and the movement of populations in response to altering environmental conditions. The decrease in altitude is notable, as it challenges previous assumptions about the species' preferred habitat and suggests a degree of ecological flexibility or adaptation to new conditions. This finding is an important piece of evidence that further underscores the complex relationship between odonates and their ever-changing habitats.

Checklist

Odonates in Second Survey		
Sl. No.	Scientific Name	Family
1	*Heliocypha bisignata*	Chlorocyphidae
2	*Trithemis aurora*	Libellulidae
3	*Neurobasis chinensis*	Calopterygidae
4	*Aciagrion approximans krishna*	Coenagrionidae
5	*Trithemis festiva*	Libellulidae
6	*Orthetrum pruinosum*	Libellulidae
7	*Agriocnemis pieris*	Coenagrionidae
8	*Prodasineura verticalis*	Platycnemididae
9	*Pseudagrion rubriceps*	Coenagrionidae
10	*Neurothemis tullia*	Libellulidae
11	*Zygonyx iris*	Libellulidae
12	*Orthetrum chrysis*	Libellulidae
13	*Palpopleura sexmaculata*	Libellulidae
14	*Ischnura rubilio*	Coenagrionidae
15	*Protosticta sanguinostigma*	Platystictidae
16	*Epophthalmia vittata*	Libellulidae
17	*Copera marginipes*	Chlorocyphidae
18	*Pseudagrion indicum*	Coenagrionidae
19	*Hemicordulia asiatica*	Corduliidae
20	*Copera (ghost form)*	Chlorocyphidae
21	*Copera vittata*	Chlorocyphidae
22	*Protosticta gravelyi*	Platystictidae
23	*Ischnura senegalensis*	Coenagrionidae
24	*Merogomphus tamaracherriyensis*	Gomphidae
25	*Euphaea fraseri*	Euphaeidae
26	*Phylloneura westermani*	Chlorocyphidae
27	*Orthetrum sabina*	Libellulidae
28	*Libellago indica*	Chlorocyphidae
29	*Pantala flavescens*	Libellulidae
30	*Anax immaculifrons*	Aeshnidae
31	*Epithemis mariae*	Libellulidae
32	*Vestalis gracilis*	Calopterygidae
33	*Orthetrum glaucum*	Libellulidae
34	*Esme mudiensis*	Chlorocyphidae
35	*Euphaea cardinalis*	Euphaeidae
36	*Anax guttatus*	Aeshnidae
37	*Orthetrum luzonicum*	Libellulidae
38	*Caconeura risi*	Chlorocyphidae
39	*Caconeura ramburi*	Chlorocyphidae
40	*Diplacodes trivialis*	Libellulidae
41	*Neurothemis fulvia*	Libellulidae

42	*Indosticta deccanensis*	Platystictidae
43	*Bradinopyga geminata*	Libellulidae
44	*Pseudagrion microcephalum*	Coenagrionidae
45	*Aciagrion occidentale*	Coenagrionidae
46	*Neurothemis chinensis*	Libellulidae
47	*Ceriagrion coromandelianum*	Coenagrionidae

Table 5. Checklist of odonates in the second survey

The second survey conducted across various locations in Kerala from July to December 2024 recorded a total of 47 odonate species, representing 10 distinct families. This survey highlights the rich diversity of odonates in the region, showcasing a wide variety of both common and rare species. Among the most notable findings, the Libellulidae family was the most abundant, with species such as T***rithemis aurora, Orthetrum pruinosum, Pantala flavescens,*** and ***Neurothemis tullia*** leading the survey in terms of frequency and population. The Coenagrionidae family, including species like ***Aciagrion approximans krishna, Pseudagrion rubriceps,*** and ***Ischnura rubilio***, also showed significant representation, with many species being recorded in tranquil freshwater habitats like ponds and marshes.

The Chlorocyphidae family, which includes distinctive species such as ***Heliocypha bisignata, Copera marginipes,*** and ***Libellago indica***, was well-represented, underscoring the importance of shaded, forested riparian zones for odonate populations. Additionally, the survey documented species from the Platystictidae family, such as the vulnerable ***Protosticta sanguinostigma*** and ***Protosticta gravelyi***, highlighting the critical conservation importance of maintaining pristine freshwater ecosystems.

Other notable families included the Aeshnidae, represented by ***Anax immaculifrons*** and ***Anax guttatus***, which are typically associated with larger water bodies, and the Euphaeidae family, with species like ***Euphaea cardinalis*** and ***Euphaea fraseri***, which are often found in clear, fast-flowing streams.

This survey underscores the importance of maintaining a range of aquatic habitats for the survival of diverse odonate populations and emphasizes the need for continued monitoring, especially for vulnerable species. The presence of species across various altitudes, from lowland areas to higher elevations, provides valuable insights into the adaptability of odonates in response to changing environmental conditions. Additionally, the recorded species offer an important baseline for future conservation efforts, ensuring the protection of these unique and ecologically significant insects.

Trithemis aurora

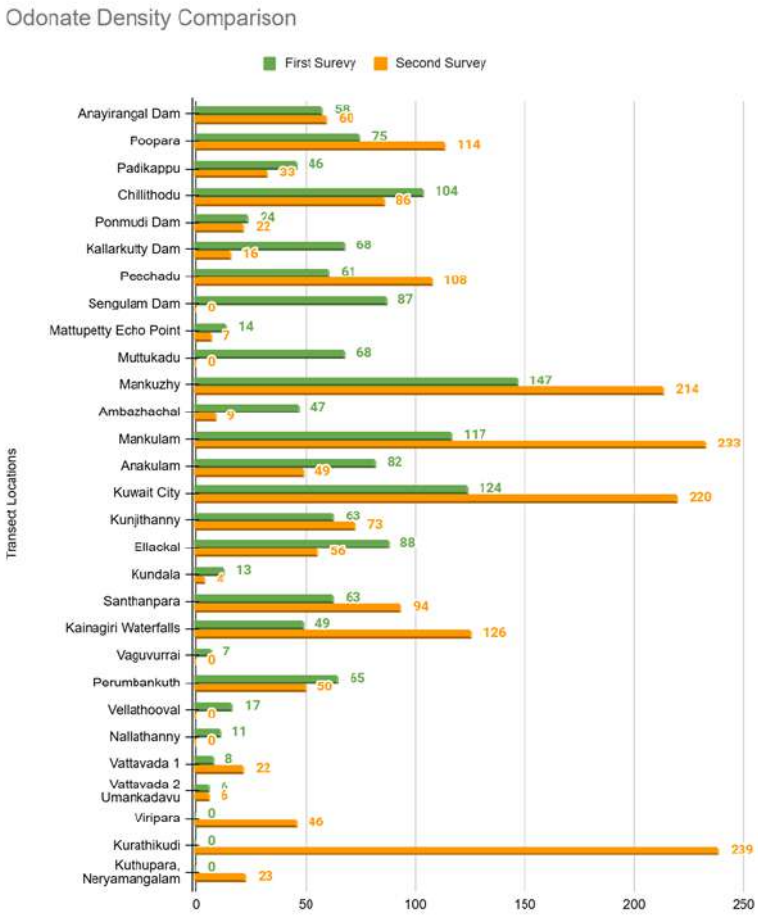
Comparative analysis

1. Odonate Density

Studying odonate density is essential for assessing freshwater ecosystem health, as odonates are sensitive bioindicators of water quality and habitat integrity. Changes in their population density can reflect shifts in environmental conditions such as pollution, eutrophication, and habitat loss. Odonates also contribute significantly to ecosystem functioning, particularly through their role in controlling aquatic insect populations. Monitoring their density provides valuable data for understanding the impacts of environmental stressors and for guiding conservation efforts. Therefore, odonate density serves as a key metric in the management and preservation of freshwater habitats.

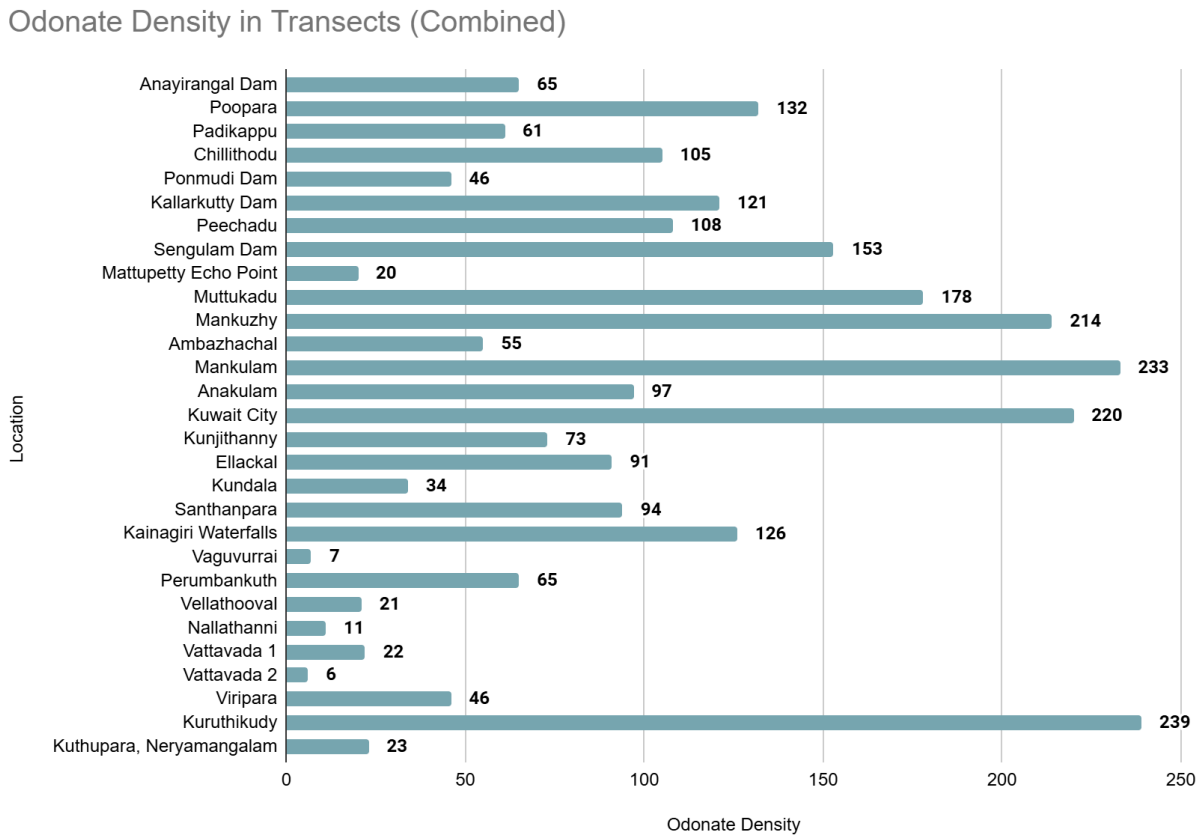
1.1. A comparison on first and second odonate survey

The comparison of odonate density across the 29 transect locations between the first and second surveys reveals considerable variation, indicating both spatial and temporal fluctuations in odonate populations. Locations such as Poopara, Mankuzhy, and Mankulam saw substantial increases in odonate density, suggesting that these areas may provide favorable environmental conditions, such as high water quality and abundant habitat for breeding. However, other sites, including Kallarkutty Dam, Sengulam Dam, and Mattupetty Echo Point, experienced significant declines or zero densities in the second survey, which could be attributed to factors like habitat degradation, pollution, or changes in water temperature and availability. The fluctuations observed underscore the importance of monitoring odonate populations as indicators of freshwater ecosystem health, with a need for further investigation into the causes of population decline and more focused conservation efforts in impacted areas. Overall, these trends highlight the importance of maintaining high-quality habitats and managing environmental stressors to support the persistence of odonate populations.



Graph 1. Odonate density comparison

1.2. Total Density



Graph 2. Odonate density in transects (combined)

A study of odonate density across 29 transect locations revealed significant variability in population distribution. The highest odonate density was recorded at Kuruthikudy (239 individuals), followed by Mankulam (233) and Kuwait City (220). These locations indicate optimal environmental conditions for odonates, suggesting high-quality habitats that support large populations. In contrast, several sites showed notably low densities, with Vattavada 2 (6), Vellathooval (21), and Mattupetty Echo Point (20) among the lowest, potentially due to factors such as habitat degradation, poor water quality, or limited breeding sites. The density distribution across the locations can be categorized into high (above 150 individuals), moderate (between 50 and 150), and low (below 50). High-density areas included Sengulam Dam (153), Muttukadu (178), and Poopara (132), indicating favorable conditions for odonate populations. On the other hand, low-density sites like Vaguvurrai (7), Nallathanni (11), and Vattavada 1 (22) may require further ecological assessment to determine potential threats to odonate populations.

Populations in regards to the transect have been impacted in every transects. And there are concerns to be raised on population decline and even decline in locations where higher populations are spotted. This raises concerns about the sustainability of these populations and highlights the need for further investigation into the factors driving these changes. Apart from habitat degradation and water quality issues, climate change is emerging as a key factor influencing odonate population fluctuations. Shifts in temperature, rainfall patterns, and the timing of seasonal changes can affect the availability of suitable breeding habitats and the timing of life cycles. Additionally, extreme weather events, such as floods or droughts, may disrupt habitat stability, further stressing already vulnerable populations. These factors, combined with pollution and human activity, could be contributing to the observed declines,

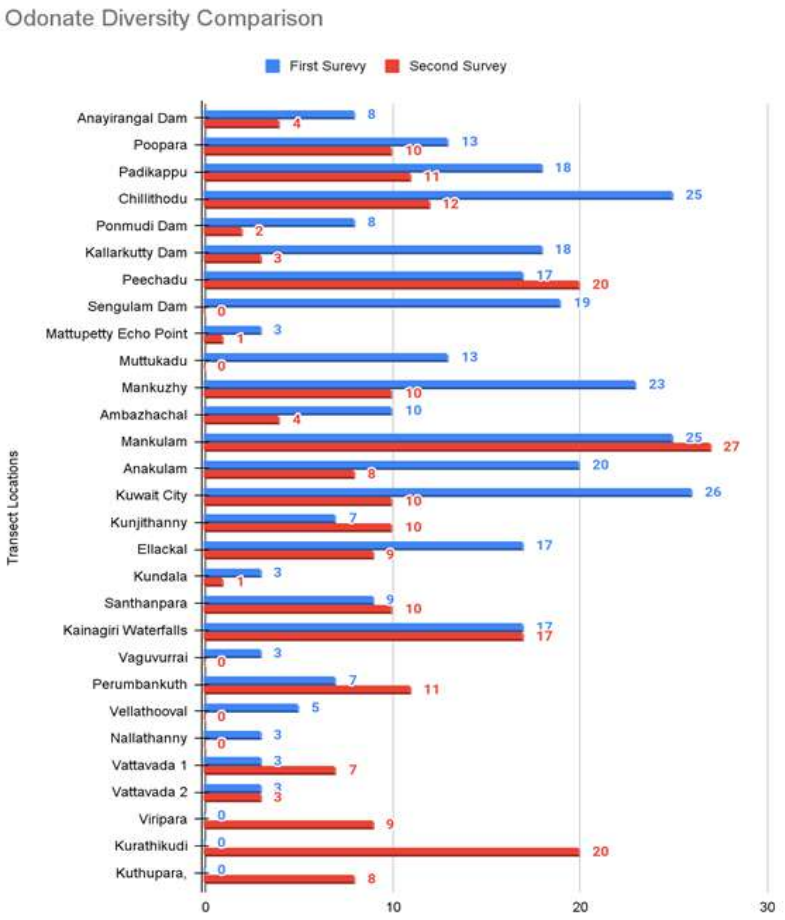
underscoring the importance of integrated conservation efforts that address both environmental and climate-related challenges.

2. Odonate Diversity

Studying odonate diversity is essential for understanding the health and functionality of freshwater ecosystems, as they are sensitive to changes in water quality and habitat conditions. Odonates, with their diverse habitats and life cycle stages, can serve as effective bioindicators of ecological changes, providing valuable insights into environmental stressors. Monitoring odonate diversity in research helps identify shifts in species composition, aiding in the detection of long-term ecological trends and informing conservation strategies.

2.1. First and Second Survey Comparison

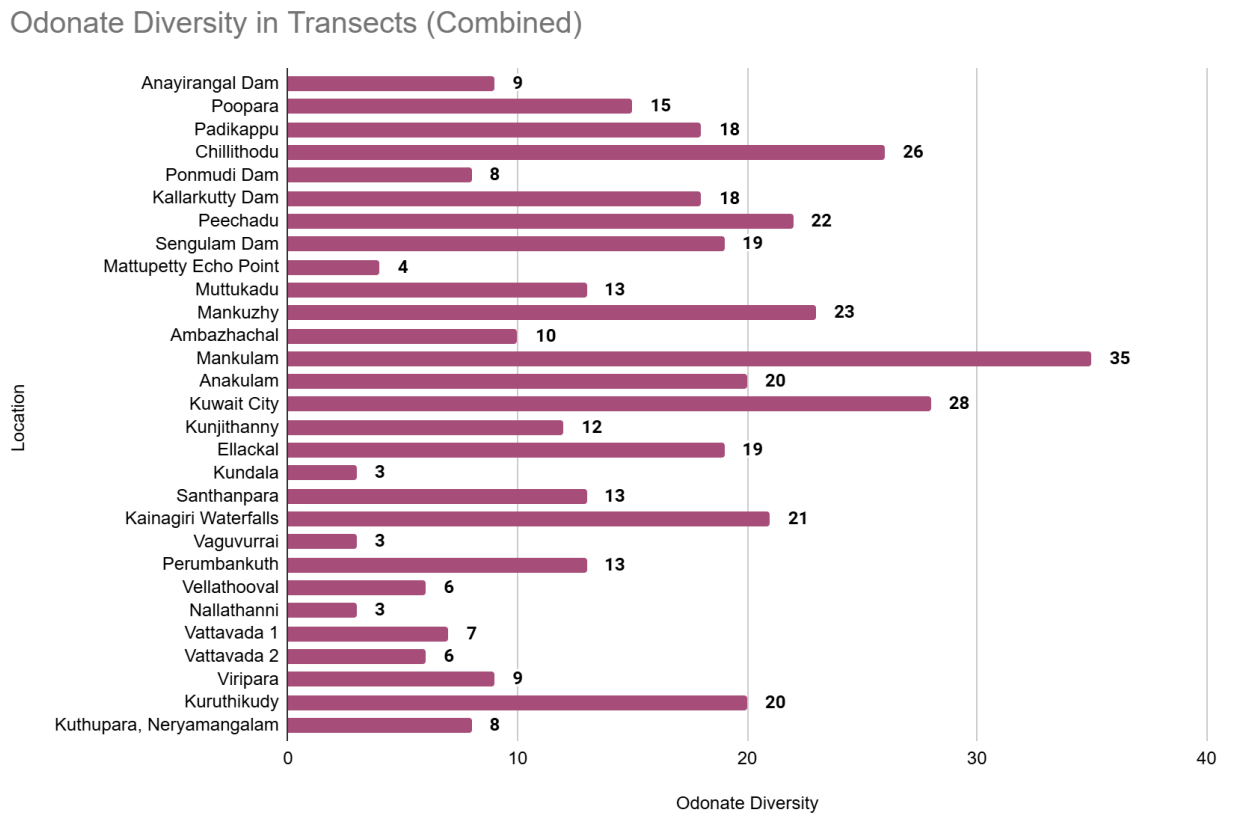
A comparative analysis of odonate diversity between the first and second surveys reveals significant fluctuations in species richness across the 29 transect locations. Many sites experienced a marked decline in odonate diversity, with locations such as Anayirangal Dam (8 to 4), Sengulam Dam (19 to 0), and Muttukadu (13 to 0) showing substantial reductions in species presence, suggesting potential environmental stressors such as habitat degradation, pollution, or climate-induced changes. Other areas, like Mankulam (25 to 27), Peechadu (17 to 20), and Kurathikudi (0 to 20), saw an increase or maintained relatively high diversity, indicating more stable or favorable ecological conditions that may support a wide range of species. Such declines in diversity may reflect broader environmental issues, including changes in water quality, altered vegetation, and the impacts of climate change, which can disrupt both the availability of suitable breeding grounds and the synchrony of life cycle events. Additionally, environmental disturbances, such as extreme weather events or human-induced habitat fragmentation, could further exacerbate the reduction in species diversity. This variation underscores the importance of continuous monitoring to better understand the factors influencing odonate diversity and to develop effective conservation strategies aimed at preserving biodiversity in freshwater ecosystems.



Graph 3. Odonate diversity comparison

2.2. Total Diversity

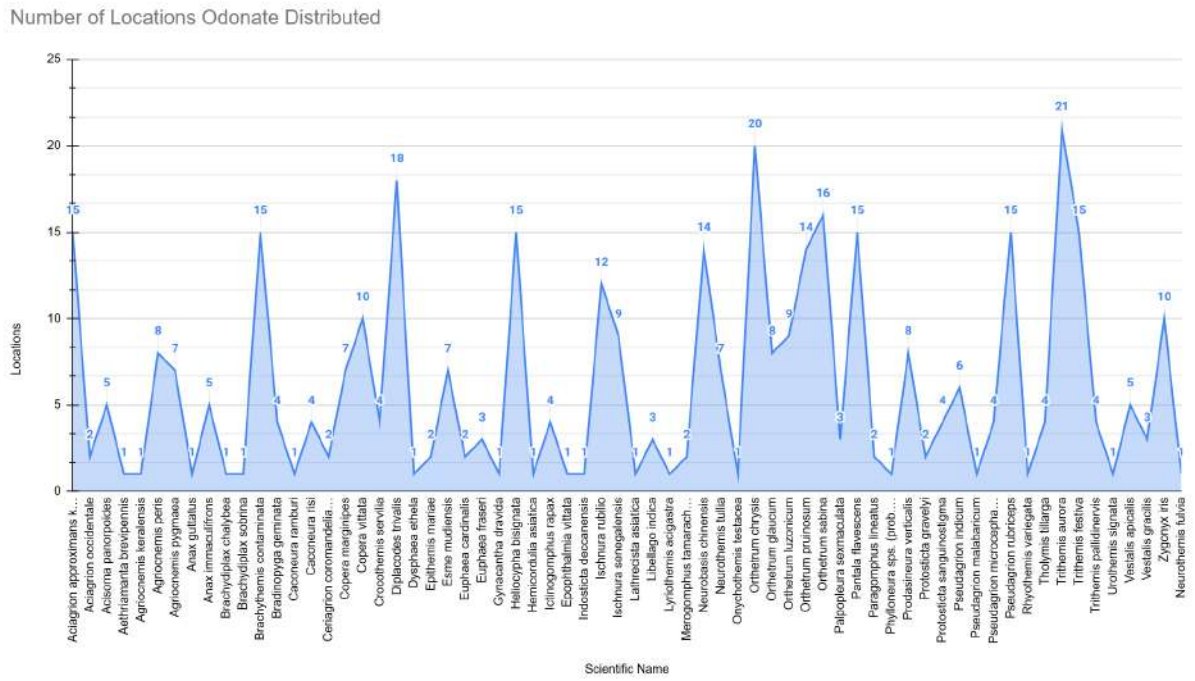
The odonate diversity across the 29 transect locations exhibits a broad range, with Mankulam (35 species) showing the highest diversity, followed by Kuwait City (28), and Chillithodu (26), indicating these locations likely have favorable environmental conditions, such as high-quality water, abundant vegetation, and stable habitats that support a wide range of odonate species. In contrast, locations like Kundala, Vaguvurrai, and Nallathanni recorded the lowest diversity (3 species), suggesting poor habitat quality and severe ecological stressors, which could be linked to factors like pollution, water temperature changes, or habitat loss. Sites such as Ponmudi Dam (8), Mattupetty Echo Point (4), and Vellathooval (6) also showed low diversity, potentially due to environmental factors like low water quality, reduced vegetation, or human disturbance, all of which could limit the range of species able to thrive. In the case of Sengulam Dam (19), despite moderate diversity, its environmental condition might be affected by periodic disturbances or pollution, contributing to a less stable ecosystem compared to higher diversity locations. The variation in odonate diversity across these sites emphasizes the importance of understanding local ecological factors—such as habitat structure, water quality, and climate variability—that influence species composition and abundance. This highlights the need for targeted conservation strategies, particularly for areas with low diversity, to mitigate environmental stressors and protect critical habitats for odonate populations.



Graph 4. Odonate diversity in transects (Combined)

The low species diversity observed in reservoir areas can largely be attributed to the impacts of construction and habitat alterations. The fluctuating water levels in these areas, which vary across seasons, often lead to the displacement of odonate larvae to lower regions, further limiting species survival and diversity. In contrast, areas to the south of Munnar, such as Mankulam and Chillithodu, show significantly higher odonate diversity. These regions benefit from the presence of well-established riparian forests, which provide ideal breeding and feeding habitats for odonates. The richness in biodiversity here is further supported by the relative absence of extensive human disturbances and natural forest cover. Similarly, locations like Mankuzhy and Ellackal, situated in the middle region before Munnar, also exhibit robust odonate populations, likely due to the availability of specific habitats that cater to the needs of these species. The contrast between these areas and the less diverse regions further emphasizes the importance of stable, well-preserved riparian ecosystems in supporting high odonate diversity.

2.3. Number of Locations Odonate Distributed



Graph 5.Location wise distribution details of odonates

The data reveals significant variation in odonate species abundance across the surveyed locations, with some species exhibiting high abundance while others remain rare or limited to specific regions. Species like ***Orthetrum chrysis, Trithemis aurora,*** and ***Diplacodes trivalis*** are found in higher numbers, suggesting these species thrive in areas with favorable environmental conditions, such as stable water levels, abundant riparian vegetation, and minimal human disturbance. In contrast, species like ***Aethriamanta brevipennis, Agriocnemis keralensis,*** and ***Gynacantha dravida*** are recorded in very low numbers, potentially indicating sensitivity to habitat changes or environmental stressors. The presence of both abundant and rare species across different locations highlights the diverse habitat requirements of odonates, with certain areas providing optimal conditions for species richness. Additionally, the observed trends may serve as indicators of ecosystem health, where declining or low-abundance species could reflect environmental degradation or climate-related changes. Overall, the variation in species distribution underscores the importance of monitoring and conserving odonate populations, particularly in regions showing low diversity, to ensure the stability of freshwater ecosystems.

Brachythemis contaminata was observed in 15 locations during the summer phase, likely due to

stagnant water and pollution, which can create favorable conditions for this species. The dominance of ***Orthetrum*** and ***Trithemis species*** was apparent, with these genera being widely distributed throughout Munnar. Additionally, ***Heliocypha bisignata*** and ***Neurobasis chinensis***, both of which are indicators of water quality, were recorded in approximately 50% of the locations across Munnar. ***Pseudagrion rubriceps*** was consistently found in 15 locations, except during the monsoon season, highlighting its seasonal distribution. The globally distributed species ***Pantala flavescens*** was observed in large swarms flying at high altitudes across about half of the Munnar transects. The target species ***Protosticta sanguinostigma*** was recorded in 4 locations, while ***Indosticta deccanensis*** was found in just 1. The rare sightings of several other specis, restricted to single locations, raise concerns about potential ecological shifts and the overall health of odonate populations in the region.

3. Odonates with Limited Occurrences in Surveys

Found only in First Survey	Found only in Second Survey
Libellago indica	*Hemicordulia asiatica*
Agriocnemis keralensis	*Merogomphus tamaracherriyensis*
Agriocnemis pygmaea	*Phylloneura westermani*
Ischnura rubilio	*Epithemis mariae*
Pseudagrion malabaricum	*Vestalis gracilis*
Dysphaea ethela	*Anax guttatus*
Gynacantha dravida	*Caconeura ramburi*
Ictinogomphus rapax	*Neurothemis fulvia*
Paragomphus lineatus	*Indosticta deccanensis*
Acisoma panorpoides	*Epophthalmia vittata*
Aethriamanta brevipennis	
Brachydiplax chalybea	
Brachydiplax sobrina	
Brachythemis contaminata	
Lathrecista asiatica	
Lyriothemis acigastra	
Onychothemis testacea	
Rhyothemis variegata	
Tholymis tillarga	
Trithemis pallidinervis	
Urothemis signata	

Table 6. Odonate Species with Limited Occurrences in Surveys

During the first survey, 21 odonates were observed, with sightings occurring across three distinct phases—summer, pre-monsoon, and part of the monsoon season. These species were predominantly active from January to June, corresponding to the summer and pre-monsoon periods. For instance, ***Brachythemis contaminata*** was found exclusively during the summer and pre-monsoon phases, when water levels were low and stagnant. During these times, the species' density was notably higher. ***Ischnura rubilio***, however, was not observed during the second survey phases. Other species such as ***Pseudagrion malabaricum***, ***Agriocnemis keralensis, Acisoma panorpoides, Lathrecista asiatica, Urothemis signata,*** and ***Paragomphus lineatus*** were also only recorded between January and June, suggesting their seasonal occurrence in specific habitats. Similarly, ***Trithemis pallidinervis*** was abundant during the summer phase but disappeared in the later phases. ***Tholymis tillarga***, which is commonly seen during the evening hours, was notably absent in the second survey. A rare sighting of ***Gynacantha dravida*** was made in Kuwait in February, while ***Rhyothemis variegata***, a more common species, was only spotted in Chillithodu, with just a single individual recorded.

In contrast, the second survey, conducted between July and December, yielded sightings of 10 species, all observed exclusively during this period. These included species like ***Caconeura ramburi, Neurothemis fulvia, Epithemis mariae,*** and ***Vestalis gracilis***, which were found in relatively higher numbers. Additionally, single individuals of ***Hemicordulia asiatica, Merogomphus tamaracherriyensis, Anax guttatus,*** and ***Epophthalmia vittata*** were recorded. A rare sighting of a ***Phylloneura westermani*** was reported from Viripara, it was not reported Munnar landscape. One of the key target species, ***Indosticta deccanensis***, was spotted with nine individuals in Neryamangalam during the second survey, indicating a successful presence in this region.

4. Odonate Distribution Based on MSL

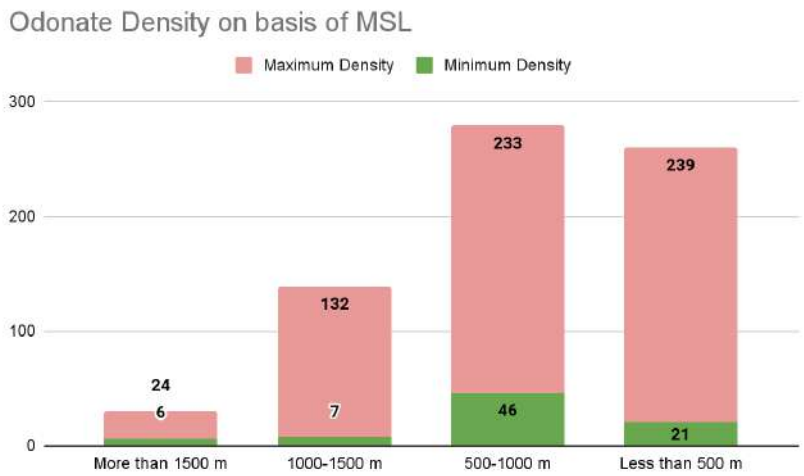
Odonate distribution based on Mean Sea Level (MSL) is crucial for understanding species habitat preferences and elevational ranges, as many odonate species are sensitive to altitude-related changes in temperature, humidity, and water availability. By mapping distribution along MSL, it can identify critical habitats and potential environmental stressors that affect species at different elevations. This information is essential for conservation planning, as it helps target areas most vulnerable to climate change or human disturbance, ensuring more effective protection of odonate populations.

MSL	Odonate Density
More than 1500 m	6-24
1000-1500 m	7-132
500-1000 m	46-233
Less than 500 m	21-239

Table 7. Odonate Density based on MSL

4.1. Odonate Density on basis of MSL

The data on odonate density across different Mean Sea Level (MSL) elevations reveals clear patterns in species distribution related to altitude. At elevations above 1500 meters, odonate density is relatively low, ranging from 6 to 24 individuals, likely due to harsher environmental conditions such as cooler temperatures and lower water availability. In the 1000-1500 meter range, densities increase significantly, from 7 to 132 individuals, indicating more favorable conditions for odonates, such as moderate temperatures and suitable breeding habitats. The highest densities are found in the 500-1000 meter range, where odonate populations range from 46 to 233 individuals, suggesting these mid-elevation areas offer optimal conditions for species diversity and abundance. In contrast, areas below 500 meters, while still supporting a wide range of species (21-239 individuals), may experience higher ecological pressures due to factors such as human disturbance or fluctuating water levels.



Graph 6. Odonate Density based on MSL

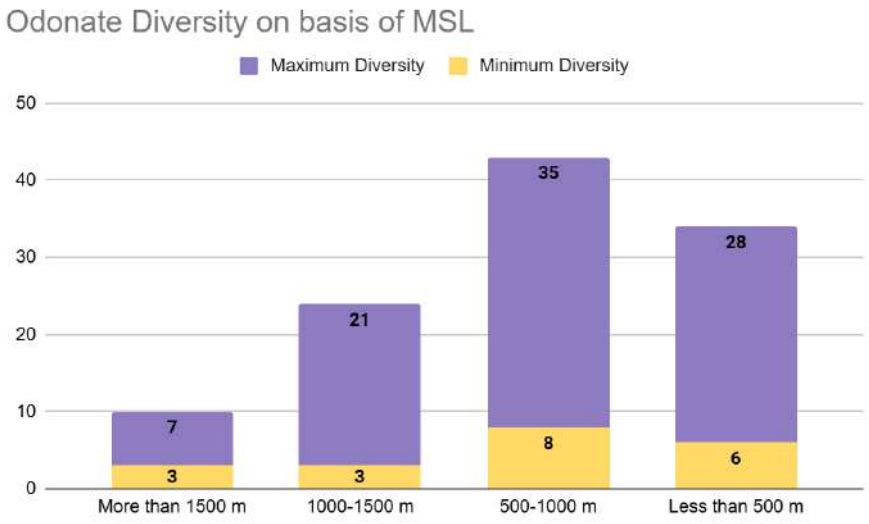
Natural forests are scarce at higher altitudes in Munnar due to the expansion of tea plantations and eucalyptus forests. Riparian natural forests, in particular, are rare, with only a few remaining along river transects. However, regions like Mankulam, Mankuzhy, Kuwait, Kainagiri, and Kurathikudi, which fall within the 300 to 1000-meter elevation range, support higher odonate densities due to the presence of suitable habitats. Additionally, areas such as Muttukadu and Sengulam also exhibit higher odonate densities, likely owing to the availability of optimal conditions for breeding and feeding

4.2. Odonate Diversity on basis of MSL

MSL	Odonate Diversity
More than 1500 m	3-7
1000-1500 m	3-21
500-1000 m	8-35
Less than 500 m	6-28

Table 8. Odonate diversity based on MSL

The data on odonate diversity across different Mean Sea Level (MSL) ranges reveals distinct patterns related to altitude. At elevations above 1500 meters, odonate diversity is relatively low, ranging from 3 to 7 species, likely due to harsh environmental conditions such as cooler temperatures and less stable habitats. In the 1000-1500 meter range, diversity increases, with species richness ranging from 3 to 21, suggesting that these areas provide more favorable conditions for a wider range of odonate species. The highest diversity is observed in the 500-1000 meter range, where the number of species ranges from 8 to 35, indicating that mid-elevation zones offer the most suitable habitats for a diverse odonate community. At elevations below 500 meters, diversity remains high (6-28 species), but the broader ecological pressures associated with lower altitudes, such as human activity and fluctuating water levels, may limit the stability of these habitats. Overall, mid-elevations appear to provide the optimal balance of temperature, habitat structure, and water quality to support the greatest odonate diversity.Similar to odonate density, odonate diversity is also higher in regions on the eastern side of Munnar, particularly in areas like Mankulam, Kurathikudi, Anakulam, Kuwait, and Kainagiri, as well as to the south of Munnar, including Mankuzhy and Chillithodu, which harbor the majority of species in the transect. The higher elevated areas, however, lack sufficient resources to support a thriving odonate community, with only limited resources available and increased human interventions. These elevated regions do not provide the optimal conditions necessary for sustaining diverse odonate populations.



Graph 7. Odonate diversity based on MSL

4.3. Odonate Availability on basis of MSL

Odonates in Munnar exhibit a wide range of altitudinal variation, with most species thriving between 300 and 1200 meters MSL. Orthetrum species, in particular, are found across the full spectrum of altitudes, while ***Pantala flavescens*** shows a cosmopolitan distribution, inhabiting a wide range of elevations. Other species, such as ***Diplacodes trivalis, Ischnura rubilio, Ischnura senegalensis, Esme mudiensis, Brachythemis contaminata, Neurobasis chinensis,*** and ***Trithemis festiva***, are also found at higher altitudes.

Interestingly, ***Protosticta sanguinostigma***, which was initially expected to be found only above 700 meters, has been recorded at lower altitudes between 400 and 1100 meters. Similarly, Indosticta deccanensis, traditionally associated with altitudes above 700 meters, was observed at elevations as low as 100-200 meters MSL. These unexpected shifts in distribution patterns indicate possible adaptations to climatic changes, suggesting that odonates are adjusting their habitat preferences in response to environmental variations. Such shifts can have significant implications on predation dynamics and ecological balance. Therefore, continuous monitoring and targeted conservation efforts are essential to protect these vulnerable species and their habitats.

Sl. No.	Scientific Name	Distribution to MSL
1	*Aciagrion approximans krishna*	100-1200m
2	*Aciagrion occidentale*	300-1000m
3	*Acisoma panorpoides*	300-1000m
4	*Aethriamanta brevipennis*	1100-1200m
5	*Agriocnemis keralensis*	300-400m
6	*Agriocnemis pieris*	300-1000m
7	*Agriocnemis pygmaea*	300-1200m
8	*Anax guttatus*	1100-1200m
9	*Anax immaculifrons*	100-1200m
10	*Brachydiplax chalybea*	700-800m
11	*Brachydiplax sobrina*	700-800m
12	*Brachythemis contaminata*	300-1750m
13	*Bradinopyga geminata*	300-1200m
14	*Caconeura ramburi*	400-500m
15	*Caconeura risi*	400-800m
16	*Ceriagrion coromandelianum*	1000-1200m
17	*Copera marginipes*	600-1200m
18	*Copera vittata*	100-1100m
19	*Crocothemis servilia*	400-1000m
20	*Diplacodes trivalis*	300-1700m
21	*Dysphaea ethela*	700-800m
22	*Epithemis mariae*	700-1100m
23	*Esme mudiensis*	600-1700m
24	*Euphaea cardinalis*	1000-1200m
25	*Euphaea fraseri*	400-700m
26	*Gynacantha dravida*	300-400m
27	*Heliocypha bisignata*	300-1200m
28	*Hemicordulia asiatica*	900-1000m
29	*Ictinogomphus rapax*	400-1100m
30	*Epophthalmia vittata*	700-800m

31	*Indosticta deccanensis*	100-200m
32	*Ischnura rubilio*	300-1700m
33	*Ischnura senegalensis*	300-1750m
34	*Lathrecista asiatica*	400-500m
35	*Libellago indica*	300-800m
36	*Lyriothemis acigastra*	400-500m
37	*Merogomphus tamaracherriyensis*	400-800m
38	*Neurobasis chinensis*	300-1700m
39	*Neurothemis tullia*	300-1000m
40	*Onychothemis testacea*	300-400m
41	*Orthetrum chrysis*	100-1700m
42	*Orthetrum glaucum*	100-1700m
43	*Orthetrum luzonicum*	100-1100m
44	*Orthetrum pruinosum*	300-1700m
45	*Orthetrum sabina*	300-1700m
46	*Palpopleura sexmaculata*	300-1200m
47	*Pantala flavescens*	300-1750m
48	*Paragomphus lineatus*	700-1000m
49	*Phylloneura westermani*	1000-1100m
50	*Prodasineura verticalis*	300-1300m
51	*Protosticta gravelyi*	400-1200m
52	*Protosticta sanguinostigma*	400-1100m
53	*Pseudagrion indicum*	400-1000m
54	*Pseudagrion malabaricum*	900-1000m
55	*Pseudagrion microcephalum*	400-1300m
56	*Pseudagrion rubriceps*	300-1300m
57	*Rhyothemis variegata*	600-700m
58	*Tholymis tillarga*	300-1100m
59	*Trithemis aurora*	300-1300m
60	*Trithemis festiva*	300-1700m
61	*Trithemis pallidinervis*	300-900m
62	*Urothemis signata*	700-800m
63	*Vestalis apicalis*	300-800m
64	*Vestalis gracilis*	400-1000m
65	*Zygonyx iris*	100-1200m
66	*Neurothemis fulvia*	700-800m

Table 9. Odonate Availability based on MSL

8. Consolidated Report on Odonate Survey

8.1. Combined Checklist

The Odonate checklist includes a diverse range of species from several families, with notable differences in their distribution across various locations. The most common families represented are Libellulidae and Coenagrionidae, with many species from both families present across a wide variety of locations. Libellulidae, in particular, is the most abundant family, comprising several species that occur in multiple habitats, such as the Brown-backed red marsh hawk ***(Orthetrum chrysis)***, Crimson Marsh Glider ***(Trithemis aurora)***, and Ditch Jewel ***(Brachythemis contaminata)***. These species are found in a range of locations including Chillithodu, Mankulam, Padikappu, and Kuwait, suggesting that Libellulidae is the most ubiquitous family in the dataset.

Coenagrionidae also appears to be widely distributed, with species like the Indian Violet Dartlet ***(Aciagrion approximans krishna)*** and White Dartlet ***(Agriocnemis pieris)*** being found across multiple locations such as Anakulam, Mankulam, and Kuwait. This family is particularly abundant in smaller, more localized environments like ponds and marshes.

Other families present in the checklist include Aeshnidae (e.g., Blue Darner, ***Anax immaculifrons***), Platycnemididae (e.g., Coorg bambootail, ***Caconeura ramburi***), Gomphidae (e.g., Indian common clubtail, ***Ictinogomphus rapax***), and Calopterygidae (e.g., Black tipped Forest Glory, ***Vestalis apicalis***), but these families have fewer species represented across the locations.

In terms of distribution, Libellulidae and Coenagrionidae have a clear dominance in terms of both species richness and the breadth of their geographic spread. There are several species from both families that appear consistently across most of the locations listed, indicating their adaptability to a variety of habitats within the region. For example, Chillithodu, Mankulam, Kuwait, and Padikappu are recurring locations for both families, suggesting these areas support a high diversity of odonates.

Some species, particularly from the Euphaeidae and Platystictidae families, seem more specialized or confined to specific regions. For example, Travancore Torrent Dart ***(Euphaea cardinalis)*** and Pied Reedtail ***(Protosticta gravelyi)*** are found in specific areas like Kainagiri and Viripara, indicating these species may have more specialized habitat requirements.

In summary, Libellulidae is the most abundant and widespread family in this checklist, appearing in a broad range of locations, while Coenagrionidae follows closely behind in terms of abundance and distribution. Other families are more specialized, with some species showing restricted ranges in particular locations. This suggests that Libellulidae and Coenagrionidae are the most adaptable and common families in the surveyed habitats.

Odonate Checklist

Sl. No.	Scientific Name	Family	Common name	Locations
1	***Aciagrion approximans krishna*** (Fraser,1921)	Coenagrionidae	Indian Violet Dartlet	Poopara, Padikappu, Chillithodu, Peechadu, Sengulam, Mankuzhy, Ambazhachal, Mankulam, Anakulam, Kuwait, Kunjithanny, Ellackal, Kainagiri, Vellathooval, Kurathikudi
2	***Aciagrion occidentale*** (Laidlaw,1919)	Coenagrionidae	Green striped slender dartlet	Peechadu, Anakulam
3	***Acisoma panorpoides*** (Rambur,1842)	Libellulidae	Trumpet tail	Ellackal, Kuwait, Anakulam, Mankulam, Sengulam
4	***Aethriamanta brevipennis*** (Rambur, 1842)	Libellulidae	Scarlet Marsh Hawk	Kainagiri
5	***Agriocnemis keralensis*** (Peters,1981)	Coenagrionidae	Kerala Dartlet	Anakulam

6	*Agriocnemis pieris* (Laidlaw,1919)	Coenagrionidae	White Dartlet	Kurathikudi, Kunjithanny, Kuwait, Anakulam, Mankulam, Peechadu, Padikappu, Perumbankuthu
7	*Agriocnemis pygmaea* (Rambur, 1842)	Coenagrionidae	Pygmy Dartlet	Poopara, Kallarkutty, Sengulam, Mankulam, Anakulam, Kuwait, Vellathooval
8	*Anax guttatus* (Burmeister, 1839)	Aeshnidae	Blue tailed green darner	Kainagiri
9	*Anax immaculifrons* (Rambur, 1842)	Aeshnidae	Blue Darner	Kuthupara (Neryamangalam), Kurathikudi, Kainagiri, Mankulam, Sengulam
10	*Brachydiplax chalybea* (Brauer, 1868)	Libellulidae	Blue Dasher	Mankulam
11	*Brachydiplax sobrina* (Rambur, 1842)	Libellulidae	Little blue Marsh Hawk	Mankulam
12	*Brachythemis contaminata* (Fabricius,1793)	Libellulidae	Asian Groundling/ Common Amber Wing/ Ditch Jewel	Aanayirangal, Chillithodu, Ponmudi, Kallarkutty, Sengulam,Mattupetty, Mankuzhy, Ambazhachal, Mankulam, Kuwait, Kunjithanny, Ellackal, Kundala, Vellathooval, Nallathanni
13	*Bradinopyga geminata* (Rambur, 1842)	Libellulidae	Granite ghost	Kainagiri, Anakulam, Mankulam, Chillithodu
14	*Caconeura ramburi* (Fraser,1922)	Platycnemididae.	Coorg bambootail	Kurathikudi
15	*Caconeura risi* (Fraser, 1931)	Platycnemididae	Wayanad Bambootail	Kurathikudi, Ellackal, Chillithodu, Mankulam
16	*Ceriagrion coromandelianum* (Fabricius, 1798)	Coenagrionidae	Yellow Wax-tail	Poopara, Santhanpara
17	*Copera marginipes* (Rambur, 1842)	Platycnemididae	Yellow Bush Dart	Poopara, Chillithodu, Peechadu, Sengulam, Mankuzhy, Mankulam, Ellackal
18	*Copera vittata* (Selys, 1863)	Platycnemididae	Blue bush dart	Perumbankuthu, Padikappu, Chillithodu, Peechadu, Mankuzhy, Kuwait, Kunjithanny, Viripara, Kurathikudi, Kuthupara
19	*Crocothemis servilia* (Drury, 1770)	Libellulidae	Oriental Scarlet	Ellackal, Kallarkutty, Mankuzhy, Muttukaadu
20	*Diplacodes trivalis* (Rambur, 1842)	Libellulidae	Ground skimmer	Poopara, Padikappu, Chillithodu, Ponmudi, Kallarkutty, Peechadu, Sengulam, Muttukadu, Ambazhachal, Mankulam, Anakulam, Kuwait, Kunjithanny, Santhanpara, Kainagiri, Vaguvurrai, Vattavada, Umankadavu
21	*Dysphaea ethela* (Fraser, 1924)	Euphaeidae	Black Torrent Dart	Ellackal
22	*Epithemis mariae* (Laidlaw, 1915)	Libellulidae	Rubytailed Hawklet	Mankulam, Viripara
23	*Esme mudiensis* (Fraser, 1931)	Platycnemididae	Travancore Bambootail	Vattavada, Vaguvurrai, Viripara, Kainagiri, Mankuzhy, Chillithodu, Padikappu
24	*Euphaea cardinalis* (Fraser, 1924)	Euphaeidae	Travancore Torrent Dart	Kainagiri, Viripara
25	*Euphaea fraseri* (Laidlaw, 1920)	Euphaeidae	Malabar Torrent Dart	Perumbankuthu, Chillithodu, Kurathikudi
26	*Gynacantha dravida* (Lieftinck, 1960)	Aeshnidae	Brown Darner	Kuwait
27	*Heliocypha bisignata* (Hagen in Selys, 1853)	Chlorocyphidae	Stream ruby	Kurathikudi, Kainagiri, Santhanpara, Ellackal, Kunjithanny, Kuwait, Anakulam, Mankulam, Ambazhachal, Mankuzhy, Muttukaadu, Peechadu, Chillithodu, Poopara, Perumbankuthu
28	*Hemicordulia asiatica* (Selys, 1878)	Corduliidae	Asian emerald	Peechadu

29	*Ictinogomphus rapax* (Rambur, 1842)	Gomphidae	Asian Tiger	Ponmudi, Kallarkutty, Sengulam, Santhanpara
30	*Epophthalmia vittata* (Burmeister, 1839)	Gomphidae	Common Torrent Hawk	Mankulam
31	*Indosticta deccanensis* (Laidlaw, 1915)	Platystictidae	Saffron Reedtail	Kuthupara (Neryamangalam)
32	*Ischnura rubilio* (Selys, 1876)	Coenagrionidae	Dawn bluetail/ Golden Dartlet	Perumbankuthu, Aanayirangal, Poopara, Kallarkutty, Sengulam, Mattupetty, Muttukaadu, Mankuzhy, Mankulam, Anakulam, Kuwait, Kainagiri
33	*Ischnura senegalensis* (Rambur, 1842)	Coenagrionidae	Common Bluetail/ Senegal Golden Dartlet	Kainagiri, Kundala, Mattupetty, Ellackal, Kuwait, Anakulam, Semgulam, Aanayirangal, Perumbankuthu
34	*Lathrecista asiatica* (Fabricius, 1798)	Libellulidae	Long Winged Skimmer/ Asiatic bloodtail	Kallarkutty
35	*Libellago indica* (Fraser, 1928)	Chlorocyphidae	Indian yellow lined gem	Kuwait, Chillithodu, Mankuzhy
36	*Lyriothemis acigastra* (Selys, 1878)	Libellulidae	Long Winged Skimmer/ Asiatic bloodtail	Kallarkutty
37	*Merogomphus tamaracherriensis* (Fraser, 1931)	Gomphidae	Giant Clubtail	Perumbankuthu, Mankulam
38	*Neurobasis chinensis* (Linnaeus, 1758)	Calopterygidae	Stream Glory	Perumbankuthu, Chillithodu, Kallarkutty, Peechadu, Muttukaadu, Mankuzhy, Mankulam, Anakulam, Kuwait, Ellackal, Kainagiri, Vattavada, Umankadavu, Kurathikudi
39	*Neurothemis tullia* (Drury, 1773)	Libellulidae	Pied Paddy Skimmer	Padikappu, Chillithodu, Peechadu, Sengulam, Mankulam, Kuwait, Kurathikudi
40	*Onychothemis testacea* (Laidlaw, 1902)	Libellulidae	River Hawker	Kuwait
41	*Orthetrum chrysis* (Selys, 1891)	Libellulidae	Red faced Skimmer/ Brown Backed Red Marsh Hawk	Poopara, Chillithodu, Padikappu, Kallarkutty, Peechadu, Muttukaadu, Mankuzhy, Ambazhachal, Mankulam, Anakulam, Kuwait, Kunjithanny, Kainagiri, Viripara, Vellathooval, Nallathanni, Vattavada, Umankadavu, Kurathikudi, Kuthupara
42	*Orthetrum glaucum* (Brauer, 1865)	Libellulidae	Asian Skimmer/ Blue Marsh Hawk	Poopara, Chillithodu, Peechadu, Ellackal, Vattavada, Umankadavu, Kuruthikudi, Kuthupara
43	*Orthetrum luzonicum* (Brauer, 1868)	Libellulidae	Tricoloured Marsh Hawk	Padikappu, Chillithodu, Sengulam, Anakulam, Kuwait, Santhanpara, Viripara, Kuruthikudi, Kuthupara
44	*Orthetrum pruinosum* (Burmeister, 1839)	Libellulidae	Common Red Skimmer/ Crimson tailed Marsh Hawk	Chillithodu, Kallarkutty, Peechadu, Muttukaadu, Mankuzhy, Ambazhachal, Mankulam, Kuwait, Kunjithanny, Ellackal, Kainagiri, Vattavada, Umankadavu, Kuruthikudi
45	*Orthetrum sabina* (Drury, 1770)	Libellulidae	Green Skimmer	Padikappu, Chillithodu, Ponmudi, Kallarkutty, Sengulam, Muttukaadu, Mankuzhy, Ambazhachal, Mankulam, Anakulam, Kuwait, Kunjithanny, Ellackal, Santhanpara, Kainagiri, Umankadavu
46	*Palpopleura sexmaculata* (Fabricius, 1787)	Libellulidae	Asian Widow	Mankulam, Kuwait, Kainagiri

47	*Pantala flavescens* (Fabricius, 1798)	Libellulidae	Global wanderers/ Globe Skimmer	Chillithodu, Ponmudi, Peechadu, Sengulam, Mattupetty, Mankuzhy, Mankulam, Anakulam, Kuwait, Kunjithanny, Ellackal, Kundala, Kainagiri, Viripara, Kurathikudi
48	*Paragomphus lineatus* (Selys, 1850)	Gomphidae	Lined hooktail	Ellackal, Muttukaadu
49	*Phylloneura westermani*	Platycnemididae	Myristica Bambootail	Viripara
50	*Prodasineura verticalis* (Selys, 1860)	Platycnemididae	Red stripped threadtail	Aanayirangal, Perumbankuthu, Poopara, Padikappu, Peechadu, Mankuzhy, Mankulam, Kuwait
51	*Protosticta gravelyi* (Laidlaw, 1915)	Platystictidae	Pied Reedtail	Kainagiri, Kurathikudi,
52	*Protosticta sanguinostigma* (Fraser, 1922)	Platystictidae	Red Spotted Reedtail	Perumbankuthu, Mankuzhy, Viripara, Kurathikudi
53	*Pseudagrion indicum* (Fraser 1924)	Coenagrionidae	Indian Sprite	Chillithodu, Kallarkutty, Peechadu, Sengulam, Muttukaadu, Mankulam
54	*Pseudagrion malabaricum* (Fraser 1924)	Coenagrionidae	Jungle sprite	Sengulam
55	*Pseudagrion microcephalum* (Rambur, 1872)	Coenagrionidae	Blue Sprite	Aanayirangal, Kallarkutty, Peechadu, Mankuzhy
56	*Pseudagrion rubriceps* (Selys, 1876)	Coenagrionidae	Orange faced Sprite	Aanayirangal, Poopara, Padikappu, Chillithodu, Ponmudi, Kallarkutty, Peechadu, Sengulam, Muttukaadu, Mankuzhy, Ambazhachal, Mankulam, Kuwait, Ellackal, Vellathooval
57	*Rhyothemis variegata* (Linnaeus, 1763)	Libellulidae	Common Picture Wing	Chillithodu
58	*Tholymis tillarga* (Fabricius, 1798)	Libellulidae	Evening Skimmer	Muttukaadu, Mankulam, anakulam, Santhanpara
59	*Trithemis aurora* (Burmeister, 1839)	Libellulidae	Crimson Marsh Glider	Aanayirangal, Perumbankuthu, Poopara, Padikappu, Chillithodu, Ponmudi, Kallarkutty, Peechadu, Sengulam, Muttukaadu, Mankuzhy, Ambazhachal, Mankulam, Anakulam, Kuwait, Kunjithanny, Ellackal, Santhanpara, Kainagiri, Vellathooval, Nallathanni
60	*Trithemis festiva* (Rambur, 1842)	Libellulidae	Black Stream Glider	Poopara, Padikappu, Chillithodu, Peechadu, Mankuzhy, Ambazhachal, Mankulam, Anakulam, Kuwait, Kunjithanny, Ellackal, Santhanpara, Kainagiri, Vattvada, Kuthupara
61	*Trithemis pallidinervis* (Kirby, 1889)	Libellulidae	Dancing Dropwing	Ponmudi, Kallarkutty, Sengulam, Kuwait
62	*Urothemis signata* (Rambur, 1842)	Libellulidae	Scarlet Basker	Mankuzhy
63	*Vestalis apicalis* (Selys, 1873)	Calopterygidae	Black tipped Forest Glory	Chillithodu, Mankualam, Anakulam, Kuwait, Kurathikudi
64	*Vestalis gracilis* (Rambur, 1842)	Calopterygidae	Clear winged Forest Glory	Peechadu, Mankulam, Kurathikudi
65	*Zygonyx iris* (Selys,1869)	Libellulidae	Iridescent Stream Glider	Perumbankuthu, Peechadu, Mankuzhy, Mankulam, Kuwait, Ellackal, Kainagiri, Vaguvurrai, kurathikudi, Kuthupara
66	*Neurothemis fulvia* (Drury, 1773)	Libellulidae	Fulvous forest skimmer	Mankulam

Table 10. Checklist of odonates

Figure 32.(from top; left to right) ***Aciagrion approximans krishna, Aciagrion occidentale, Acisoma panorpoides, Agriocnemis keralensis, Agriocnemis pieris, Agriocnemis pygmaea, Anax immaculifrons, Brachythemis contaminata***

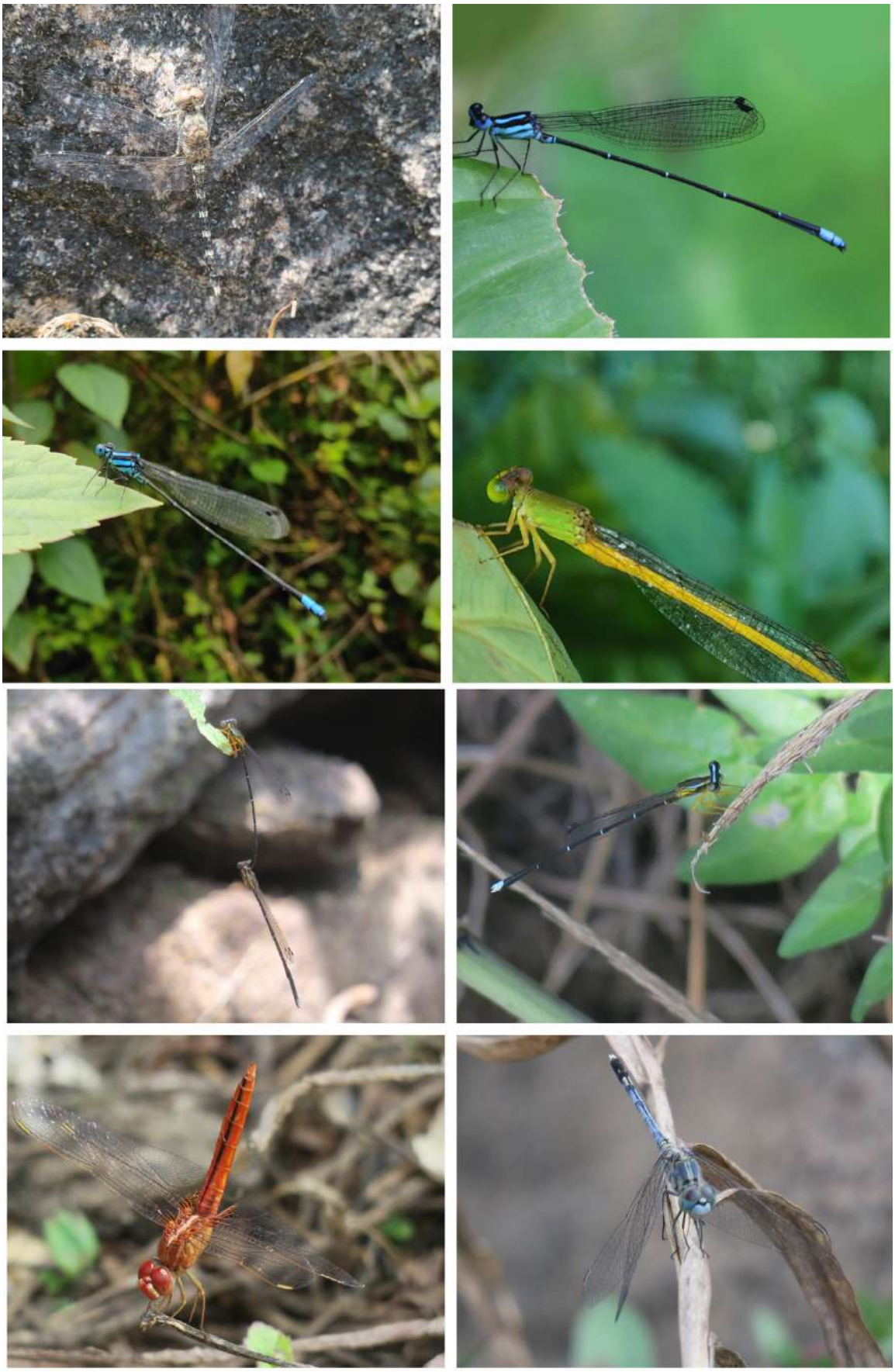


Figure 33. (from top; left to right) ***Bradinopyga geminata, Caconeura ramburi, Caconeura risi, Ceriagrion coromandelianum,Copera marginipes, Copera vittata, Crocothemis servilia, Diplacodes trivalis***

Figure 34. (from top; left to right) ***Dysphaea ethela, Epithemis mariae, Euphaea cardinalis, Euphaea fraseri, Gynacantha dravida,Heliocypha bisignata, Anax guttatus,Epophthalmia vittata***

Figure 35. (from top; left to right) ***Ictinogomphus rapax, Indosticta deccanensis, Ischnura rubilio, Ischnura senegalensis, Libellago indica, Merogomphus tamaracherriensis, Neurobasis chinensis, Neurothemis tullia***

Figure 36. (from top; left to right) ***Onychothemis testacea,Orthetrum glaucum, Orthetrum chrysis, Orthetrum luzonicum, Orthetrum pruinosum, Orthetrum sabina, Zygonyx iris***, ***Prodasineura verticalis***

Figure 37. (from top; left to right) ***Palpopleura sexmaculata, Protosticta gravelyi, Protosticta sanguinostigma, Pseudagrion indicum, Pseudagrion malabaricum, Pseudagrion microcephalum, Pseudagrion rubriceps, Trithemis aurora***

Figure 38. (from top; left to right) ***Trithemis festiva, Trithemis pallidinervis, Vestalis apicalis, Vestalis gracilis,***

Phylloneura westermani spotted first time in Munnar

8.2. Endemic Odonates

The Western Ghats, a biodiversity hotspot in India, is home to a remarkable diversity of endemic odonates. These species are unique to this region and contribute significantly to its ecological richness. Notable endemic odonates include ***Aciagrion approximans krishna*** (Fraser, 1921), ***Agriocnemis keralensis*** (Peters, 1981), and ***Caconeura risi*** (Fraser, 1931), which are typically found in specific freshwater habitats within the Western Ghats. Other endemic species such as ***Esme mudiensis*** (Fraser, 1931) and ***Euphaea cardinalis*** (Fraser, 1924) further highlight the region's importance for odonate conservation. ***Euphaea fraseri*** (Laidlaw, 1920) and ***Epithemis mariae*** (Laidlaw, 1915) are also exclusive to this area, thriving in the fast-flowing streams and mountain streams of the Ghats. The ***Indosticta deccanensis*** (Laidlaw, 1915), ***Merogomphus tamaracherriensis*** (Fraser, 1931), and Protosticta species, including ***Protosticta gravelyi*** (Laidlaw, 1915) and ***Protosticta sanguinostigma*** (Fraser, 1922), represent other endemic genera that contribute to the unique faunal composition of the region. The ***Pseudagrion indicum*** (Fraser, 1924) is another endemic species found in the region's wetland habitats. A particularly enigmatic species, Phylloneura sp. (prob. westermani or a new species), remains a rare and poorly understood endemic odonate, highlighting the need for continued research in the Western Ghats. These endemic odonates not only enrich the region's biodiversity but also underscore the importance of preserving the Western Ghats' unique aquatic ecosystems.

Endemic Odonates to the Western Ghats	
Sl. No.	Odonates
1	*Aciagrion approximans krishna (Fraser,1921)*
2	*Agriocnemis keralensis (Peters,1981)*
3	*Caconeura risi (Fraser, 1931)*
4	*Esme mudiensis (Fraser, 1931)*
5	*Euphaea cardinalis (Fraser, 1924)*
6	*Euphaea fraseri (Laidlaw, 1920)*
7	*Epithemis mariae (Laidlaw, 1915)*
8	*Indosticta deccanensis (Laidlaw, 1915)*
9	*Merogomphus tamaracherriensis (Fraser, 1931)*
10	*Protosticta gravelyi (Laidlaw, 1915)*
11	*Protosticta sanguinostigma (Fraser, 1922)*
12	*Pseudagrion indicum (Fraser 1924)*
13	*Phylloneura westermani*

Table 11. Endemic Odonates of Western Ghats

8.3. IUCN Status of Odonates

Protosticta sanguinostigma and I***ndosticta deccanensis*** are two vulnerable species that are the primary focus of this project due to their threatened status within their ecosystems. Multiple sightings of ***P. sanguinostigma*** have been reported, whereas only a single observation of ***I. deccanensis*** has been recorded. Both species are at risk, particularly due to pollutants present near their habitats, which are impacting the health of their ecosystems. Therefore, it is crucial to take special precautions to protect these species. The unidentified Phylloneura species, which is considered near-threatened, also warrants attention. Some species, such as Caconeura species, ***Dysphaea ethela, Esme mudiensis, Lyriothemis acigastra,*** and ***Gynacantha dravida***, have limited data, making their conservation status unclear. Meanwhile, ***Palpopleura sexmaculata*** and ***Merogomphus tamaracherriensis*** remain as data unavailable (NA) species. All other species under consideration fall into the "Least Concern" category, suggesting they are currently not facing significant threats.

Sl. No.	Scientific Name	IUCN Status
1	*Aciagrion approximans krishna (Fraser,1921)*	LC
2	*Aciagrion occidentale (Laidlaw,1919)*	LC
3	*Acisoma panorpoides (Rambur,1842)*	LC
4	*Aethriamanta brevipennis (Rambur, 1842)*	LC
5	*Agriocnemis keralensis (Peters,1981)*	LC
6	*Agriocnemis pieris (Laidlaw,1919)*	LC
7	*Agriocnemis pygmaea (Rambur, 1842)*	LC
8	*Anax guttatus (Burmeister, 1839)*	LC
9	*Anax immaculifrons (Rambur, 1842)*	LC
10	*Brachydiplax chalybea (Brauer, 1868)*	LC
11	*Brachydiplax sobrina (Rambur, 1842)*	LC
12	*Brachythemis contaminata (Fabricius,1793)*	LC
13	*Bradinopyga geminata (Rambur, 1842)*	LC
14	*Caconeura ramburi (Fraser,1922)*	DD
15	*Caconeura risi (Fraser, 1931)*	DD
16	*Ceriagrion coromandelianum (Fabricius, 1798)*	LC
17	*Copera marginipes (Rambur, 1842)*	LC
18	*Copera vittata (Selys, 1863)*	LC
19	*Crocothemis servilia (Drury, 1770)*	LC
20	*Diplacodes trivalis (Rambur, 1842)*	LC
21	*Dysphaea ethela (Fraser, 1924)*	DD
22	*Epithemis mariae (Laidlaw, 1915)*	LC
23	*Esme mudiensis (Fraser, 1931)*	DD
24	*Euphaea cardinalis (Fraser, 1924)*	LC
25	*Euphaea fraseri (Laidlaw, 1920)*	LC
26	*Gynacantha dravida (Lieftinck, 1960)*	DD
27	*Heliocypha bisignata (Hagen in Selys, 1853)*	LC
28	*Hemicordulia asiatica (Selys, 1878)*	LC
29	*Ictinogomphus rapax (Rambur, 1842)*	LC
30	*Epophthalmia vittata (Burmeister, 1839)*	LC
31	*Indosticta deccanensis (Laidlaw, 1915)*	VU
32	*Ischnura rubilio (Selys, 1876)*	LC
33	*Ischnura senegalensis (Rambur, 1842)*	LC
34	*Lathrecista asiatica (Fabricius, 1798)*	LC
35	*Libellago indica (Fraser, 1928)*	LC
36	*Lyriothemis acigastra (Selys, 1878)*	DD
37	*Merogomphus tamaracherriensis(Fraser, 1931)*	NA
38	*Neurobasis chinensis (Linnaeus, 1758)*	LC
39	*Neurothemis tullia (Drury, 1773)*	LC
40	*Onychothemis testacea (Laidlaw, 1902)*	LC
41	*Orthetrum chrysis (Selys, 1891)*	LC
42	*Orthetrum glaucum (Brauer, 1865)*	LC
43	*Orthetrum luzonicum (Brauer, 1868)*	LC
44	*Orthetrum pruinosum (Burmeister, 1839)*	LC
45	*Orthetrum sabina (Drury, 1770)*	LC

46	*Palpopleura sexmaculata (Fabricius, 1787)*	NA
47	*Pantala flavescens (Fabricius, 1798)*	LC
48	*Paragomphus lineatus (Selys, 1850)*	LC
49	*Phylloneura westermani*	NT
50	*Prodasineura verticalis (Selys, 1860)*	LC
51	*Protosticta gravelyi (Laidlaw, 1915)*	LC
52	*Protosticta sanguinostigma (Fraser, 1922)*	VU
53	*Pseudagrion indicum (Fraser 1924)*	LC
54	*Pseudagrion malabaricum (Fraser 1924)*	LC
55	*Pseudagrion microcephalum (Rambur, 1872)*	LC
56	*Pseudagrion rubriceps (Selys, 1876)*	LC
57	*Rhyothemis variegata (Linnaeus, 1763)*	LC
58	*Tholymis tillarga (Fabricius, 1798)*	LC
59	*Trithemis aurora (Burmeister, 1839)*	LC
60	*Trithemis festiva (Rambur, 1842)*	LC
61	*Trithemis pallidinervis (Kirby, 1889)*	LC
62	*Urothemis signata (Rambur, 1842)*	LC
63	*Vestalis apicalis (Selys, 1873)*	LC
64	*Vestalis gracilis (Rambur, 1842)*	LC
65	*Zygonyx iris (Selys,1869)*	LC
66	*Neurothemis fulvia (Drury, 1773)*	LC

Table 12. IUCN Conservation Status of Odonates

8.4. Issues faced

8.4.1. Climate Change

Climate change poses a significant threat to odonates, as their life cycle is closely tied to environmental conditions such as temperature and rainfall. Munnar's ecosystems are sensitive to shifts in temperature and precipitation patterns, which can alter the timing of seasonal events like mating, larval development, and emergence. Elevated temperatures can accelerate the drying of wetlands, while erratic rainfall can lead to floods, destabilizing habitats. Additionally, climate change may lead to the loss of high-altitude habitats that odonates rely on, as their specific environmental needs become harder to meet. These changes can result in the displacement of species, reduced breeding success, and shifts in distribution.

8.4.2. Habitat or Riparian Loss

Odonates are highly dependent on riparian ecosystems—habitats along rivers, streams, and wetlands—for breeding and larval development. The loss of riparian habitats due to deforestation, agricultural encroachment, and urbanization in Munnar has diminished the availability of suitable breeding grounds for odonates. The destruction of vegetation along water bodies increases sedimentation, which can smother eggs and larvae, while also reducing the amount of shade, increasing water temperatures, and decreasing oxygen levels in aquatic environments. Loss of riparian zones disrupts the delicate balance of these habitats, leading to a decline in odonate populations.

8.4.3. Pesticide Pollution from Plantations

Munnar is known for its tea and coffee plantations, which rely heavily on chemical pesticides to control pests. These pesticides often leach into nearby water bodies during rainfall or irrigation, contaminating the habitats of aquatic organisms like odonates. Pesticides can be toxic to both the aquatic larvae of odonates and their adult forms. Exposure to these chemicals can impair the development of larvae, reduce survival rates, and disrupt reproductive cycles. In some cases, pesticide residues can accumulate in the food web, affecting both predator and prey species, further contributing to the decline of odonate populations.

8.4.4. Unscientific Waste Management

Improper waste disposal, especially plastic waste, is a growing issue in Munnar. Poor waste management practices lead to the accumulation of solid waste in water bodies, which can significantly impact odonate habitats. Plastics and other waste materials can physically obstruct aquatic habitats, reducing space for larvae to develop. Additionally, organic waste can contribute to water pollution, leading to the eutrophication of aquatic ecosystems. As nutrient levels increase, harmful algal blooms can deplete oxygen levels in the water, suffocating aquatic organisms, including odonate larvae. The presence of waste in natural habitats also alters the aesthetic and ecological quality of the area, further deterring species dependent on pristine conditions.

8.4.5. Hydroelectric Projects

Hydroelectric projects in the Western Ghats, including those near Munnar, alter natural river flows by damming rivers for power generation. This leads to the alteration of aquatic ecosystems, changing water levels, flow patterns, and sedimentation rates. Odonates are highly sensitive to these changes, as their larvae require specific flow conditions for development. Fluctuating water levels can strand larvae, disrupt breeding sites, and reduce the availability of suitable habitats. The construction of dams can also impede the natural migration of species and lead to the fragmentation of habitats, making it difficult for odonates to thrive in the affected areas. Existing dams and ongoing projects really affect odonates.

8.4.6. Uncontrolled Tourism

Munnar's popularity as a tourist destination has led to an increase in human activity in the region. Uncontrolled tourism contributes to habitat degradation, pollution, and the disturbance of wildlife, including odonates. Excessive foot traffic near water bodies can trample vegetation, compact soil, and disturb breeding sites. Increased waste generation, noise, and light pollution further exacerbate these pressures. Additionally, the construction of tourist infrastructure like resorts and roads can lead to habitat fragmentation, limiting the movement of odonates between breeding and feeding sites. These disturbances can significantly reduce the abundance and diversity of odonates in the region.

8.4.7. Land Use Change

Land use changes in Munnar, such as the expansion of agriculture and urban development, are transforming the natural landscape and disrupting the habitats of odonates. The conversion of forests and wetlands into agricultural fields or urban areas directly impacts the availability of suitable breeding sites for odonates. The loss of forest cover also reduces the amount of organic material entering water bodies, which can affect the food availability for aquatic larvae. Changes in land use may also lead to increased sediment runoff into rivers and streams, further degrading water quality and making it unsuitable for odonate larvae and other aquatic species.

8.4.8. Invasive Species

The introduction of invasive species in Munnar, both terrestrial and aquatic, can have a detrimental impact on native odonate populations. Invasive plants in water can overtake natural vegetation in aquatic habitats, reducing the available space for odonates to breed and develop. Similarly, the introduction of predatory or competitive species, such as certain fish or amphibians, can reduce the survival rate of odonate larvae. Invasive species can also alter the water chemistry and flow patterns, further disturbing the ecological balance and making it more difficult for native odonate species to thrive.

8.4.9. Eutrophication

Eutrophication, caused by an excess of nutrients such as nitrogen and phosphorus in water bodies, is a significant problem in Munnar's aquatic ecosystems. Agricultural runoff, sewage, and industrial effluents contribute to the nutrient load in rivers and streams, leading to an overgrowth of algae. This algal bloom can block sunlight from reaching submerged plants, deplete dissolved oxygen in the water, and create hypoxic conditions that are harmful to aquatic organisms, including odonate larvae. Eutrophication can also lead to the loss of biodiversity, as it creates a more homogenous and less hospitable environment for species that rely on clear, oxygen-rich water.

8.4.10. Alteration of Water Flow and Sedimentation

The alteration of natural water flow due to human

activities such as construction, agriculture, and deforestation has profound impacts on the aquatic habitats of odonates in Munnar. Changes in the flow of rivers and streams can disrupt the stability of water bodies, leading to erosion or sedimentation. Increased sedimentation can smother aquatic plants and eggs, reducing habitat quality for odonates. The accumulation of silt can also affect the feeding behavior of aquatic insects and reduce the oxygen levels in the water, making it unsuitable for the larvae to develop. Alterations to water flow can lead to a decrease in the diversity of aquatic life and a loss of habitat connectivity, both of which are detrimental to odonate populations.

These problems highlight the complex web of environmental stressors affecting odonates in Munnar. Effective conservation strategies must address these issues holistically, integrating habitat restoration, sustainable land management, and pollution control measures to safeguard these important insect species and their ecosystems.

8.5. Inference on Threatened Odonates in Munnar

Out of the 66 species of odonates observed across various locations in Munnar, two notable species fall under the vulnerable category. Although the project proposal focuses on three species, ***Chlorogomphus xanthoptera*** was not spotted despite a year-long research effort across multiple sites in Munnar. No traces of this species were found during surveys conducted in all seasons. In contrast, ***Protosticta sanguinostigma*** was successfully located at four different locations, and ***Indosticta deccanensis*** was observed at one site.

Protosticta sanguinostigma

The damselfly species is typically found in shaded areas, especially within bamboo forests, which are present at the four locations where it has been observed. The first sighting occurred in the Mankuzhy region during the summer, with only two individuals spotted. During the monsoon, a considerable population was recorded in Perumbankuthu and Viripara. The species was also observed in Kurathikudi during post monsoon, within a dense forest area.

However, the species faces several threats, including plastic pollution, pesticide runoff from cardamom estates in Mankuzhy, and the impacts of tourism and boating in Perumbankuthu. Additionally, pesticide runoff in Viripara further threatens the damselfly population. To protect this species, measures must be implemented to mitigate these threats. Proper regulation of pesticide use within safe limits is essential to safeguard the organisms dependent on the environment. Furthermore, alternative locations for boating should be identified to avoid disturbing this threatened species. Sustainable tourism practices should be adopted in these areas to ensure the protection of odonates and their natural habitats while supporting local tourism.

Indosticta deccanensis

The species is exclusively found in the Kuthupara area of Neryamangalam, within a dense forest ecosystem that includes small streams. The odonate was observed in a transect at a relatively lower altitude. However, pollution is a significant concern in this area. Open defecation was observed near the stream, and plastic diaper waste was found along the roadsides where the streams flow nearby.

Despite being located within a forest, the pollution levels in this region are high. Practices such as open defecation need to be addressed by promoting the use of modern sanitation facilities, including household toilets or public bio-toilets. There should also be a proper disposal system for diapers, such as incinerators, to prevent further environmental contamination. Additionally, it is crucial to raise awareness and encourage people to avoid littering in public spaces or forested areas. Enhanced monitoring by the local self-government (LSG) is also necessary to ensure proper waste management practices are followed.

The species may have been displaced from higher altitudes and adapted to lower elevations. However, this adaptation is unlikely to be sustainable in the long term. The habitat changes are concerning, and immediate conservation efforts are needed to protect and preserve the ecosystem to ensure the continued survival of this species.

8.6. Inference on Transect with Odonates

A total of 29 transects were studied over various phases, revealing a wide range of odonate density and diversity, from high to low. It was observed that transects with characteristics of healthy forest riparian zones, good light penetration, adequate shade, and well-structured water columns supported higher odonate populations. Conversely, transects like Nallathanni, Vellathooval, and Vaguvurrai exhibited poor ecosystems, unable to sustain odonate life. In contrast, transects such as Mankulam, Kurathikudy, Kuwait, and Mankuzhy were identified as ideal habitats, providing favorable conditions for the odonate lifecycle.

Climate change has notably affected the transects, with shifts in temperature and altitude compared to previous years, influencing odonate distribution across Munnar. These environmental changes, along with localized habitat preferences, have contributed to varying odonate populations in different regions. Additionally, pollution has exacerbated the situation, with plastic waste and pesticide runoff severely impacting water quality, which in turn harms the survival and reproduction of odonates. Moreover, habitat destruction due to tourism and land use changes further strains the already fragile ecosystems.

9. Conclusion

The conservation of odonates in Munnar is crucial, as these species are indicators of the health of aquatic ecosystems. The challenges posed by climate change, habitat loss, pesticide pollution, waste mismanagement, uncontrolled tourism, and invasive species threaten the delicate balance of these ecosystems. However, through targeted conservation measures, such as improving habitat quality, reducing pollution, managing tourism sustainably, and addressing the impacts of climate change, it is possible to safeguard the future of odonates in Munnar. Collaborative efforts involving local communities, government authorities, and conservationists are essential to protect these vulnerable species and ensure that Munnar's rich biodiversity continues to thrive for generations to come. By adopting these recommendations, we can work towards a sustainable coexistence between nature, wildlife, and human activity in this unique and ecologically important region.

10. Recommendations

10.1. Mitigate Climate Change Impacts

- Monitor temperature and rainfall patterns to understand climate effects on odonates.
- Restore high-altitude habitats with native vegetation to stabilize ecosystems.
- Establish protected areas for vulnerable odonate species.

10.2. Conserve Riparian Ecosystems

- Create riparian buffer zones to prevent deforestation and soil erosion.
- Control sedimentation through sustainable farming practices.
- Protect and restore vegetation along water bodies to improve water quality and shade.

10.3. Reduce Pesticide Pollution

- Promote integrated pest management (IPM) on plantations to reduce pesticide use.
- Enforce pesticide regulations near water bodies.
- Raise awareness about the impact of pesticides on aquatic life.

10.4. Improve Waste Management

- Implement waste segregation and recycling programs to prevent plastic pollution.
- Ban single-use plastics and promote eco-friendly alternatives.
- Educate locals and tourists about the impact of littering on ecosystems.

10.5. Control Uncontrolled Tourism

- Adopt sustainable tourism practices, limiting tourist numbers and impact on habitats.
- Develop eco-friendly infrastructure with minimal ecological footprint.
- Enforce tourism regulations to reduce habitat disturbance.

10.6. Prevent Land Use Changes

- Enforce zoning laws to protect odonate habitats from urban and agricultural encroachment.
- Encourage conservation-oriented land practices through incentives for landowners.

10.7. Manage Invasive Species

- Control invasive species through early detection and removal programs.
- Restore native vegetation along water bodies to improve habitat quality.

10.8. Address Eutrophication

- Reduce nutrient runoff from agriculture and sewage through better management.
- Upgrade wastewater treatment facilities to prevent water pollution.
- Monitor water quality for early signs of eutrophication.

10.9. Regulate Water Flow and Sedimentation

- Work with dam operators to maintain stable water flows and prevent habitat disruption.
- Implement erosion control measures to reduce sedimentation in water bodies.

10.10. Strengthen Conservation Laws

- Integrate odonate conservation into broader biodiversity policies.
- Involve local communities in conservation efforts and provide education on best practices.

11. Summary

Odonate surveys were conducted throughout Munnar, with potential transects identified and phase-wise surveys carried out from January to December. During the surveys, targeted species such as ***Indosticta deccanensis*** and ***Protosticta sanguinostigma*** were successfully spotted. However, ***Chlorogomphus xanthoptera*** was not observed at any location in Munnar. This absence serves as a warning sign of the ongoing changes in Munnar's ecosystem.

The conservation of odonates in Munnar is essential as these species serve as indicators of the health of aquatic ecosystems. However, they face multiple threats, including climate change, habitat loss, pesticide pollution, unscientific waste management, uncontrolled tourism, and the spread of invasive species. Climate change, particularly altered rainfall patterns and rising temperatures, disrupts the delicate timing of odonate life cycles. Habitat degradation due to deforestation, urbanization, and agricultural expansion further diminishes breeding grounds. Pesticide runoff from plantations and improper waste disposal, particularly plastics and diapers, contribute to water pollution, harming both aquatic larvae and adult odonates. Additionally, unchecked tourism and invasive species disrupt local ecosystems, making it increasingly difficult for native species to thrive.

To safeguard odonates in Munnar, focused conservation strategies are needed. These include habitat restoration, pollution control, sustainable tourism practices, and measures to reduce the impact of climate change. Increased monitoring and collaboration between local communities, government authorities, and conservationists are crucial to implementing these measures effectively. By fostering a balance between human activities and wildlife preservation, Munnar's biodiversity, including its vulnerable odonate populations, can be protected for future generations. Such efforts will ensure the sustainability of the region's unique ecosystems while promoting ecological harmony.

Report of survey on odonates in munnar landscape targeting the conservation of fresh water habitat & threatened species

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