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A study on species diversity of benthic macro invertebrates in freshwater lotic ecosystems in Gadchiroli district Maharashtra

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ABSTRACT

A study was conducted to evaluate the potential of benthic macro-invertebrates community assemblages in predicting the water quality status. Three sampling stations with various environmental quality gradients were selected at the Wainganga, Gadhavi and Khobragadhi River in Gadchiroli district in order to determine differences or changes in the benthos community associated with variability in water quality. The diversity indices like Shannon-Wiener index, Evenness or Shannon equitability index and Margalef's index were calculated. According to Shannon-Wiener index of species diversity, all the selected sampling sites fall under moderate pollution. The Shannon equitability index values showed a greater equitability in the apportionment of individuals among the species in all the sites while Margalef's index of species richness reveals that the site-I had more healthy body and have higher species diversity among all sampling sites. The species diversity of site-II is greater than site-III. The site-III had poorer in species diversity and nutrient material.

KEYWORDS

Species diversity, Shannon-Wiener index, Evenness index, Margalef's index

INTRODUCTION

Benthic macro-invertebrates of freshwaters represent a highly discriminatory variable as these animals are confined to micro-habitats, continuously receiving organic matter produced in or flushed into an ecosystem. The benthic organisms can survive in polluted environment and a wide assemblage of organisms belonging to different classes and orders constitute the zoo-benthos. The benthic communities are usually dominated by different species of oligochaete worms, gastropodes, pelecypodes and various minor insect larvae.

The benthic macro-invertebrates community of the lotic ecosystem, like other communities has a series of attributes that do not reside in its individual species components and have meaning only with reference to the community level of integration such as species diversity, growth in the form and structure, dominance, relative abundance and trophic structure. One of these attributes or many of these or all, depending upon situation may be changed with the changing ecology of the water body concerned. Species are distributed individualistically according to their own genetic characteristics and population of most of the species tends to change gradually along the environmental gradients. Most species are not in obligatory associations with other species, which suggests that association is formed with many combinations of species, and vary continuously in space and time. Hence, a study on benthic macro-invertebrates community composition and dynamics of different population of the community becomes a reliable source to provide the picture of environmental status and influence of changing limnology of the water body concerned.

Benthic macro-invertebrates perform a variety of functions in freshwater ecosystem they have an important influence on nutrient cycle, primary productivity, decomposition and translocation of material (Wallace and Webster, 1996; Covich et al., 1999). They are the most commonly used for bio-monitoring in lotic habitat worldwide (Bonada et al., 2006). They play an important role in the mineralization and recycling of organic matter and are an important tool for improving and preserving water quality (Bilgrami and Dutta Munshi, 1985; Venkateswarlu, 1986). Alteration produced in the physical and chemical status of the riverine ecosystem becomes recognizable through elasticity of the community structure of the organisms (Wilhm & Dorris, 1968; Cairns & Dickson, 1971)) Thus benthic macro-invertebrates make ideal subject for biological assessment of water quality (Hynes,

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1970). Lot of work is done on lotic ecosystems in India by several workers such as Kulshreshtha el al., (1988); Krishnamoorthy and Sarkar (1979); Khan (1982) and Shukla et al., (1989).

In the present study, by adopting the qualitative approach along with application of quantitative index of pollution which enabled comparison of Pollutional load of three different lotic ecosystems in Gadchiroli district viz. Wainganga, Gadhavi and Khobragadhi River. The Shannon-wiener index of species diversity of benthic macro-invertebrate in fact summarizes physico-chemical and hydro-biological information in a significant manner, condensing it in a single index. Equitability and species richness of benthic macro-invertebrates is also discussed with the help of Evenness and Margalef's diversity index.

STUDY AREA:

S-I: The site on Wainganga River is situated near Wadsa city located at 20°36'00.08"N and 79°57'00.52"E representing the lotic systems disturbed by various anthropogenic activities, the site receiving the sewage, dirt form washed clothes, vehicles cleaning, idol immersion and animal washing activities, fishing activities and other activities in huge manner.

S-II: The site on Gadhavi River is situated near Armori city located at 20°26'28.31"N and 79°59'22.46"E victimized with the human disturbances and received waste from cattle washing, vehicle washing, idol immersion, cremation, nirmalya immersion and also used for fishing activities and watermelon farming.

S-III: The site on Khobragadhi River is situated near Deolgaon town located at 20°23'55.53"N and 79°59'23.33"E remaining almost natural and far away from the much human disturbances. But due to the water applied for irrigation to the nearby agriculture fields, it is also contaminated with the agriculture activities.

MATERIAL AND METHOD

The benthic macro-invertebrates samples were collected for qualitative and quantitative estimation. The collection were made at each site with Ekman-Dredge of scooping capacity 15.2 x 15.2 sq. cm. of the river substrate and screened through metallic sieve no. 40 of mesh size 0.545 mm. sieved material was transferred to white enamel tray partially filled with water. The benthic macro-invertebrates were sorted out by forceps and classified them species wise, counted and catalogued. the identification up to species by following the keys from Edmondson, (1959); K. Vanamala Naideu, (2005); Pennack, (1989); Tonapi, (1980); Subba Rao, (1989).

On the data available after total number of macro-invertebrates counting in a sample, number per square/meter occurrence of macro-invertebrates were then computed using the formula formulated by Welch, (1948), this formula is,

$$N = \frac{o}{a \cdot s} \times 10{,}000$$

Where, N = Number of macro-invertebrates 1 sq. m. of profoundal bottom

O = No. of macro-invertebrate (actually counted) per sampled area,

a = Transverse area of Ekman dredge in sq. cm, and

s = Number of sample taken at one sampling site.

The data harvested from monthly samples were blended to provide the value of Shannon-Wiener Index. The Shannon-Wiener index of species diversity (H) (Shannon-Weaver, 1964) is defined as,

$$H = -\sum_{i=1}^{S} Pi \; Ln \, Pi$$

Where, S = Total number of species in a sample,

Pi = *ni/N* = Proportion of individuals of the total sample belonging to the i^{th} species.

N = Total number of individual of all the species,

ni = Number of individuals belonging to the i^{th} species.

The Shannon equitability (or evenness) index was obtained from Shannon-Weiner index. Evenness is to refer the absolute distribution of relative abundance of species at a site. The index is

$$J = \frac{H}{ln \, S}$$

Where, J = Evenness index

H = Shannon-Weiner index value,

l = log normal

S =Total number of species in sample

The Margalef's Index of Species Richness (D) is simple ratio between total species (S) and total numbers of individual (N). It can be used to compare one community with another. The index is

$$D = \frac{S - 1}{\ln N}$$

Where, D = Margalef's index
S = Number of species in sample
ln = log normal
N =Total number of individuals in sample

RESULT

The population of benthic macro-invertebrates from three sampling sites comprised of 42 species belonging mainly to oligochaeta, insecta, pelecypoda and gastropoda (Table.1). The organisms were represented by Oligochaeta: *Nais andina, Nais communis, Stylaria fossularis, Brachiodrilus hortensis, Dero cooperi, Dero indica, Pristina sperberae, Tubifex tubifex, Limnodrilus hoffmeisteri, Limnodrilus udekemianus, Branchiura sowerbyi, Lumbriculus variegates.* Gastropoda: *Vivipara bengalensis, Cyclophorus aurantiacus, Melania striatella tuberculata, Melania scabra, Faunus ater, Lymnaea luteola, Lymnaea acuminate, Anisus convexiusculus, Planorbis exustus, Ariophanta bajadera, Ariophanta bristrialis.* Pelecypoda: *Corbicula regularis, Lamellidens marginalis, Lamellidens corrianus.* Insecta: *Tabanus larvae, Eristalsis larvae, Atherix larvae, Simuliaum larvae, Culex larvae, Chironomus larvae, Limnophora larvae, Berosus larvae, Hydrocanthus iricolor, Pelocoris femoratus, Aphylla nymph (Aeshnidae), Dragonfly nymph (Libellulidae), Dragonfly nymph (Gomphidae), Laccophilus anticatus, Laccotrephes maculates, Chauliodes larvae*

The monthly Shannon-Wiener index value of the benthic macro-invertebrates in the present investigation ranges from 1.253-2.987 at site I, at site-II from 1.496 to 2.451and at site-III from 1.345 to 2.164 in the year 2006. In the year 2007, the site-I ranges from 1.329 to 2.714, at site-II from 1.395 to 2.528 and at site-III from 1.262 to 2.135 (Table 2). The monthly values of the diversity index at site-I was at its highest viz. 2.987 in March 2006, whereas its highest values at site-II and III stood at 2.528 and 2.164 in March 2007 and March 2006 respectively. The lowest diversity value at site-I was 1.253 in October 2006, at site-II 1.395 in July 2007 and at station III 1.262 in November 2007. The diversity index was zero where the macro-invertebrates were totally absent or not recorded. The annual mean monthly values at site I, II and III were 2.026, 1.718 and 1.430 respectively in the year 2006 while in 2007, 1.893, 1.694 and 1.371 at site I, II and III respectively.

The Evenness Index of benthic macro-invertebrates at site I, II and III in the study period 2006 and 2007 is given in Table 3. In the year 2006, the range of index was 0.8265 (January) to 0.9648 (July) at site-I, while index range 0.7687 (July) to 0.8888 (March) at site-II and the index range 0.7506 (June) to 0.9563 (December) at site-III. In the year 2007, the range of index was 0.7568 (May) to 0.9587 (October) at site-I, while index range 0.8550 (November) to 0.9469 (June) at site-II and the index range 0.7652 (May) to 0.9449 (October) at site-III.

The Margalef's Index of benthic macro-invertebrates at site I, II and III in the study period 2006 and 2007 is given in Table 4. In the year 2006, the range of index was 0.5067 (October) to 3.7934 (March) at site-I, while index range 0.9703(July) to 2.8494 (February) at site-II and the index range 0.7771 (June) to 1.9067 (March) at site-III. In the year 2007, the range of index was 0.6165 (October) to 2.9152 (March) at site-I, while index range 0.7482 (July) to 2.5884 (February) at site-II and the index range 0.8088 (November) to 1.9972 (March) at site-III.

DISCUSSION

It is clearly perceived that the three sites did not show very sharp differences in the mean values of diversity index among each other. Shannon-Weiner index is a sensitive indicator of pollution and its values do not fluctuate widely. This index is an index applied to biological systems by derived from a mathematical formula used in communication area by Shannon in 1948 (Mandaville, 2002). It is the most preferred index among the other diversity indices. The index values are between 0.0 – 5.0. Results are generally in 1.5–3.5 and it exceeds 4.5 very rarely. The values above 3.0 indicate that the structure of habitat is stable and balanced; the values under 1.0 indicate that there are pollution and degradation of habitat structure. Staub et al.,

(1970) proposed another scale of pollution status in terms of species diversity as: Shannon-Weiner index value 3.0-4.5 is slight pollution, 2.0-3.0 is light pollution, 1.0-2.0 moderate pollution and 0.0-1.0 is heavy pollution, according this scale, all the sites under slight pollution to moderate pollution.

TABLE 1: SPECIES WISE DISTRIBUTION OF BENTHIC MACROINVERTEBRATES

S.N.	BENTHIC MACROINVERTEBRATE	Site-I		Site-II		Site-III	
	OLIGOCHAETA	**2006**	**2007**	**2006**	**2007**	**2006**	**2007**
1	*Nais andina*	-	-	+	+	+	+
2	*Nais communis*	-	-	+	+	+	+
3	*Stylaria fossularis*	+	+	+	+	-	-
4	*Brachiodrilus hortensis*	+	+	-	-	-	-
5	*Dero cooperi*	-	-	+	+	+	+
6	*Dero indica*	-	-	+	+	+	+
7	*Pristina sperberae*	+	+	-	-	-	-
8	*Tubifex tubifex*	+	+	+	+	-	-
9	*Limnodrilus hoffmeisteri*	+	+	-	-	-	-
10	*Limnodrilus udekemianus*	+	+	-	-	-	-
11	*Branchiura sowerbyi*	+	+	-	-	-	-
12	*Lumbriculus variegatus*	+	+	-	-	-	-
	GASTROPODA						
13	*Vivipara bengalensis*	+	+	+	+	+	+
14	*Cyclophorus aurantiacus*	+	+	-	-	-	-
15	*Melania striatella tuberculata*	+	+	-	-	-	-
16	*Melania scabra*	+	+	+	+	+	+
17	*Faunus ater*	+	+	-	-	+	+
18	*Lymnaea luteola*	+	+	-	-	-	-
19	*Lymnaea acuminata*	+	+	+	+	-	-
20	*Anisus convexiusculus*	+	+	+	+	+	+
21	*Planorbis exustus*	+	+	+	+	+	+
22	*Ariophanta bajadera*	-	-	-	-	+	+
23	*Ariophanta bristrialis*	-	-	-	-	+	+
	PELECYPODA						
24	*Corbicula regularis*	+	+	+	+	+	+
25	*Lamellidens marginalis*	+	+	+	+	+	+
26	*Lamellidens corrianus*	+	+	-	-	-	-
	INSECTA						
27	*Tabanus larvae*	+	+	+	+	-	-
28	*Eristalsis larvae*	+	+	+	+	-	-
29	*Atherix larvae*	+	+	-	-	-	-
30	*Simuliaum larvae*	+	+	-	-	-	-
31	*Culex larvae*	+	+	+	+	+	+
32	*Chironomus larvae*	+	+	+	+	-	-
33	*Limnophora larvae*	+	+	+	+	+	+
34	*Berosus larvae*	+	+	-	-	-	-
35	*Hydrocanthus iricolor*	+	+	+	+	+	+
36	*Pelocoris femoratus*	+	+	+	+	+	+
37	*Aphylla nymph (Aeshnidae)*	+	+	+	+	+	+
38	*Dragonfly nymph (libellulidae)*	+	+	-	-	-	-
39	*Dragonfly nymph (Gomphidae)*	+	+	-	-	-	-
40	*Laccophilus anticatus*	+	+	+	+	+	+
41	*Laccotrephes maculatus*	-	-	+	+	-	-
42	*Chauliodes larvae*	+	+	+	+	-	-

TABLE 2: MONTHLY VARIATION OF SHANNON – WEINER INDEX (H)

Sr. No	Year	Month	Site-I	Site-II	Site-III
1	2006	January	2.054	2.040	1.994
2		February	2.915	2.451**	1.984
3		March	2.987**	2.407	2.164**
4		April	2.921	2.448	1.916
5		May	2.753	2.166	1.394
6		June	2.492	1.876	1.345*
7		July	2.120	1.496*	1.458
8		August	0***	0***	0***
9		September	0***	0***	0***
10		October	1.253*	1.656	1.426
11		November	2.163	1.843	1.622
12		December	2.658	2.242	1.861
13	2007	January	2.106	1.696	1.904
14		February	2.622	2.502	1.884
15		March	2.714**	2.528**	2.135**
16		April	2.669	2.508	2.112
17		May	2.373	2.167	1.762
18		June	2.370	1.969	1.765
19		July	1.725	1.395*	0***
20		August	0***	0***	0***
21		September	0***	0***	0***
22		October	1.329*	1.832	1.693
23		November	2.341	1.778	1.262*
24		December	2.468	1.954	1.941

	Year	2006	2007
* Minimum	S – I	1.253 / October	1.329 / October
	S – II	1.496 / July	1.395 / July
	S – III	1.345 / June	1.262 / November
** Maximum	S – I	2.987 / March	2.714 / March
	S – II	2.451 / February	2.528 / March
	S – III	2.164 / March	2.135 / March
***Not Recorded	S – I	August and September	August and September
	S – II	August and September	August and September
	S – III	August and September	July, Aug. & September

In the present study, it is evident that Shannon-Weiner index value ranges from 1.2 to 2.9 in three ecosystems, this indicating that all the ecosystems show moderate pollution. Khan et al, (2007) showed the diversity index ranging from 1.20 to 1.49 in their study, Bijoy Nandan (2007) reported that the Shannon-Weiner index ranged from 1.39 to 2.06 from five different sampling sites. Anbalagan et al., (2004) observed values ranged 1.883 to 2.493 from 4 sampling station and Sharma et al., (2008) showed the diversity index was altered from 3.44 to 1.98 in their observation.

The investigation is supported by above findings. Jhingran et al., (1989) showed the monthly variation of the Shannon-Weiner index of benthic macro-invertebrates from three stations at Patna. The index value was found to vary from 0.346 to 1.238 at station-III, and indicates severe environmental stress, 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,

reflects a comparatively low load of pollution. Prater et al., (1980) showed the highest value of index was 3.03 when the greater numbers of species were present and lowest value of index was 1.82 when smaller numbers of species were recorded from the different sampling station at Sandusky River, Ohio.

The usefulness of the diversity index for assessing water quality is based on the assumption that clean river have high diversity indices, because benthic community of clean river contain many species of relatively equal number of individual species (Wilhm and Dorris, 1966). Wilhm and Dorris (1966) proposed a relationship between species diversity and pollution status of sampling sites as; species diversity value greater than 3.0 is clean water, values in the range of 1.0-3.0 indicate moderate pollution and values less than 1.0 indicate heavy pollution. According to them, all the selected sampling sites fall under moderate pollution.

TABLE 3: MONTHLY VARIATION OF EVENNESS INDEX (J)

Sr. No	Year	Month	Site-I Wainganga River	Site-II Gadhavi River	Site-III Khobragadhi River
1	2006	January	0.8265*	0.8507	0.9075
2		February	0.8747	0.8324	0.8616
3		March	0.8470	0.8888**	0.8708
4		April	0.8674	0.8829	0.8321
5		May	0.8449	0.8444	0.7780
6		June	0.8621	0.7823	0.7506*
7		July	0.9648**	0.7687*	0.9059
8		August	0***	0***	0***
9		September	0***	0***	0***
10		October	0.9039	0.8510	0.8860
11		November	0.9020	0.8863	0.9052
12		December	0.8599	0.8741	0.9563**
13	2007	January	0.8475	0.9465	0.9158
14		February	0.8362	0.8656	0.7857
15		March	0.8330	0.8746	0.8323
16		April	0.8291	0.9045	0.8234
17		May	0.7568*	0.9037	0.7652*
18		June	0.8365	0.9469**	0.8488
19		July	0.8864	0.8667	0***
20		August	0***	0***	0***
21		September	0***	0***	0***
22		October	0.9587**	0.9414	0.9449**
23		November	0.8870	0.8550*	0.7841
24		December	0.8538	0.8893	0.8833

	Year	2006	2007
* Minimum	S – I	0.8265 / January	0.7568 / May
	S – II	0.7687 / July	0.8550 / November
	S – III	0.7506 / June	0.7652 / May
** Maximum	S – I	0.9648 / July	0.9587 / October
	S – II	0.8888 / March	0.9469 / June
	S – III	0.9563 / December	0.9449 / October
***Not Recorded	S – I	August and September	August and September
	S – II	August and September	August and September
	S – III	August and September	July, Aug. & September

TABLE 4: MONTHLY VARIATION OF MARGALEF INDEX (D)

Sr . No	Year	Month	Site-I Wainganga River	Site-II Gadhavi River	Site-III Khobragadhi River
1	2006	January	1.5691	1.7988	1.6028
2		February	3.2904	2.8494**	1.6392
3		March	3.7934**	2.0033	1.9067**
4		April	3.1418	2.0401	1.4876
5		May	2.7550	1.6438	0.8236
6		June	1.8911	1.3789	0.7721*
7		July	1.1256	0.9703*	0.8112
8		August	0***	0***	0***
9		September	0***	0***	0***
10		October	0.5067*	1.1758	0.9184
11		November	1.4070	1.2834	1.0586
12		December	2.7330	1.9902	1.2923
13	2007	January	1.5635	1.0140	1.3719
14		February	2.6976	2.5884**	1.7315
15		March	2.9152**	2.3942	1.9972**
16		April	2.7108	2.1021	1.8730
17		May	2.4356	1.4042	1.3684
18		June	1.7935	1.0258	1.0854
19		July	0.8871	0.7482*	0***
20		August	0***	0***	0***
21		September	0***	0***	0***
22		October	0.6165*	1.3170	1.1209
23		November	1.8443	1.3582	0.8088*
24		December	2.2753	1.3741	1.5523

	Year	2006	2007
* Minimum	S – I	0.5067 / October	0.6165 / October
	S – II	0.9703 / July	0.7482 / July
	S – III	0.7721 / June	0.8088 / Nov.
** Maximum	S – I	3.7934 / March	2.9152 / March
	S – II	2.8494 / February	2.5884 / February
	S – III	1.9067 / March	1.9972 / March
***Not Recorded	S – I	August and September	August and September
	S – II	August and September	August and September
	S – III	August and September	July, Aug. & September

No single diversity index is completely effective in describing community structure over a large range of situations. However, indices may be used under numerous conditions and can facilitate the ecological interpretation of vast data sets. They can be considered as a useful way to condense data and people with little biological expertise can easily understand them (Norris, 1995). In a survey of freshwater lotic and lentic studies, Resh and McElravy (1993) showed that about 40% of studies used such indices.

Another major component of species diversity is evenness or equitability, it is also referred as Shannon equitability index, because this index obtained from Shannon-Weiner index, proposed by Pielou (1966). Evenness is thought to denote a balanced relation between species and individual richness of a sample. This numerical digit (0 to1) expresses the absolute distribution of relative abundance of species at specific site. According to Mukherji and Nandi (2004) higher the values indicate a low concentration of dominance of species diversity at a specific site.

In the present Investigation the Evenness index for benthic macro-invertebrates from 3 sampling sites are presented in the table no. 3. At sampling site-I, the Evenness index ranged from 0.8265 to 0.9648, from 0.7687 to 0.8888 at site-II and from 0.7506 to 0.9563 at site-III, in the year 2006. In the year 2007, the value ranged from 0.7568 to 0.9587 at site-I, from 0.8550 to 0.9469 at site-II and from 0.7652 to 0.9449 at site-III. The Evenness values showed a greater equitability in the apportionment of individuals among the species in site-I, II and III. When all species in a sample are equally abundant an evenness index would decrease toward zero as the relative abundance of the species diverges away from evenness (Anitha et al., 2005).

Khan et al., (2004) observed the value ranging from 0.213 to 0.434 from different station in their pollution monitoring study. Young et al., (2007) produced the positive correlation among different diversity indices with evenness index. Kokes and Vojtiskova (1999) calculated several diversity indices along with equitability index. Fricova et al., (2007) also used similar diversity index and revealed that there was lowest standard deviation in different sampling sites. Farara and Burt (1997) in the assessment of St. Clair River, Observed that the evenness values were closely associated with the diversity values, with the lowest values occurring at the stations with the lowest diversity.

The species richness or Margalef's diversity index (D) is expressed by simple ratio between total species and total number (or importance value N), the Margalef's diversity index are proposed by Margalef (1958), Larger the index value the more healthy the body of water, when it tend towards 1.0, pollution is thought to increase and damage should be suspected.

In the present Investigation the Margalef's diversity index for benthic macro-invertebrates from 3 sampling sites are presented in the table no. 4. At sampling site-I, the Margalef's diversity index varied considerably from 0.5067 to 3.7934, from 0.9703 to 2.8494 at site-II and from 0.7721 to 1.9067 at site-III in the year 2006. In the year 2007, value ranges from 0.6165 to 2.9152 at site-I, from 0.7482 to 2.5884 at site-II and from 0.8088 to 1.9972 at site-III.

The Margalef's diversity index reveals that, the site-I had more healthy body and have higher species diversity among all sampling sites. The species diversity of site-II is greater than site-III. The site-III had poorer in species diversity and nutrient material. According to Margalef (1956) the higher diversity values reflect the suitability of habitat for the organism in one hand while on the other the high species diversity has been reported to be correlated with longer food chain and complex food web of the ecosystems and also more stable community. Extremely low species richness and low abundance are commonly observed in physically disturbed areas with poor condition of colonization by aquatic organism (Young et al., 2007). Similar findings were reported by Pereira and De Luca (2003) in Rio Grande do Sul River, Brazil; they correlated different diversity indices to morpho-metric factors of river.

Khan et al, (2004) observed the value ranging from 0.278 to 0.691 in their pollution monitoring study in Tamil Nadu, India. Garn (1998) in his extensive survey for benthic communities calculated Margalef's index, with mean value of 4.42 which indicate a diverse assemblage of benthic macro-invertebrates at the Keshena site in Wolf river, Wisconsin, US. Szczytko (1991) also found mean value of 4.16, which is within very good water quality classification. In the present investigation also Evenness values closely associated with Diversity value that is lowest values securing at the stations with lower diversity and higher values coinciding with higher diversity of species.

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