Journal of Environmental Biology

April 2006, 27(2) 191-198 (2006)

Influence of cooling water discharges from Kaiga nuclear power plant on selected indices applied to plankton population of Kadra reservoir

S. Zargar and T. K. Ghosh
Environmental Biotechnology Division, National Environmental Engineering Research Institute (NEERI),
Nehru Marg, Nagpur-440 020, India

(Received: 15 January, 2005 ; Accepted: 5 July, 2005)

Abstract: *Condenser cooling water for the Kaiga nuclear power plant, Kaiga of Karnataka state is drawn at the rate of 1,25,205 m^3hr^{-1} from the Kadra reservoir and discharged back to the reservoir through a 1.2 km long open channel. The heated effluents reduce solubility of oxygen and accelerate loss of oxygen locally due to increased biological activity. Applications of biological indices are the effective tool for the assessment of qualities of water and biota. During the study period of two years 49 and 22 genera of phytoplankton and zooplankton respectively were recorded at surface waters. Diversity indices indicate oligotrophic nature of the lake. Dissimilarity was more amongst the plankters in between intake and discharge points. Preference of habitats indicates marginal change of rankings of plankton in zones within 500m and beyond 500m from the point of discharge. Studies revealed that there was negative impact of evaluated temperature on plankton upto 500 m from discharge point.*

Key words: *Cooling water, Reservoir, Plankton, Biological indices.*

Introduction

A large number of biotic indices have been developed to assess water quality (Metcalfe-Smith, 1966). Biotic indices are highly specialized for a particular type of water pollution, usually organic pollution (Washington, 1984). A biotic index takes into account of the sensitivity or tolerance of individual species or groups to pollution for a site. The data may be qualitative (presence-absence) or quantitative (relative abundance or absolute density). It may conveniently classify the analysis methods for freshwater under; *Pollution indices,* which are derived from the responses of certain `indicator` taxa to known pollution (usually organic pollution); *diversity indices*, which describe the structure of communities of organisms and ,when the structure is changed by pollution or other stress, may be used to measure the extent to which a stressed community differs from an ideal structure; *comparative indices*, which may be used to compare the degree of similarity between community (or subjected to known and measured stress) in either a spatial (‘upstream and downstream’) or temporal (‘before and after’) context. Alterations in density, taxonomic and trophic structure, diversity and dominance of plant and animal species are quantified and related to pollution studies for evaluating ecological impacts in the receiving waters (Ghosh, 2001). Meaningful assessment of river water quality can be made from survey results and their relative or absolute abundance (Dussart *et al*., 1980). Present communication deals with various indices for assessment of aquatic biota of Kadra reservoir, receiving cooling water discharges from two units each of 220 MW of Kaiga nuclear power plant, Karwar, Karnataka. These two units were in operation since December 1999.

Materials and Methods

Sample collection and identification: The plankton samples were collected with the help of a boat from the Kadra reservoir at nine locations (Fig. 1), namely, intake point (1), discharge point (DP: 2), 50 m from DP (3), 100 m from DP (4), 500 m from DP (5), 1000 m from DP (6), 100 m from right side (90º) of 100 m point (7), 100 m from right side (90º) of 500 m point (8) and dam site point (12 km from DP: 9) in each month from January 2001 to December 2002. The unfiltered water samples were collected for phytoplankton, preserved in lugol’s solution and enumerated following Lackey Drop (microtransect) method (Lackey, 1938) under microscope. Identification of phytoplankton was undertaken using taxonomic keys from Bellinger, (1992); Prescott, (1978) and Desikachary (1959, 1987). Water samples were collected by operating simple conical net (bolting silk no. 20, pore size 75 μm) for zooplankton preserved in 4% formalin solution and enumerated under microscope using Sedgwick Rafter (S-R) cell. The identification of zooplankters was confirmed be referring the keys (Battish, 1992; Pennak, 1978; Ward and Whipple, 1966).

Application of biological indices: A number of indices have been developed for the assessment of qualities of water & biota, and these have been reviewed by Hellawell (1978), Lagler (1956), Hanes (1980) and Ghosh (1998). In the present study *Shannon Wiener*, *Palmer Pollution*, *Species Evenness, Similarity* and *Habitat* indices were applied to the data, generated from plankton samples of Kadra reservoir.

Shannon Wiener Index, the most commonly accepted index in past few decades, is based on both the number of species present and the relative abundance of each species. This index is usually used to calculate species diversity but comparisons are also made using the different taxonomic levels (Hellawell, 1978). Species Evenness Index was determined by using Pielou’s (1966) formula. This index is used to assess how evenly the species were distributed in any sampling point. Palmer Pollution Index employs taxa of algae (Palmer, 1969).

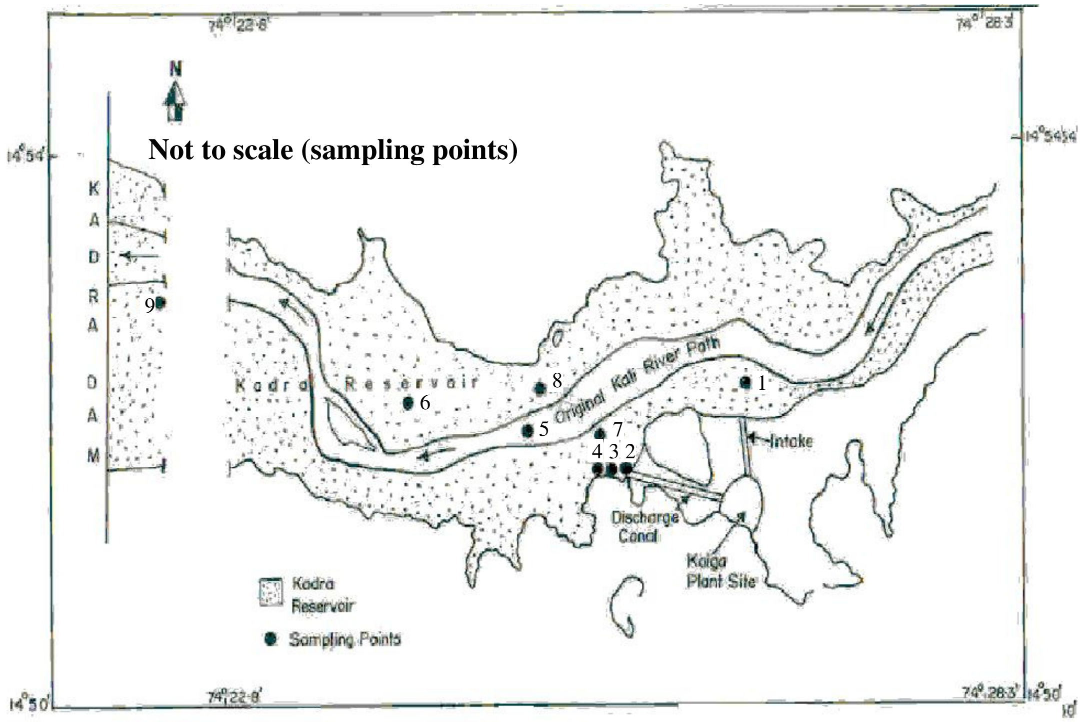

Fig. 1: Map indicating sampling points at Kadra reservoir.

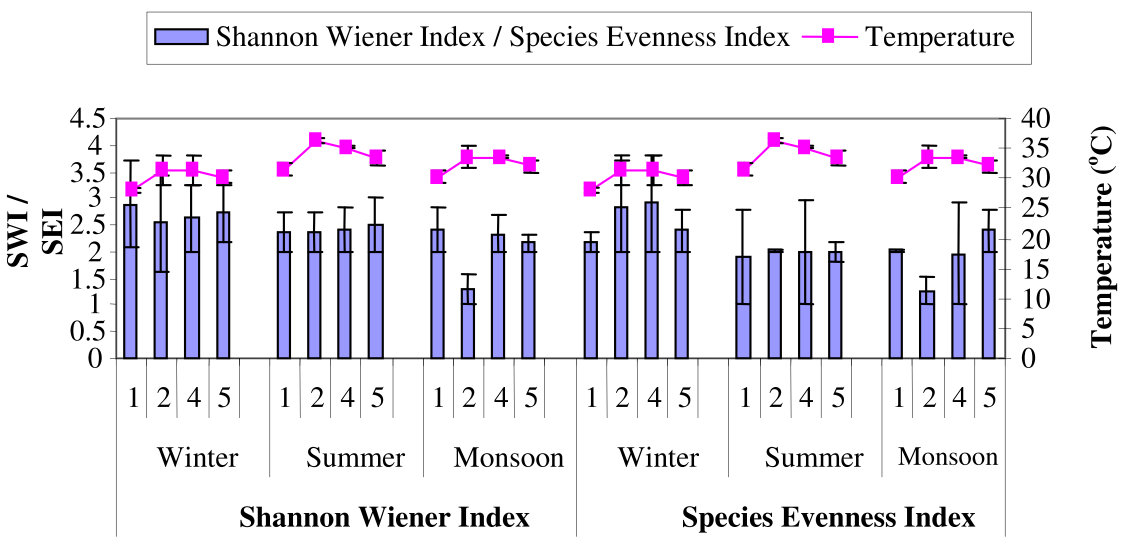

Fig. 2: Seasonal variations of Shannon Wiener Index (SWI) and Species Evenness Index (SEI) of phytoplankton at select points of Kadra reservoir.

The most tolerant genera and species were given ratings which are used to calculate the index. An alga is recorded as 'present', if there are more than 50 individuals /ml. The sum of the ratings of the algae present is then calculated (Hellawell, 1978). Similarity index approaches to assess association based on presence, absence or binary data. When species of stations A and B are compared on the basis of their presence or absence in samples from different locations, similarity index (S) of Sorensen can be applied. In order to evaluate preference of the aquatic biota to the reservoir ecosystem the data were analysed in detail leading to Habitat Index. The index is primarily based on density and availability of a species at different stations within the ecosystem. The steps to determine habitat index have been described elsewhere (Ghosh, 2002). Standard error was done using statistical software Statistica version 5.0.

Winter									
Sampling point	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	1.0	0.47	0.47	0.53	0.61	0.72	0.46	0.63	0.77
2		1.0	0.81	0.79	0.59	0.66	0.58	0.51	0.40
3			1.0	0.64	0.62	0.64	0.45	0.59	0.60
4				1.0	0.59	0.60	0.76	0.60	0.59
5					1.0	0.61	0.42	0.53	0.73
6						1.0	0.42	0.68	0.67
7							1.0	0.30	0.46
8								1.0	0.55
9									1.0
Summer									
Sampling point	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	1.0	0.36	0.59	0.35	0.63	0.77	0.49	0.74	0.66
2		1.0	0.83	0.88	0.50	0.37	0.68	0.43	0.46
3			1.0	0.80	0.49	0.60	0.71	0.41	0.37
4				1.0	0.38	0.37	0.69	0.40	0.55
5					1.0	0.75	0.48	0.74	0.66
6						1.0	0.53	0.81	0.64
7							1.0	0.54	0.54
8								1.0	0.69
9									1.0
Monsoon									
Sampling point	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	1.0	0.36	0.59	0.35	0.63	0.77	0.49	0.74	0.75
2		1.0	0.83	0.88	0.50	0.37	0.68	0.43	0.40
3			1.0	0.80	0.49	0.60	0.71	0.41	0.36
4				1.0	0.38	0.37	0.69	0.40	0.28
5					1.0	0.75	0.48	0.74	0.58
6						1.0	0.53	0.81	0.82
7							1.0	0.54	0.53
8								1.0	0.76
9									1.0

:< 0.41 :0.41-0.60 :0.61-0.75 :> 0.75

Fig. 3: Seasonal variation of similarity Index of phytoplankton among different points of Kadra reservoir.

Results and Discussion

Phytoplankton: During the study period 49 genera of phytoplankton were identified from water samples collected from Kadra reservoir. Four major groups, viz. bacillariophyceae, cyanophyceae, chlorophyceae & pyrohphyceae were recorded. Groups bacillariophyceae, cyanophyceae and chlorophyceae were represented primarily by *Navicula* sp., *Melosira* sp., *Synedra* sp. etc.; *Anacystis* sp., *Chroococus* sp., *Synechosystis* sp., *Anabaena* sp. etc.; and *Chlorella* sp., *Scenedesmus* sp., *Ankistrodesmus* sp., *Pediastrum* sp. etc. respectively. It is reported that excessive growth of certain algal genera, such as, *Scenedesmus*, *Anabaena*, *Aphanizomenon*, *Anacystis*, *Oscillatoria*, *Pediastrum*, *Melosira* etc. indicate nutrient enrichment of aquatic bodies (Palmer, 1969; Kumar, 1990). Although these plankters were present in the Kadra reservoir, the density was not much higher.

Shannon Wiener diversity values were generally higher in winter and summer seasons as compared to monsoon season (Fig. 2). Minimum diversity of phytoplankton was found at 20 m from DP in monsoon when the temperature was found to be 34ºC. Martin Creek Power station on the Delaware showed distinct reductions in species-diversity when temperature in the discharge point had reached 37ºC (Langford, 1983). The alterations in the phytoplankton community were

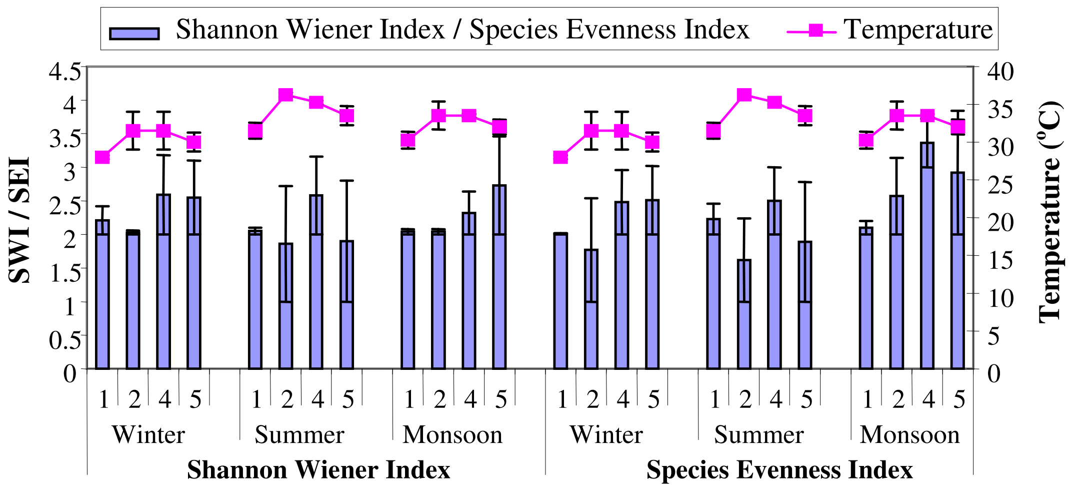

Fig. 4: Seasonal variations of Shannon Wiener Index (SWI) and Species Evenness Index (SEI) of zooplankton at select points of Kadra reservoir.

only partially reflected in a slight decrease in species diversity at the heated water area (DP and 100m from DP, points) as depicted in Fig 2. Several studies shown that species diversity of phytoplankton decreased in areas consistently heated over 30ºC (Patrick, 1969; Trembley, 1960; Simmons, 1974; Langford, 1983). In contrast, Carpenter (1973) and McMahon and Docherty (1975) reported that phytoplankton diversity may increase with small temperature increments (5 – 10ºC) provided that the maximum temperature does not exceed 32 – 35ºC. It is widely accepted that species diversity decrease in aquatic communities under stress (Odum, 1971; Wetzel, 1975).This may be applicable to cases of more severe pollution, but in the present study the species diversity index did not alter remarkably due to alterations in phytoplankton structure and dynamics. Since pollution tolerant species replaces the susceptible species, Green and Vascoto (1978) had earlier opined that the relation between high diversity and high environment quality was not always valid.

Species Evenness Index (SEI) values, as depicted in Fig. 2, varied from 1.27 (monsoon, DP, 33.5ºC) to 2.91 (winter, 100 m from DP, 31.5ºC). The values indicate that distribution of phytoplankton genera was most uneven at DP as compared to 100 m from DP, where the genera were most evenly distributed. Palmer Pollution Index (PPI) values (0) support the oligotrophic nature of the lake water at all sampling points throughout the study period. The PPI value was 'zero' since none of the phytoplankton genera was found above 50 no. ml^{-1} in any of the water sample collected from different sampling points of Kadra reservoir. Similarity Index values denote that availability of similar types of genera amongst certain points like intake and DP, DP and 500 m etc. were poor in all the seasons (Fig 3). The decrease in Sorenson's similarity index between these stations in this study indicated less faunal overlap and predictability of community composition. The decrease in predictability of community composition could be correlated with increase in water temperature due to discharge of warm water in the reservoir. However, increased (>0.6) similarity indices were recorded in stations between intake & 500 m, intake & 1000 m, intake & dam site, DP & 50 m, DP & 100 m, 1000 m & dam site and 1000 m & 100 m from right side(90º angle) of 500 m. Habitat Index of each genus of plankton was evaluated in two zones of the reservoir (Table 1), namely, Zone 1 comprising of sampling points within 500 m from DP (DP, 50 m from DP, 100 m from DP,100 m from right side (90º angle) of 100 m point, 500 m from DP and100 m from right side (90º angle) of 500 m point) and Zone 2 covering the points beyond 500 m from DP (intake, 1000 m from DP and dam site). The index values reveal that *Melosira* sp. and *Anacystis* sp. were the most preferred phytoplankton at Zone1 and Zone 2 respectively. Kumar (1990) reported that the extra load of certain algae, such as, *Melosira* sp., *Anacystis* sp. etc. is an indication of nutrient enrichment of the water body. However, in Kadra reservoir, phytoplankton did not find to be correlated with nutrients significantly. Although, the average temperature values at Zone 1 were found to be 33ºC, Zone 2 had 30ºC. Thus, it may be inferred that the temperature 33ºC and 30ºC may be favorable for *Chlorella* sp. and *Anacystis* sp. respectively. According to Hickmann and Klarer (1974), temperature ranges 27-36ºC is favorable to *Chlorella* sp. Although *Zygnema* sp., *Spirulina* sp., *Gomphonema* sp. etc. were not recorded at zone 1, these were found to be present at Zone 2. It, thus, clearly indicates that these phytoplankters avoid higher temperature, and prefer zone 2 possessing comparatively less temperature (30ºC). Wallace (1955) reported optimum growth temperature of *Gomphonema* sp. between 22-26 ºC, much lesser than Zone 1. Lower rankings of C*erasterias* sp., *Selenastrum* sp. etc. indicated that these genera did not prefer the Kadra reservoir habitat irrespective of temperature.

Zooplankton: Moore (1996) reported that zooplankton have direct and indirect effects due to elevated temperature ($\geq$ 25ºC).

Table – 1: Ranking of phytoplankton based on Habitat Index in two zones of the Kadra reservoir.

S No.	Phytoplankton	Zone 1 (within 500m from discharge point)		Zone 2 (beyond 500m from discharge point)	
		Habitat index	Ranking	Habitat index	Ranking
	Melosira sp.	10.15	1	10.17	2
	Chlorella sp.	9.83	2	9.31	3
	Anacystis sp.	8.73	3	10.52	1
	Cyclotella sp.	5.62	4	4.14	7
	Ceratium sp.	5.47	5	2.22	14
	Oscillatoria sp.	5.03	6	3.4	11
	Navicula sp.	4.53	7	1.27	22
	Scenedesmus sp.	4.45	8	4.7	6
	Staurastrum sp.	4.23	9	6.15	4
	Chlorococcum sp.	4.16	10	4.75	5
	Fragillaria sp.	3.11	11	3.61	9
	Euastrum sp.	2.65	12	1.97	15
	Ankistrodesmus sp.	2.49	13	2.95	12
	Nitzschia sp.	2.46	14	0.66	29
	Synechocystis sp.	2.42	15	1.83	17
	Stauroneis sp.	2.13	16	0.19	40
	Pediastreum sp.	2.12	17	0.79	27
	Desmedium sp.	2.1	18	1.54	21
	Chroococus sp.	1.96	19	3.99	8
	Rhizosolenia sp.	1.71	20	1.04	24
	Microspora sp.	1.58	21	0.55	30
	Dictylococcus sp.	1.49	22	1.95	16
	Merismopedia sp.	1.38	23	1.54	21
	Phormedium sp.	1.25	24	0.86	26
	Synedra sp.	1.22	25	2.22	14
	Arthrodesmus sp.	1	26	3.41	10
	Ulothrix sp.	0.98	27	2.49	13
	Closteridium sp.	0.8	28	1.15	23
	Frustulia sp.	0.79	29	Absent	NA
	Raphidiopsis sp.	0.63	30	1.56	20
	Scleriopsis sp.	0.52	31	0.37	35
	Apimyxa sp.	0.44	32	0.97	25
	Mougeotia sp.	0.44	33	0.41	33
	Tetraedron sp.	0.4	34	0.22	38
	Asterionella sp.	0.29	35	0.47	31
	Scytonema sp.	0.24	36	Absent	NA
	Closteriopsis sp.	0.23	37	0.23	37
	Pinnularia sp.	0.21	38	0.35	36
	Oocystis sp.	0.16	39	Absent	NA
	Selenastrum sp.	0.16	39	0.09	41
	Mastogloia sp.	0.14	40	Absent	NA
	Aphynomyzone sp.	0.12	41	0.45	32
	Phacus sp.	0.1	42	0.4	34
	Cerasterius sp.	0.08	43	0.41	33
	Cocconeis sp.	Absent	NA	0.2	39
	Cosmarium sp.	Absent	NA	1.58	19
	Gomphonema sp.	Absent	NA	0.55	30
	Spirulina sp.	Absent	NA	1.64	18
	Zygnema sp.	Absent	NA	0.73	28

NA: Not applicable

Winter

Sampling point	1	2	3	4	5	6	7	8	9
1	1.0	0.59	0.63	0.53	0.71	0.77	0.66	0.88	0.87
2		1.0	0.87	0.66	0.61	0.50	0.71	0.60	0.55
3			1.0	0.85	0.63	0.68	0.71	0.63	0.51
4				1.0	0.71	0.62	0.82	0.58	0.64
5					1.0	0.82	0.70	0.74	0.83
6						1.0	0.58	0.60	0.74
7							1.0	0.64	0.80
8								1.0	0.83
9									1.0

Summer

Sampling point	1	2	3	4	5	6	7	8	9
1	1.0	0.50	0.53	0.72	0.81	0.82	0.77	0.72	0.81
2		1.0	0.71	0.76	0.61	0.66	0.91	0.72	0.65
3			1.0	0.79	0.69	0.68	0.69	0.69	0.68
4				1.0	0.69	0.65	0.82	0.68	0.73
5					1.0	0.79	0.74	0.69	0.84
6						1.0	0.63	0.74	0.70
7							1.0	0.71	0.70
8								1.0	0.71
9									1.0

Monsoon

Sampling point	1	2	3	4	5	6	7	8	9
1	1.0	0.56	0.50	0.66	0.66	0.78	0.79	0.71	0.85
2		1.0	0.78	0.78	0.73	0.70	0.77	0.71	0.70
3			1.0	0.86	0.72	0.79	0.82	0.67	0.79
4				1.0	0.69	0.65	0.77	0.63	0.57
5					1.0	0.82	0.68	0.77	0.79
6						1.0	0.61	0.66	0.82
7							1.0	0.69	0.68
8								1.0	0.78
9									1.0

:< 0.51 :0.51-0.60 :0.61-0.75 :> 0.75

Fig. 5: Seasonal variation of Similarity Index of zooplankton among different points of Kadra reservoir.

The intensity of temperature stress may be magnified by exposure of aquatic organisms to other environmental stresses, such as, low oxygen levels, salinity changes, desiccation etc. (Hawkes, 1969). However, Marlene *et al*. (1986) suggested that apart from thermal stresses, mechanical stresses appeared to be the major cause of zooplankton mortality during condenser cooling. During the study period, 22 genera of zooplankton were identified from water samples of Kadra reservoir. Four major groups of zooplankton, namely, copepoda, rotifera, cladocera and diptera were found to inhabit the water body. The copepoda was represented by *Cyclops* sp., *Diaptomus* sp., and Nauplius larvae, while cladocerans were represented by *Bosmina longirostris*, *Bosminopsis dietersi* and *Ceriodaphnia reticulata*. Among rotifers, a total of 15 genera were found, of which *Brachionus* was represented by six species, viz. *B. calyciflorus*, *B. angularis*, *B. caudatus*, *B. havanaensis*, *B. rubens* and *B. quadricauda*. These were recorded in almost all the sampling points. Rotifers, viz. *Brachionus* sp., *Tricocerca* sp., *Lepadella* sp., *Lecane* sp., *Filinia* sp. etc. contributed significantly to zooplankton productivity in Kadra reservoir. Literature revealed that these rotifers were commonly found in the mesotrophic and oligotrophic waters (Battish, 2002) and are significant component of zooplankton (Wetzel, 2001). Dominance of rotifers amongst the zooplankton was also recorded earlier in wide varieties of Indian lakes (Prabhavati and Sreenivasan, 1977; Sharma and Michael, 1980). Shannon Wiener Index (SWI) values (Fig. 4) varying from 1.86 (summer, DP, 36.2ºC) to 2.73 (monsoon, 500 m from DP, 32.0ºC)

Table – 2: Ranking of zooplankton based on habitat index in two zones of the Kadra reservoir.

SN	Zooplankton	Zone 1 (within 500m from discharge point)		Zone 2 (beyond 500m from discharge point)	
		Habitat index	Ranking	Habitat index	Ranking
1	Nauplius	20.80	1	25.00	1
2	*Cyclops* sp.	14.23	2	14.3	2
3	*Ceriodaphnia reticulata*	11.3	3	10.63	3
4	*Bosmina longirostris*	8.74	4	8.62	4
5	*Diaptomus* sp.	7.98	5	7.46	5
6	*Brachionus qudridenta*	6.46	6	6.46	6
7	*Bosminopsis dietersi*	5.74	7	3.71	8
8	*Brachionus caudatus*	2.93	8	4.44	7
9	*Keratella quardrata*	2.30	9	2.26	10
10	*Tricocerca* sp.	2.26	10	2.65	9
11	*Gastropus* sp.	2.26	10	0.72	18
12	*Brachionus rubens*	1.80	11	1.95	12
13	*Brachionus havanaensis*	1.74	12	1.85	13
14	*Filinia* sp.	1.65	13	1.44	14
15	*Keratella cochlearis*	1.65	13	1.03	16
16	*Brachionus angularis*	1.59	14	2.17	11
17	*Tetramastix opoliensis*	1.27	15	1.44	14
18	*Lepadella* sp.	1.27	15	0.80	17
19	*Brachionus calyciforus*	1.22	16	1.33	15
20	Diptera larvae	1.01	17	0.66	19
21	*Lecane* sp.	0.9	18	0.54	21
22	*Cephallodella* sp.	0.63	19	0.6	20

indicated semi-productive nature of the Kadra reservoir water. In general, marginal increase in zooplankton diversity was found from DP onwards. In contrast, studies in British river had shown both increase and decrease in the diversity below power station discharge (Langford, 1972). Evenly distribution of species, as indicated by Species Evenness Index (SEI) values, was found to be maximum in monsoon at 100 m from DP where temperature was 33.5ºC, whereas minimum was recorded in summer at DP where temperature was 36.2ºC (Fig. 4). The Similarity Index values indicated more similar compositions in the zooplankton community amongst the points DP, 50 m from DP and 100 m from DP, and also amongst intake, 500 m from DP, 1000 m from DP, 100 m from right side (90º angle) of 100 m point and dam site. In general, Similarity Index values between intake and the points close to DP were comparatively less as compared to those of other stations (Fig. 5) during different seasons. Habitat index of each genus of zooplankton at zones 1 and 2 of the reservoir (Table 2) indicated that preferable zooplankton of both the zones were Nauplius larva, *Cyclops* sp., *Ceriodaphnia* sp., *Bosmina* sp., *Diaptomus* sp. etc. The zooplankton *Cephalodella* sp., *Lecane* sp. and Diptera larva were least common at both the zones. These plankters do not prefer the Kadra reservoir irrespective of temperatures. On the other hand, *Tricocerca* sp., *Brachionus angularis* and *Brachionus calyciforus*, which were ranked at 10, 14 and 16 in zone 1, preferred the zone 2 of less temperature by improving the rankings at 9, 11 and 15 respectively. The decrease in population of some species from the heated area could be correlated with elimination or poor density of phytoplankton, which are their preferred food (Bowen, 1976). In general, the plankton showed high sensitivity to elevated temperature, resulting in decreased diversity and similarity indices near the discharge point. While Palmer's index values of phytoplankton indicated the reservoir as oligotrophic nature, Shannon diversity indices of the plankton denoted the reservoir as semi productive. Dissimilarity was more amongst the plankters in between mixing and non-mixing zones. Preference of habitats indicates marginal change of rankings of phytoplankton and zooplankton in zones within 500m and beyond 500m from the point of discharge. Applied indices were also valuable for determining mixing and non mixing zones of Kadra reservoir. The data base would serve as reference source of power plant authorities using once-through condenser cooling system and discharging warm waters in fresh water lakes /rivers, and also to regulating agencies while evaluating water quality standards.

Acknowledgments

The authors are grateful to the Director NEERI, Nagpur for infrastructure facilities, to Dr. T. Chakrabarti, NEERI, Nagpur and to Dr. S.K. Apte, BARC, Mumbai for helpful suggestions during the investigation. We acknowledge the financial support from Board of Research in Nuclear Sciences (BRNS sanction No. 99/36/23/BRNS/1869), Department of Atomic Energy, Government of India.

References

Battish, S. K.: Freshwater zooplankton of India. Oxford and IBK Publishing Co., New Delhi (1992).

Battish, S.K.: Zooplankton of polluted waters *In*: Ecology of polluted waters (*Ed*: Arvind Kumar). A.P.H. publishing corporation, New Delhi, pp. 629-654 (2002).

Bellinger, E. G.: A key to common algal: freshwater, estuarine and some coastal species. The institution of water and environment management, London (1992).

Bowen, M.: Effects of a thermal effluent on the ostracods of par pond, south carolina *In*: Thermal ecology (*Eds*: G.W. Esch and R.W. McFarlane). Technical information centre, Energy Research and Development Administration, E.R.D.A. Symposium Series (Conf. 750425), Springfield, Virgenia, pp. 219-226 (1976).

Carpenter, E. J.: Brackish water phytoplankton response to temperature elevation. *Ibid,* **1,** 37 (1973).

Desikachary, T. V.: The atlas of diatoms. Madras Science Foundation. Madras (1959).

Desikachary, T.V. : Atlas of diatoms. T.T. Maps & Publications private limited, Madras (1987).

Dussart, G.B.J., E.R. Mycock and D. Scott: An alternative biological water quality index. *Specul. Sci. technol.,* **3**, 257-265 (1980).

Ghosh, T.K. : Application of different indices for assessment of aquatic biota in EIA studies *In*: Ecology of polluted waters and toxicology (*Ed*: K.D. Mishra). Technoscience Publications, Jaipur, India, pp. 1-18 (1998).

Ghosh, T.K.: Pre-operational monitoring and assessment of aquatic biota in environmental impact assessment studies. *Rad. Prot. Env.,* **24(1&2)**, 55-61(2001).

Ghosh, T.K.: Application of habitat index to shrimps, harvested from Dhanu creek region. *Environ. Conser. J.*, **3(3)**, 67-70 (2002).

Green, R.H. and G.L. Vascoto: A method for the analysis of environmental factors controlling patterns of species compositions in aquatic communities. *Water Res.*, **12**, 583-590 (1978).

Hanes, T.: Vegetation and wildlife impact analysis *In*: Environmental impact analysis handbook (*Eds*: J.G. Rrau and D.C. Wooten). McGraw-Hill Book Comp., New York, pp.7.1-7.59 (1980).

Hawkes, H.A.: Biological changes of applied significance from waste heat *In*: Biological aspects of thermal pollution (*Eds*: P. A. Krenkel and F. L. Parker). Vanderlbilt University Press, pp.5-53 (1969).

Hellawell, J.M.: Biological surveillance of rivers. Water Research Centre, Medmenham (1978).

Hickmann, M. and D.M. Klarer: The growth of some epiphytic algal in a lake receiving thermal effluent. *Arch. Hydrobiol*., **74**, 403-426 (1974).

Kumar, H.D.: Introductory Phycology. Pub. Affiliated East West Press P. Ltd., (1990).

Lackey, J.B.: The manipulation and counting of river plankton and changes in some organisms due to formalin preservation. Pub. Health Rep., 53, 2080 (1938).

Lagler, K.F.: Freshwater fishery biology. WMC Brown Co., Dubuque, Iowa (1956).

Langford, T. E.: A comparative assessment of thermal effects in some British and North American rivers *In*: River ecology and man (E*d*: R. T. Oglesby). Academid press. New York and London (1972).

Langford, T. E.: Electrical generation and the ecology of natural waters. Liverpool University press, Liverpool (1983).

Marlene, S. E., J. W. Glenn and I. Donna: The effects of power plant on zooplankton mortalities: eight years study at the Donald c. cook nuclear plant. *Water Res.*, **20(6)**,725-734 (1986).

McMahon, J.W. and A.E. Docherty: Effects of heat enrichment on species succession and primary production in fresh water plankton. IAEA-Environmental effects of cooling systems at Nuclear Power Stations, Vienna: International Atomic Energy Agency, pp. 529 - 545 (1975).

Metcalfe-Smith, J. I.: Biological water quality assessment of rivers: use of macro-invertebrate communities *In*: River restoration (*Eds*: G. Petts and P. Calow). Balckwell, Oxford, pp. 17-43 (1966).

Moore, M.V.: Consequences of elevated temperatures for zooplankton assemblages in temperature lakes. *Arch. Hydrobiol*., **135(289)**, (1996).

Odum, E.P.: Fundamentals of ecology. W.B. Saunders Co. Philadelphia London, Toronto (1971).

Palmer, C.M.: Composite rating of algae tolerating organic pollution. *British Phycol. Bull.*, **5**, 78-92 (1969).

Patrick, R.: Some effects of temperature on freshwater algae *In*: Biological aspects of thermal pollution (*Eds:* F. L. Parker and P. A. Krenkel). Vanderbilt University press, USA, pp. 161-185. (1969).

Pennak, R.W.: Freshwater invertebrates of the United States. John Wiley & Sons, A willey-inter science publication, New York (1978).

Pielou, E.C.: An introduction to mathematical ecology. New York, Wiley-Interscience (1966).

Prabhavati, G. and A. Sreenivasan: Ecology of warm freshwater zooplankton of Tamil- nadu. Spl. Publ. UNESCO/NIO (1977).

Prescott, G. W.: How to know the fresh water algae. Wm. C. Brown Company Publishers, USA (1978).

Sharma, B.K. and R.G. Michael : Synopsis of taxonomic studies on indian rotatoria. *Hydrobiologia*, **73**, 229-236 (1980).

Simmons, C.N.: Species-specific responses of freshwater organisms to elevated water temperatures. Waikato Valley Authority Technical Publication (1974).

Trembley, F.J.: Research projects on effects of condenser discharge water on aquatic life progress report 1956-1959. Bethlehom, Pennsylvania: Institute of Research, Lehigh University (1960).

Washington, H. G.: Diversity, biotic and similarity indices-A review with special relevance to aquatic ecosystems. *Water Res.*, **18(6)**, 653-694 (1984).

Wallace, N.: The effect of temperature on the growth of some freshwater diatoms. *Not. Nat. Acad. Nat. Sci. Philadelphia*, **280**, (1955).

Ward, H.B. and Whipple, G.C.: Fresh water biology. John Wiley & Sons, USA. (1966).

Wetzel, R.G.: Limnology. W.B. Saunders Co., Philadelphia, London, Toronto (1975).

Wetzel, R.G.: Limnology Lakes and River Ecosystem. Academic Press, London (2001).

Correspondence to:

Dr. T. K. Ghosh

Deputy Director, Environmental Biotechnology Division

National Environmental Engineering Research Institute (NEERI)

Nehru Marg, Nagpur-440 020 (M.S.), India

E-mail: ghoshtk2@rediffmail.com

Tel.: +91-712-2249762

Fax: +91-712-2249961