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# Response of Biomass and Production of Zooplankton Community in Upper Ganges to Tehri Dam Construction in Garhwal Himalaya

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## ABSTRACT

Response of secondary production of zooplankton community (protozoans, rotifers, copepods and cladocerans) inhabiting fluvial system of the Upper Ganges (Garhwal Himalaya) to Asia's biggest dam, the Tehri Dam construction has been assessed over a four year period (November 2000 - October 2004). No major change in the biomass (maximum: 65.0 g wet weight $l^{-1}$; minimum: 11.4-13.7 g wet weight $l^{-1}$) was observed at the impacted site ($S_2$) in comparison to the biomass recorded (maximum: 67.3 g wet weight $l^{-1}$; minimum: 8.0-9.1 g wet weight $l^{-1}$) at the reference site ($S_1$). It was also inferred that no marked detrimental impact was observed on the net monthly and daily production of zooplankton community in response to Tehri Dam construction.

***Keywords:*** Secondary production, zooplankton, upper Ganges, Tehri Dam, Garhwal Himalaya

## INTRODUCTION

The analysis of the flow of matter and energy through an ecosystem requires knowledge of secondary production. The secondary production can be defined as the amount of tissue elaborated by all non-primary producers (inhabiting secondary trophic level in an ecosystem) per unit time per unit area (Water and Crawford, 1973). The measurement of secondary production is thought essential to the management of aquatic resources, probably due to trophic-dynamic view of ecology (Downing and Rigler, 1984). Johnson (1974) has suggested that enhancement of secondary production may be important to the development of freshwater aquaculture. The most concrete freshwater resource is, of course, fish. Because many fish depend to a high degree upon zooplankton and benthos for food (Zelinka, 1977), a variety of processes of zooplankton and benthos may facilitate management of fish stock (Downing and Rigler, 1984).

Winberg (1971) and Waters (1977) have pointed out that variations in rates of secondary production could be used to detect pollution and environmental stress. Thus, the basic aim of the present study on the biomass and production of zooplankton community of the lotic environment of the upper Ganges (Garhwal Himalaya) was to detect the possible impact of environmental stress caused by the Asia's biggest and one of the most controversial dams, the Tehri Dam, and to suggest ameliorative measures for the enhancement of secondary production to the development of freshwater aquaculture in the upcoming Tehri Dam Reservoir.

## SITE DESCRIPTION

The Tehri Dam, which is one of the five biggest dams of the world, has attracted the attention of environmentalists the world over in the recent past. The Tehri Dam (260.5 m high) is being constructed across the lotic fluvial ecosystem of upper Ganges (1.5 km downstream of the confluence of Bhagirathi and Bhilangana) at Tehri of Garhwal Himalaya, Uttaranchal, India (30° 23' N; 78° 29' E). The entire lotic environment of upper Ganges will be transformed into a large reservoir with a gross storage capacity of $2.60 \times 10^9 m^3$ at full supply level.

The riverine zone under study is characterized by riffles and pools. Riffles are characterized by rapids, cascades and low gradient shallow zones at many places. Pools of this fluvial system consist of various types of habitats. Secondary channel pool and back water pool habitats are common at the site of the dam construction. Some dammed pools are also present.

## MATERIAL AND METHODS

For the purpose of assessing the response of biomass and production of zooplankton community in the Upper Ganges to Tehri Dam construction, two sampling sites were selected; one above the dam site ($S_1$) as a reference site (640 m above m.s.l) embracing many rapids and pools. The reference site ($S_1$) was free from any environmental impact and was chosen as a standard, while the impacted site ($S_2$) received the impact of all the primary actions (construction of diversion tunnels, approach adits (road) to power house, rock stripping of dam abutment and construction of head race tunnels) caused by the construction activities of Tehri Dam.

Various parameters of aquatic environment influenced by Tehri Dam construction were monitored for four years (November 2000 - October 2004) on a fortnightly basis. Physico-chemical parameters were analyzed following standard limnological methods (Welch, 1948; Golterman *et al.*, 1978; and APHA, 1981). All the physico-chemical parameters were recorded between 08:00 - 10:00 hr. Zooplankters were sampled by pouring ten litre of water through a plankton net with mesh apertures of about 50 μm. Five to ten replicates from both the sites ($S_1$ and $S_2$) were obtained. Identification and enumeration were made in a Sedgwick-Rafter counting cell.

To get the biomass (wet weight) of zooplankton, volumes for all species and developmental stages were calculated by measuring their dimensions and assuming an appropriate geometric shape, which closely resembled them (Mc Cauley, 1984). The cell volume was assumed to be occupied by protoplasm having specific gravity near 1.0 (i.e. 1 ml = 1 g) and was converted on this basis to wet biomass. The secondary productivity for zooplankton community was determined by the biomass method as suggested by Winberg (1971). The regression analysis and the calculation of the t-test for net secondary production of zooplankton and environmental variables were made.

## RESULTS

The physico-chemical parameters of the fluvial system of the upper Ganges at both the sites (reference site-$S_1$; impacted site-$S_2$) are summarized in Table 1 and 2. The Dam construction activities have caused a morphometric transformation of the habitat at the impacted site ($S_2$), altering substrate characteristics, hydromedian depth, water velocity, clarity of water and total dissolved solids. A significant change in the oxygen concentration was also noticed.

The zooplankton community of the study area was mainly composed of protozoans, rotifers, copepods and cladocerans. The qualitative distribution and abundance of different zooplanktonic taxa are presented in Table 3. The monthly variations in the biomass ( $g\ l^{-1}$), net monthly production ( $g\ l^{-1}\ month^{-1}$) and net daily production ( $g\ l^{-1}\ day^{-1}$) recorded at the

**Table 1. Physico-chemical characteristics of lotic environment at the reference site ($S_1$) of Bhagirathi recorded over a four-year period (November 2000 - October 2004) amounting to 96 observations**

| Parameter | $\overline{X}$ | C.V. |
|---|---|---|
| Air Temperature ($^0$C) | 23.58 | 31.80 |
| Water Temperature ($^0$C) | 14.43 | 18.92 |
| Water Velocity (m sec $^{-1}$) | 1.48 | 54.22 |
| Turbidity (NTU) | 115.26 | 91.42 |
| Transparency (m) | 1.39 | 45.39 |
| pH | 7.60 | 0.89 |
| Dissolved Oxygen (mg l $^{-1}$) | 9.78 | 46.46 |
| Phosphates (mg l$^{-1}$) | 0.031 | 42.11 |
| Nitrates (mg l$^{-1}$) | 0.025 | 52.00 |
| Silicates (mg l$^{-1}$) | 0.045 | 90.69 |

**Table 2. Physico-chemical characteristics of lotic environment at the impacted site ($S_2$) of Bhagirathi recorded over a four-year period (November 2000 - October 2004) amounting to 96 observations**

| Parameter | $\overline{X}$ | C.V. |
|---|---|---|
| Air Temperature ($^0$C) | 23.98 | 31.46 |
| Water Temperature ($^0$C) | 15.09 | 17.85 |
| Water Velocity (m sec $^{-1}$) | 1.351 | 59.961 |
| Turbidity (NTU) | 128.73 | 84.46 |
| Transparency (m) | 1.201 | 44.496 |
| pH | 7.54 | 1.59 |
| Dissolved Oxygen (mg l $^{-1}$) | 8.17 | 8.49 |
| Phosphates (mg l$^{-1}$) | 0.035 | 43.646 |
| Nitrates (mg l$^{-1}$) | 0.032 | 40.89 |
| Silicates (mg l$^{-1}$) | 0.045 | 68.927 |

**Table 3. Qualitative distribution and abundance of zooplankton in different seasons recorded at the reference site ($S_1$) and the impacted site ($S_2$) of the Bhagirathi over a four-year period (November 2000 - October 2004)**

| Taxon | Winter (Nov, Dec, Jan, Feb) | | Summer (Mar, Apr, May, Jun) | | Monsoon (Jul, Aug) | | Autumn (Sep, Oct) | |
|---|---|---|---|---|---|---|---|---|
| | $S_1$ | $S_2$ | $S_1$ | $S_2$ | $S_1$ | $S_2$ | $S_1$ | $S_2$ |
| **Protozoans** | | | | | | | | |
| *Campanella* | - | - | - | + | - | - | - | + |
| *Centropyxis* | - | - | - | + | - | - | - | + |
| *Carchasium* | - | - | + | ++ | - | + | + | + |
| *Epistylis* | - | + | + | ++ | - | + | + | + |
| *Zoothamnium* | + | + | + | ++ | - | + | + | + |
| **Rotifers** | | | | | | | | |
| *Ascomorpha* | ++ | + | ++ | + | - | - | ++ | + |
| *Bracionus* | +++ | + | ++ | + | - | - | ++ | + |
| *Keratella* | ++ | ++ | + | + | - | - | + | + |
| *Lecane* | + | + | + | + | - | - | + | + |
| *Mytilina* | ++ | + | + | + | - | - | + | + |
| *Philodina* | +++ | ++ | ++ | + | - | - | + | + |
| *Trichocera* | +++ | ++ | ++ | + | - | - | + | + |
| **Copepods** | | | | | | | | |
| *Cyclops* | + | + | +++ | ++ | - | - | + | - |
| *Diaptomus* | + | + | +++ | + | - | - | + | + |
| *Naupli* | + | + | ++ | + | - | - | + | + |
| **Cladoceran** | | | | | | | | |
| *Ceriodaphnia* | + | - | ++ | - | - | - | + | + |

+++ Abundant; ++ Common; + Rare; - Absent

**Table 4. Net secondary production of zooplankters recorded at $S_1$ (reference site) and $S_2$ (impacted site) for the year 2000-2001**

| Date of sampling | Period (days) | $S_1$ Biomass ($\mu g\ l^{-1}$) | $S_1$ Net monthly production ($\mu g\ l^{-1}$) | $S_1$ Net daily production ($\mu g\ l^{-1}$) | $S_2$ Biomass ($\mu g\ l^{-1}$) | $S_2$ Net monthly production ($\mu g\ l^{-1}$) | $S_2$ Net daily production ($\mu g\ l^{-1}$) |
|---|---|---|---|---|---|---|---|
| 16 Oct 2000 | - | 40.05 | - | - | 38.20 | - | - |
| 16 Nov 2000 | 31 | 45.60 | 5.55 | 0.179 | 43.32 | 5.12 | 0.0165 |
| 14 Dec 2000 | 27 | 52.44 | 6.84 | 0.253 | 46.74 | 3.42 | 0.127 |
| 15 Jan 2001 | 31 | 59.28 | 6.84 | 0.221 | 55.86 | 9.12 | 0.294 |
| 14 Feb 2001 | 29 | 67.26 | 7.98 | 0.275 | 64.98 | 9.12 | 0.314 |
| 15 Mar 2001 | 29 | 6384 | -3.42 | -0.118 | 63.84 | -1.14 | 0.039 |
| 16 Apr 2001 | 31 | 27.36 | -36.84 | -0.177 | 26.22 | -37.62 | -1.214 |
| 15 May 2001 | 28 | 23.94 | -3.42 | -0.122 | 27.36 | -1.14 | 0.041 |
| 14 Jun 2001 | 29 | 15.96 | -7.98 | -0.275 | 17.10 | -10.26 | -0.354 |
| 15 Jul 2001 | 30 | 9.12 | -6.48 | -0.216 | 11.40 | -5.70 | -0.190 |
| 16 Aug 2001 | 31 | 7.98 | -1.14 | -0.037 | 13.68 | 2.28 | 0.074 |
| 16 Sep 2001 | 30 | 21.66 | 13.68 | 0.456 | 19.38 | 5.70 | 0.190 |
| 14 Oct 2001 | 27 | 34.20 | 12.54 | 0.464 | 33.06 | 13.68 | 0.507 |
| **Total net annual production:** | | | **53.4 $\mu g\ l^{-1}\ yr^{-1}$** | | | **49.6 $\mu g\ l^{-1}\ yr^{-1}$** | |
| **Net monthly Production ( $\bar{x}$ ):** | | | **4.5 $\mu g\ l^{-1}\ month^{-1}$** | | | **4.1 $\mu g\ l^{-1}\ month^{-1}$** | |

Table 5. Net secondary production of zooplankters recorded at $S_1$ (reference site) and $S_2$ (impacted site) for the year 2001-2002

| Date of sampling | Period (days) | $S_1$ Biomass ($\mu g\ l^{-1}$) | $S_1$ Net monthly production ($\mu g\ l^{-1}$) | $S_1$ Net daily production ($\mu g\ l^{-1}$) | $S_2$ Biomass ($\mu g\ l^{-1}$) | $S_2$ Net monthly production ($\mu g\ l^{-1}$) | $S_2$ Net daily production ($\mu g\ l^{-1}$) |
|---|---|---|---|---|---|---|---|
| 18 Nov 01 | 34 | 43.32 | 9.12 | 0.268 | 45.60 | 12.58 | 0.369 |
| 14 Dec 01 | 27 | 50.16 | 6.84 | 0.253 | 52.44 | 6.84 | 0.253 |
| 15 Jan 02 | 27 | 5.86 | 5.70 | 0.211 | 54.72 | 2.28 | 0.084 |
| 14 Feb 02 | 34 | 61.56 | 5.70 | 0.168 | 63.84 | 9.12 | 0.268 |
| 15 Mar 02 | 27 | 60.42 | -1.14 | -0.042 | 63.84 | 0.00 | 0.000 |
| 16 Apr 02 | 27 | 27.36 | -33.06 | -1.224 | 30.78 | -33.06 | -1.224 |
| 15 May 02 | 27 | 22.80 | -4.56 | -0.169 | 22.80 | -7.98 | -0.296 |
| 14 Jun 02 | 34 | 14.82 | -7.98 | -0.235 | 15.96 | -6.84 | -0.201 |
| 15 Jul 02 | 27 | 12.54 | -2.28 | -0.084 | 13.68 | -2.28 | -0.084 |
| 16 Aug 02 | 30 | 11.40 | -1.14 | -0.038 | 12.54 | -1.14 | -0.038 |
| 16 Sep 02 | 31 | 23.94 | 12.54 | 0.405 | 23.94 | 11.40 | 0.368 |
| 14 Oct 02 | 30 | 30.78 | 6.84 | 0.228 | 29.64 | 5.70 | 0.190 |
| 14 Oct 01 | 27 | 34.20 | 12.54 | 0.464 | 33.06 | 13.68 | 0.507 |
| **Total net annual production:** | | | **46.7 $\mu g\ l^{-1}\ yr^{-1}$** | | | **47.8 $\mu g\ l^{-1}\ yr^{-1}$** | |
| **Net monthly Production ( $\bar{x}$ ):** | | | **3.9 $\mu g\ l^{-1}$ month $^{-1}$** | | | **4.0 $\mu g\ l^{-1}$ month $^{-1}$** | |

**Table 6. Net secondary production of zooplankters recorded at $S_1$ (reference site) and $S_2$ (impacted site) for the year 2002-2003**

| Date of sampling | Period (days) | $S_1$ | | | $S_2$ | | |
|---|---|---|---|---|---|---|---|
| | | Biomass ($\mu g\ l^{-1}$) | Net monthly production ($\mu g\ l^{-1}$) | Net daily production ($\mu g\ l^{-1}$) | Biomass ($\mu g\ l^{-1}$) | Net monthly production ($\mu g\ l^{-1}$) | Net daily production ($\mu g\ l^{-1}$) |
| 17 Nov 02 | 31 | 42.18 | 11.40 | 0.368 | 47.88 | 18.24 | 0.588 |
| 15 Dec 02 | 27 | 47.88 | 5.70 | 0.211 | 46.74 | -1.14 | -0.042 |
| 15 Jan 03 | 30 | 54.72 | 6.84 | 0.228 | 50.16 | 3.42 | 0.114 |
| 16 Feb 03 | 31 | 57.00 | 2.28 | 0.074 | 60.42 | 10.26 | 0.253 |
| 16 Mar 03 | 27 | 61.56 | 4.56 | 0.169 | 67.26 | 6.84 | 0.253 |
| 16 Apr 03 | 30 | 26.22 | -35.34 | -1.178 | 25.08 | -42.18 | -1.406 |
| 14 May 03 | 27 | 23.94 | -2.28 | -0.084 | 25.08 | 0.00 | 0.000 |
| 16 Jun 03 | 32 | 17.10 | -6.84 | -0.214 | 18.28 | -6.80 | -0.213 |
| 14 Jul 03 | 27 | 13.68 | -3.42 | -0.127 | 14.82 | -3.46 | -0.128 |
| 17 Aug 03 | 33 | 12.54 | -1.14 | -0.035 | 13.68 | -1.14 | -0.035 |
| 15 Sep 03 | 27 | 22.80 | 10.26 | 0.367 | 22.80 | 9.12 | 0.326 |
| 13 Oct 03 | 27 | 36.48 | 13.68 | 0.507 | 34.20 | 11.40 | 0.422 |
| **Total net annual production:** | | **54.7 $\mu$ g $l^{-1}$ $yr^{-1}$** | | | **59.3 $\mu$ g $l^{-1}$ $yr^{-1}$** | | |
| **Net monthly Production ( $\overline{x}$ ):** | | **4.6 $\mu$ g $l^{-1}$ $month^{-1}$** | | | **4.9 $\mu$ g $l^{-1}$ $month^{-1}$** | | |

Table 7. Net secondary production of zooplankters recorded at $S_1$ (reference site) and $S_2$ (impacted site) for the year 2003-2004

| Date of sampling | Period (days) | $S_1$ Biomass ($\mu g\ l^{-1}$) | $S_1$ Net monthly production ($\mu g\ l^{-1}$) | $S_1$ Net daily production ($\mu g\ l^{-1}$) | $S_2$ Biomass ($\mu g\ l^{-1}$) | $S_2$ Net monthly production ($\mu g\ l^{-1}$) | $S_2$ Net daily production ($\mu g\ l^{-1}$) |
|---|---|---|---|---|---|---|---|
| 16 Nov 03 | 33 | 39.90 | 3.42 | 0.104 | 41.04 | 6.84 | 0.207 |
| 14 Dec 03 | 27 | 55.86 | 15.96 | 0.591 | 53.58 | 12.54 | 0.464 |
| 15 Jan 04 | 31 | 63.84 | 7.98 | 0.257 | 58.14 | 4.56 | 0.147 |
| 14 Feb 04 | 29 | 64.98 | 1.14 | 0.039 | 59.28 | 1.14 | 0.039 |
| 15 Mar 04 | 28 | 69.94 | 4.56 | 0.163 | 66.12 | 6.84 | -0.221 |
| 16 Apr 04 | 31 | 37.62 | -31.98 | -1.029 | 33.06 | -33.06 | -1.066 |
| 14 May 04 | 27 | 23.94 | -13.68 | -0.507 | 23.94 | -9.12 | -0.338 |
| 15 Jun 04 | 31 | 15.96 | -7.98 | -0.258 | 17.10 | -6.84 | -0.221 |
| 16 Jul 04 | 29 | 13.68 | -2.28 | -0.079 | 17.10 | 0.00 | 0.000 |
| 15 Aug 04 | 29 | 11.40 | -2.28 | -0.079 | 13.68 | -3.42 | -0.118 |
| 16 Sep 04 | 31 | 27.36 | 15.96 | 0.515 | 26.22 | 12.54 | 0.405 |
| 16 Oct 04 | 29 | 38.76 | 11.40 | 0.393 | 35.34 | 9.12 | 0.314 |
| **Total net annual production:** | | | **60.4 $\mu g\ l^{-1}\ yr^{-1}$** | | | **53.6 $\mu g\ l^{-1}\ yr^{-1}$** | |
| **Net monthly Production ($\bar{x}$):** | | | **5.0 $\mu g\ l^{-1}\ month^{-1}$** | | | **4.5 $\mu g\ l^{-1}\ month^{-1}$** | |

**Table 8. Regression analysis and t-test for net secondary production (zooplanktonic) and environmental variables**

| Environmental variables | Reference Site ($S_1$) | | Impacted Site ($S_2$) | | t | p |
|---|---|---|---|---|---|---|
| | a | b | a | b | | |
| Water Temperature | 89.6743 | -3.7265 | 87.9946 | -3.4493 | 5.709 | <0.01 |
| Water Velocity | 64.8909 | -19.6629 | 60.3752 | -18.1106 | 13.118 | <0.01 |
| Turbidity | 50.3897 | -0.1202 | 49.4891 | -0.1055 | 7.826 | <0.01 |
| Transparency | 2.8157 | 23.6654 | 5.2129 | 25.5634 | 10.955 | <0.01 |
| pH | 177.6729 | 28.0986 | 518.1666 | -63.9332 | 4.514 | <0.01 |
| Dissolved Oxygen | 145.4888 | 19.7605 | -117.243 | 18.7488 | 9.883 | <0.01 |
| Phosphates | 70.7570 | -1124.04 | 56.2141 | -603.458 | 1.288 | <0.05 |
| Nitrates | 65.0673 | -1132.25 | 73.5317 | -1190.38 | 14.721 | <0.01 |
| Silicates | 36.7189 | -20.7155 | 33.1939 | 63.2135 | 0.562 | <0.05 |
| $P_g$* | 5.6918 | 0.0228 | 10.0292 | 0.0221 | 13.448 | <0.01 |

•Gross primary productivity

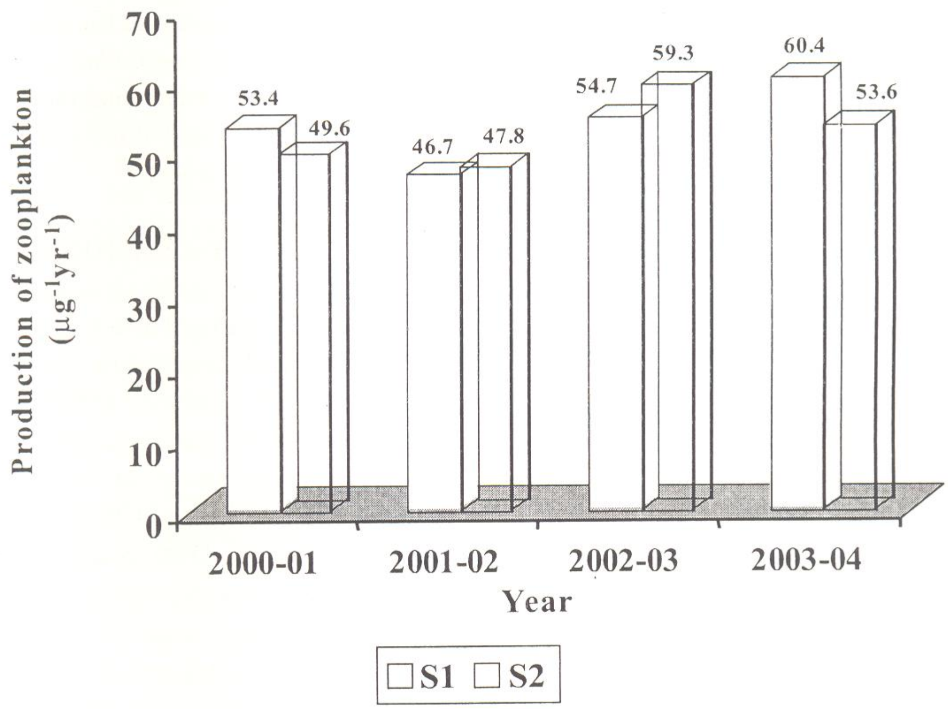


**Fig. 1. Representation of the net primary production of zooplankton estimated at the reference site ($S_1$) and the impacted site ($S_2$) over a four-year period (2000-2004)**

reference site $S_1$ and the impacted site $S_2$, have been portrayed in Tables 4-7.

**Biomass**

Overall contribution by zooplankton towards secondary production is very low compared with benthic aquatic insects inhabiting the metarhithronic stretch of the upper Ganges. The maximum biomass of the zooplankton at the reference site (67.3μgl$^{-1}$) was recorded in February and minimum (8.0 - 9.1μg l$^{-1}$) in the monsoon months (July - August), when the study area used to experience heavy precipitation (Table 4).

No considerable change in the biomass (maximum: 65.0 μg l$^{-1}$; minimum: 11.4 - 13.7 μg l$^{1}$) was observed at the impacted site ($S_2$) as a consequence of the impact of Tehri Dam construction activities (Table 4). The same influence of the engineering works on the biomass was observed in the successive years of observations (Table 5-7).

**Net Monthly and Daily Production**

Maximum monthly production (13.7 μ g l$^{-1}$ month$^{-1}$) was observed in September at $S_1$ with a positive value of growth during autumn and winter months. A negative growth was recorded in summer (March - June) and monsoon (July - August) months (Table 4). The same trend in the variations in monthly production was observed in the subsequent years (Tables 5, 6 and 7). The maximum net daily production (0.46 μg l$^{-1}$ day$^{-1}$) was observed in October indicating a positive growth in all the months of autumn and winter months. A negative growth was observed in summer and monsoon months (Tables 4-7).

No visible impact was observed in the net monthly and daily production of zooplankton estimated at $S_2$ (impacted site).

**Annual Net Production**

The total net annual production (μg l$^{-1}$ yr$^{-1}$) of zooplankton at the reference site ($S_1$) and the impacted site ($S_2$) estimated over a four-year period is depicted in Fig. 1. No change in the annual production as influenced by Tehri Dam construction activities was observed. It was 53.4 μg l$^{-1}$ yr$^{-1}$ at the reference site ($S_1$) during the year 2000-01 and 49.6 μg l$^{-1}$ yr$^{-1}$ at $S_2$ (impacted site). A minor increase in net annual zooplankton production was observed at $S_2$ (47.9 μg l$^{-1}$ yr$^{-1}$ and 54.7 μg l$^{-1}$ yr$^{-1}$) during the years 2001-02 and 2002-03, respectively. Again, in the year 2003-04, it shows some change in the annual production recorded at $S_1$ (60.4 μ g l$^{-1}$ yr$^{-1}$) and $S_2$ (53.6 μg l$^{-1}$ yr$^{1}$).

**Statistical Treatment of Data**

The regression coefficient (b) and t-test computed for net secondary production of zooplankton and environmental variables at reference site ($S_1$) and impacted site ($S_2$) have been presented in Table 8.

## DISCUSSION

Among the most obvious aspects of the environment that might affect animal production are the average temperature, the ability of the ecosystem to produce sufficient food of acceptable quality, the character of the substrate, and the concentration of respirable oxygen (Downing and Rigler, 1984). In the present studies, the Tehri Dam construction activities have caused a morphometric transformation of habitat at the impacted site ($S_2$) altering substrate characteristics, hydromedian depth, water velocity, clarity of water and total dissolved solids. A significant change in the oxygen concentration was also noticed as a consequence of Tehri Dam construction activities. However, zooplankton production did not show any change, as these organisms have nothing to do with the bottom substrates, as zooplankton are surface dwellers (Fig. 1).

An important factor in streams and rivers seems to be the current velocity (Downing and Rigler, 1984). Hamill *et al.* (1979) and Neves (1979) all suggest that secondary production decreased with increasing water flow rate. A sharp decrease and negative secondary production of zooplankton in the river during summer (March - June) and the monsoon months (July - August) of high water velocity due to melting of snow at the higher reaches in summer, and frequent flash floods in monsoon, is in fair agreement with the observations made by Zelinka (1979), Hamill *et al.* (1979) and Neves (1979). In the present studies on the Upper Ganges, zooplankton production has negative regression coefficient (b = -19.6629; b = -18.1106) with the water velocity of ecosystem (Table 8). Temperature has also been known to influence secondary production of zooplankton. Marchant and Hynes (1981) stated that growth rates increase with increased temperature. On the other hand, Pidgaiko *et al.* (1972) concluded that temperature variations could have either a positive or negative effect on secondary production depending upon geographic location and basin morphometry. In the present study, the secondary production of zooplankton has a negative regression (b = -3.7265; b = -3.4493) with the temperature variation.

The t-test applied to regression coefficients (b values) computed for reference site ($S_1$) and impacted site ($S_2$) was found insignificant (t = 0.8361) which indicates that the environmental variables have similar impact on secondary production of zooplankton at both the sites.

A community of heterotrophs can fix no energy than the amount made available to them by primary producers. Edmondson (1974) has reasoned that the rate of primary production must set the upper limit for secondary production. Using similar logic, many contributors have suggested that rates of production of freshwater zooplankton are positively related to food availability (Nauwerck *et al.*, 1980). Others have found that rates of zooplankton production are positively related to rates of primary production (Makarewicz and Likens, 1979; Smyly, 1979).

In the present studies on the Upper Ganges, a positive regression coefficient (b = 0.0228; b = 0.0221) was found between secondary production of zooplankton and primary production of phytoplankton periphytic community (Table 8). The value of primary production ($P_g$) was recorded very high during autumn (September - October) and winter seasons (November - February) in the Upper Ganges (Sharma, 2005). So, a high secondary production during the same period (autumn and winter) is expected.

Some production ecologists have suggested the importance of allochthonous materials to secondary production in both lakes and streams (Edmondson, 1974; Waters, 1977; Adcock, 1979). In the case of the Upper Ganges ecosystem,the trophic state is heterotroph and it receives organic matter of allochthonous origin, which is used for the maintenance of its biota. This allochthonous matter is washed into the lotic ecosystem during flash floods of monsoon, and provides a source of energy to secondary producers enhancing their production in post monsoon (autumn and winter) period.

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