There exists a slightly different scale[22] in terms of species diversity ($\bar{H}$), which is 3.0–4.5, 2–3, 1–2, 0–1, the degrees of pollution being slight, light, moderate and heavy respectively, also indicating a negative correlation between the Shannon–Wiener index and pollution level.

METHODS

The annual cycle of species diversity among benthic macroinvertebrates was studied at three stations on river Ganga at Patna from July 1985 to June 1986. The city of Patna, situated on the right bank of the Ganga, is located at 25° 37′ N and 85° 21′ E. The three stations selected for observations were designated stations I, II and III (figure 1). The distances between stations I and II, and between II and III are 2.4 km and 3.2 km respectively. The observation stations were located about 100 m downstream from bathing centres (called 'Ghat' in local parlance) and also from discharge points of effluents, of which there are four, two slightly upstream of station I and one each slightly upstream of stations II and III.

Twice-a-month collections were made with an Ekman dredge covering an area 225 cm^2 of the substratum. The material collected was sifted through a No. 40 sieve and the organisms were collected and identified. The two samples of a month were pooled to constitute monthly collection, and all the 24 of the year grouped to determine the annual value of the Shannon–Wiener index.

RESULTS AND DISCUSSION

The macroinvertebrates encountered are listed in table 1. Figure 2 presents the changes in the Shannon–Wiener index during the period of study.

The derived annual mean monthly $\bar{H}$ values are: 1.394, 1.333 and 0.754 at stations I, II and III respectively. The three stations do not show a very significant difference in the means, though the mean monthly species diversity value of station III is much less compared to those of the other two stations. The Shannon–Wiener index values show the pollution load at each station reflected by the diversity of benthic macroinvertebrates. In the present study, the Shannon–Wiener index was found to vary from 0.346 to 1.238 at station III, which is indicative of severe environmental stress, while the range at station II, 0.689 to 2.434, is indicative of an intermediate state of environmental pollution, and the range at station I, 0.798 to 2.608, indicates a comparatively low load of pollutants. The wide range of fluctuation of the monthly Shannon–Wiener diversity index of benthic macroinvertebrates during the study period needs explanation.

The index was at its lowest at station I (0.798) in January 1986; at station II (0.689) in October 1985; and at station III (0.346) in September 1985. This is attributable to possible annihilation of the benthic fauna, probably caused by the additive effects of the high current of snow-melt waters from the Himalayas, added to all along by tributaries originating from the Himalayas in the north, and of toxicants. A

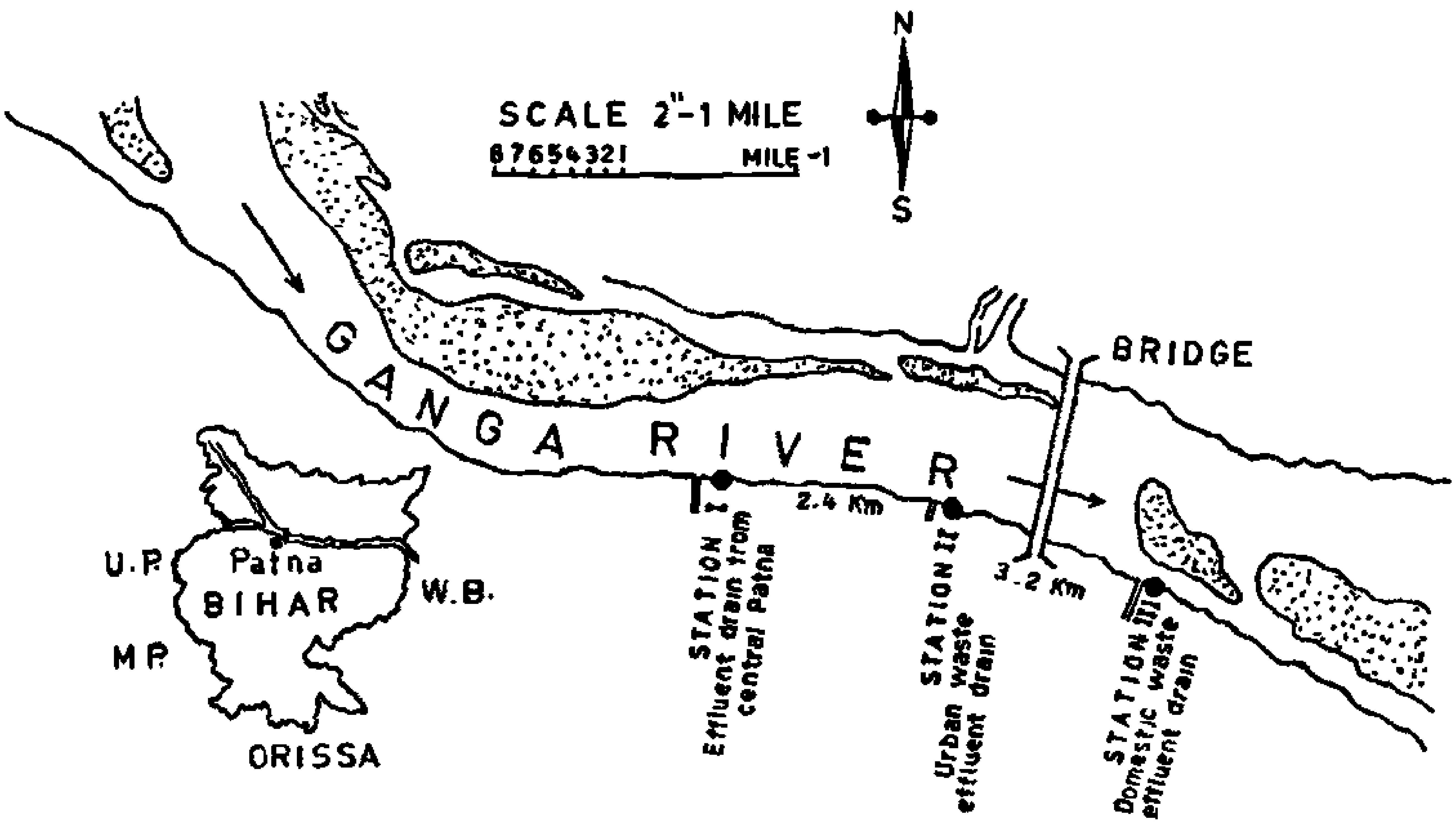

Figure 1. Location map of the three sampling stations (I, II and III) on river Ganga at Patna.

Table 1 *List of benthic macroinvertebrates collected from river Ganga at Patna*

Species	Station I	Station II	Station III
Polychaeta			
Namalycastis indica	+	+	–
Oligochaeta			
Tubifex sp.	–	+	+
Nais simplex	–	–	+
Limnodrillus hoffmeisteri	–	–	+
Insecta			
Chironomus sp.	–	+	+
Dragonfly nymph	+	+	+
Pelecypoda			
Lemellidens consorinus (Lea)	+	+	–
Lemellidens marginalis	+	–	–
Parreysia (Parreysia) *corrugata* var. *nagpoorensis* (Lea)	+	+	–
Indonia coerulea (Lea)	+	+	–
Corbicula striatella Deshayes	+	+	–
Gastropoda			
Digoniostoma pulchella (Benson)	+	+	–
Viviparus bengalensis (Lamarck)	–	+	–
Glessula sp.	+	+	+
Melania striatella tuberculata (Muller)	+	+	–
Melania (Plotia) *scabra* (Muller)	+	+	+
Melania scabra var. *elegans*	+	+	–
Lymnea sp.	+	–	+
Total	13	14	8

+, Present; –, Absent.

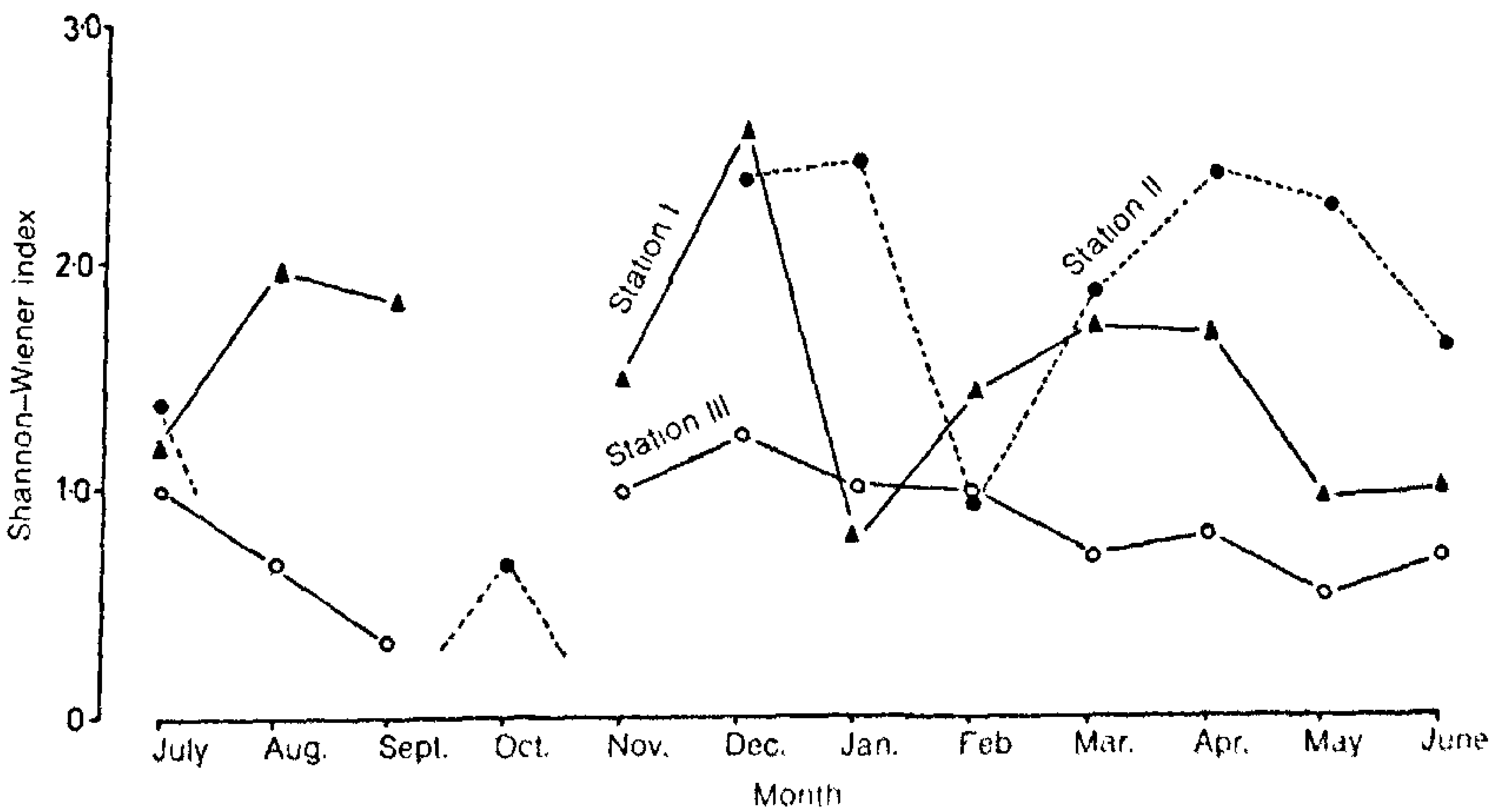

Figure 2. Monthly variation in Shannon–Wiener index ($\bar{H}$) values at stations I, II and III from July 1985 to June 1986.

similar observation was recorded in Keystone reservoir in the USA[23]. The somewhat lower values of the index during other months, viz. May 1986 at station I, February 1986 at station II, and August 1985 and February to June 1986 at station III, are probably attributable to the continued residual effect of the pollutants settled at the bottom leading to reduced diversity of benthic macroinvertebrates. The diversity index is zero where macroinvertebrates are totally absent, having been annihilated by the heavy pollution load. The high value of the diversity index at station I (2.608) in December 1985, at station II (2.434) in January 1986, and at station III (1.238) in December 1985 might be due to a reduced discharge of effluents into the river, as well as to low (winter) temperature and consequent decrease in the amount of organic matter, resulting in greater diversity of the benthic macroinvertebrates. Exposed to progressively increasing amount of domestic discharge and urban runoff, the benthos at station III is found to be less able to support a diverse and stable macrobenthic community, and a state of maximum pollution prevails. The present study shows that the species distribution patterns are indicative of the sum total of environmental perturbations, quite naturally resulting in reduction in the number of the sensitive species and a phenomenal increase in the number of the tolerant ones. This could be depicted in a species distribution pattern[24]. Monsoonal inundations, which dilute the pollution, the snow-melt waters in summer from the Himalayas, the managerial policy of waste release, the ambient temperature of the receiving water, and errors of random sampling together constitute a complex system. The diversity of benthic macroinvertebrates reacts to the net result of pollutional load. The relatively constant values of the Shannon–Wiener index at the farthest downstream-placed station, 5.6 km downstream of Patna, reflects a relatively stabilized level of pollution from all effluent points, taking all reacting and interacting factors into account. The varying values of the index in different months at the other stations reflect a variable pollutional load from individual effluent drains interacting with abating forces like dilution of water from various sources.

CONCLUSION

The Shannon–Wiener species diversity index ($\bar{H}$) can be of utility for the evaluation of the stresses to the benthic macroinvertebrate populations due to changes in water quality. It can serve also as a direct indication of the cumulative effect of environmental stresses on benthic organisms.

29 August 1988; Revised 6 December 1988

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