



## Historical Ecological State of a Mountain River: Developing Benchmarks for River Management and Restoration

Tanuja Bartwal<sup>1\*</sup> • Prakash Nautiyal<sup>1</sup>

<sup>1</sup>Aquatic Biodiversity Unit, Department of Zoology, Hemvati Nandan Bahuguna Garhwal University (A Central University), Srinagar Garhwal, 246174, Uttarakhand, India

\*Corresponding Author Email: tanujabartwal24@gmail.com

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**Abstract:** Anthropogenic influences on alpine rivers are gradually increasing. Srinagar Garhwal, located on the banks of the Alaknanda River, a tributary of the Ganga, is one of the largest human settlements in the basin. A five-year study was planned to measure short-term changes in the ecological health of this river. For this work, we re-examined diatom mounts for 1991-92 (1<sup>st</sup> period) and 1995-96 (2<sup>nd</sup> period) and subjected them to species count for determining van Dam ecological categories. The tolerant N-autotroph, polyoxybiontic,  $\beta$ -mesosaprobe, mesotrophic, and aquatic to aerophilic categories predominated in both periods, but their percentage increased considerably in the 2<sup>nd</sup> period. A rise in the proportion of these categories, with the exception of polyoxybiontic, indicates deterioration of ecosystem health. Scrutiny of the categories indicated that only 9 taxa accounted for 21.6% of the polyoxybiontic category compared to 17 taxa for 20.6% of the tolerant N<sub>2</sub> autotroph, which can also be used to enhance river health evaluation, especially in categories with few taxa accounting for a substantial percentage. This study will serve as a historical reference for the river health. The present growth of hydropower plants, together with numerous stressors, is increasing the source of disturbance, emphasizing the importance of having benchmarks for ecological states.

**Keywords:** Alaknanda River • Diatom • Ecological state • Short-term • Reference conditions

### Introduction

River ecosystems are extremely diverse. They run through the highlands, plateaus, and plains of India. They provide a range of habitats and thus support remarkable biodiversity, despite the Earth's limited supply of freshwater. Rivers are under stress, the degree of which is proportional to human habitations and development, as well as shifting landuse from woods, meadows, marshes, agricultural, to built-up areas. The seemingly calm mountains are actually highly stressed as a result of tourist and pilgrim activities, as well as general development in urbanised pockets along the river.

In view of this, it becomes necessary to regularly monitor the state of the river ecosystem health from time-to-time, required for managing and restoring rivers. This would require historical information on ecological state at definite time scales, classified here as short and long-term periods. The authors have

envisaged to make a short-term assessment of past ecosystem health to be used as benchmark for rejuvenating river health. There are very few studies on the long or short-term health assessments of river (Harding and Taylor 2014, Smith et al. 2017, Ovaskainen et al. 2018). Most are undertaken at intervals of one or two years (Kalyoncu and Serbetci 2013, Dalu et al. 2016, Sawaiker and Rodrigues 2017).

This study uses van Dam ecological categories (van Dam et al. 1994) to make a short-term periodic assessment of the Alaknanda River at Srinagar during 1<sup>st</sup> period (1991-92) and 2<sup>nd</sup> period (1995-96). Differential species (Lange-Bertalot 1979) was used to classify sensitive and tolerant taxa and Hofmann index (Hofmann 1994) for saprobic condition.

Diatom are the useful to infer the past water quality (Taylor et al. 2005, Yallop et al. 2009). This study examines the possibility of using diatom samples for deciphering the changing



riverscape over a period of time. The deposited<sup>1</sup> diatom mounts were considered as samples of the river Alaknanda at Srinagar (near Alkeshwar temple) for this short-term study.

### Study area and Methodology

Srinagar is located on the pilgrim route to Badri-Kedar. Due to ever-increasing number of pilgrims and tourists, it has gradually grown in dimensions; horizontally and vertically due to development (Government and private infrastructure). Subsistence agriculture in the Srinagar-Chauras valley facilitated by wide terrace before the year 1980 was gradually replaced by increase in built-up area. The gushing river was gradually experiencing interference from non-point sources of pollution. The Srinagar Hydroelectric Project silenced the pristine roaring river in the year 2015.

The samples of 1<sup>st</sup> and 2<sup>nd</sup> periods were examined in light of the above facts. Due to rapid changes in diatom taxonomy re-examination meet the requirements of current taxonomy and nomenclature from that in 1990's. The species count data was generated using Olympus CX41 Trinocular Microscope from the samples and imported into the OMNIDIA Software ver 6.0.8 for (Lecointe et al. 1993), preparing diatom inventories to compute the van Dam ecological data, differential species and saprobic condition, apt for determining the ecosystem health of the Himalayan rivers and recording periodic

changes (in 1<sup>st</sup> and 2<sup>nd</sup> period) in the ecological state of the Alaknanda.

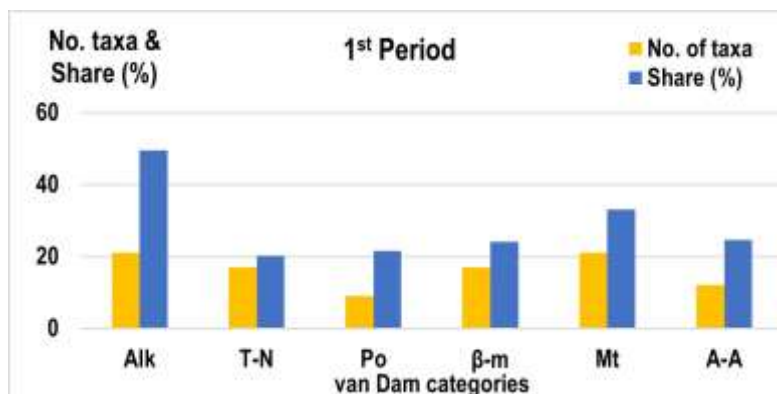
### Results

**van Dam ecological variable and their categories:** The van Dam ecological traits show prevalence of alkaliphilic, tolerant N-autotroph, polyoxybiontic (100% O<sub>2</sub> saturation), β-mesosaprobe (BOD-2-4 mg l<sup>-1</sup>), mesotrophic and aquatic to aerophilic categories in both the periods. The number of taxa were high (21) for alkaliphilic and mesotrophic, categories followed by 17 taxa for tolerant N- autotroph and β-mesosaprobe. The share of these taxa was relatively high for mesotrophic (33%) and alkaliphilic (49.5%) compared to others (20.2 to 24.5%). Only nine taxa amounting to 21.7% contributed to polyoxybiontic category.

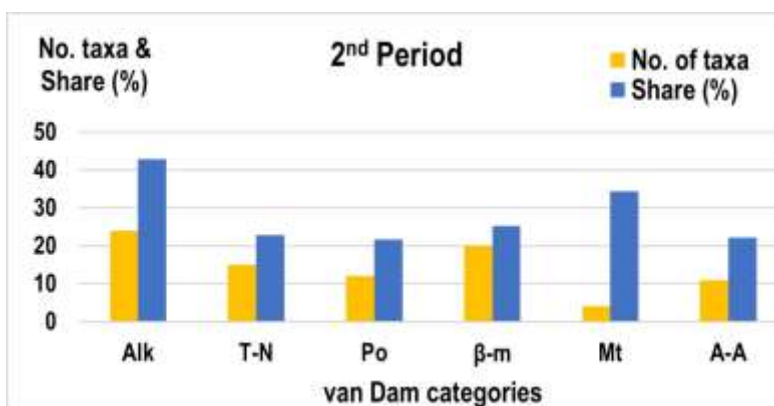
In the 2<sup>nd</sup> period the number of taxa were high for alkaliphilic (24), mesotrophic (21), β-mesosaprobe (20) and tolerant N- autotroph (15). The share of these taxa was relatively high for mesotrophic (34.4%) and alkaliphilic (42.9%) compared to others (21.7 to 25.2%). In this period 12 taxa amounting to 21.6% contributed to polyoxybiontic category. Notably, only four taxa contributed to a much larger share (34.4%) of the mesotrophic category (Fig 1 and 2).

**Differential species:** Three categories comprising 5.8 % most pollution tolerant (5 taxa), 6 % less frequent sensitive (7 taxa) and 18% more sensitive abundant (9 taxa), were recorded. The share of more sensitive abundant taxa (19.8%) increased somewhat in the 2<sup>nd</sup> period, whereas the shares of less frequent sensitive taxa (5.2%) and the most pollution tolerant (3.4%) decreased slightly, although the number of taxa was same (9) for more sensitive abundant category (Table 1).

<sup>1</sup> The Alaknanda R. has been studied at Srinagar for diatom flora, ecology (Nautiyal R. 1993) for D. Phil. program and for MoEn funded studies on conservation and migration ecology of Himalayan mahseer fish (Nautiyal 1997, recorded abundance of diatom species). All diatom mounts have been stored in Aquatic Biodiversity Unit, Department of Zoology. Co-incidentally, the river has been sampled at same location for all past studies, which facilitated comparisons between the periods.



**Fig 1.** van Dam ecological variable and their categories and number of taxa contributing to the share (%) during the 1<sup>st</sup> period. Acronyms: Alk- alkaliphilic, T-N- tolerant N- autotroph, Po- polyoxybiontic, β-m- β-mesosaprobe, Mt-mesotrophic, A-A- aquatic to aerophilic



**Fig 2.** van Dam ecological variable and their categories and number of taxa contributing to the share (%) during the 2<sup>nd</sup> period. Acronyms same as in Fig 1.

**Table 1.** Category share (as %) of differential species, saprobic condition and number of taxa for various ecological categories during 1<sup>st</sup> and 2<sup>nd</sup> period.

Differential species and Saprobic condition	1 <sup>st</sup> period		2 <sup>nd</sup> period	
	No. of taxa	% share	No. of taxa	% share
More sensitive (abundant)	9	18	9	19.8
More sensitive less frequent	7	6	5	5.2
Most pollution tolerant*	5	5.8	3	3.4
Oligosaprobic	1	4.8	1	2.3
Oligo-β-mesosaprobic	5	46.4	7	38.5
β-α-mesosaprobic	11	19.9	10	24.7

**Saprobic condition:** Oligosaprobic (46.4%) condition predominates in the 1<sup>st</sup> period. The number of taxa (11) were high for β-α-mesosaprobic condition (19.9 %). In the 2<sup>nd</sup>

period the share of oligosaprobic taxa decreases (38.5 %), while β-α-mesosaprobic condition increases (24.7%). The number of



taxa (7) increases for oligosaprobic condition (Table 1).

### Discussion

This study investigates historical ecological state of the Alaknanda R. in the decade of 1990-2000 at 5-year interval for 1<sup>st</sup> and 2<sup>nd</sup> period. The categories are similar between the two periods but their share increases slightly in the 2<sup>nd</sup> period except for polyoxybiontic category attributed to some disturbances in this period. The difference lies in the number of taxa and their share, which also varies mildly. The share of most categories' ranges from 20-25% except the mesotrophic and alkaliphilic categories (33 to 49.5%) during both the periods. Further increase should be avoided. There are some notable features; such as fewer taxa (9, 12) contributing to polyoxybiontic category in respective period. This is a matter of concern as this category represents O<sub>2</sub> requirements of the community and a few taxa in this community are an indication of stressed state. The community is expected to have greater number of taxa representing oxygenation.

Overall, the river appears to be mildly impacted as evident specifically from the dominance of  $\beta$ -mesosaprobe, mesotrophic and aquatic to aerophilic categories in both years. The higher share of aquatic category is noticeably missing. There are previous studies with similar results. Investigations on the Mandakini, a glacierfed tributary of the Alaknanda, revealed similar categories in its upper and middle stretch which turned eutraphentic in its mouth zone (Nautiyal et al. 2015). Moderate O<sub>2</sub> (50% saturation) and eutraphentic categories were observed in the Khanda Gad, a springfed tributary of the Alaknanda at Billokedar little downstream of Srinagar (Nautiyal and Mishra 2013). This suggests deterioration of the Alaknanda river-system in the vicinity of Srinagar. The

mestraphentic state was observed in the Nandakini, Pinder and Mandakini near the snow line. However, the eutrophic state was recorded in the lean period (Nautiyal and Bartwal 2022). Kawecka (2008) observed acidophilous oligo-mesotraphentic group of diatoms in the headwaters of the Gasienicowa valley, Poland over many years. Investigations on the distantly located Doon valley the Song and Asan drainages of the Ganga and Yamuna river systems respectively, revealed good oxygenation (continuously high). Saprobity and trophic status was largely  $\beta$ -mesosaprobous and eutraphentic, respectively in most of the streams attributed to urbanization stress in the form of discharges from thickly populated Dehradun (62 MLD sewage) and satellite towns (Singh et al. 2018).

In the Alaknanda impacted by hydropower development at Srinagar since 2015, the discharge - deficient stretch between dam and power house was characterised by circumneutral/ alkaliphilous, fresh brackish, N-autotrophic-sensitive/tolerant, O<sub>2</sub> continuously high, oligo- to  $\beta$ -mesosaprobic taxa (Nautiyal et al. 2018). There was more variation in trophic and moisture state. The trophic state relates well with intermittent supply of nutrients attributed to variations in the flow. The moisture state is related to the increase and decrease in the water levels as a result of required power generation. Thus, the substrate that was submerged sometime back and exposed during sampling harbor diatom taxa that can live in both conditions in contrast to riffles where continuously submerged substrate will mostly harbor taxa that are strictly aquatic forms. In a recent study the flow regulated stretches were found in mesotrophic state and tail of impounded section of Srinagar hydropower was eutrophic (Bartwal and Nautiyal 2023).

According to Lange-Bertalot differential species classification, the total number of



sensitive taxa (either abundant or less frequent) are more than the pollution tolerant forms in 1<sup>st</sup> compared to 2<sup>nd</sup> period. In contrast saprobic condition of Hofmann index suggest decline in share of oligosaprobic and oligo- $\beta$ -mesosaprobic, but increase in  $\beta$ - $\alpha$ -mesosaprobic category showing certain degradation in the 2<sup>nd</sup> period. Further, *Gomphonema parvulum* (Kützing) Kützing, *Navicula veneta* Kützing, *Nitzschia palea* (Kützing) W. Smith, *Nitzschia communis* Rabenhorst and *Synedra ulna* (Nitzsch) Ehrenberg are the most tolerant taxa in both the periods and first four taxa are also polysaprobic. However, the number and share of tolerant taxa decrease in the 2<sup>nd</sup> period.

Such diatom-based assessments using van Dam ecological categories are still fragmentary. There are hardly any periodic assessments to serve as tool for assessing the state of primary producer community in stream/river ecosystems. Rakowska and Szczepocka (2011) made biological assessment (diatom indices) of water quality restoration in the lowland mid-sized Bzura River over the period of 30 years (1972 and 2003–2004). In order to identify the intended condition to which present conditions are compared, Stoddaed et al. (2006) provide particular terms: "minimally disturbed condition" (MDC), "historical condition" (HC), "least disturbed condition" (LDC), and "best achievable condition" (BAC).

The Alaknanda R. during past years (1991-92 and 1995-96) cannot be considered as truly pristine, but can be used as a reference point for devising management and restoration measures and strategies.

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