POTENTIAL SHIFT IN ZOOPLANKTON DIVERSITY DURING LATE WINTER IN RESPONSE TO CLIMATE CHANGE

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Abstract. Climate changes have large impacts on zooplankton community structure specially temperature that can reduce in biomass of zooplankton and that consider the link between primary producers and upper trophic levels and important to regulation of aquatic ecosystems. In this study we tested the effects of climate changes specially temperature on zooplankton biodiversity and community structure, also tested some environmental factors (pH, dissolved oxygen, PO4, NO3, and DIC) and chlorophyll-a in mesocosm experiment included 16 enclosures which filled with water, aquatic plants and sediment were extracted from the bottom of water pool with heating system for 8 enclosure. This study concluded that elevation temperature could change zooplankton biodiversity and community structure, early flowering plants, pH raising, increase in the chlorophyll-a, decline in PO4 and DIC concentrations.

Keywords. zooplankton, biomass, subtropics, climate change, early spring

1. Introduction

Zooplankton is tiny organisms are heterotrophic, lives in different aquatic ecosystems whether a was freshwater, running water, standing and salty water. Depended on the size zooplankton divided in to micro zooplankton, macro zooplankton, also these zooplankton essential for food web and food chains [1]. These organisms characterized by horizontal and vertical movement in the ecosystems water, some of them spend all of their life cycle with in Colum water called holoplankton while these spend part of their life in Colum water called meroplankton [2, 3]. So present of the environment factors such DO, nutrient [TN, TP] and TSS, TDS, EC and pH are important for the presence and distribution of zooplankton directly and indirectly also zooplankton can be consider as biological component that used as indicator of tropic status of the water systems and also zooplankton easier to know then phytoplankton and have fast responses to changes under adverse environmental factors so can used as "bio indicator" for pollution and distribution water studies [4]. Zooplankton depending in feeding on phytoplankton, protozoa, bacteria, organic matter, and other invertebrates [5] were variability of these invertebrates and other nutrient important to distribution and diversity of these organisms while the composition of zooplankton species determine by environmental tolerance[6]. This study comes to investigate whether the increasing of temperature, due to climate change, affected zooplankton community structure during late winter or not!!
2. MATERIAL AND METHOD
Mesocosm designed as set of enclosures (16 enclosures), filled with water [input and outlet], has been put the sediment were extracted from the bottom of a standing water pool has inlet and outlet in Kufa river (Fig. 1). *Lemna minor*, *Hydrilla sp.* and *Ceratophyllum demersum* were planted in these enclosures to as main producers and enhancing the habitat of zooplankton community [7]. The temperature of eight enclosures was raised (2±1.2°C) by heating system, while the other enclosures were ambient [control enclosures]. After stabilizing the enclosures for two days, abiotic and biotic parameters were recorded after manipulation water temperature (WT) (Fig. 2). Group 1: Eight enclosures with ambient WT (18.8±0.8 °C), and Group 2: Eight enclosures with increased WT (20 ±1.5 °C).

In each enclosure take chemical and physical parameter are measurement were temperature, dissolved oxygen, and pH were measured by Multi 340i meter [WTW company/ made in Germany]. For measurement nutrients, (NO₃, PO₄), filtered 40 ml water sample take from inclosure in the week these filtered through GF/F filters and stored in freezer, Nitrate (NO₃) was measured according to [8].

![Figure 1](image1.png)

**Figure 1.** The site of the river which researchers took sediment and aquatic plants from it (31°56'20.2"N 44°28'44.7"E).

![Figure 2](image2.png)

**Figure 2.** The design of study.
Soluble reactive phosphorus (PO4) were calculated with spectrophotometric - ammonium molybdate method [9]. Dissolved inorganic carbon (DIC) and carbon dioxide (CO2) were calculated in order to total alkalinity by titration, pH, water temperature, and salinity, [10]. While chlorophyll-a were measured by filtering 100 ml of water sample with filter paper 0.45μm GF/F – filters and directly covered in aluminum foil and stored in freezer at -20 °C than with ethanol 95% for 24 hrs in dark place and measured with UV- Spectrometer (EMC Lab Germany). Zooplankton sample were collected by vertical net-hauling using 20 μm mesh size 20 cm diameter net, and preserved with Lugol’s solution, and stored cold (6 °C) until classification and counting by light and inverted microscope according to different references [11, 12, 13, 14, 15]. Dominance Index, Shannon Index, and Evenness were also calculated. For statistical analysis, IBM-SPSS statistics 24 was used to test treatment responses versus controls. Treatment effect are considered statistical significant as P value < 0.05. For creation the plots and tables, SigmaPlot 9.0 software, and Microsoft excel were used.

3. RESULTS

During period of the study, in normal condition, the dissolved oxygen concentration of 16 enclosure were between 3.61 mg/L – 7.27mg/L, while after raising temperature the DO was between 2.38mg/L – 9.12mg/L (Fig. 3). The water temperature of the enclosures were between 13.40°C – 25.3°C, while after raised temperature, there was significantly differences (13.50°C – 29.7°C, Fig.4). The results of pH were 7.62 – 8.41 before rising temperature, then the pH after raising temperature was ranged between 7.70 – 9.20 (Fig. 5). Before raising temperature, the results of carbon dioxide was very low with high dissolved oxygen, while after raising temperature we observed a gradually increases in carbon dioxide as shown in Fig. 6. The highest value of NO3 was in control enclosures (7.265 μg-N/L), while the lowest value was 0.88 μg-N/L. With rising temperature the highest value was 5.276 μg-N/L and the lowest value was 1.30 μg-N/L (Fig. 7a). The phosphate values in control enclosures ranged between 0.01 μg-P/L to 0.634 μg-P/L, while in treatment enclosures ranged between < 0.001 μg-P/L - 0.195 μg-P/L (Fig. 7b). DIC concentrations in this study was ranged between 165.530 μMol/L-283.575 μMol/L in control enclosures. While after raising temperature DIC concentration was ranged between 107.13 μMol/L-271.459 μMol/L (Fig. 8). Chlorophyll-a concentration before raising temperature were ranged between <0.00 mg.L -1 to 0.004 mg.L -1, while after raising temperature were ranged between <0.00 mg.L -1 to 0.007 mgL -1 (Fig. 9). During the current study, we concluded that the zooplankton density increase gradually according to raising water temperature, the highest average value was (23.2×10^4 Ind.L^-1) after rise temperature, while the average of original density before rise temperature was (17.2×10^4 Ind.L^-1), (Fig. 10). Also, we listed 40 species of 15 family and three groups of zooplankton [Rotifera > Crustacea > Diptera]. Moreover the rotifer’s species was dominant (27 species) (Table 1). D-Index showed that the dominance decreasing with increasing temperature significantly. Also, H-Index changed significantly with treatment compared with control, moreover there is a different in that index with time of experiment, therefor we showed that the rising temperature affected negatively on evenness index comparative with control.

4. DISCUSSION

Water temperature was the main driver could affect zooplankton biomass [3]. Another study recorded the same result that temperature is affected more than the ocean acidification on zooplankton but ocean acidification can be modify temperature impacts, as well the atmospheric carbon dioxide concentration, that caused global warming and ocean acidification, enter the water resources to cause change in pH and raising temperature that reduced body size, number of zooplankton species and increase metabolic rates [16]. The temperature effect on body size of some types of zooplankton that have important for function of aquatic food web can be directly affected on fishes food [17]. As well some studies identical to the same current study included water temperature levels limit the abundance of zooplankton and can cause death in all stage of life [18, 19 ]. Temperature is more important to health and quality of water were global warming that cause high temperature of water lead to raise salinity which can affect directly number and types of zooplankton and phytoplankton [20]. As well, high temperature cause decrease of
dissolved oxygen that consider important element to life of plankton were the decline of DO cause eutrophication that prevent light penetration and therefore death most water organisms and less photosynthesis processes, this result adverse the current result were raising temperature lead to early spring and flowering plants that cause raise amount of dissolved oxygen [19, 21, 22]. Also, high temperature could causes frequency and distribution disease fishes [23]. The Acidity [pH] result from overlap of many factors including the rate of respiration, production of CO2, eutrophication, photosynthesis, and temperature of global warming [20, 24]. In the current study were increase temperature lead early spring that cause increase DO this lead to raise pH average, also increase zooplankton biodiversity. Dissolved oxygen is a key of life driver for all organisms and low levels lead to negative effect on water ecosystems. DO consider as a factor that limited life in water environment were organisms take it and release CO2 [25]. DO produced by phytoplankton and aquatic plants by photosynthesis processes during the day and consumed by organisms respiration, rate of metabolism, breakdown organic matter by microbes, eutrophication of algal blooms and increase salinity [25, 26, 27, 28]. In the current study, showed significant affects were raise water temperature lead to early spring that cause flowering plants and increase dissolved oxygen in the treatment enclosures. While high temperature cause decline DO this agree with [29, 30]. Phosphorus is critical element that have main role in the growth of producers were increase phosphorus value in the normal temperature while decline phosphorus appears in high temperature [20]. In the current study, showed decline (P-value <0.05) because of flowering of plants in the early spring and consume more nutrients, similar to some results that reported [31]. Water conditions limited by water temperature and dissolved nutrients were nitrate causes decrease by phytoplankton community, blooms of algae, primary production [32]. In the current study there is no significant effects of nitrate during increase temperature (P-value >0.05) were another study recorded same results [20]. Chlorophyll-a is a pigment that used in the photosynthesis process by primary producers to production food for consumers, were decline in the photosynthesis in high temperature lead to reduction of phytoplankton biomass that important in the carbon cycle and zooplankton abundance also there is no related between chlorophyll-a and nutrients [20, 33, 34, 35]. Zooplankton is a weak swimmer feed on phytoplankton and bacteria to get organic matter that transport to consumers after eaten or decompose them [4]. When zooplankton migrate through water column to get food are eating by predators this depended on swimming velocity that increase with raising temperature [36]. As well, some studies discuss effects of temperature on future feeding of predators on zooplanktons were capacity feeding of cold water corals with temperature range of capture food is 8°C, were temperature impact on flow velocity of water [37, 38]. In addition, temperature affect zooplankton community structure, zooplankton biomass, and appearance or disappearance of species [39, 40, 41]. These results adverse the results of the current study were found 40 species disappear 9 species of them and appear 13 species after raising temperature to reach 29°C and occurrence early spring that increase biodiversity of the zooplankton [37].

Finally, the results of the current study shows significant effects after raising water temperature were arrived highest value of the temperature [29°C]. Since early spring causes blooming of plants, plants could consume nutrients for their growth, this explains the results that appeared during this study, the decrease in the amount of phosphorus, the decrease in the amount of dissolved inorganic carbon, and the increase in the amount of dissolved oxygen, as this increase in the amount of oxygen led to an increase in the value of pH. Also we noted that the blooming of plants and algae, which led to a high percentage of chlorophyll-a [phytoplankton biomass].This explains the significant differences that showed an increase biodiversity of zooplankton.

5. CONCLUSION
This study concluded that elevation temperature could change zooplankton biodiversity, early spring in water that lead to flowering plants, cause raise the pH of water, increase in the chlorophyll-a rate, PO4 concentration and DIC.

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**Figure 3.** The relationship between the Dissolved oxygen and the period of study of control and treatment enclosure [A], and comparative between values of control and treatment enclosures of the dissolved oxygen before and after raising temperature during period of study [B].

**Figure 4.** The relationship between water temperature [°C] and the period of study of control and treatment enclosure [A], and comparative between values of control and treatment enclosures of the water temperature [°C] before and after raising temperature [B].

**Figure 5.** Comparative between pH values of control and before and after raising temperature.
Figure 6. The relationship between CO2 [μg/L] time line of study of control and treatment enclosures [A], and comparative between pH values of control and treatment enclosures over experiment [B].

Figure 7. Comparative between NO3 [A], and PO4 [B] values in control and treatment enclosures over the experiment.

Figure 8. Comparative between DIC values of control and treatment.

Figure 9. Comparative between chlorophyll-a values of control and treatment enclosures.
Figure 10. Comparative between zooplankton density $[\text{Ind/L}] \times 10^4$ values of control and treatment.

Table 1. List of the zooplankton species appearance.

| Group | Suborder | Family | Genus | Before rising temperature | After rising temperature |
|-------|----------|--------|-------|---------------------------|-------------------------|
|       |          |        |       | Control | Treatment   | Control | Treatment |
| Brachionidae |               |        |    | +        | +          | +        | +          |
| Euchlanidae |               |        |    | +        | +          | 0        | 0          |
| Lecaneidae |               |        |    | +        | 0          | 0        | 0          |
| Leucothoneidae |            |        |    | 0        | +          | +        | +          |
| Rotatoria |               |        |    | 0        | +          | 0        | +          |
| Lepidodrilidae |              |        |    | 0        | +          | 0        | +          |
| Trichocercaidae |             |        |    | 0        | +          | 0        | +          |
| Mytilidae |               |        |    | +        | +          | 0        | +          |
| Procellariidae |              |        |    | +        | 0          | 0        | +          |
| Testudinellidae |             |        |    | 0        | 0          | +        | +          |
| Colacida |               |        |    | 0        | 0          | 0        | +          |
| Calanoida |               |        |    | 0        | +          | 0        | +          |
| Ctenophora |               |        |    | 0        | +          | 0        | +          |
| Daphniidae |               |        |    | 0        | +          | 0        | +          |
| Cladocera |               |        |    | 0        | +          | 0        | +          |
|     | Cricotidae |        |    | 0        | +          | 0        | +          |
|     | Branchiopoda |        |    | 0        | +          | 0        | +          |
|     | Branchiura |        |    | 0        | +          | 0        | +          |
|     | Branchiura minor |  |    | 0        | +          | 0        | +          |
|     | Branchiura major | |    | 0        | +          | 0        | +          |
|     | Branchiura australis | |    | 0        | +          | 0        | +          |
|     | Branchiura pacifica | |    | 0        | +          | 0        | +          |
|     | Branchiura sp. | |    | 0        | +          | 0        | +          |
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