APPLICATION OF TROPHIC STATUS CLASSIFICATION TO STREAMS- A CASE STUDY OF A KASHMIR HIMALAYAN STREAM

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Abstract

The management of streams needs that the nutrient status of these ecosystems is well delineated and a terminology is agreed upon so that researchers and managers can communicate the status of a stream ecosystem to each other for their better management. The trophic status classification criteria to be used for streams is presently being given serious consideration in the scientific literature and following the clue an attempt was made in the present study to understand the trophic status of Doodhganga, a Kashmir Himalayan mountain stream. The results obtained showed that the criteria suggested by different authorities may partly fit to describe the trophic status of Doodhganga stream, so modifications to these classification systems may be needed for making them more suitable for the stream. It is also suggested that extensive studies in the Himalayan region may be carried out in this regard so that a consensus is reached between different workers for adopting a classification which will help in the management of these precious resources.

Keywords: *Trophic status; stream; phosphorus; chlorophyll; conductivity*

Introduction

Trophic state refers to the nutritional status of a water body. As biological production (both primary and secondary) ultimately depends on the nutrient status of a water body, trophic state also reflects the biological production of water bodies. In case of lakes conventional systems exist for classifying them into trophic categories using nutrients and algal biomass (Hutchinson, 1967; Porcella *et al.,* 1980; OECD, 1982; Ryding and Rast, 1989; Wetzel, 2001). On the other hand, stream ecosystems have been described on the basis of carbon (Dodds, 1997) and position in the watershed (Vannote *et al.,* 1980), but boundaries separating stream types based on producer biomass and nutrients across watersheds are lacking (Dodds *et al.,* 1998). Given this scenario worldwide many attempts are being made to develop classifications for characterising streams on the basis of nutrient concentration and primary production (Dodds, 2006; Choi *et al.*, 2015; Yun and An, 2016).

The Himalayan region is endowed with numerous freshwater streams and their management is paramount for the prosperity of the region as a whole. One of the important research arenas is to understand the trophic status of these ecosystems so that comparisons can be made between different lotic systems and management criteria may be fixed. The present study was conducted on 'Doodhganga', a Kashmir Himalayan mountain stream. In this study the trophic status classification suggested by Dodds *et al.* (1998) and the enrichment classification suggested by Biggs (1995) were used. The trophic status classification as suggested by Dodds *et al.* (1998) has given trophic status categories of streams on the basis of mean benthic chlorophyll, maximum benthic chlorophyll, sestonic chlorophyll, total nitrogen and total phosphorus (Table 1). Out of these variables mean benthic chlorophyll, maximum benthic chlorophyll and total phosphorus were used to categorise the Doodhganga stream.

Table 1: Trophic status criteria for streams as per Dodds *et al.* (1998)

Variable (Units)	Oligotrophic--Mesotophic Boundary	Mesotophic--Eutrophic Boundary
Mean benthic chlorophyll (mg m^{-2})	20	70
Maximum benthic chlorophyll (mg m^{-2})	60	200
Sestonic chlorophyll (µg/L)	10	30
Total nitrogen (µg/L)	700	1500
Total phosphorus (µg/L)	25	75

The enrichment groupings (Table 2) for streams as suggested by Biggs (1995) uses the mean conductivity values and a range of benthic chlorophyll 'a' concentration.

Table 2: Enrichment groupings of streams as per Biggs (1995)

Enrichment Category	Mean Conductivity µS cm^{-1}	Benthic Chlorophyll 'a' Range mg m^{-2}
Un-enriched	87	0.5-3
Moderately enriched	106	3-60
Enriched	271	25-260

Study Area

Kashmir valley, paradise on earth, lies between 33° 20' and 34° 54'N latitudes and 73° 55' and 75° 35'E longitudes and covers an area of 15,948 km^2. Topographically, it is a deep elliptical bowl-shaped valley bounded by the lofty mountains of the Pir-Panjal Range in the South and South-West and the Greater Himalayan Range in the North and East, with 64% of the total area being mountainous. The valley is an asymmetrical fertile basin, stretching from South-East to North-Westerly direction. Its diagonal length (from South-East to North-West corner) is 187km, while the breadth varies considerably, being 115.6km along the latitude of Srinagar (Kaul, 1977). The altitude of the valley floor at Srinagar, the capital city, is 1,600m a.s.l. and the highest peak among its surrounding mountains is that of the Kolahoi or 'Gwashibror' with a height of 5,420m. Traversing the valley is the River Jhelum and its tributaries. The Jhelum (also called Vitasta/Vyeth) has been and continues to be the key element of the ecosystem of Kashmir. Kashmir is indeed the gift of Jhelum. It is born of it, made up of the material brought down by its numerous tributaries; and is united with it through every fibre of its being (Raza et al., 1978). The shielded valley of Kashmir is characterized by distinct orographic features and snow clad peaks and resembles the mountainous and continental parts of the temperate latitudes. Thus, the Valley of Kashmir has a continental climate marked by well defined seasonality. The average rainfall at Srinagar is 659 mm per annum and most of the precipitation occurs in the form of snow during winter and early spring.

Doodhganga stream takes its origin on the eastern slopes of the Pir Panjal mountain range of Himalaya below the Tatakuti peak which is at an altitude of more than 4500m a.s.l. The source waters of the stream in the upper reaches are the snow fields, springs and a number of smaller lakes. The surface geology in the study area is dominated by sand/clay beds with lower floodplain reaches having accumulation of sand and silt mixed with clay. The Doodhganga drainage basin has extremely steep slopes of more than 70% restricted to the upper reaches which are generally snow covered. These slopes are followed by comparatively lesser steep slopes of 60-70% which reflect the different aspects of mainly the Karewa formations (plateau-like features developed in thick accumulations of the Pleistocene glacial moraines) in the middle parts of the study area. Downhill sides of these Karewa formations are characterized by moderate slopes which cover the major proportion of the middle reaches of the study area. The downstream catchment area and the flat table lands on the Karewa formations are under nearly level to level slopes (0-1%) (Hussain, 2011). A description of the study sites (Figure 1) is given below:

Study Site 1: It was located just outside the Branwar forest area close to the Branwar village (33° 53' 18.6"N and 74° 40' 45.6"E) at an altitude of 2015m a.s.l.

Study Site 2: It was located at Chadora just before the entrance of the stream into the main Chadora town (33° 56' 34.2"N and 74° 47' 39.7"E) at an altitude of 1629m a.s.l.

Study Site 3: It was located at Wathora on Doodhganga stream before its confluence with the Shaliganga stream (33° 58' 17.9"N and 74° 48' 35.2"E) at an altitude of 1596m a.s.l.

Study Site 4: It was located at Wathora on Shaliganga stream (33° 58' 19.7"N and 74° 48' 34.1"E) which is the major contributor of water to the Doodhganga stream in the area. The altitude of the site was 1600m a.s.l

Study Site 5: It was located at Kral Pora (33° 59' 21.4"N and 74° 48' 44.9"E) before the place where from the Doodhganga Drinking Water Treatment Plant draws water from the stream. The altitude at the site was 1598m a.s.l.

Study Site 6: It was located at Natipora (34° 02' 43.4"N and 74° 48' 32.2"E) at an altitude of 1593m a.s.l. The immediate catchment of the stream in this area is densely populated.

Study Site 7: It was located at Bemina (34° 04' 10.0"N and 74° 45' 51.5"E) at an altitude of 1595m a.s.l. before the place where the stream empties itself in to the Flood Spill Channel, which in turn feeds water to the Hokarsar wetland, a Ramsar site of international fame.

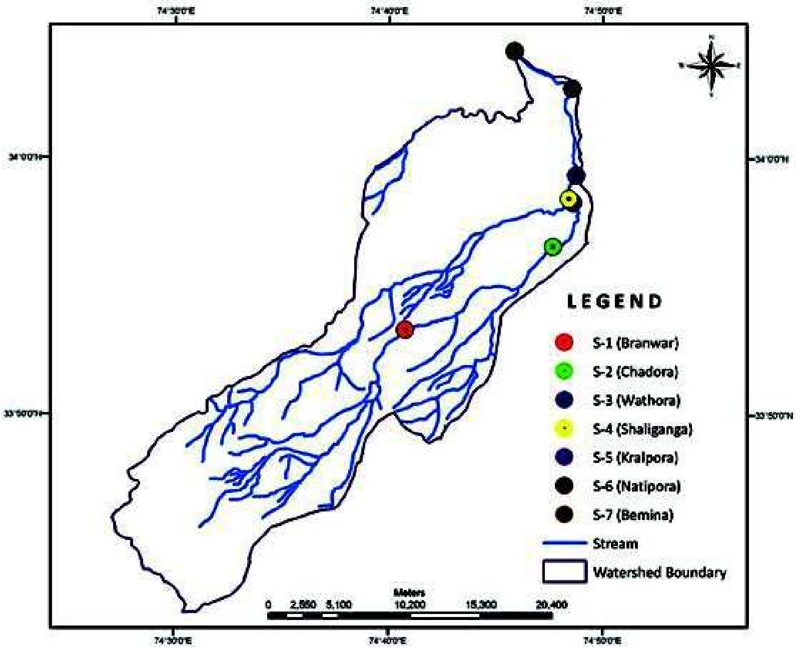

Fig. 1: Map showing location of study sites on Doodhganga stream, Kashmir

Materials and Methods

During base flow/low flow conditions monthly sampling was conducted at different study sites on Doodhganga stream during January, 2005 to December, 2006 and following parameters were analyzed using standard methods. In case of rains, a gap of at least two days was kept between the cessation of rain and sampling.

i. Conductivity was determined by electrometric method using a laboratory conductivity meter. The conductivity meter was calibrated using a standard solution of 0.01M KCl and the readings were taken at 25°C. Results were expressed as µS/cm and the values obtained for two year study were averaged to obtain a mean value (APHA, 1998).

ii. Total phosphorus was determined by ascorbic acid spectrophotometric method after digestion of the unfiltered water samples by a combination of sulphuric acid and nitric acid. Results obtained were expressed as µg/L and the values obtained for two year study were averaged to obtain a mean value (APHA, 1998).

iii. Benthic algal samples were collected at each study site using multi-habitat approach (Barbour *et al.,* 1999). A 100m stream reach was selected and all substrates and habitats roughly in proportion to their aerial coverage were sampled. Benthic algal samples were collected from defined areas by scratching submerged stones, sticks, pilings and other available substrates and by isolating periphyton from sand/silt by a spatula and collection in a Petri dish. At each sampling station the samples were mixed together to make a composite sample and a known portion of the sample was used for chlorophyll "a" estimation. The chlorophyll from samples was extracted by using acetone and then the procedure followed was as described in APHA (1998) and Biggs and Kilroy (2000).

Results

Using the criteria as suggested by Dodds *et al.* (1998) it was obtained that the different study sites on Doodhganga stream behaved differently and were accordingly categorized (Table 3). Site 1 was categorized as mesotrophic on the basis of total phosphorus while it was categorised as oligotrophic on the basis of mean and maximum chlorophyll. Site 2 shifted to eutrophic condition on the basis of total phosphorus while it remained as oligotrophic on the basis of mean and maximum chlorophyll.

Downstream on the basis of total phosphorus Site 3 fell into the eutrophic category while on the basis of mean and maximum chlorophyll, it turned to be in the mesotrophic category. Downstream all the other sites fell in the category of eutrophic on the basis of total phosphorus while on the basis of mean and maximum chlorophyll, different situations were encountered. Sites 4 and 5 were in the oligotrophic category while sites 6 and 7 fell in the mesotrophic category.

Thus, conclusively, it may be stated that on the basis of total phosphorus, Site 1 was in mesotrophic condition while all other study sites were in the eutrophic category. On the basis of mean and maximum chlorophyll, sites 1 and 2 as upstream sites were oligotrophic while downstream all other study sites were mesotrophic with sites 4 and 5 exceptionally falling in the oligotrophic category.

Table 3: Site-wise trophic status of Doodhganga stream obtained after applying the criteria of Dodds *et al.* (1998)

Variable	Value	Trophic Category
Site 1		
Total Phosphorus (µg/L)	53.4	Mesotrophic
Mean Benthic Chlorophyll (mg m^{-2})	8.68	Oligotrophic
Maximum Benthic Chlorophyll (mg m^{-2})	35.46	Oligotrophic
Site 2		
Total Phosphorus (µg/L)	86	Eutrophic
Mean Benthic Chlorophyll (mg m^{-2})	19.72	Oligotrophic
Maximum Benthic Chlorophyll (mg m^{-2})	44.33	Oligotrophic
Site 3		
Total Phosphorus (µg/L)	152.9	Eutrophic
Mean Benthic Chlorophyll (mg m^{-2})	28.11	Mesotrophic
Maximum Benthic Chlorophyll (mg m^{-2})	68.89	Mesotrophic
Site 4		
Total Phosphorus (µg/L)	241.7	Eutrophic
Mean Benthic Chlorophyll (mg m^{-2})	5.16	Oligotrophic
Maximum Benthic Chlorophyll (mg m^{-2})	11.58	Oligotrophic
Site 5		
Total Phosphorus (µg/L)	130.4	Eutrophic
Mean Benthic Chlorophyll (mg m^{-2})	9.21	Oligotrophic

Maximum Benthic Chlorophyll (mg m^{-2})	16.84	Oligotrophic
Site 6		
Total Phosphorus (µg/L)	139	Eutrophic
Mean Benthic Chlorophyll (mg m^{-2})	25.9	Mesotrophic
Maximum Benthic Chlorophyll (mg m^{-2})	107.27	Mesotrophic
Site 7		
Total Phosphorus (µg/L)	115.1	Eutrophic
Mean Benthic Chlorophyll (mg m^{-2})	39.71	Mesotrophic
Maximum Benthic Chlorophyll (mg m^{-2})	118.48	Mesotrophic

On applying the criteria as suggested by Biggs (1995) the different study sites on the Doodhganga stream were categorized into different enrichment categories (Table 4). Accordingly, Site 1 was categorized as un-enriched on the basis of mean conductivity while it was categorized as moderately enriched on the basis of benthic chlorophyll 'a' concentration. Site 2 was categorized as enriched and moderately enriched on the basis of mean conductivity and benthic chlorophyll 'a' concentration respectively. Site 3 was categorized as enriched on the basis of both these criteria. Further, sites 4 and 5 were categorized as enriched on the basis of mean conductivity while they were categorized as moderately enriched on the basis of benthic chlorophyll 'a' concentration. Still further sites 6 and 7 got categorized as enriched on applying both of these criteria.

Table 4: Site-wise enrichment categorization of Doodhganga stream obtained after applying the criteria of Biggs (1995)

Variable	Value	Trophic Category
Site 1		
Mean Conductivity µS cm^{-1}	77.96	Un-enriched
Benthic Chlorophyll 'a' Range mg m^{-2}	0.06-35.46	Moderately enriched
Site 2		
Mean Conductivity µS cm^{-1}	142.95	Enriched
Benthic Chlorophyll 'a' Range mg m^{-2}	3.62-44.33	Moderately enriched
Site 3		
Mean Conductivity µS cm^{-1}	193.53	Enriched

Benthic Chlorophyll 'a' Range mg m^{-2}	6.12-68.89	Enriched
Site 4		
Mean Conductivity µS cm^{-1}	199.16	Enriched
Benthic Chlorophyll 'a' Range mg m^{-2}	1.84-11.58	Moderately enriched
Site 5		
Mean Conductivity µS cm^{-1}	198.14	Enriched
Benthic Chlorophyll 'a' Range mg m^{-2}	3.37-16.84	Moderately enriched
Site 6		
Mean Conductivity µS cm^{-1}	242.20	Enriched
Benthic Chlorophyll 'a' Range mg m^{-2}	0.14-107.27	Enriched
Site 7		
Mean Conductivity µS cm^{-1}	242.18	Enriched
Benthic Chlorophyll 'a' Range mg m^{-2}	0.56-118.48	Enriched

Discussion and Conclusion

As against lakes, there is no well established criterion for categorization of streams into different trophic types. Although a number of attempts have been made in this direction the consensus between different researchers seems to be lacking. Streams occasionally are classified as eutrophic or oligotrophic (Hornberger *et al.*, 1977; Kelly and Whitton, 1995) but no conventional criteria have been used for these terms when applied to lotic systems. In this study, the criteria as proposed by Dodds *et al.* (1998), were used to categorise the Doodhganga stream into a trophic category and in addition the criteria suggested by Biggs (1995, 1996) was employed to categorise the stream into an enrichment category.

To categorise the different study sites into trophic categories (Dodds *et al.*, 1998), the mean benthic chlorophyll, the maximum benthic chlorophyll and the total phosphorus concentration in the stream water were used. The study sites showed different categorization when different criteria were used. On the basis of total phosphorus concentration in the water, Site 1 was categorized as mesotrophic while as, all the other study sites were categorized as eutrophic. On the other hand, when the mean and the maximum benthic chlorophyll concentrations were considered sites 1 and 2 were categorized as oligotrophic while the downstream study sites were categorized as mesotrophic with the exception of sites 4 and 5 which fell in the oligotrophic category, which seems to be an anomaly and can be attributed to the smothering action of the fine aggrading sediment which reduces the chlorophyll content of the algal components in the periphyton at these two study sites. So it may be concluded that although in general the increased nutrient enrichment downstream is indicated by this classification, there are some peculiar stream features which may at times interfere with the classification of the stream into a distinct trophic category and there appears to be variability in the categorization on the basis of total phosphorus content and the benthic chlorophyll concentration.

While employing the enrichment criteria as proposed by Biggs (1995) it was found that on the basis of mean conductivity values Site 1, which was the most upstream study site was categorized as un-enriched while all the other study sites downstream were categorized as enriched. On the basis of benthic chlorophyll 'a' concentration ranges, sites 1, 2, 4 and 5 were categorized as moderately enriched while the other study sites were categorized as enriched. So there is a discord in the categorization of study sites in an enrichment category on the basis of mean conductivity and the benthic chlorophyll 'a' ranges. Pertinently sites 3, 6 and 7 were categorized as enriched on the basis of application of both the said criteria, implying that the disagreement between the two criteria was limited in extent and it can be inferred that the enrichment categories as proposed by Biggs (1995) originally for New Zealand streams can be applied to a reasonable accuracy in case of Doodhganga stream. In addition it may be suggested that in order to remove the discord arising from application of different criteria, modifications may be needed to make the categorization more suited to conditions in the Himalayan region. It is high time that extensive studies in different areas of the Himalaya are carried out so that a consensus can be reached at by different workers for trophic status categorisation of Himalayan streams which shall help in the better management of these ecosystems.

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