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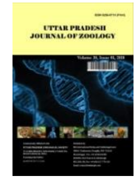

ANALYSIS OF DETRITUS STANDING STOCK IN WESTERN NAYAR RIVER FROM GARHWAL HIMALAYA, UTTARAKHAND

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AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration among all authors. Author MS designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors MR and AKD managed the analyses of the study. Author FF managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Detritus is defined as any form of non living organic matter, including different types of plant tissues, animal tissues, dead microbes, faeces as well as products secreted, excreted or exuded from organisms. It serves as a habitat, e g., shelters and breeding sites, etc., and also holds a very important place in food chain, yet are widely neglected by the aquatic biologists. In the present contribution a hypothesis was planned to study the monthly fluctuation in detritus standing stock based on variable riparian vegetation in the river Western Nayar in Garhwal Himalaya, Uttarakhand, India. It was observed that maximum detritus was retained by the stream in a portion where riparian vegetation was dominated by mixed forest and medicinal plants. It was followed by the portion having quercus species as dominant riparian vegetation. Detritus retention in the stream was maximum in winters may be due to low level of current velocity and water temperature. However, due to its high quantity, the periphyton and macrozoobenthic population was also observed high that shows its importance. This is a significant contribution to aquatic study in the region.

Keywords: Detritus; riparian; Western Nayar; Uttarakhand.

1. INTRODUCTION

Detritus of aquatic ecosystems is organic material suspended in water and accumulated on river bed floors, which are referred as stream snow. Dead plants or animals, material derived from animal tissues (such as skin cast off during moulting, etc) gradually lose their form, due to both physical processes and the action of decomposers including grazers, bacteria and fungi. Decomposition, the process through which

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organic matter is decomposed, takes place in many stages. Materials like proteins, lipids and sugars with low molecular weight are rapidly consumed and absorbed by microorganisms and organisms that feed on dead matter. Other compounds, such as complex carbohydrates are broken down more slowly.

Various microorganisms are involved in the decomposition or break down the organic materials in order to gain the resources they require for their own survival and proliferation. Headwater streams are usually influenced by riparian vegetation through shading and as the source of organic matter inputs. These low-light, relatively constant temperature headwaters receive significant amounts of coarse particulate organic matter (CPOM; >1-mm diameter) from the watershed. Their most striking biological features are the paucity of primary producers (algae and vascular plants) and the abundance of invertebrates that feed on CPOM [1,2]. The shift from heterotrophy to autotrophy usually occurs in the range of third- or fourth-order (intermediate-sized) streams, though the transition is gradual and varies with geographic region. Fourth and above order streams are generally wide and the canopy of vegetation does not close over them. Direct inputs of CPOM from the riparian zone are lower because of the reduced ratio of length of bank to area of river bottom. Detritus material transported from upstream is largely as fine particulate organic material.

Leaf and wood inputs of the organic material that falls or slides into first-order streams may be flushed less than 50 % to downstream. In general, small streams are very retentive [3]. Debris dams serve as effective retention devices for smaller organic material, allowing time for microbial colonization and utilization, and for invertebrate consumption of this material. Functionally**,** the invertebrates of streams flowing through forests have evolved to gouge, scrape, and shred wood and leaves and to gather the fine organic matter derived from breakdown of coarser material [4].

Many important studies have been conducted in the past on the detritus inputs from the adjoining vegetation worldwide. Some of the important contributors are Anderson and Sedell [5], Vannote, et al. [6], Prochazka, et al., (1991), Wallace, and Webster [7], Abelho, and Graça, [8], Canhoto and Grace [9], Abelho, [10], Richardson and Danehey, [11]. Benfield, et al*.,* [12], Leberfinger, et al*.,* [13] and Sagir and Dobriyal [14,15]. It is noteworthy that in Western Nayar river although the riparian vegetation is studied but detritus ecology and its impact on biodiversity is completely lacking. Hence, the present study is undertaken.

2. MATERIALS AND METHODS

Physiography of the study area: The River Nayar originates from the Dhoodhatoli Mountain at an elevation of 3116 m. Dhoodhatoli Khatil – anticline divide the basin of the Eastern Nayar and Western Nayar which make a confluence near Satpuli at 620 masl. After confluencing at Naugaon kamand (Satpuli), the river enters in a gorge from Marora to Vyasghat where it finally confluences with the river Ganga (Fig. 1). The Western Nayar valley presents a unique set of ecological characteristics over a complex variety of systems that incorporate forests, meadows, grasslands, marshes and rivulets, as well as wildlife, geology and several other phyto-geographically distinctive peculiarities. The occurrence of diverse topographical and climatic factors has resulted in the remarkable biodiversity of the river as a result of which flora also correspondingly differ over its different parts.

The present study is conducted at four different spots, namely Seoli, Inkleswar, Sankarsain, and Chippalghat in the river Western Nayar. These spots are selected on the basis of different riparian vegetation. The first spot is Seoli which is dominated by *Quercus leucotrichophora,* the second is Inkleswar, dominated by *Pinus roxburgii*, the third spot is Sankarsain which is dominated with herbs and shrubs, and the fourth spot is Chippalghat which is dominated by the toxin producing and other medicinal plants like *Euphorbia royleana* and *Sapium insign,* etc.

Methodology for Detritus analysis: Detritus was collected monthly from January 2015 to December 2017 from Western Nayar at four different stations. Course detritus were collected from $1ft^2$ areas and brought to laboratory in poly-pack sampler for analysis. It was further sun dried and biomass was taken as gDW/ft^2 after drying in oven at 105˚C for 24 h. Further ash free dry weight was measured after heating it in muffle furnace at 550˚C for 1 hour as g ash free dry weight $(AFDW)/ft^2$. The similarity of detritus in all the four sampling stations was compared using multivariate cluster analysis. In order to find out its influence on biodiversity, the detritus standing stock was correlated with periphytic and macrozoobenthic density. Periphyton were analysed as $units.cm^{-2}$ [16] and macrozoobenthos as $units.m^{-2}$ [17].

3. RESULTS AND DISCUSSION

The monthly values of dry weight (DW) and ash free dry weight (AFDW) of biomass of the detritus at four different station of the study area for two years are given in the Tables 1 to 8. At station first (Seoli) DW values varied from 2.21 g ft^{-2} in July to 7.42 g ft^{-2} in January 2015 and 1.02 g ft^{-2} in August and highest value 6.22 g ft^{-2} recorded in the month of January in 2016 (Tables 1 and 2). At station 2 (Inkleswar) maximum DW that is 6.50 was recorded in the month of December and lowest in the month of August (i.e. 2.81 g ft^{-2}) in 2015 and same trend followed in 2016 (Tables 3 and 4). At station 3 (Sankarsain) maximum DW of detritus was seen in the month of December (4.02 g ft^{-2}) and minimum in the month of July (1.15 g ft^{-2}) in 2015 and in 2016 maximum DW was found in January and minimum in the month of July (Tables 5 and 6). At station 4 that is Chippalghat, highest DW was recorded in January (8.68 g.ft^{-2}) and lowest in the month of August (3.78 g.ft^{-2}) but in 2016, highest value of DW was recorded in December (8.78 g.ft^{-2}) and lowest in August (2.83 g.ft^{-2}) (Tables 7 and 8).

Ash free dry weight of the study area also showed great variation. Maximum AFDW at S-1 in 2015 and 2016 was observed in the month of December (3.28 g.ft^{-2}) –January (3.03 g.ft^{-2}) and minimum in the month of August (0.89 and 0.45 g.ft^{-2} respectively). S-2, S-3 and S-4 Site also showed maximum AFDW of detritus in the month of January and December and minimum in the month of July and August in both the years (Tables 1-8).

AFDW and DW values of detritus showed great variation among four stations during the study period. Maximum AFDW and DW of the detritus were recorded in winter months and minimum during monsoon. During winter months, the current velocity is low as compare to monsoon months so more litter fall accumulated that formed detritus. Analysis of seasonal data revealed that maximum detritus was found in winter season followed by spring, summer, autumn and least in monsoon season as shown in Fig. 2. In monsoon season current velocity is high as compare to winter months so fewer amounts of detritus accumulates in the river. Our observation on more detritus formation in winter (Fig. 3) supports the finding of Iqbal and Webster [18] in river Exe. Cluster Analysis showed that the spots S-2 and S-4, having almost similar biomass of detritus production, clustered closely and the spots S-1 and S-3 clustered in another group due to their similarity in detritus formation during 2015, but during 2016, the spots S-1 and S-3 showed more similarity so they cluster closely and S2 and S4 grouped into another cluster. The different clusters in both the years were due to different environmental conditions of the river. This might be the effect on the amount of biomass formation of the particular site (Figs. 2-3).

According to Abelho (1996), mixed forest (*Pinus spp.* & *Quercus spp* etc) and other eucalyptus plantations differ in the yearly amount of organic matter production in central Portugal. Same results were seen in the western Nayar River. Mixed forest produce more litter fall as compare to *Quercus* at Seoli. Leaves that enter the stream systems are normally transported short distances but are usually caught by the structures on the stream bed to form assemblages of leaf packs.

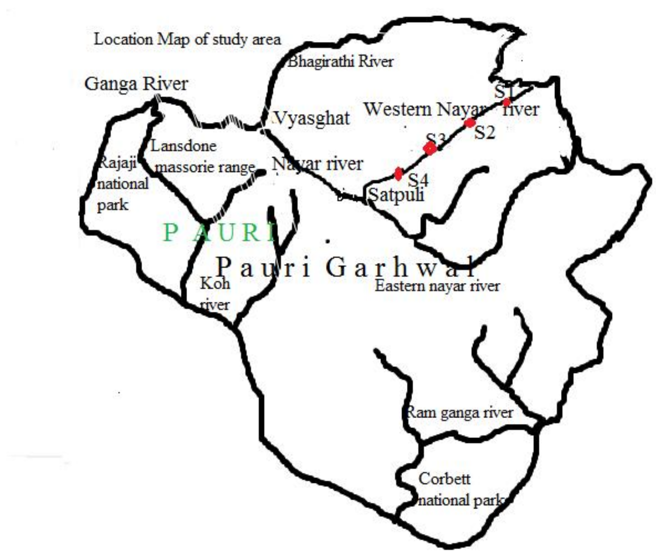

Fig. 1. Map of study area (River Western Nayar in Pauri Garhwal)
S1-Seoli, S2-Inkleswar, S3-Sankarsain and S4-Chippalghat

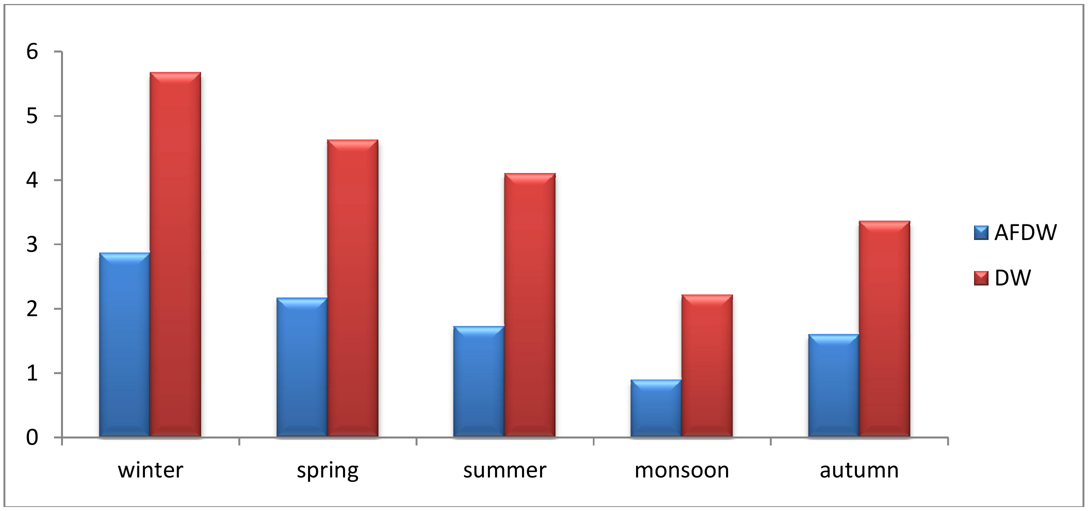

Fig. 2. Seasonal variation of DW g/ft^2 and AFDW g/ft^2 in Western Nayar River

After being trapped, these leaf packs are 'processed' in place by components of the stream aquatic community in a series of clear steps [12]. Within one or two days after the leaves have entered the stream, many soluble nutrients leach out of the leaf's cellular matrix and enter the water. However, there is an evidence that some soluble materials remain in dead leaves long after they have been immersed in water [13]. The statement is also observed true in western Nayar River. Grass, herbs, and shrubs as a source of detritus have received little attention as an allochthonous resource, most likely because of the conclusions from our studies attributing them to low nutrient concentrations and hence the thinking that they make a poor food resource to macro-invertebrate consumers. Similar opinion was made by Menninger and Palmer, [19].

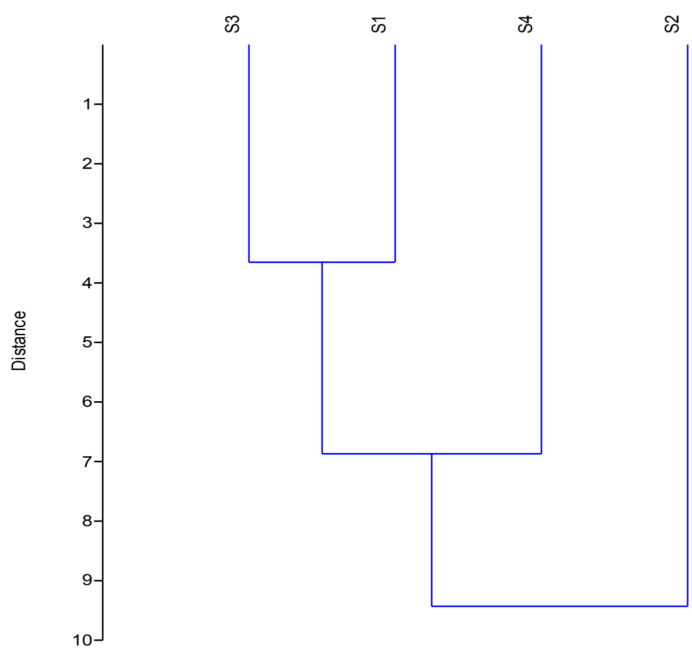

Fig. 3. Cluster analysis of AFDW at four different stations during 2015
Spots (1= Seoli, 2= Inkleshawar, 3= Sankarsain, 4= Chippalghat)

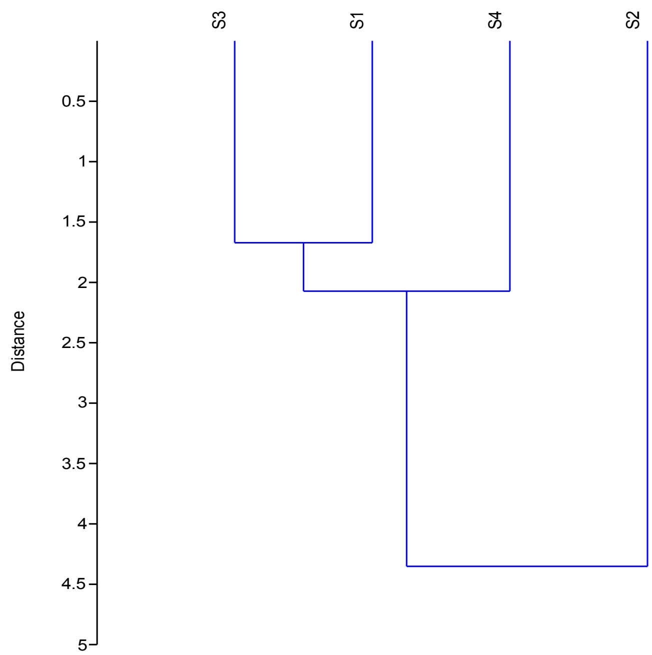

Fig. 4. Cluster analysis of AFDW at four different sampling station during 2016 Spots (1= Seoli, 2= Inkleshawar, 3= Sankarsain, 4= Chippalghat)

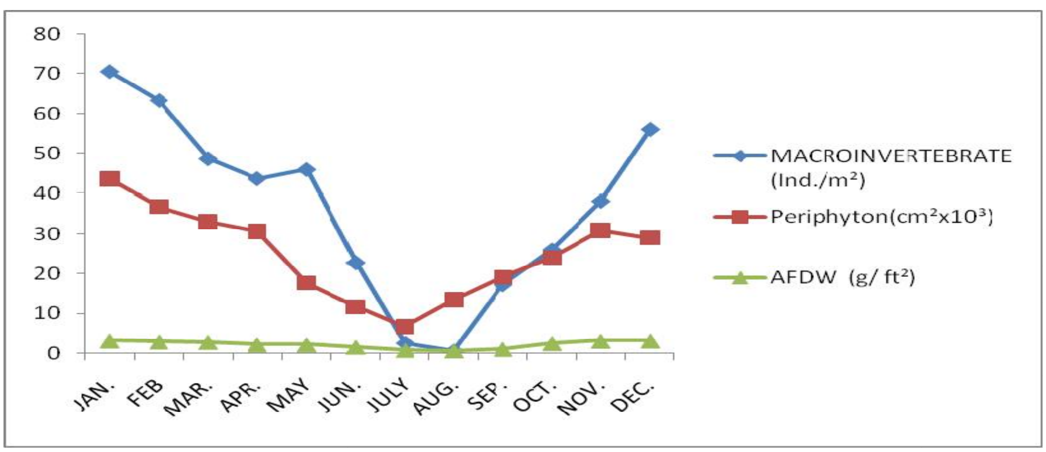

Fig. 5. Comparative analysis of biotic parameters (detritus, periphyton and macrozoobenthos) at Spot No 1 (Seoli)

Increased organic carbon accompanied by low atmospheric exchange can make habitats to be temporarily anoxic with low oxygen levels < 2 mg l^{-1} that can lead to death of aquatic animals. Organic materials in aquatic ecosystems may have anoxic zones associated with them. Decaying leaves have anoxic zones at their surfaces. Kaushik and Hynes [20] noted that detritivores prefer leaves that have been subject to microbial colonization and "conditioning". They observed that in the early stages of decay, the nitrogen and protein content of such leaves increases, and assumed that the increase was due to microbial biomass developing on the leaves. Consumption of leaf plus microbes would therefore provide a more nutritious diet to an animal than a sterile leaf. Subsequent studies have confirmed this assumption and have demonstrated further that animals choose to eat leaf patches that are colonized by fungi when these organisms are at the height of their metabolic activity [21].

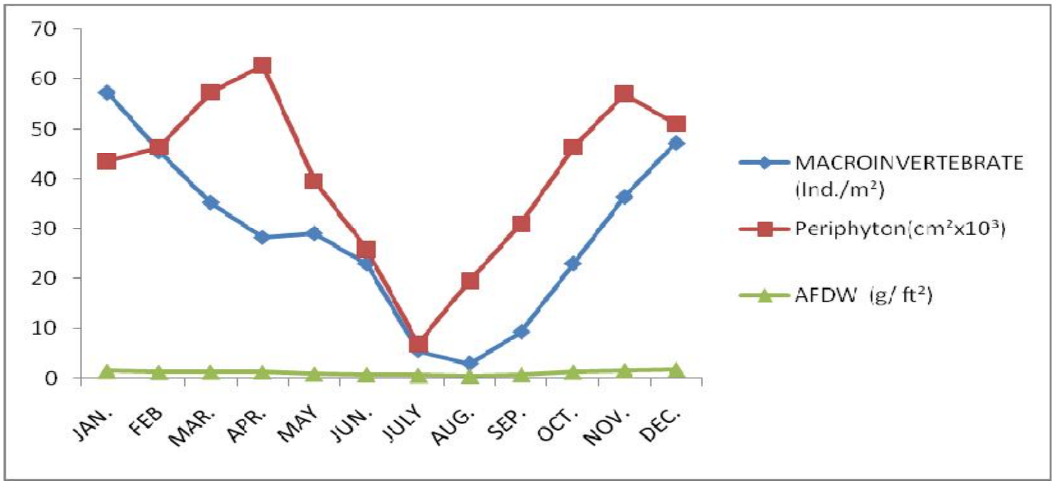

Fig. 6. Comparative analysis of biotic parameters (detritus, periphyton and macro- zoobenthos) at Spot No 2 (Inkleshwar)

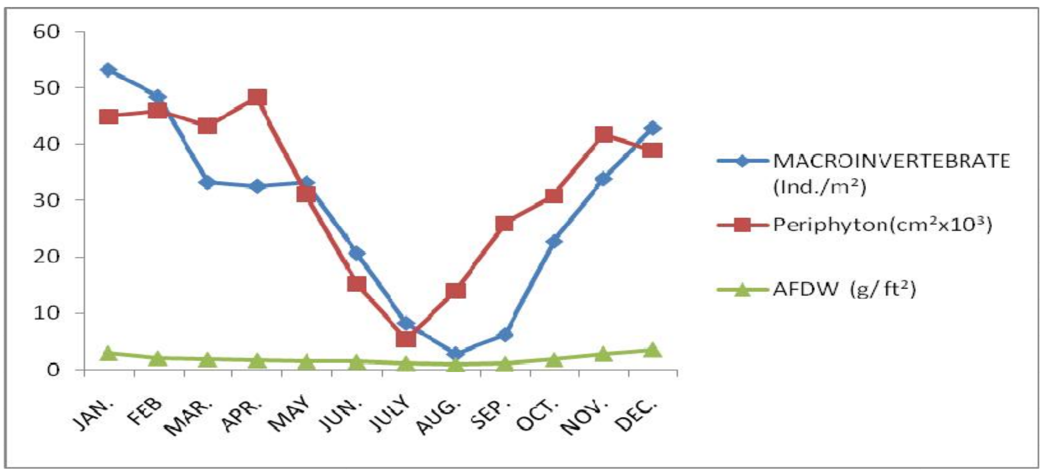

Fig. 7. Comparative analysis of biotic parameters (detritus, periphyton and macro- zoobenthos) at Spot No 3 (Sankarsain)

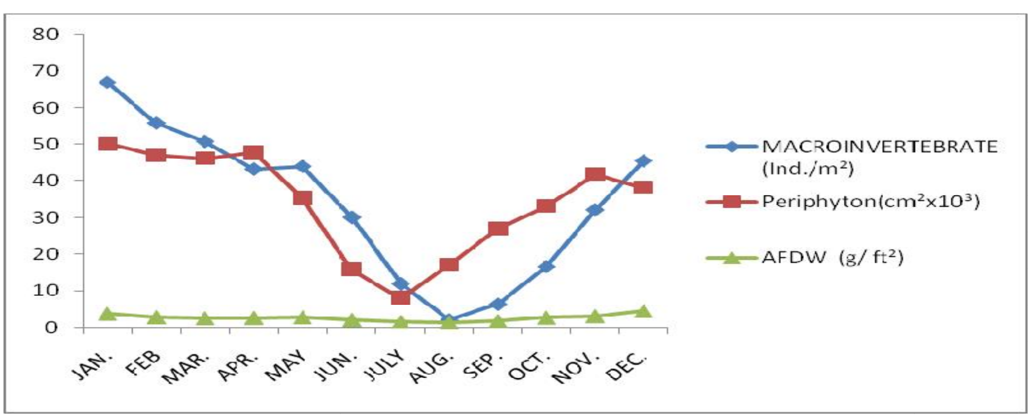

Fig. 8. Comparative analysis of biotic parameters (detritus, periphyton and macro- zoobenthos) at Spot No 4 (Chippalghat)

Table 1. Monthly variation in biomass of the detritus (g,ft^{-2}) at S-1 (Seoli) during 2015

Months	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Fresh weight material(g)	12.25	12.38	10.73	11.48	8.32	8.3	4.38	4.8	5.75	7.2	10.05	13.45
Dry weight of material (g)	7.42	7.31	6.65	7	5.34	4.73	2.21	2.52	2.2	4.09	6.8	7.04
Ash free weight(g)	3.24	3.15	3.13	3.02	2.75	2.38	1.01	0.81	1.02	2.78	3.25	3.28

Table 2. Monthly variation in biomass of the detritus (g,ft^{-2}) at S-1 (Seoli) during 2016

Months	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Fresh weight material(g)	13.75	12.88	9.32	7.04	7.16	4.73	2.78	2.5	4.05	6.1	9.03	11.95
Dry weight of material(g)	6.22	5.01	4.65	3.03	3.34	1.63	1.31	1.02	2.1	4.3	4.9	5.04
Ash free weight(g)	3.03	2.65	2.41	1.33	1.54	0.72	0.53	0.45	1.06	2.17	2.85	2.96

Table 3. Monthly variation in biomass of the detritus (g,ft^{-2}) at S-2 (Inkleswar) during 2015

Months	JAN.	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP.	OCT	NOV	DEC
Fresh weight material(g)	11.00	9.01	9.10	8.38	7.48	6.08	6.02	5.32	5.70	6.10	10.18	11.95
Dry weight of material (g)	6.01	4.82	5.23	4.92	4.02	3.32	3.01	2.81	3.0	3.11	6.23	6.50
Ash free weight(g)	3.72	2.32	2.25	2.08	2.00	1.95	1.41	1.01	0.82	1.80	3.08	3.90

Table 4. Monthly variation in biomass of the detritus (g,ft^{-2}) at S-2 (Inkleswar) during 2016

Months	JAN.	FEB	MAR.	APR.	MAY	JUN.	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
Fresh weight material(g)	9.74	9.41	9.20	8.01	7.28	6.08	5.01	4.02	6.10	8.10	10.16	10.80
Dry weight of material (g)	4.05	3.52	3.33	3.28	4.32	2.62	1.98	2.00	3.71	3.81	4.23	5.03
Ash free weight(g)	2.25	1.92	1.50	1.35	1.18	1.05	0.97	0.91	1.41	2.10	2.66	3.32

Table 5. Monthly variation in biomass of the detritus (g,ft^{-2}) at S-3 (Sankarsain) during 2015

Months	JAN.	FEB	MAR.	APR.	MAY	JUN.	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
Fresh weight material(g)	6.30	4.38	4.732	6.48	3.32	3.35	2.80	2.01	3.01	4.40	6.01	7.83
Dry weight of material (g)	3.92	2.51	2.90	4.29	2.01	2.13	1.15	1.38	1.78	2.03	3.32	4.02
Ash free weight(g)	1.76	1.50	1.63	1.82	0.91	0.88	0.65	0.51	0.72	1.39	1.93	2.14

Table 6. Monthly variation in biomass of the detritus (g,ft^{-2}) at S-3 (Sankarsain) during 2016

Months	JAN.	FEB	MAR.	APR.	MAY	JUN.	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
Fresh weight material(g)	5.25	4.55	4.32	4.42	3.98	3.30	2.08	1.90	3.05	4.52	4.77	5.65
Dry weight of material (g)	2.75	2.34	1.70	1.90	1.80	1.37	1.01	0.81	1.28	2.83	2.02	2.12
Ash free weight(g)	1.06	0.93	0.88	0.82	0.70	0.47	0.41	0.31	0.72	1.10	1.14	1.22

Table 7. Monthly variation in biomass of the detritus (g,ft^{-2}) at S-4 (Chippalghat) during 2015

Months	JAN.	FEB	MAR.	APR.	MAY	JUN.	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
Fresh weight of material(g)	15.21	12.05	9.02	13.01	10.05	10.1	7.2	8.67	9.5	10.18	14.20	16.1
Dry weight of material(g)	8.68	6.82	5.55	8.06	6.21	5.30	4.06	3.78	4.70	5.09	8.75	8.56
Ash free weight(g)	3.51	3.23	2.80	3.04	2.19	2.01	1.9	1.68	2.10	2.79	3.02	4.90

Table 8. Monthly variation in biomass of the detritus (g,ft^{-2}) at S-4 (Chippalghat) during 2016

Months	JAN.	FEB	MAR.	APR.	MAY	JUN.	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
Fresh weight of material(g)	12.41	10.05	10.02	13.5	12.3	9.35	7.85	6.05	9.45	11.18	12.34	18.1
Dry weight of material(g)	6.80	6.21	5.50	6.56	6.01	4,05	3.60	2.83	4.71	5.03	7.02	8.78
Ash free weight(g)	3.72	2.23	2.07	2.04	3.19	2.0	0.98	0.80	1.24	2.39	3.03	3.90

Table 9. Monthly mean values of dry weight of detritus (g,ft^{-2}) at different sampling station

Months	JAN.	FEB	MAR.	APR.	MAY	JUN.	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
S1	6.82	6.16	5.65	5.015	4.34	3.18	1.76	1.77	2.15	4.195	5.85	6.04
S2	3.335	2.425	2.3	3.095	1.905	1.75	1.08	1.095	1.53	2.43	2.67	3.07
S3	5.03	4.17	4.28	4.1	4.17	2.97	2.495	2.405	3.355	3.46	5.23	5.765
S4	7.74	6.515	5.525	7.31	6.11	5.3	3.83	3.305	4.705	5.06	7.885	8.67
Average	5.73125	4.8175	4.43875	4.88	4.13125	3.3	2.29125	2.14375	2.935	3.78625	5.40875	5.88625

Table 10. Monthly mean values of ash free dry weight of detritus (g,ft^{-2}) at different sampling station

Months	JAN.	FEB	MAR.	APR.	MAY	JUN.	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
S1	3.135	2.9	2.77	2.175	2.145	1.55	0.77	0.63	1.04	2.475	3.05	3.12
S2	1.41	1.215	1.255	1.32	0.805	0.675	0.53	0.41	0.72	1.245	1.535	1.68
S3	2.985	2.12	1.875	1.715	1.59	1.5	1.19	0.96	1.115	1.95	2.87	3.61
S4	3.615	2.73	2.435	2.54	2.69	2.005	1.44	1.24	1.67	2.59	3.025	4.4
Average	2.78625	2.24125	2.08375	1.9375	1.8075	1.4325	0.9825	0.81	1.13625	2.065	2.62	3.2025

From the above discussion it can be clearly concluded that detritus is an important energy source for streams and rivers. However, actual availability depends on the extent to which it is retained within the system. The retentive capacity of a watercourse detritus is governed by the structure of the channel, the nature of the substratum, flow rate, rainfall and types of riparian vegetation along the river bank. Dobson and Hildrew [22] manipulated the litter-retention characteristics of four low-order streams and found increased shredder populations associated not only with introduced litter traps, but in the stream bed between traps. They concluded that resource limitation may be a decisive factor in controlling populations of invertebrates in low-order streams. Leaching is more rapid in dried leaves than in fresh, senescent leaves where the cell walls retain their integrity longer. Most leaching occurs within 24 hours of submersion, accompanied by losses of up to 30% in mass, but it may continue for up to 2 weeks depending on leaf species [23]. Wood has very little soluble matter and rapid mass loss through leaching has not been observed, although a slow loss of soluble matter is believed to occur during decomposition. *Quercus* dominated forest have high litter-fall as compare to other vegetation in Western Nayar valley, which impart maximum detritus to Nayar river at spot 1 (Seoli), followed by spot 4 with mixed forest vegetation dominated by medicinal plants like *Sapium* and *Euphorbia* (Tables 9-10). Minimum detritus was recorded at spot 3 (Sankarsain) which is dominated by herbs and shrubs, because the weight of detritus material of herbs and shrubs is very low and its unable to settle down in the river substratum and followed by S2 (Inkleswar) which is dominated by Pinus vegetation, Pinus needle accumulates faster in the river but took longer times for leaching and decompose and in coniferous forest vegetation where needle-fall is less seasonal. In the herbs and shrubs dominated spot, litter is mainly in the form of dead grasses and Leaf litter either falls, freshly abscessed, into the water, or dries along the riparian zone and is blown or washed into the watercourse.

While interpreting the biodiversity data of Western Nayar, it was noticed that higher concentration of detritus always encouraged the growth of periphyton and macrozoobenthos (Figs. 5-8). This observation corroborates with Rios and Bailey [24] who examined the influence of riparian vegetation on benthic population in the Upper Thames river in Ontario and observed that the population of ephemeroptera, plecoptera and trichoptera increased significantly with an increase in tree covers in riparian area.

4. CONCLUSION

The vegetation around River Nayar contributes detritus and help significantly in soil conservation, productivity and aquatic biodiversity. The present study also suggests that the riparian vegetation directly or indirectly helps the aquatic fauna for feeding, breeding and spawning**.** The detritus in the Western Nayar River also alter the physio-chemistry of the river.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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