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Original Article

Multivariate Analysis of Copepod's Distribution in Jallo Lake, Lahore Pakistan

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ABSTRACT

Copepods are valuable zooplankton found globally. Fish eat them. Any water ecosystem has food chains and webs. Their diversity and density depend on physicochemical factors. **Objective:** The Jallo Lake was targeted for the investigation of the spatio-temporal distribution of copepods from January to December 2023. **Methods:** Copepods were collected from Jallo Park's freshwater with a zooplankton mesh. These organisms were species-classified using conventional keys. Separate water samples were taken to examine physicochemical characteristics. Sedgwick Rafter chamber for species counting. PAST software was used for PCA I & II and CCA. **Results:** Ten species and their nauplius larvae from seven orders were identified in this study. The study examined conductivity, oxygen saturation, dissolved oxygen, pH, and transparency. Air and water temperature was also recorded. Analysis of Variance (ANOVA) for physicochemical properties, excluding transparency, was statistically significant at (= 0.05, P = 0.000). Copepod variety and density peaked in June and July and dropped in October and December. The dendrogram showed three cluster-level variations. Plotting copepod species and month abundance curves. Principal component analysis (PCA I, PCA II) was used to correlate months, copepod species, and physicochemical parameters. Canonical component analysis (CCA) shows diversity similarities between sites on the same water body and links species abundance to environmental conditions. **Conclusions:** Only ten copepod species from seven orders and nauplius larvae were isolated from the aquatic body under research during the study months. Copepod diversity and density in freshwater lakes depended on environmental conditions.

INTRODUCTION

Zooplankton have a cosmopolitan distribution, and they can be found in almost every water body [1]. They are a source of energy that is transferred to other organisms found in water [2]. Zooplankton can be broken down into three basic categories: rotifers, copepods, and cladocerans, in which Rotifers are the most common type of microorganism [3]. The capacity of copepods to thrive in a wide variety of environments has resulted in a significant diversity of these organisms [4]. There is evidence that zooplankton play a significant part in the formation of the foundation of food chains and food webs [5]. In habitats with a high quantity of food and threats from predators, copepods reach the adult stage earlier than in other situations [6]. An increase in the availability of food also results in an increase in the accumulation of lipids and growth. The food value of copepods, which are a significant source of nourishment, was evaluated [7]. Copepods consume a wide variety of foods and are impacted by the signals generated by predators in their habitat. Additionally, the formation and accumulation of lipids in

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fish might be supported by their high nutritional content. Copepods are one of the most important contributors to the preservation of aquatic ecology and biology, as they provide a substantial amount of food for other aquatic creatures [8]. In spite of the fact that they have a relatively low feeding need, copepods play an important role in the rearing of early larvae of fish and other aquatic organisms [9]. The pattern of vertical dispersion in copepods, which encompasses a variety of food webs, is an important ecological phenomenon that is impacted by a wide range of circumstances and has a significant impact on the behavior of copepods [10]. They exhibit a large range in their density and diversity from the top to the bottom, which is crucial when their ecology is taken into consideration. Not only is this characteristic discrepancy affected by the season, but it is also affected by day and night, and it can lead to the occurrence of visible alterations [11]. There is a strong correlation between the vertical distribution and density of zooplankton, particularly copepods, and the availability of food resources. Zooplankton consists of a wide diversity of organisms, such as copepods and rotifers, which can result in increased growth and survival rates. Copepods were responsible for an increase in both the accessibility and availability of important fatty acids found in fat [12]. As the primary component of the food chain and the primary source of food for a great number of fish species in the pelagic zone, copepods are the dominant species in the zooplankton biomass [13]. Copepods are important bio-indicators of ecosystem pollution and climate change in coastal waters that have been influenced by human activity. Because of these influences, biological systems may be impacted [14]. To a large extent, copepods are utilized in ecotoxicology research pertaining to water bodies, particularly when reproductive characteristics are taken into consideration. A decrease in the amount of nutrients that were introduced into the system was the cause of the decline in primary production. As a consequence of this, the structure of the marine food web might change depending on the availability of nutrients [15]. An analogous pattern was seen, which resulted in a reduction in the number of small copepods in the natural environment. Research on the ways in which marine food webs react to alterations in the natural environment is essential for accurately forecasting the future functions and structures of marine ecosystems. An initial investigation on the zooplankton found in freshwater was carried out to gain an understanding of the relationship between the amount and quality of food [16].

The primary aim of this study was to analyze the effects of physical and chemical factors on copepods in a lake, as well as to analyze their quantity and dispersion within the lake. In addition, it focused primarily on determining the extent to which the water conditions have an impact on the copepod population. Over several months, it examined the variations in the number of copepods, the species richness, the diversity indices, and the evenness distribution. By addressing these objectives, our goal was to get a thorough understanding of the dynamics of copepods in the lake ecosystem as well as their responses to a variety of environmental conditions.

METHODS

A man-made freshwater lake at Jallo Wildlife Park was selected for sampling. It was built in 1978 in the District Lahore, 28 kilometers from the "Wagha Border" (International Border between Pakistan and India), and covers 456 acres. The latitude is around 31°34'21 to the north and 74°28'38 to the east. Sampling was done at four separate points: I for the Eastern side, II for the Southern side, III for the Western side, and IV for the Northern side, all of which began at the boat stand. Every sampling point was further subdivided into a, b, and c subpoints (Figure 1).

Figure 1: Jallo Lake aerial view (Courtesy Google Maps); The eastern side is JS1, the southern side is JS2, the western side is JS3, and the northern side is Js4.

Water samples were collected for a complete year, from January to December 2023. Every month, water samples were collected between 11:00 a.m. and 12:00 p.m. Water samples were collected in Biological Oxygen Demand (BOD) containers with a volume of one litre. These sample containers were first bathed in hydrochloric acid, then rinsed with sanitized water and dried. For the adaptation of containers before the assembling of samples, these vessels were rinsed with lake water at least three times. All physicochemical parameters have been recorded using specific equipment and instruments. Copepods were mostly classified based on their fifth set of legs. They were recognized using extrinsic morphology and proposed keys [17,18]. Copepod microphotographs were taken with an

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inverted digital camera. An Olympus Microscope was used for quantitative analysis. The Sedgwick Rafter was used to count copepods [19]. Sedgwick Rafter is a glass slide that can hold a sample of 1 ml water. The glass slide is about 50mm long and 20mm broad. A perfect row lengthwise is termed a strip, which has 20 rows net in Sedgwick Rafter [20].

The formula was written as:

$$\text{Number/ml} = C \times 1000\,\text{mm} / L \times D \times W \times S$$

All the data were measured as mean ± SEM to calculate the Cluster Analysis, Principal Component Analysis (PCA I & II), and Canonical Component Analysis (CCA). These were observed using the digital software PAST (Version 4.3past exe) and XL stat (version Cloud).

RESULTS

An abundance curve was plotted between the copepod species and months. A parabolic curve was obtained that showed the life span of copepod species with time (Figure 2).

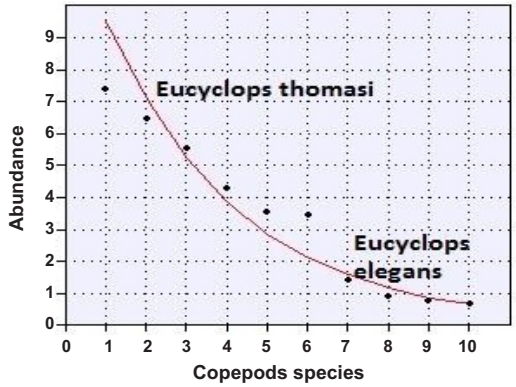

Figure 2: Abundance Curve Indicates the Relative Abundance of Copepod Species

A cladogram was plotted with the species obtained. In this dendrogram, there were three major cluster levels or groups in the dendrogram, which were formed by nine (9) copepod species (Figure 3).

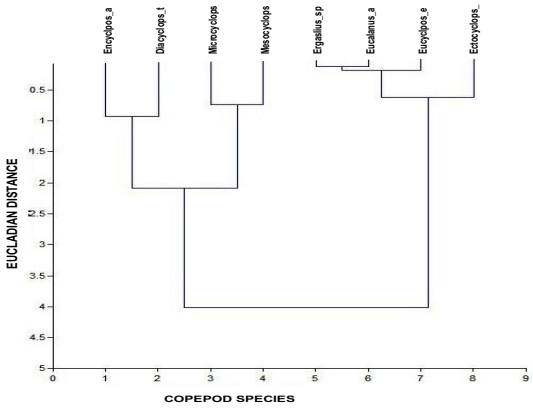

Figure 3: A dendrogram or cladogram diagram showing the cladistic relationship between the copepod species located in Jallo Lake

Euclidian values (distances) and the clads indicate the degree of association among the copepod species at Jallo Lake. Principal Component Analysis were applied for as fellows:

I) PCA-I between Copepod species and months.

II) PCA-II between Physicochemical parameters and months.

The biplot graph of PCA I indicated the relationship between months and copepod diversity (Figure 4).

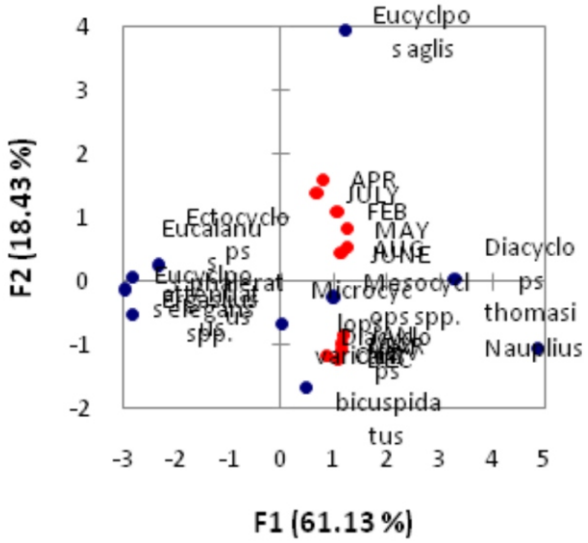

Figure 4: PCA – I indicate the correlation between the richness of copepod species in different months.

The biplot graph of PCA II showed that oxygen saturation was on the upper right side while electrical conductivity was on the lower right side (Figure 5).

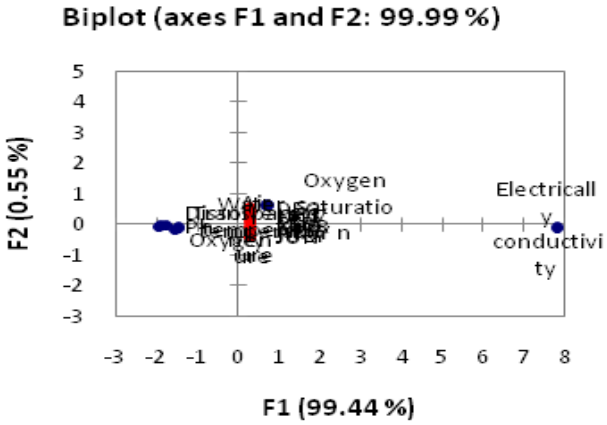

Figure 5: PCA –II (Principal Component Analysis –II) indicates the correlation between the physicochemical parameters of Jallo Lake and their variation in different months.

CCA was performed to explore the distribution of copepods regarding the abiotic and biotic factors that were represented as F1 and F2. Here, sites indicated the months (Figure 6).

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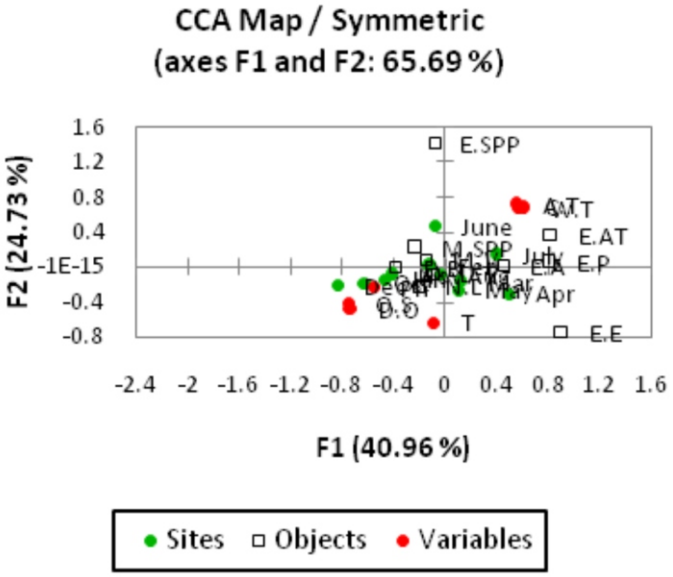

Figure 6: CCA shows the correlation between Copepods' species abundance in different months during the study period and fluctuations in the Physico-chemical Parameters

DISCUSSION

The presence of large numbers of *Diacyclops thomsai* shows the lake was suitable for its growth [21]. A similar sort of result was also reported by McKinstry and Campbell [22]. All species were at a specific Euclidian distance, indicating their interrelationship with each other [23]. The physicochemical parameters, i.e., pH, Water temperature, Air temperature, Transparency, Conductivity, and Dissolved oxygen were on the lower left side of the central axis. Results of the Current study coincided with the results of Santos *et al* [24]. It showed how strongly the changes have taken place. They used the PCA to explain the distribution of copepods and the effects of its corresponding physicochemical parameters under study. They used the PCA to explain the distribution of copepods and the effects of its corresponding physicochemical parameters under study. In the biplot, species that were present at various sides, such as upper left, upper right, and bottom right, displayed a positive relation with months. However, species that were found in the lower-left side showed negative relation with months and species found near to the centerline (origin) showed a strong positive or negative relationship with months as *Mesocyclops species, Microcyclops varicans, Diacyclops bicuspidatus showed* a strong positive correlation, and *Eucyclops aglis* and *nauplius* showed a weak positive correlation with months. Abo-Taleb *et al.*, gave similar types of reasons [25]. *Eucyclops aglis* was on the upper right side. Copepod species, i.e., *Mesocyclops species*, *M. varicans*, *Diacyclops bicuspidatus*, and *Diacyclops thomasi*, were on the lower right side of the graph. *Ectocyclops phaleratus* and *Eucalanus attenuates* were on the left upper side. *Eragaslius* species and *Eucyclops elegans* were at the lower left side of the biplot graph. This Graph (CCA Map/Symmetric graph) showed that *Eucalanus attenuates* (E.AT), *Ergaslius species* (E.sp), *Ectocyclops phaleratus* (E.P), and *Eucyclops aglis* (E.A) along with the Air temperature (A.T.), Water temperature (W.T.) and Conductivity were in the upper right side. Only *Eucyclops elegans* copepod species was on the lower right side. *Mesocyclops* species, *Diacyclops bicuspidate*, and *Microcyclops* variants were present in the upper left-hand of the graph. *Diacyclops* occupied the lower left hand along with four variables, i.e., Oxygen saturation (O.S.), pH, Dissolved Oxygen (DO), and Transparency (T). Bulut and Saler reported similar results[26]. They concluded that there was a strong association between the abiotic and biotic factors. In other words, copepods diversity was sensitive to a minor change.

CONCLUSIONS

The present study found moderate diversity of nine species of copepods in Jallo Lake, Lahore, belonging to seven different orders. The species of copepods obtained from this lake were interlinked in food chains and food webs. The lake water was somewhat suitable for copepods' growth because the most abundant species was *Diacyclops thomsai*, which is commonly found in such water bodies. However, fluctuations in physicochemical parameters affected the overall growth of the copepod population.

Authors Contribution

Conceptualization: FN, AN, AQKS
Methodology: NA, FA, SK
Formal analysis: SH, AA
Writing, review and editing: SH, AN, FB

All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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