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Assessing the Effectiveness of using Macroinvertebrate Diversity Indices as Indicators of Ecosystem Health in Dal Lake Kashmir India

Kousar Jan[1], Waheed Ahmad Hurrah[2], Rajendra Chouhan[1] and Shiasta Masarat[3]*
[1]Department of Zoology MVM Bhopal (Madhya Pradesh), India.
[2]Department of Environmental Science and Limnology,
Barkatullah University Bhopal (Madhya Pradesh), India.
[3]Hydrobiology Research Laboratory, S.P. College, Srinagar (J&K), India.

(Corresponding author: Kousar Jan)*
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ABSTRACT: Macroinvertebrate diversity indices for evaluating freshwater quality are crucial instruments for environmental management and monitoring. These indexes offer important information on the biodiversity and general health of aquatic ecosystems. We can determine how pollution, habitat degradation, and other stressors affect the quality of the water by counting the type and amount of Macroinvertebrate species that are there. Indices like Shannon Diversity Index, Shannon Equitability Index, Simpson Index, Margalef Index, Menhinick's Index, and Berger Parker Index were carried out during six seasons of Kashmir *i.e.*, Sonth, Grishum, Vahrath, Harud, Wande, and Shishur respectively from September 2020 to August 2021 in Dal Lake Srinagar. In the present study Low diversity indices, such as the Shannon Wiener Index in the current study, generally point to a lack of species richness or variation within the community. This could be the result of things like pollution, habitat degradation, stress from the environment, or other disturbances that have shifted the abundance of some species or decreased the number of various species that are there.

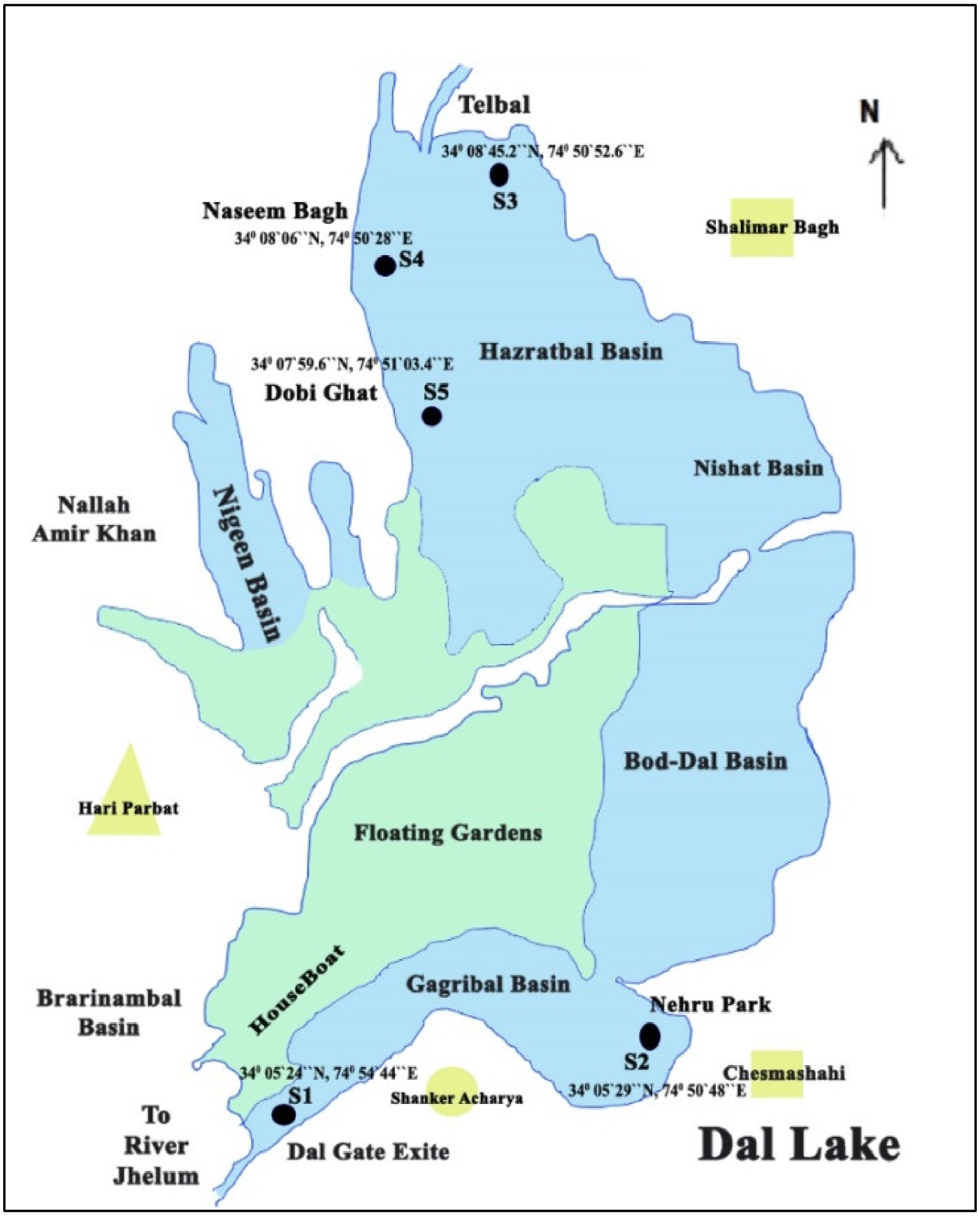
Keywords: Macroinvertebrates, Diversity Indices, Pollution, Anthropogenic pressure, Eutrophication, Bio-indicators.

INTRODUCTION

Dal Lake is an urban Lake, popularly renowned as the "liquid jewel," it is one of the most stunning locations on the earth, with the dimensions of 4.62 miles (7.44 km) in length and 2.2 miles (3.5 km) in breadth, located in Srinagar, the summer capital of Jammu and Kashmir, India. It has a catchment area of 122 sq miles (316 sq kilometres). Dal Lake lies in the foot of Zabarwan Mountain. On the Lake's left side, Takht-i-Suliman is located, while on its right side, Hill of Hari-Parbat is located, The region's economy has benefited greatly from its status as it is the cradle of Kashmiri civilisation. Dal Lake, a World-famous Lake of the Kashmir valley is located between latitude 34°05′ and 34°09′N and longitude 74°49′ and 74°53′ E at an altitude of 1584 masl. (Sir Walter Roper Lawrence, 2014). Dal Lake is enriched in Macroinvertebrate Diversity Macroinvertebrates are diverse and include Annelida, Arthopoda and Mollusca (Adoni, 1985; Girgin *et al.,* 2003). They are an important food source for fish and other aquatic organisms and are involved in nutrient cycling and decomposition processes (Allan, 1995). They play an essential role in the aquatic habitat and aquatic web. Macroinvertebrates have been used for the indication of water quality in standard water management (Ziglio *et al.,* 2006). Macroinvertebrates are attractive targets of biological monitoring efforts as they are a diverse groups of long lived, sedentary species that react strongly and often, predictably to human influence on aquatic ecosystems (Sharma *et al.,* 2009; Dixon *et al.,* 2003) that are most frequently used in bio-monitoring studies (Ogbeibu *et al.,* 2002; Balachandran *et al.,* 2012) as their responses to organic and inorganic pollution have been extensively (Washington, 1984; Ikomi *et al.,* 2005; Latha *et al .,* 2010). By studying the diversity of Macroinvertebrate communities using these indices, an insight into the health and functioning of aquatic ecosystems can be gained (Hewitta, 1991). Changes in diversity indices can indicate shifts in community structure, impacts of pollution or habitat degradation, and overall ecosystem health (George *et al.,* 2009). Therefore, the relationship between Macroinvertebrates and diversity indices plays a crucial role in understanding and monitoring the ecological status of aquatic environments (Kumar *et al.,* 2013).

METHODOLOGY AND MAP

Samples were taken in different seasons from the different sites as shown in dots on the Map of Dal Lake. For the collection of Macro-invertebrates, the bottom sediments were collected with the help of Ekman's Dredge having an area of $15\times15 cm^2$.



Certain organisms were also collected by hand picking method. At each site the sample was taken in triplicate and then pooled together the samples were properly mixed with site water and passed through a sieve with a mesh size of 300mm (Thorne *et al.,* 1997). The individuals were sorted out manually using forceps and brushes and were preserved plastic bottles in 4% formalin and 70% alcohol depending upon the type of organisms to be preserved. The soft-bodied organisms were preserved in 70% alcohol while the shelled organisms like molluscs in 4% formalin and the density of Macroinvertebrates were calculated by using (Welch, 1948; Borror *et al.,* 1976). For qualitative analysis preserved samples were identified to the lowest possible taxonomic level according to standard taxonomic works of Edmondson *et al*. (1993); Pennak (1978); Adoni *et al.* (1985); Stroud Water Research Centre (2015). In the changed climate of Kashmir, six distinct annual seasons are observed; Sonth (Spring Season) from mid-March to mid-May, Grishum (Hot Season) from mid-May to mid-July, Vahrath (Rainy Season) from mid-July to mid-September, Harud (Autumn Season) from mid-September to mid-November, Wande (Cold Season) from mid-November to mid-January, Shishur (Severe Cold Season) from mid-January to mid-March.

RESULT AND DISCUSSION

Diversity indices are efficient in indicating physical and toxic pollution which stress most species in a community without encouraging replacement species. However, although high diversity does indicate good quality water, low diversity may not necessarily indicate low quality. To evaluate the distribution and diversity between sampling sites, Statistical analysis of biological indices, such as Shannon-Wiener index (Shannon *et al.,* 1963), Shannon Equitability Index and Simpson's Diversity index, (Magurran, 2004); Menhinick's Diversity Index, Margalef Diversity Index, Berger-Parker index (Caruso *et al*., 2007) was performed using diversity index formulas respectively.

{1}. Shannon-Wiener index: $H = -\Sigma pi * \ln(pi)$. Where, Σ: A Greek symbol that means "sum", ln : Natural log, pi: The proportion of the entire community made up of species *i* . The higher the value of H, the higher the diversity of species in a particular community, the lower the value of H, the lower the diversity.

{2}. Shannon Equitability Index: $EH = H / \ln(S)$. Where, H: The Shannon Diversity Index, S: The total number of unique species. This value ranges from 0 to 1 where 1 indicates complete evenness.

{3}. Simpson Diversity Index: $D = \Sigma ni(ni-1) / N(N-1)$. Where ni: The number of organisms that belong to species i, N: The total number of organisms. The value for Simpson's Diversity Index ranges between 0 and 1. The higher the value, the lower the diversity (Simpson, 1949).

{4}.Menhinick's Diversity Index: $D_{Mn}= S \sqrt{}N$.
Where, S: total number of species. N: number of species.

{5}. Margalef Diversity Index: $D_{Mg}= S\text{-}1/ \ln N$. Where, S: number of species. N: total number of species

{6}. Berger-Parker index: $d = N_{max} / N$. Where N_{max}: number of individuals in the most abundant species and N: total number of individuals in the sample For the Annelida the highest value of Shannon Diversity Index was obtained in Harud 2020 i.e (2.46) and the lowest value was obtained in Shishur 2021 i.e (1.7). Highest value of Shannon Equitability Index was obtained in Shishur 2021 i.e (0.9) and lowest value was obtained in Vahrath 2021 *i.e.* (0.72). Value of Simpson Diversity Index was obtained highest in Harud 2020 i.e (0.9) and lowest was found in Shishur 2021 i.e (0.8). Margalef Diversity Index value was found highest in Harud 2020 i.e (1.93) and lowest was found in Wande 2020-2021 i.e. (0.0018). Menhinick's Diversity Index value was found highest in Grishum 2021 i.e (0.21) and lowest value was found in Shishur 2021 i.e (0.1) and Berger Parker Index value was found highest in Grishum 2021 i.e (0.27) and the lowest value was found in Harud 2020 i.e (0.27) respectively. High diversity indices in Annelids are a sign of a well-balanced environment with a wide range of species. By preserving water quality and nutrient levels, these varied populations of Annelida can aid in nutrient cycling, sediment bioturbation, and overall ecosystem stability, hence reducing the consequences of eutrophication (Betal *et al.,* 1965). On the other hand, low Annelida diversity indices may indicate pollution, environmental stress, or habitat deterioration (Rashid *et al.,* 2014). Under such circumstances, a deficiency of diversified Annelida species may result in inadequate nutrient cycling, deteriorated sediment quality, and heightened susceptibility to eutrophication. Algal blooms, nutritional imbalances, oxygen deprivation, and general ecological dysfunction can arise from this. Thus, keeping an eye on and comprehending the Annelida diversity indices in connection to eutrophication might offer important insights regarding the condition of aquatic environment Table 1.

Table 1: Diversity Indices of Annelida in different Seasons.

Macro-Invertebrates	Statistical Indices	Harud 2020	Wande 2020-2021	Shishur 2021	Sonth 2021	Grishum 2021	Vahrath 2021
	Shannon Diversity Index	2.46	1.99	1.7	2.12	2.02	2.07
	Shannon Equitability Index	0.84	0.8	0.9	0.8	0.73	0.72
	Simpson Diversity Index	0.9	0.84	0.8	0.85	0.83	0.84
Annelida	Margalef Diversity Index	1.93	0.0018	0.7	1.86	1.56	1.66
	Menhinick's Diversity Index	0.18	0.16	0.1	0.13	0.21	0.14
	Berger Parker Index	0.17	0.19	0.24	0.21	0.27	0.23

For the Arthopoda the highest value of Shannon Diversity Index was obtained in Vahrath 2021 i.e (2.98) and the lowest value is obtained in Wande 2020- 2021 i.e (1.51). Shannon Equitability Index value was obtained highest in Vahrath 2021 i.e (0.92) and lowest value was obtained in Wande 2020-2021 i.e (0.73). Simpson Diversity Index value was obtained highest in Harud 2020 i.e (0.93) and lowest value was found in Shishur 2021 i.e (0.7). Margalef Diversity Index value was found highest in Harud 2020 i.e (3.2) and lowest was found in Wande 2020-2021 i.e (0.88). Menhinick's Diversity Index Value was found highest in Harud 2020 i.e (0.31) and lowest value was found in Wande 2020-2021 i.e (0.15) and the Berger Parker Index value was found highest in Shishur 2021 i.e (0.47) and the lowest value was found in Harud 2020 i.e (0.13) respectively. The presence of a large and diverse population of species in the environment is indicated by the greatest Arthropod diversity indexes. Because many species have distinct responsibilities in preserving ecological balance, this great variety may help to increase the resilience of ecosystems. A great diversity of Arthropods can contribute to overall ecosystem health and natural biological control mechanisms in the setting of water contamination, hence reducing the negative consequences of pollution (Sharma *et al.,* 2009). On the other hand, when Arthropod diversity indices are at their lowest, it indicates that the ecosystem's species richness and abundance are declining. Because of the increased susceptibility of the ecosystem to the effects of water pollution, this decline in variety may cause ecological instability. Reduced ecosystem services, such nutrient cycling and pest management, which are critical for preserving ecosystem function in the face of pollution, may arise from lower variety. In general, keeping an eye on Arthropod diversity indices in connection to water pollution can assist in evaluating the ecological effects of pollution and provide guidance for conservation initiatives aimed at preserving biodiversity and the health of ecosystems Table 2.

Table 2: Diversity Indices of Arthopoda in different Seasons.

Macro-Invertebrates	Statistical Indices	Harud 2020	Wande 2020-2021	Shishur 2021	Sonth 2021	Grishum 2021	Vahrath 2021
	Shannon Diversity Index	2.97	1.51	1.81	2.72	2.93	2.98
	Shannon Equitability Index	0.87	0.73	0.8	0.84	0.9	0.92
	Simpson Diversity Index	0.93	0.72	0.7	0.91	0.9	0.9
Arthopoda	Margalef Diversity Index	3.2	0.88	1.21	2.7	2.75	2.72
	Menhinick's Diversity Index	0.31	0.15	0.24	0.25	0.28	0.26
	Berger Parker Index	0.13	0.37	0.47	0.22	0.19	0.19

For the Mollusca the highest value of Shannon Diversity Index was obtained in Sonth 2021 i.e (2.41) and the lowest value is obtained in Harud 2020 i.e (1.86). Shannon Equitability Index value was obtained highest in Shishur 2021 i.e (1) and lowest value was obtained in Harud 2020 i.e (0.73). Simpson Diversity Index value was obtained highest in Shishur 2021 i.e (1) and lowest value was found in Harud 2020 i.e (0.72). Margalef Diversity Index value was found highest in Grishum 2021 i.e (1.35) and lowest value was found in Wande 2020-2021 i.e (0.96). Menhinick's Diversity Index value was found highest in Wande 2020-2021i.e (0.21) and lowest value was found in Grishum 2021 i.e (0.15) and Berger Parker Index value was found highest in Harud 2020 i.e (0.5) and the lowest value was found in Sonth 2021 i.e (0.12) respectively. By analysing the ways in which human activities affect the distribution and abundance of mollusc species within a particular environment, diversity indices in molluscs may be linked to anthropogenic pressure. Mollusc populations can be directly or indirectly impacted by anthropogenic pressures such pollution, habitat loss, overexploitation, and climate change, which can alter species richness, evenness, and diversity indices. It is possible to evaluate the condition of mollusc populations and the ecosystem as a whole by looking at the link between diversity indicators and anthropogenic pressure. While an increase in diversity indices can point to a more robust ecosystem under less anthropogenic strain, a reduction in these indices could imply deterioration in species richness and evenness as a result of human activity. Knowing this link can assist guide management plans and conservation initiatives to lessen the harmful effects of human activities on mollusc diversity (Strayer *et al.,* 2006) Table 3.

Table 3: Diversity Indices of Mollusca in different Seasons.

Macro-Invertebrates	Statistical Indices	Harud 2020	Wande 2020-2021	Shishur 2021	Sonth 2021	Grishum 2021	Vahrath 2021
	Shannon Diversity Index	1.86	1.88	2.4	2.41	2.35	2.37
	Shannon Equitability Index	0.73	0.9	1	0.97	0.95	0.95
	Simpson Diversity Index	0.72	0.83	1	0.9	0.9	0.9
Mollusca	Margalef Diversity Index	1.29	0.96	1.4	1.3	1.35	1.3
	Menhinick's Diversity Index	0.12	0.21	0.2	0.18	0.13	0.2
	Berger Parker Index	0.5	0.24	0.13	0.12	0.15	0.14

CONCLUSIONS

The current study aimed to provide a comprehensive overview of the variety and composition of benthic Macroinvertebrates in order to assess the aquatic health status by utilising the aquatic benthic fauna. A high index denotes more ecological complexity and variety. The current study's low index values unequivocally demonstrate the lake's considerable human activity and pollution which is the adverse cause of Eutrophication. These indicators are useful for evaluating ecosystem health and biodiversity, providing guidance for conservation initiatives, and tracking ecosystem reactions to changes in the environment across time (Thorne *et al.,* 1997). Furthermore demonstrated was the value of biological data in the identification of pollution. Understanding the ecology of Macroinvertebrates is essential to comprehending the health of the lake environment. Thus, ideally, the study will serve as a reference repository for further research on the aquatic health of the area's freshwater ecosystems. In order for different organisations, including governmental, academic, and non-profit organisations, to take action for more effective sustainable management in the Dal Lake specifically and others around the nation generally, the information gathered is essential in providing baseline data.

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