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Riparian Vegetation Along River Ganga Near Haridwar City And Its Role In The Presence And Community Structure Of Aquatic Mites

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Abstract: Riparian vegetation is referred to the vegetation along any water body more specifically rivers. It acts as a transitional zone between terrestrial and aquatic ecosystems and serves as its barrier too. It provides resources to the micro and macro invertebrates present in the aquatic ecosystem by providing shade, detritus, plant materials, etc. In the said study a total of 78 species belonging to 38 different families were recorded from Haridwar city along river Ganga and identified with the help of subject matter experts.

Keywords: Aquatic mites • Haridwar city • Riparian vegetation • River Ganga.

Introduction

The word riparian is derived from the Latin word *riparius* which means belonging to a bank of a river. A riparian zone (RZ) or riparian habitat indicates a transitional zone between terrestrial and aquatic ecosystems. National Research Council (2002) has defined riparian zones as vegetated areas related to a natural body of water, such as a river. It is considered as a connecting link between terrestrial and aquatic biota owing to the exchange of nutrients and energy flow between them (Gregory *et al.*, 1991; Verry *et al.*, 2000) thereby making it highly rich zone of biodiversity. The riparian zone is the broader zone extending from the river bank to the flood plains.

There is direct or indirect involvement of riparian vegetation in maintaining nutrient balance, energy flow in the ecosystems and it also provides various resources to the aquatic micro and macro invertebrates. It also contributes to controlling sediment load to the water bodies which affects the water quality. Vegetation in the riparian corridor is diverse with a layered natural architecture that provides rich habitat for wildlife. It provides cover, food water and travel routes that connect riparian and a planned habitat maintaining a vital web of diverse species spawning habitat.

Riparian vegetation plays an important role in the ecosystem in many different ways such as it protects water quality by reducing nutrient and pollutant inputs, protects water quality by trapping sediments, modifies stream temperature by providing shade, supply organic matter to aquatic ecosystems, maintains river banks by preventing stream bank erosion, helps in enhancement of local biodiversity, provides corridors/pathways for wildlife movement, improves aesthetic, educational, recreational and scientific values, etc. (Smith and Smith, 2004). Furthermore, the ecological significance of riparian zone is due to the interrelationship between vegetation, soil and water in that area (Pandey *et al.*, 2022).

Aquatic plants along with riparian vegetation provide the substrate required for the completion of life cycle of numerous aquatic faunal communities including aquatic mites (Pesic et.al., 2019a,b; 2020a,b; 2022a,b; Bahuguna et.al., 2019, 2020; Bahuguna and Dobriyal 2020, 2022; Negi et.al., 2021a,b; Sharma et.al, 2022a,b,2023; Baluni and Chandola 2019; Baluni et.al., 2022 and Rana et.al., 2022a,b,2023) and their hosts and thus aquatic plants are exploited by several species of aquatic mites. Balodi *et al.* (2004) provided details on riparian vegetation of Eastern Nayar while Sagir and Dobriyal (2017, 2018) and Sagir *et al.*, 2018 studied riparian vegetation of Western Nayar. Chamoli (2020) worked on the weed flora of the riparian areas of the Rudraprayag district, Uttarakhand.

Various fragmentary studies have been carried out to recognize the role and assess the significance of riparian vegetation. This study is an attempt to analyze the impact of riparian vegetation on the occurrence and survival of aquatic mites.

Material And Methods

Study Area

The Haridwar city lies between latitude 29º 55' 04.64" N to 29º 58' 10.79" N and longitude 78º 09' 39.95" E to 78º 10' 37.34" E in Haridwar district, Uttarakhand. Haridwar City is a famous pilgrimage place owing to the presence of the river Ganga. The river water is employed for various industrial, domestic and agricultural purposes. Sampling was carried out between latitude 29°58'19.14" N - 29°53'53.30" N and longitude 78°11'18.84" E - 78°10'05.36" E along both the banks of river Ganga.

Methodology

The riparian vegetation was collected from both banks of the river Ganga near Haridwar City. Regular monitoring was done for the period of two years from November 2019 to December 2021 to recognize and assess the variability and pattern of riparian vegetation across the Ganga River. Riparian vegetation collected along both the river banks of Ganga near Haridwar city was identified with the help of local inhabitants and then was confirmed with the help of different keys of available floras of Uttarakhand and Himalayas for their taxonomical specification (Gaur, 1999). For the validation and authenticity of information gathered subject matter experts of HNB Garhwal University have been consulted. The information gathered was further categorized into the family, vernacular name, availability, and habit to analyze the riparian vegetation precisely.

Result And Discussion

The plants collected during study of two years were categorized based on their availability and the habit they possess (tree, shrub, herb, etc.). Overall, 78 species belonging to 38 different families (Table 1) were identified by using secondary sources, with the help of local inhabitants and subject matter experts. Habit-wise categorization was done and in total 08 types of habit (Figure 1) were exhibited by 78 collected species viz. trees (16 species with 21% of total), shrubs (28 species with 36% of total), herbs (14 species with 18% of total), fern (01 species with 01% of total), weeds (04 species with 05% of total), climbers (02 species with 03% of total), free-floating plant (01 species with 01% of total) and grasses (12 species with 15% of total) (Figure 2). These 78 collected species were further divided into their presence in riparian zone along the Ganga River near Haridwar city as abundant (10 species), common (53 species) and rare (15 species) (Figure 3). Family Poaceae were found to be dominant amongst 38 families with 12 species recorded from this family followed by Fabaceae (08 species), Malvaceae (05 species), Solanaceae and Euphorbiaceae (04 species each) and Rutaceae and Asteraceae (03 species each). Rest eight families having two species each and 23 families were with only one species each (Figure 4). During the study, it was observed that few patches are with less diversity but the limited species are

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dominant in that area with good density and some areas are with more diversity but having low density as per river flow and seasonal variation. Photographs of some of the collected riparian vegetation are given in Plate 1.

Table 1. List of species recorded from both the banks of Ganga River near Haridwar city

Sl. No.	Botanical Name	Family	Vernacular name	Availability	Habit
1.	*Chenopodium* sp.	Amaranthaceae	Bathua	C	Shrub
2.	*Lannea coromandelica*	Anacardiaceae	Jhinghan	C	Tree
3.	*Mangifera indica*	Anacardiaceae	Aam	C	Tree
4.	*Centella asiatica*	Apiaceae	Brahmi	C	Herb
5.	*Calotropis gigantea*	Apocynaceae	-	C	Shrub
6.	*Phoenix sylvestris*	Arecaceae	Khajur	R	Tree
7.	*Agave americana*	Asparagaceae	Rambans	R	Shrub
8.	*Asplenium trichomanes*	Aspleniaceae	-	C	Fern
9.	*Parthenium hystrophorus*	Asteraceae	Gajar ghas	A	Weed
10.	*Xanthium strumarium*	Asteraceae	Chota dhatura	C	Weed
11.	*Artemisia nilagirica*	Asteraceae	Kunja	C	Herb
12.	*Cannabis sativa*	Cannabaceae	Bhang	C	Shrub
13.	*Cleome* sp.	Cleomaceae	Hurhur	R	Herb
14.	*Terminalia arjuna*	Combretaceae	Arjun	C	Tree
15.	*Terminalia* sp.	Combretaceae	-	R	Shrub
16.	*Ipomoea carnea*	Convolvulaceae	Sadasuhagan	A	Shrub
17.	*Cuscuta* sp.	Convolvulaceae	Amar bel	C	Climber
18.	*Dioscorea belophylla*	Dioscoreaceae	Taidu/ Tarud	C	Climber
19.	*Eriocaulan* sp.	Eriocaulaceae	-	C	Herb
20.	*Mallotus phillipinensis*	Euphorbiaceae	Rohini	C	Tree
21.	*Ricinus communis*	Euphorbiaceae	Arand	A	Shrub
22.	*Trewia nudiflora*	Euphorbiaceae	Gutel	R	Tree
23.	*Jatropha curcas*	Euphorbiaceae	Ratanjot	C	Shrub
24.	*Acacia catechu*	Fabaceae	Khair	C	Tree
25.	*Cassia mimosoides*	Fabaceae	Patwa ghas	R	Shrub
26.	*Cassia occidentalis*	Fabaceae	-	C	Shrub
27.	*Cassia tora*	Fabaceae	Panwar	C	Shrub
28.	*Dalbergia sissoo*	Fabaceae	Sheesham	C	Tree
29.	*Desmodium triflorum*	Fabaceae	Kandaliya	C	Herb
30.	*Uraria* sp.	Fabaceae	-	C	Herb
31.	*Arbus* sp.	Fabaceae	-	R	Herb
32.	*Hydrilla verticillata*	Hydrocharitaceae	-	C	Herb
33.	*Hyptis* sp.	Lamiaceae	-	C	Shrub
34.	*Ocimum* sp.	Lamiaceae	-	C	Herb
35.	*Woodfordia fruticosa*	Lythraceae	-	C	Shrub
36.	*Sida acuta*	Malvaceae	Bala	C	Shrub
37.	*Sida cordata*	Malvaceae	Bhiyli	C	Shrub
38.	*Sida cordifolia*	Malvaceae	Kunghi	C	Shrub
39.	*Sterculia foetida*	Malvaceae	-	C	Tree
40.	*Bombax ceiba*	Malvaceae	Semal	R	Tree
41.	*Azadirachta indica*	Meliaceae	Neem	C	Tree
42.	*Ficus benghalensis*	Moraceae	Badh/ Bargad	C	Tree
43.	*Ficus religosa*	Moraceae	Peepal	C	Tree
44.	*Moringa oleifera*	Moringaceae	-	C	Shrub
45.	*Syzygium cumini*	Myrtaceae	Jamun	C	Shrub
46.	*Nymphaea pubescens*	Nymphaeaceae	Water lily	C	Herb
47.	*Argemone mexicana*	Papaveraceae	Satyanashi	A	Weed
48.	*Apluda mutica*	Poaceae	Charol	C	Grass
49.	*Cynodon dactylon*	Poaceae	Dub ghas	A	Grass
50.	*Digitaria* sp.	Poaceae	-	R	Grass
51.	*Eragrostis* sp.	Poaceae	-	C	Grass

Sl. No.	Botanical Name	Family	Vernacular name	Availability	Habit
52.	*Oplismenus* sp.	Poaceae	-	C	Grass
53.	*Paspalidium* sp.	Poaceae	-	A	Grass
54.	*Paspalum notatum*	Poaceae	-	A	Grass
55.	*Poa annua*	Poaceae	Annual blue grass	A	Grass
56.	*Saccharum spontaneum*	Poaceae	Kans	C	Grass
57.	*Stenotaphrum secundatum*	Poaceae	Buffalo ghas	R	Grass
58.	*Arundo* sp.	Poaceae	-	C	Grass
59.	*Chrysopogon zizanioides*	Poaceae	-	C	Grass
60.	*Rumex* sp.	Polygonaceae	-	C	Shrub
61.	*Eichhornia crassipes*	Pontederiaceae	-	C	Free floating plant
62.	*Monochoria hastata*	Pontederiaceae	-	C	Herb
63.	*Potamogeton* sp.	Potamogetonaceae	-	C	Weed
64.	*Ranunculus sceleratus*	Ranunculaceae	Jaldhania	R	Herb
65.	*Ziziphus mauritiana*	Rhamnaceae	Ber	C	Shrub
66.	*Aegle mermelos*	Rutaceae	Bael	R	Tree
67.	*Citrus* sp.	Rutaceae	Nimbu	C	Shrub
68.	*Murraya koenigii*	Rutaceae	Karri patta	A	Shrub
69.	*Verbascum thapsus*	Scrophulariaceae	-	R	Shrub
70.	*Physalis* sp.	Solanaceae	-	C	Herb
71.	*Solanum indicum*	Solanaceae	Jungali bhata	C	Shrub
72.	*Datura stramonium*	Solanaceae	-	C	Shrub
73.	*Nicotiana tabacum*	Solanaceae	Van tambakhu	C	Shrub
74.	*Holoptelea intergrifolia*	Ulmaceae	Papri/ Kanju	C	Tree
75.	*Holoptelea* sp.	Ulmaceae	-	R	Tree
76.	*Urtica dioica*	Urticaceae	Kandali/ Bichughass	C	Shrub
77.	*Lantana camara*	Verbenaceae	Kurri/ Big sage	A	Shrub
78.	*Phyla nudiflora*	Verbenaceae	-	R	Herb

A= Abundant, C= Common, R= Rare

Lotic ecosystems are characterized by multi-dimensional environmental gradients (Ward, 1989). Cummins and Spengler (1978) observed in their study that the riparian vegetation enormously impacted the water streams as they work as processing units for these water systems. The vegetation across the river provides shade to the river by its branches and hangings which in turn keep it cool and also come up with dead organic matter or detritus. Shading not only influences the water quality but also regulates the activities of algae and macrophytes which are primary producers.

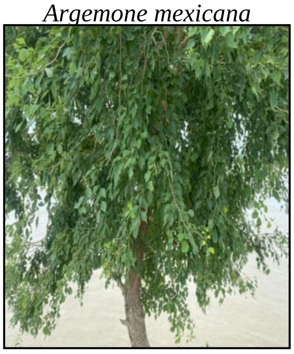
Heterogeneous microhabitats provided by riparian zones are due to its transition from terrestrial ecosystem to aquatic ecosystem (Rykken *et al.*, 2007), for both terrestrial and aquatic populations, thereby supporting biodiverse communities (Ramey and Richardson, 2017).

Tree branches, dead leaves, needles, twigs, logs, buds, fruit and dissolved organic matter are supplied by riparian vegetation. This additional availability of organic matter is a prime requisite to the aquatic biota as they act as its primary energy source (Hynes 1963; Cummins, 1974). As per Fisher and Likens (1973), the riparian vegetation covered with the heavy forest canopy having a higher frequency of shade might provide 99% of the annual input of energy to the aquatic ecosystem.

Argemone mexicana

Cannabis sativa

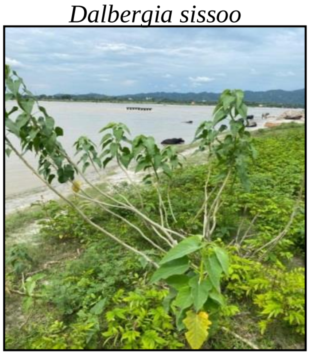
Cassia tora



Dalbergia sissoo

Ficus benghalensis

Holoptelea sp.



Ipomoea carnea

Murraya koenigii

Physalis sp.

Ricinus communis

Sida cordifolia

Ziziphus mauritiana

Plate 1: Riparian vegetation recorded from banks of river Ganga near Haridwar city

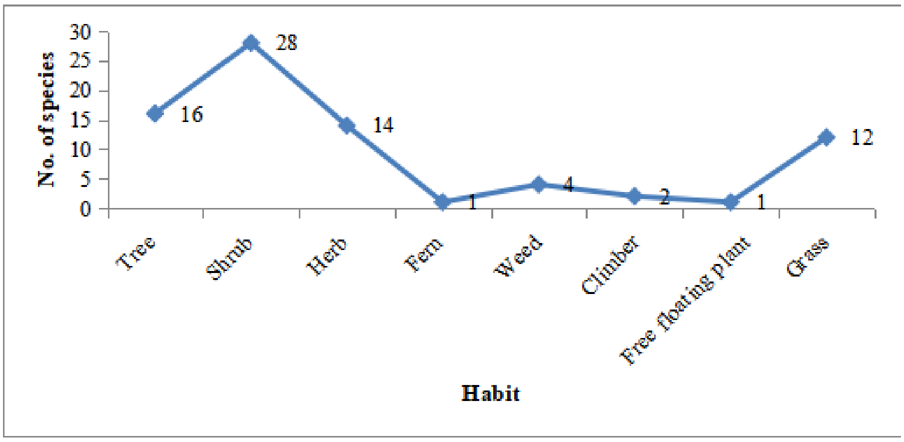


Figure 1. Variation in riparian species habit recorded from banks of river Ganga near Haridwar city

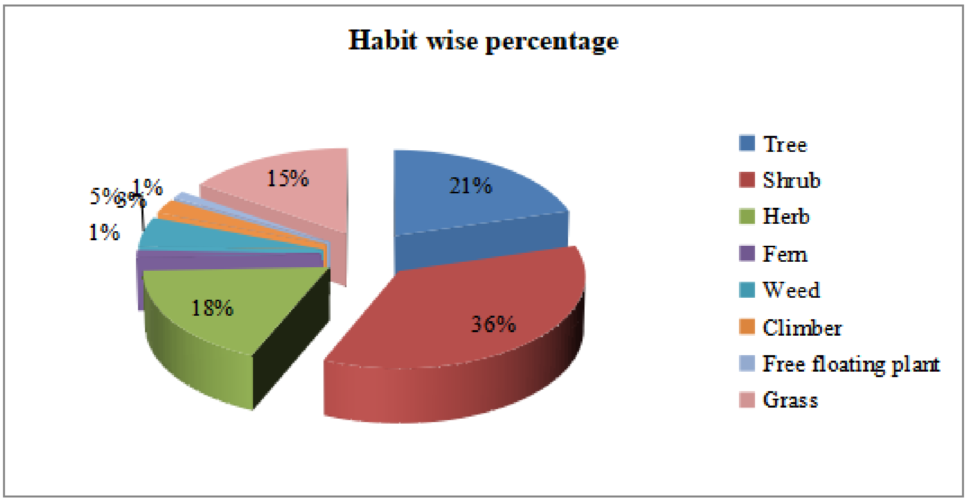


Figure 2. Percentage of variation in riparian species habit recorded from banks of river Ganga near Haridwar city

Rich riparian diversity was found along river Ganga from Haridwar City. The highly diverse riparian vegetation of the area plays a significant role in the regulation of environmental processes along the course of river Ganga. Shading and covering provided by the canopy helps in regulating the intensity of light penetration thereby maintaining the temperature of the water body and nearby area. Quinn and Hickey (1990) reported a strong correlation between macroinvertebrate community and shade which depicts the influence of shade on the distribution of macroinvertebrates including aquatic mites. Reduction in riparian vegetation along the streamside may result in 2 to 5˚C increase in water temperature of the stream which in turn affects life attributes of aquatic invertebrates (Bilby and Ward, 1991).

The hydrological dynamics of a river system bring forth the essential resources including nutrients to the riparian community for uptake by riparian plants (primary producers) and flow in the aquatic food web through transmission up to a higher trophic level (Thomas *et al.*, 2003; Vannote *et al.*, 1980; Xiang *et al.*, 2016).

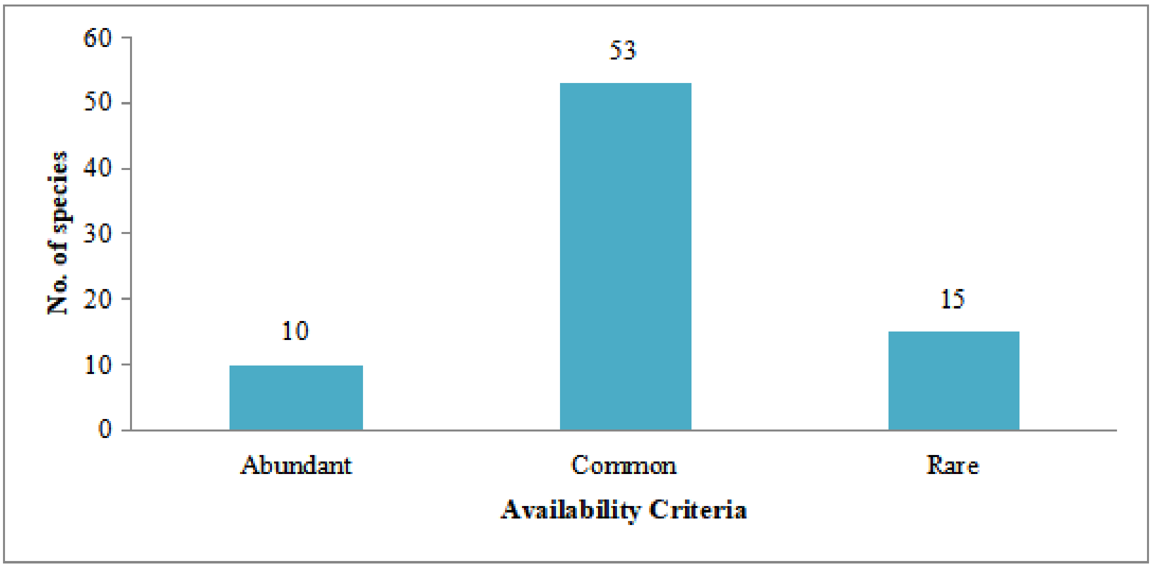


Figure 3. Availability criteria of recorded riparian species from banks of river Ganga near Haridwar city

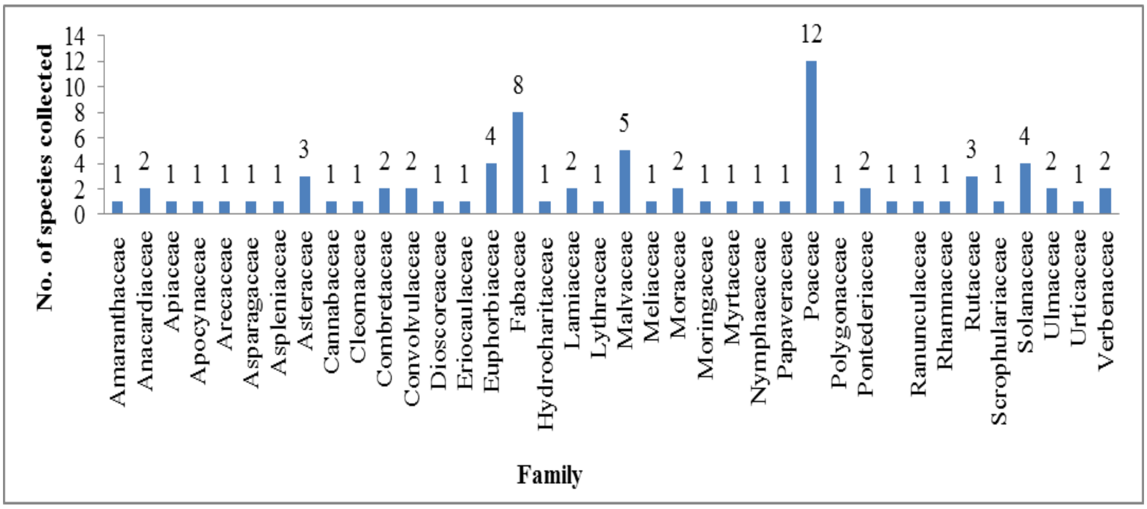


Figure 4. Family wise distribution of riparian species recorded from banks of river Ganga near Haridwar city

The various ways opted by the aquatic organism to make use of and to process the organic matter provided by riparian vegetation was studied by Cummins 1973, 1975; Cummins and Klug 1979; Anderson and Sedell 1979; Howkins and Sedell 1981 and Hefting *et al.*, 2005. Interaction of macroinvertebrates including aquatic mites with the riparian vegetation of the area plays a significant role in determining the health of the ecosystem of that area. Barton *et al.* (1985) have reported that the structure and function of aquatic communities *i.e.*, macroinvertebrates are highly affected by the riparian vegetation. Riparian zone provides an increased benthic surface area in terms of inorganic and organic substrates (Hussain and Pandit, 2012), beneficial for the colonization of aquatic faunal communities including aquatic mites. Leaves, litters, and woody debris shredded from plants act as breeding spots, feeding material for numerous aquatic fauna (Bilby, 1981; Shilla and Shilla, 2012; Zanetti *et al.*, 2016) besides minimizing the water flow thereby reducing the extent of flowing water towards erosion and sediment transportation. This enhances sediment deposition amidst the vegetation enabling the enrichment of downstream sections of a water channel (WRC, 2000).

River systems and streams are described by a variety of physicochemical factors along the riverside and throughout the length of the river or stream. Alteration in the system to any extent either from natural or anthropogenic activities impacts the water quality of the system and also hampers the biological association (Thoker *et al.*, 2015). Biological association of riparian vegetation and aquatic faunal diversity signals towards the health comprising water quality of the river. As per the studies conducted by Biesiadka and Kowalik (1991), Rousch *et al.* (1997), Di Sabatino *et al.* (2002) and Dohet *et al.* (2008) the aquatic mites are eminent water quality biomarkers. The present study demonstrates that the region harbours a high variety of floral diversity thereby supporting high macroinvertebrate density and diversity including aquatic mites.

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