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Population Dynamics of Copepods as Influenced by Heavy Metals in Khanki Headworks, Pakistan

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ABSTRACT

Copepods grow in diverse freshwater habitats, totaling around 2,814 species. As foremost zooplankton, they lead biomass and are pivotal in aquatic ecosystems. The ever-increasing issue of heavy metals contamination affects organisms differently. Copepods, with their broad geographic range, can be valuable bio monitors for metal growth. **Objective:** To evaluate the effects of heavy metals and fish diversity on the population dynamics of copepods in Khanki Headworks, Pakistan. **Methods:** For the analysis of heavy metals month wise water samples (1000 ml) from four selected sites were collected for one year (February 2021 to January 2022). Atomic Absorption Spectrophotometry was employed for the analysis of heavy metals. Month wise copepods samples were collected with planktonic net (mesh size: 37μm). **Results:** In total, seven species and four genera of copepods were identified. Mesocyclops edax was the most dominant copepod species. Three heavy metals zinc (Zn), arsenic (As) and nickel (Ni) were estimated in following order of concentrations Zn> Ni> As. **Conclusions:** Current investigation revealed that heavy metals generally govern the population dynamics of copepods.

INTRODUCTION

Copepods exploit nearly all kinds of freshwater habitats. They are plentiful (almost 2,814 species) in freshwater [1]. Copepods are the major zooplankton as they dominate biomass and contribute as crucial interlink in aquatic ecosystems [2, 3]. Heavy metals contamination and pollution of aquatic ecosystems is a growing ecological issue [4]. At low concentrations few metals (Mn, Zn, Cu) are utilized for metabolic activity, whereas, others (Pb, Ni, Cd) are non-essential for organisms [5]. However, high concentrations of these metals are hazardous [6]. Heavy metals usually have the tendency of bioaccumulation in aquatic habitats [7, 8]. Heavy metals pose serious health risks to humans like nervous system derangement by arsenic (As), cardiovascular risk due to zinc (Zn) and lung cancer by nickel [9]. Copepods play a central role in the biogeochemical cycling of different metals through their perpendicular and horizontal movements [10]. This is one of the courses for the transportation of metals along the water column and among various water masses. Consequently, zooplankton (copepods) can be utilized as bio monitor species for heavy metals because of their wide geographic range, huge biomass, high ability to accumulate metals, and trophic status in the marine environment [11-15]. Khanki Headworks is not only important for irrigation purposes but it is also very productive for fisheries as well. It receives extensive loads

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of different (organic and inorganic) pollutants via industrial and agricultural drains. By considering the toxicity risks of heavy metals, basic information regarding their concentration levels in aquatic ecosystems is required [16, 17].

Hence, the objective of the present investigation was to evaluate the influence of heavy metals on population dynamics of copepods.

METHODS

Khanki Headworks was selected as study area. It is a diversion headworks located in Chenab River, Punjab, Pakistan. It is one of the oldest Headworks in Pakistan, that was built in 1889, to avoid the threats of floods. Lower Chenab canal and fifty-nine minor distributaries supply water to three million acres of barren lands. It is an attractive site for aquaculture projects due to its rich fish fauna. Copepods sampling was executed for a period of one year from February 2021 to January 2022. Planktonic net (37 µm) was utilized for copepods month wise sampling. Four sites were picked (each with 3 sub-locations) for sampling purpose and twelve Copepods samples were collected from four sites, by passing 60 Liters of water through planktonic net. The residue accumulated in the net was poured in plastic bottles (50 ml). For further analysis and fixation formalin solution (5%) was added to these bottles [18, 19]. Identification of copepods species was made possible with standard keys i.e., Taxonomic atlas of copepods and checklist by Ward and Whipple [20-23]. Identification characters were taken into consideration such as arrangement of ovarian bags, shape of metasomes, antenna segments, caudal rami, urosome and general body shape. Sedgewick-Rafter counting chamber (1 mm deep, 20 mm wide and 50 mm long), was employed for the counting of copepods. Copepods samples were examined and photographed with an inverted microscope (Model: LEICA HC 50/50) fitted with suitable 5 mega pixel camera. Month wise, 12 water samples (1000 ml) were collected in 1 liter plastic bottles for the determination of heavy metals from four selected sites. Each sampling location was separated in 3 sub-sites. Samples from all sub-sites were mixed to form a single composite sample. Then water samples were acidified with nitric acid (HNO_3). Atomic Absorption Spectrophotometer was utilized for the analysis of heavy metals [24].

Data Analysis

Diversity indices such as Shannon-Weaver and Simpson were executed to evaluate the biodiversity and density of copepods in water. Shannon-Weaver equation $H=-\Sigma Pi (\ln Pi)$ is used for the measurement of species diversity. Its values range between 0-4.6 by using the log (ln). Simpson dominance index (D), determines the probability that two individuals selected at random from a sample are part of the same species. Its value ranges between 0 and 1. For the measurement of Simpson dominance index (D), Simpson equation $D = \Sigma n(n-1) / N(N-1)$, was used. Simpson diversity index (1-D), describes the probability that two organisms selected at random from a sample are part of different species. Value range of this index (1-D), is between 0-1. It was computed by $SID = 1 - D$ [25, 26]. Species richness is estimation of different species of the organisms present in a specific area. Species richness was computed by following Margalef calculation formula, $SR = (S - 1)/\log n N$ [27]. Species evenness is assessment of the relative abundance of various species constituting the richness of a specific area. Species evenness was determined according to Pielou equation, $E = H/\log n S$ [28]. On account of similarities and dissimilarities in abundance, copepods of four sites were categorized into various clusters (groups) by dendrograms. Hierarchical Cluster Analysis (HCA) was executed using Past software to analyze the ancestral similarities among copepod species. Past software was employed for the plotting of Abundance curve to analyze the relative abundance of different copepods species. Relationships between heavy metals and various months were analyzed by Principal Component Analysis (PCA), whereas, correlations between copepods species, heavy metals and different months were determined by CCA (Canonical Correspondence Analysis). PCA and CCA were executed using XL stat 2022.

RESULTS

During one year study period (February 2021 to January 2022), we identified seven species of copepods associated to 4 genera and single family. *Mesocyclops edax* was noted as the most dominant copepod species, whereas, *Microcyclops varicans* manifested minimum abundance. In abundance curve of copepods species highest abundance was manifested by *Mesocyclops edax* (45.25±11.64) positioned at the top of the curve, whereas, *Microcyclops varicans* (7±1.7) showed least abundance and it was present at the bottom of the curve (figure 1).

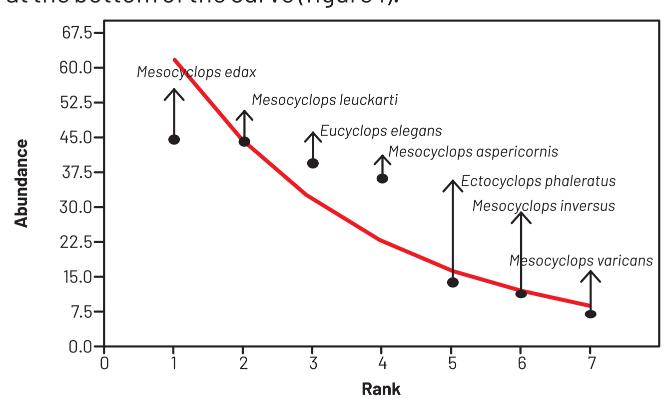

Figure 1: Abundance curve of copepods species collected from Khanki Headworks (February 2021 to January 2022)

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Although only one species of Eucyclops was observed in all months, it was noted as the most abundant genus of copepods throughout study period (figure 2).

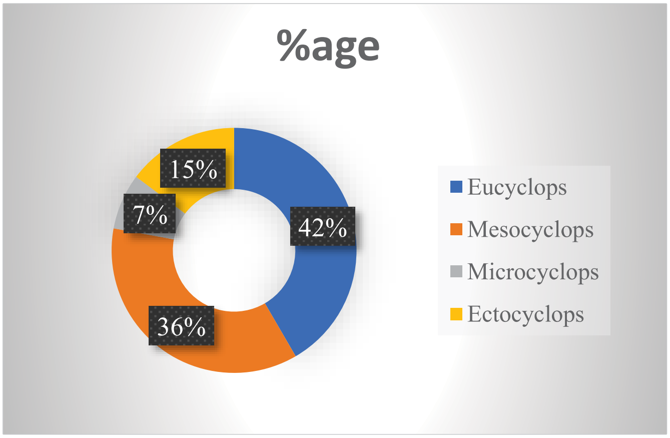


Figure 2: Relative percentage (%) of copepod genera isolated from Khanki Headworks

Comparative analysis of 7 crustacean (copepods) species was represented by a dendrogram in Agglomerative Cluster Analysis and 3 clusters were constructed on dendogram at eucladian distance 6. Cluster 1 was comprised of Microcyclops varicans, Ectocyclops phaleratus and Mesocyclops inversus. Cluster 2 included Mesocyclops leuckarti, Mesocyclops edax and Eucyclops elegans, whereas, cluster 3 consisted of Mesocyclops aspericornis. At Euclidian distance 10.5 all the clusters (groups) merged into a single group (figure 3).

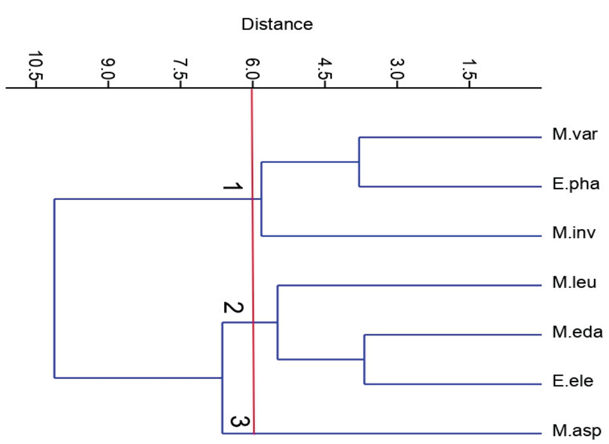


Figure 3: : Cluster analysis of copepod species based on similarities and dissimilarities in abundance at Khanki Headworks from February 2021 to January 2022

Shannon-Weaver diversity index (H) quantified highest values of copepods diversity in June and lowest values in January. Similar trend was evaluated by Simpson diversity index and its high value range for copepods diversity was computed in June and low value range in January (figure 4).

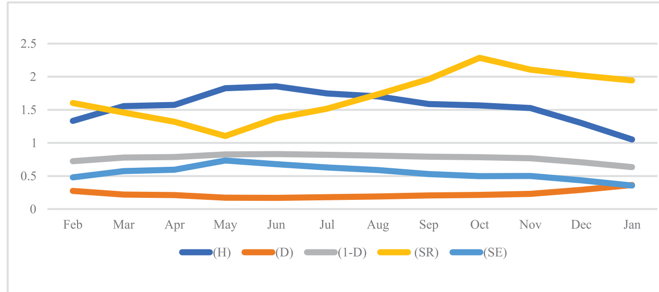
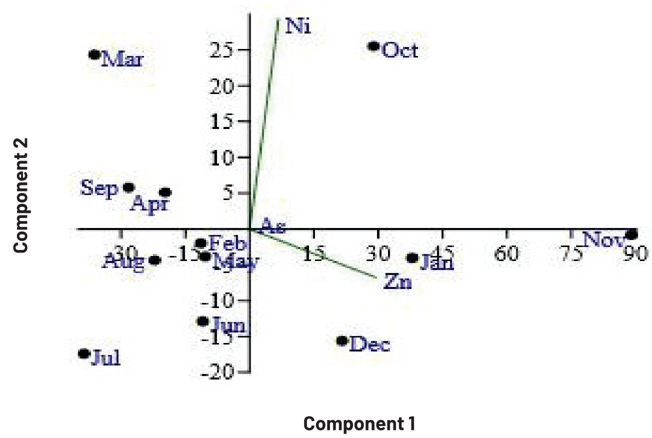


Figure 4: : Seasonal fluctuations of diversity indices of copepods identified from Khanki Headworks

H (Shannon-weaver diversity index), D (Simpson index of dominance), 1-D (Simpson index of diversity), SR (Species richness), SE (Species evenness)

Scatter plot of Principal Component Analysis (PCA), for heavy metals displayed 81.27% variance at principal component (PC) 1 and 10.87% at PC 2. Heavy metals (Zn, Ni, As) are showing close relationship with four months (Oct, Nov, Dec, Jan) and their concentration levels were also high in these months, whereas, the abundance and diversity of copepods species declined in these respective months showing negative correlation between heavy metals and copepods (figure 5).



CCA symmetric map manifested the effects of heavy metals on the population dynamics of crustaceans (copepods) during one year study period. All copepods' species are showing negative interaction with heavy metals concentration levels. While, Mesocyclops edax, Mesocyclops aspericornis and Mesocyclops leuckarti are manifesting weak negative correlation with heavy metals and these species are present closer to heavy metals. In contrast, Eucyclops elegans, Ectocyclops phaleratus, Mesocyclops inversus and Microcyclops varicans depicting strong negative relationship with heavy metals and they are present farther away from metals on CCA ordination triplot (figure 6).

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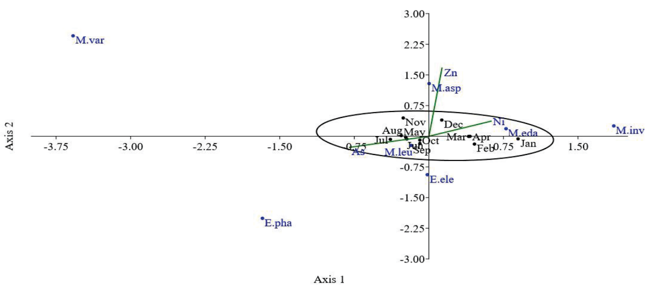

Figure 6: CCA triplot showing ordination of 7 copepods species according to the effect of 3 heavy metals

Estimation of heavy metals

During recent investigation 3 heavy metals (arsenic, nickel, zinc) were explored with spectrophotometer. However, their concentrations varied during different months in following descending order Zn> Ni> As. Their high concentrations were noted in winter months especially from October 2021 to January 2022 (figure 7).

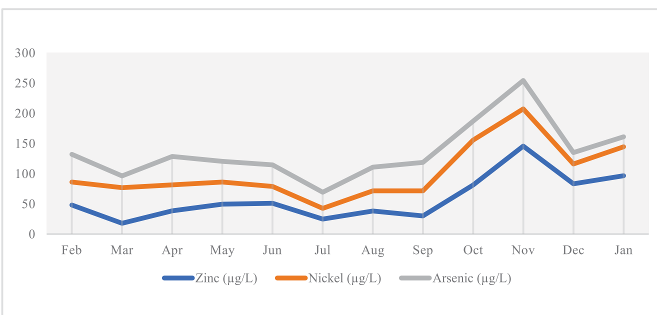

Figure 7: Seasonal variations of relative concentrations of 3 Heavy metals (µg/L) in the water of Khanki Headworks (February 2021 to January 2022)

DISCUSSION

The idea behind this study was to evaluate the seasonal changes in community structure of copepods. After qualitative examination of zooplankton samples, 7 Copepods species were noted. Mesocyclops edax was noticed as most common and abundant species recorded in all study months, as described earlier by Maqbool et al. [29]. Eucyclops was the most abundant genus with only 1 species, whereas, Mesocyclops was the most diverse genus with 4 species. In summer months, crustaceans (copepods) exhibited an exponential growth in abundance and diversity, whereas, in winter season lowest abundance of copepods was observed, it was in accordance with earlier studies of Shah et al., and Maqbool et al. [29, 30]. High temperature was observed to be favorable for most species [18, 31]. Greatest diversity of copepods (7 species) was spotted in June and least diversity was detected in January (3 species). According to results of Shannon-Weaver index (H), greatest (1.85) biodiversity was enumerated in June and minimum (1.05) in the month of January, similar trend was reported by Maqbool et al., 2015 [29]. Values of Simpson diversity index (1-D), ranged from 0.63 to 0.83, being greatest in June and lowest in January, as investigated previously by Ejaz et al. [32]. Simpson index of dominance (D) manifested lowest value range for copepods (0.17) in June, whereas, highest value range (0.36) in January, similar pattern was recorded previously by Ejaz et al. [33]. Hierarchical cluster analysis was executed for copepods species and 3 clusters were established on dendrogram at Euclidian distance 6. Cluster 1 contained 2 species. Cluster 2 and 4 were comprised of only one species, whereas, cluster 3 was manifested by 3 species. Three heavy metals (zinc, nickel and arsenic) were assessed during present study. Concentration level of Zn was observed highest in all months followed by Ni and As. However, negative correlation was established between most of copepod's species and concentration of heavy metals. These observations were in accordance with results of previous researchers [34-36]. According to PCA findings high concentrations of heavy metals were measured in winter months from October 2021 to January 22. In winter months (October to January), concentration levels of heavy metals increased gradually. In contrast, population dynamics (density and diversity) of copepods showed downward trend in these months. This pattern validated the negative influence of heavy metals on the abundance of copepods. CCA results depicted generally negative interactions between heavy metals and copepods species. Rauf et al., also reported negative relationship between heavy metals and zooplanktons [37].

CONCLUSIONS

Our findings discovered that heavy metals exert negative influence on the abundance and diversity of copepods. In winter months concentration levels of heavy metals (Ni, As, Zn) surged, whereas, copepods density gradually decreased in these months. Even diversity of copepods reduced and only 3 species were recorded in January.

Authors Contribution

Conceptualization: MAR, NR
Methodology: MAR
Formal analysis: MAR, HA
Writing-review and editing: MAR
All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The author declares no conflict of interest.

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