

SEASONAL PATTERNS OF AQUATIC INSECT ABUNDANCE AND THEIR RELATIONSHIP WITH PHYSICO-CHEMICAL PARAMETERS IN ANAKDEV (DARA) HOT WATER SPRING, NORTH MAHARASHTRA

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Abstract

Hot spring ecosystems represent unique and sensitive habitats where biological communities are strongly influenced by physico-chemical conditions. The present study investigates the seasonal abundance of aquatic insects and their relationship with physico-chemical parameters in Anakdev Hot Water Spring. A total of 179 insect individuals belonging to five species, *Branchithemis contaminata*, *Enithares* sp., *Notonecta glauca*, *Orthetrum* sp., and *Patrus limbatus* were recorded across three seasons (rainy, summer, and winter). The rainy season exhibited the highest insect abundance (79 individuals), supported by increased water availability, higher dissolved oxygen, and nutrient enrichment. Summer conditions, characterized by elevated temperature and total dissolved solids, favoured thermophilic species, particularly *Patrus limbatus*, which attained peak abundance during this season. Winter recorded the lowest abundance (44 individuals), with dominance of oxygen-dependent species such as *Notonecta glauca*. Correlation analysis revealed species-specific responses to environmental variables, highlighting temperature, dissolved oxygen, and nutrient levels as key drivers of community structure. The study demonstrates that seasonal variation in physico-chemical parameters strongly influences aquatic insect assemblages, emphasizing the importance of thermal springs as dynamic ecosystems requiring targeted ecological monitoring and conservation.

Introduction

Thermal springs represent one of the most intriguing subjects in scientific research, as many aspects of their natural forms, origins, and ecological functioning remain poorly understood. During an extensive review of literature and research articles published in standard journals, several significant research gaps were identified, making this topic particularly compelling for further investigation. Although some geological

and geographical studies on thermal springs have been conducted, ecological studies especially from a biological perspective are limited. Globally, the diversity of insects inhabiting thermal springs is remarkably low, with only four insect orders, namely Diptera, Coleoptera, Hemiptera, and Odonata, being commonly reported, each represented by only a few genera (Calosi et al., 2007). Furthermore, "There is relatively

scarce information on aquatic insect population associated with high-plains water spring habitats of the western region.” United States (Ferrington, L. C. Jr., 1995).

In contrast, the insect fauna of hot springs in the Yellowstone ecosystem of Montana and Wyoming has been relatively well documented (Brues. C. T., 1928). Tepid springs, which are relatively unique habitats of the High Plains, deserve greater attention due to their ecological significance. The environmental conditions of these tepid springs closely resemble those of present-day thermal springs (Castenholz, R.W. 1969). In India, considerable research has been conducted at both national and state levels on the diversity of bacteria, and to some extent on algal diversity, in thermal spring ecosystems (Acharya et al., 2012; Singh et al., 2013).

Spring ecosystems, though small in size, are vital hydrological features that provide stable habitats and support unique faunal assemblages; however, they are highly vulnerable to anthropogenic disturbances such as groundwater pollution and reduced water availability. As among the most threatened ecosystems, spring habitats often experience deterioration in water quality resulting from landscape modifications. Aquatic insects play a

crucial role in environmental assessment, as pollution-sensitive as well as pollution-tolerant taxa serve as reliable bioindicators of water quality, yet they remain relatively under-studied. In this context, the present study aimed to assess the diversity of aquatic insects in spring habitats around the MTNR, with particular emphasis on the villages of Tunua and Fatumnasi located in close proximity to the nature reserve (Semiun & Duhan, 2021).

Seasonal variations are clearly observed in the temperature of Anakdev hot spring water in the Middle Tapi Basin, indicating that it does not remain constant throughout the year. Water temperatures are comparatively higher during the summer season (May) due to limited mixing at the spring source. In contrast, during the rainy season (September), increased mixing with underground and surface water occurs at the source, resulting in a noticeable decrease in water temperature (Wagh R.V. *et al.*, 2013).

Materials and Methods

Study Area of Anakdev (Dara) hot spring.

Anakdev Hot Spring, locally known as Dara or Unapdev, is a distinct geothermal feature of the region. Geographically, the hot water spring is found in Dara village

near Shahada city in the Nandurbar District of Maharashtra, India, approximately 24 km north of Shahada, at 21°72'5041" N latitude and 74°43'8362" E longitude (Fig-01). The hot spring emerges at the point where a dyke intersects the Susari River channel, highlighting its geological significance (Wagh R. V. et al., 2013). It discharges hot water continuously at a rate of about 44 liters per minute, with an average annual temperature of approximately 45 °C. The water temperature exhibits seasonal fluctuations of nearly 6 °C, and a gradual increase in temperature has also been recorded over time.

Seasonal field investigations were carried out at the Anakdev (Dara) hot springs between March 2023 and April 2025 to Sample and analyze environmental and hydrochemical parameters During each survey, in-situ measurements such as hot water temperature and Surrounding air

temperature was measured during the sampling period. Temperature measurements were obtained using digital thermometers (Model ST-9269) "having a temperature range of -50 °C to 200 °C with an accuracy of ±1 °C (Khairnar, K. *at el.*,2025). To ensure reliable readings, the thermometers were held in position for an adequate duration until stable values were achieved. For physicochemical analysis, one-liter water samples were collected seasonally from each sampling location, directly at the spring source. The samples were immediately transferred into clean, contamination-free bottles and subsequently transported to the S. J. Mimasa Water Testing Laboratory, Satana, for subsequent chemical analysis (Khairnar, K. *at el.*,2025). These testing were conducted to evaluate the overall water quality of the hot spring system (Mohammed H. S. Zangana, 2015).



Fig No-01 This figure shows the location of the study area at Anakdev (Dara) Hot Spring, situated in North Maharashtra, India.

Result and Discussion

Study of Seasonal Abundance of Anakdev Hot Water Spring.

A total of 179 insect individuals belonging to five species were recorded from Anakdev

Hot Springs during three distinct seasons rainy, summer, and winter (Table-02). Clear

seasonal variation in insect abundance and species composition was observed, indicating the strong effect of varying environmental factors such as temperature, water level, and seasonal hydrological fluctuations on species assemblages was investigated (Doria, M. de F. 2015).

The rainy season supported the highest insect abundance, with 79 individuals recorded, suggesting favourable ecological conditions including increased water availability, higher humidity, and enhanced vegetation cover that promote feeding and breeding activities. During this season, *Branchythemis contaminata* and *Patrus limbatus* were the most abundant species, each contributing 22 individuals. *Enithares* sp. also showed a substantial presence (16 individuals), followed by *Notonecta glauca* (11) and *Orthetrum* sp. (8). The relatively even dominance of multiple species during the rainy period reflects improved habitat suitability and greater resource availability resulting from increased moisture and nutrient input.

In the summer season, total insect abundance declined to 56 individuals, likely due to elevated temperatures and reduced water levels, which may negatively affect habitat quality. Despite this overall decline, *Patrus limbatus* exhibited a pronounced increase, reaching its maximum abundance (31 individuals),

indicating strong physiological or behavioural adaptation to warmer conditions. *Branchythemis contaminata* (10 individuals) and *Enithares* sp. (7 individuals) maintained moderate populations, whereas *Notonecta glauca* (4) and *Orthetrum* sp. (4) were comparatively less abundant, suggesting sensitivity to summer stress conditions.

The winter season recorded the lowest overall abundance, with 44 individuals, which may be attributed to lower temperatures and seasonal changes in water chemistry that reduce insect activity. During this period, *Notonecta glauca* emerged as the dominant species (16 individuals), indicating a preference for cooler conditions. *Enithares* sp. also maintained a notable presence (15 individuals), while *Branchythemis contaminata* (7) and *Orthetrum* sp. (6) occurred in smaller numbers. Notably, *Patrus limbatus* was completely absent during winter, highlighting a strong seasonal dependency in its life cycle or behavioural patterns.

An analysis of species-wise abundance revealed distinct dominance patterns among the aquatic insects recorded from Anakdev Hot Springs. *Patrus limbatus* emerged as the most abundant species overall, contributing 53 individuals, followed by *Branchythemis contaminata*

(39 individuals) and *Enithares* sp. (38 individuals), all of which made substantial contributions to the total insect assemblage. *Notonecta glauca* showed moderate abundance (31 individuals) with pronounced seasonal variation, attaining its highest numbers during the winter season. In contrast, *Orthetrum* sp. was the least abundant species (18 individuals), remaining consistently present but in comparatively lower numbers across all seasons.

Clear seasonal trends in total insect abundance were evident, with the rainy season supporting the highest population (79 individuals), followed by summer (56 individuals) and winter (44 individuals). This seasonal pattern underscores the influence of fluctuating environmental conditions particularly water availability, temperature, and habitat structure on the population dynamics of aquatic insects inhabiting thermal spring ecosystems.

Overall, the seasonal abundance patterns at Anakdev Hot Springs demonstrate marked temporal fluctuations driven by seasonal environmental variability. While species such as *Branchythemis contaminata* and *Enithares* sp. were recorded throughout the year, indicating broad ecological tolerance, *Patrus limbatus* exhibited strong seasonal peaks, reflecting specific habitat or temperature preferences. These differential

responses among species highlight variations in adaptability and ecological requirements, collectively contributing to the biodiversity, resilience, and ecological stability of the hot spring ecosystem.

Correlation Analysis of Physico-Chemical Parameters and Aquatic Insect Abundance in Anakdev Hot Springs

The insect community in Anakdev Hot Springs shows clear seasonal variations driven by changes in water temperature, chemistry, and nutrient availability. Across the recorded periods, five species were observed (Table-02) *Branchythemis contaminata*, *Enithares* sp, *Notonecta glauca*, *Orthetru* sp, and *Patrus limbatus*, with a total of 179 individuals recorded over all seasons. The rainy season supports the highest overall abundance with 79 individuals, followed by summer with 56, and winter with the lowest abundance at 44 individuals.

During the rainy season, the dominant species are *Branchythemis contaminata* and *Patrus limbatus*, each with 22 individuals, while *Enithares* sp also maintains moderate numbers. This increase in abundance is associated with higher water availability, nutrient influx from runoff, and moderate dissolved oxygen levels (around 7.35 mg/L). Elevated nitrate and sulphate concentrations during this season create

nutrient-rich conditions, favouring species that thrive in fresh, oxygenated water with moderate ionic content. *Branchythemis contaminata* shows a strong positive correlation with dissolved oxygen, rainfall, and nutrient availability, indicating that its abundance is closely linked to rainy season conditions. Similarly, *Enithares sp* is positively influenced by moderate water hardness and nutrient availability but is sensitive to high summer temperatures.

In summer, (Table-2 and Fig-03) *Patrus limbatus* peaks at 31 individuals, highlighting its thermophilic nature. Summer water temperatures range from 43 to 44°C, with slightly alkaline pH (7.5–9.42), moderate organic load (COD 16.7–19.5 mg/L and BOD 10.7–11.05 mg/L), and variable TDS (148–512 mg/L). The combination of high temperature and elevated TDS creates favourable conditions for thermophilic species like *Patrus limbatus*, while species sensitive to heat and low dissolved oxygen, such as *Notonecta glauca*, decline in abundance. Summer abundance patterns indicate a positive correlation of *Patrus limbatus* with temperature and TDS, whereas species like *Branchythemis contaminata* and *Enithares sp* show negative correlation with elevated summer temperatures.

During winter, *Notonecta glauca* becomes the most abundant species with 16

individuals, reflecting its preference for cooler conditions and slightly higher dissolved oxygen levels (7.2–7.3 mg/L). Water chemistry in winter remains moderately alkaline (pH 7.42–8.82) with stable temperatures (42–44°C), moderate TDS, and low nutrient concentrations. Winter conditions favour species that are cold-tolerant and oxygen-dependent. In contrast, *Patrus limbatus* is completely absent during winter, demonstrating a negative correlation with lower temperatures and slightly reduced TDS. *Branchythemis contaminata* and *Enithares sp* maintain moderate abundance, showing some resilience to winter conditions but lower numbers compared to the rainy season.

Orthetrum sp shows consistently low abundance across all seasons, indicating high sensitivity to environmental fluctuations. Its abundance correlates weakly with hardness and alkalinity but negatively with high TDS and extreme temperature fluctuations, suggesting a narrow ecological tolerance.

Species-specific correlations with physico-chemical parameters can be summarized as follows:

1. *Branchythemis contaminata*: Positively correlated with dissolved oxygen, rainfall, and nutrient

- concentrations (nitrates and sulphates); negatively affected by high summer temperatures.
2. *Enithares* sp: Positively influenced by moderate hardness and rainy season nutrient influx; negatively correlated with high temperatures during summer.
 3. *Notonecta glauca*: Strong positive correlation with higher dissolved oxygen and cooler temperatures; abundance declines with summer heat and lower DO.
 4. *Orthetrum* sp: Weak positive correlation with moderate hardness and alkalinity; negatively impacted by high TDS and extreme seasonal fluctuations.
 5. *Patrus limbatus*: Strong positive correlation with high water

temperature and TDS, thriving in summer; completely absent in winter, showing negative correlation with low temperature and moderate winter TDS.

The seasonal shifts in insect abundance at Anakdev Hot Springs are tightly linked to physico-chemical conditions. Rainy season nutrients and moderate DO favour generalist and nutrient-responsive species, summer warmth and high TDS favour thermophilic species, and winter conditions support oxygen-dependent and cold-tolerant species. These patterns reflect temporal niche partitioning driven by environmental and chemical gradients, maintaining a diverse and seasonally dynamic insect community in this thermal spring ecosystem.

TABLE 1: The study presents the Pearson Correlation Coefficient Matrix (r) of the physico-chemical parameters at Anakdev (Dara) hot spring.

Parameter	Temp	pH	CO D	BOD	TDS	Alk	Hard	Mg	SO ₄	Cl	Na	Fe	NO ₃	PO ₄	DO
Temperature	1	-0.1	0.67	0.23	0.49	0.7	0.32	0.62	0.22	0.65	0.65	0.69	0.62	0.24	- 0.29
pH	-0.1	1	-0.2	-0.38	- 0.39	-0.47	0.13	-0.28	-0.58	-0.33	-0.31	-0.37	-0.65	0.01	-0.2
COD	0.67	-0.2	1	0.69	0.56	0.47	0.3	0.43	0.47	0.45	0.43	0.16	0.62	0.73	- 0.07
BOD	0.23	-0.38	0.69	1	0.06	0.08	-0.35	-0.09	0.91	-0.03	-0.07	-0.26	0.64	0.78	0.34
TDS	0.49	-0.39	0.56	0.06	1	0.63	0.41	0.57	0.27	0.73	0.71	0.69	0.6	-0.13	- 0.69
Alkalinity	0.7	-0.47	0.47	0.08	0.63	1	0.41	0.64	0.15	0.74	0.74	0.9	0.79	-0.24	- 0.65
Hardness	0.32	0.13	0.3	-0.35	0.41	0.41	1	0.7	-0.2	0.64	0.63	0.53	0.12	-0.3	- 0.85
Magnesium	0.62	-0.28	0.43	-0.09	0.57	0.64	0.7	1	-0.16	0.68	0.69	0.85	0.61	-0.3	-0.8
Sulphate	0.22	-0.58	0.47	0.91	0.27	0.15	-0.2	-0.16	1	0.12	0.1	-0.07	0.75	0.52	0.35

Chloride	0.65	-0.33	0.45	-0.03	0.73	0.74	0.64	0.68	0.12	1	0.99	0.87	0.67	-0.28	-0.77
Sodium	0.65	-0.31	0.43	-0.07	0.71	0.74	0.63	0.69	0.1	0.99	1	0.87	0.63	-0.3	-0.78
Iron	0.69	-0.37	0.16	-0.26	0.69	0.9	0.53	0.85	-0.07	0.87	0.87	1	0.55	-0.47	-0.58
Nitrate	0.62	-0.65	0.62	0.64	0.6	0.79	0.12	0.61	0.75	0.67	0.63	0.55	1	0.18	-0.24
Phosphate	0.24	0.01	0.73	0.78	-0.13	-0.24	-0.3	-0.3	0.52	-0.28	-0.3	-0.47	0.18	1	0.53
DO	-0.29	-0.2	-0.07	0.34	-0.69	-0.65	-0.85	-0.8	0.35	-0.77	-0.78	-0.58	-0.24	0.53	1

TABLE 2: Seasonal Abundance and Distribution of Insects in Anakdev Hot Springs.

Season Abundance in Anakdev Hot Springs Insects.					
Sr.no	Insects name	Rainy	Summer	Winter	Grand Total
1	<i>Branchythemis contaminata</i>	22	10	7	39
2	<i>Enithares sp</i>	16	7	15	38
3	<i>Notonecta glauca</i>	11	4	16	31
4	<i>Orthetrum sp</i>	8	4	6	18
5	<i>Patrus limbatus</i>	22	31	0	53
Total count		79	56	44	179

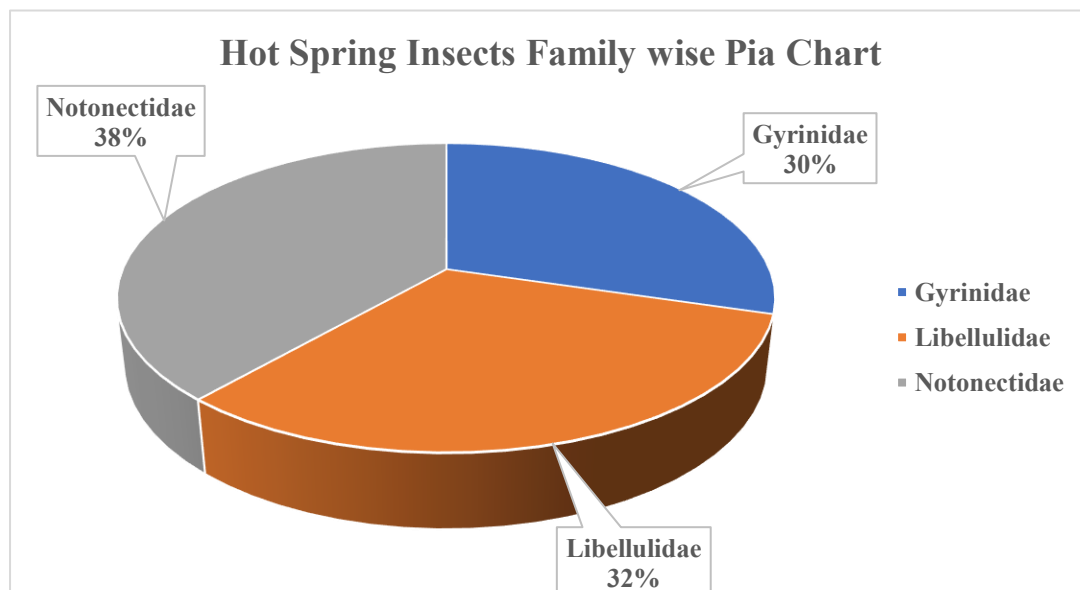


Fig. 2: Showing the pia Chart is percentage wise of Distribution of Hot Spring insects in Anakdev (Dara) study Area.

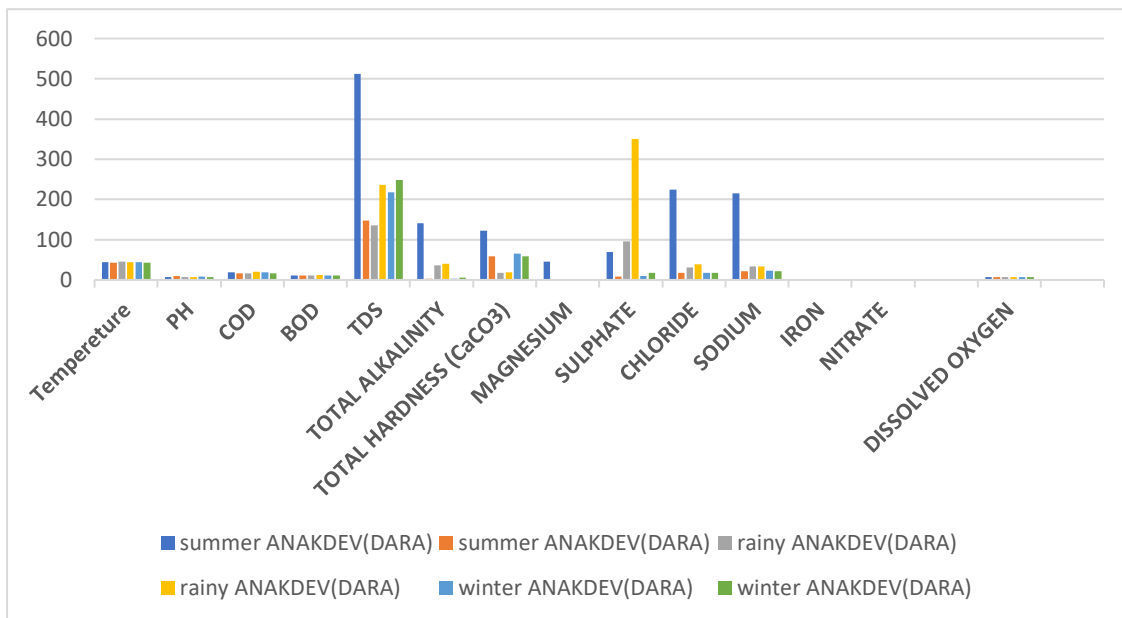


Fig. 3: Bar chart showing seasonal variation in analysis of the physico-chemical Characters at Anakdev (Dara) hot spring.

Conclusion

The present study documents clear seasonal variation in the abundance and community composition of aquatic insects inhabiting Anakdev Hot Water Spring. A total of 179 individuals belonging to five species were recorded across three seasons rainy, summer, and winter indicating strong temporal fluctuations driven by seasonal environmental conditions.

The rainy season supported the highest insect abundance (79 individuals), reflecting favourable ecological conditions such as increased water availability, enhanced nutrient input from surface runoff, higher humidity, and moderate dissolved oxygen levels. The relatively even dominance of *Branchythemis contaminata* and *Patrus limbatus*, along

with substantial contributions from *Enithares* sp. and *Notonecta glauca*, suggests improved habitat suitability and greater resource availability during this period. Positive correlations between insect abundance and dissolved oxygen, nitrates, and sulphates further highlight the role of nutrient enrichment and hydrological stability in shaping community structure.

In contrast, insect abundance declined during summer (56 individuals), coinciding with elevated water temperatures (43–44 °C), increased total dissolved solids, and slightly alkaline pH conditions. Despite the overall reduction in abundance, *Patrus limbatus* exhibited a pronounced seasonal peak, indicating strong thermophilic adaptation and tolerance to high TDS

levels. Other species, particularly *Notonecta glauca* and *Orthetrum* sp., showed reduced abundance, suggesting sensitivity to thermal stress and declining dissolved oxygen levels.

Winter recorded the lowest total abundance (44 individuals), likely due to reduced insect activity under cooler conditions and altered water chemistry. During this season, *Notonecta glauca* emerged as the dominant species, demonstrating a preference for cooler temperatures and higher dissolved oxygen availability. The complete absence of *Patrus limbatus* during winter indicates strong seasonal dependency and limited tolerance to lower temperatures. Species such as *Branchythemis contaminata* and *Enithares* sp. persisted at moderate levels, reflecting broader ecological tolerance.

Species-specific correlation analysis revealed distinct ecological preferences. While *Branchythemis contaminata* and *Enithares* sp. were positively associated with rainy-season nutrient enrichment and moderate physico-chemical conditions, *Patrus limbatus* showed strong positive correlation with high temperature and TDS during summer. *Notonecta glauca* was closely linked to cooler, oxygen-rich conditions, and *Orthetrum* sp. displayed narrow tolerance limits, remaining consistently low in abundance across seasons.

Overall, the observed seasonal shifts reflect temporal niche partitioning governed by variations in temperature, dissolved oxygen, nutrient availability, and ionic composition, collectively maintaining biodiversity and ecological balance within this geothermal spring ecosystem.

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