Phytosociology, biomass and net primary production of bryophyte community growing on decaying logs in silver fir forest of central Himalaya

Neerja Pande and Prachi Joshi

Botany Department, D.S.B. Campus, Kumaun University, Nainital –263 002

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The temperate, evergreen conifer forest of silver fir (*Abies pindrow* Spach.) in the Pindar catchment of Nanda Devi Biosphere Reserve in Central Himalaya offers a wide range of habitats for the establishment and expansion of liverworts and mosses. Decaying wood, one of the habitats, is a patchy, short lasting substrate for bryophytes and it was observed that with time, there was gradual change in substrate during the course of the establishment and expansion of bryophyte propagules. The present paper examines the species composition, phytosociology, pattern of biomass and net primary production of bryoflora growing on decaying logs. On the basis of availability and luxuriance of bryocover, the logs were selected. A total of 9 quadrats of 5cm X 5cm size were laid at seasonal interval on each log at three positions, i.e. top (upper surface), middle (sides of the log) and base (close to the ground) of the log. Fifteen species of bryophytes spreading over eleven families were recorded. Morphologically, taxa were grouped into leafy liverwort (1), acrocarpic mosses (3) and pleurocarpic mosses (11). Based on Importance Value Index (IVI) *Dicranum scoparium*, an acrocarpic moss, (IVI=112.38) was the dominant species while *Entodon plicatus* (IVI=51.62) co-dominated. Least dominant species was *Leucodon secundus* (IVI=1.16). Maximum percent biomass was amounted to in rainy season and it was greatest at the base (235 gm^{-2}) position of the log. Among the different morphological forms, pleurocarps added maximum 61% biomass of the total. The two pleurocarps *Entodon plicatus* and *Brachythecium salisbrosum* were the main contributor to the pleurocarpic group, whereas, *Dicranum scoparium* added 133.8 gm^{-2} biomass to the community. Net primary production was maximum (481 gm^{-2}) during the rainy season.

Key-words—Bryophyte, Biomass, Decaying logs, Habitat, Phytosociology, Silver fir.

INTRODUCTION

THE temperate forests of higher altitude Central Himalaya are predominated by different evergreen and deciduous tree species along an altitudinal gradient. Between Dhakuri and Khati *Abies pindrow* Spach. (silver fir), an evergreen conifer with several years of leaf life span, formed the dominant forest at an altitude of 2500m asl, on north aspect at 52^0 slope. Along with this dominant species, several other trees like *Quercus semecarpifolia, Symplocos chinensis, Quercus floribunda* and *Aesculus Indica* were also associated (Champion & Seth 1968).

The cool and moist temperate climate of this forest housed a number of bryophytes on a wide variety of habitats, thus forming an important component of the ecosystem. Decaying wood, one of the habitats, is a patchy, short-lasting substrate for bryophytic vegetation. It was observed that as the time progresses, gradual changes in substrate occurred during the course of the establishment and expansion of the bryophyte propagules due to the varied degrees of macro and micro environmental variations. This resulted into the change of the bryophyte vegetation with time. But these small plants were not taken into account by the workers dealing with various aspects of ecology of higher plants in forest ecosystems of higher altitudes of Pindar catchment of Nanda Devi Biosphere Reserve (Garkoti, 1992; Singh & Singh 1992). In view of this, the present study was carried out to assess the composition, phytosociology, biomass and net primary production in bryophytic vegetation growing on decaying logs in silver fir forest of Central Himalaya.

MATERIAL AND METHOD

The study site, i.e. the silver fir forest is located at an altitude of 2500m (79^0 40'-80^0 50' E longitude to 30^0 17'-30^0 40'N latitude and 52^0 slope) at north aspect between Dhakuri and Khati in the Pindar catchment of Nanda Devi Biosphere Reserve in Central Himalalya. The mean maximum, temperature ranged from 11.7^0 C (January) to 25.8^0 C (June) and

mean minimum temperature from - 0.5° C (February) to 12° C (June). Mean annual rainfall was 1958mm (Data recorded from weather station, Munsiari, 2250m).

In silver fir forest, about 1 hectare area, decaying logs having rich bryocover were selected. Bryophytic vegetation on the selected logs was quantitatively estimated during the period from May 1990 to May 1991 following the standard methods of Misra (1968), by placing 9 quadrats each of 5cm X 5cm size at three positions i.e., at the upper surface of log (top), at the sides of log (middle) and near the ground (base). Sampling was done seasonally (rainy, winter and summer). The quadrat data thus collected from each log were analysed for species composition, frequency, density, biomass, importance value index (IVI) and net primary production (Misra 1968; Pande & Singh 1989; Joshi 1993)). Bryophytes were identified in the laboratory following Kashyap (1929-32) and Gangulee (1972, 1977, 1980).

Since the fallen logs had lost all their leaves and most of the bark and it was difficult to identify the tree species, therefore, all selected logs were called decaying logs. The selected logs were marked in the field and circumference of each log was measured with tape. Various characteristics like diameter (cm.); percent decay stage; percent direct contact to ground; percent bark cover; wood texture of each log were examined following Soderstrom (1987). Moisture content (%)and pH was also determined (Brodo, 1974). The data of substrate characteristics are given Table 1.

Table 1 : Certain physical features of decaying logs in silver fir forest

Parameters	
Circumference (cm)	167.5
Decay stage (%)	85
Direct contact to ground (%)	76
Bark cover (%)	4
Wood texture	large wood pieces lost, large crevices, fissured
pH	5.34
Moisture content (%)	46.3(R)29.2(W) 25.5(S)

RESULT AND DISCUSSION

In the present study, the logs had lost approximately 95 percent of bark and were deeply fissured. Also, at places, small wood pieces were lost, thus making the surface uneven for easy colonization of propagules. On this rugged and uneven surface of logs, fifteen species of mosses and liverworts constituted the bryophytic community. Based on their morphology, the bryophytes were grouped into different classes namely, leafy liverwort (1), acrocarpous moss (3) and pleurocarpous moss (11). No thalloid liverwort was collected from the logs.

These fifteen bryophytes were spread over eleven families (Table 2). Out of these fifteen species, *Porella* sp., *Anomodon minor, Brachythecium* sp., *Leucodon secundus, Meteorium buchananii* and *Ptilium crista-casterensis* were reported only once, i.e. in the rainy season and disappeared later on. The disappearance of these species may be attributed to the fact that bark and wood pieces have been fallen off because of repeated drying and wetting of the log and also due to the low moisture status of the log in winter (29.2%) and summer (25.5%) seasons. Besides, the amounts of *Leucodon secundus,*

Table 2: Bryophytes, their morphological forms and families

S. No.	Taxon	Family	Morphological
1.	*Porella* sp.	Porellaceae	L.L
2.	*Bryoerythrophyllum wallachii*	Pottiaceae	A
3.	*Dirarum scoparium*	Dicranaceae	A
4.	*Symbephelris* sp.	Dicranaceae	A
5.	*Anodomon minor*	Thuidiaceae	P
6.	*Brachythecium salisbrosum*	Brachytheciaceae	P
7.	*Brachythecium* sp.	Brachytheciaceae	P
8.	*Entodon plicatus*	Entodontaceae	P
9.	*Luecodon secundus*	Leucodontaceae	P
10.	*Macrothamnium macrocarpum*	Hylocomiaceae	P
11.	*Macrothamnium submacrocarpum*	Hylocomiaceae	P
12.	*Meteorium buchananii*	Meteoriaceae	P
13.	*Ptilium crista-casterensis*	Hypnaceae	P
14.	*Thuidiuum cymbifolium*	Thuideaceae	P
15.	*Trachypodopsis serrulata*	Trachypodiaceae	P

L.L=Leafy liverwort; A=acrocarpous moss; P=pleurocarpous moss

Meteorium buchananii and *Ptilium crista-casterensis* were also very small thus restricting the expansion of these species in rather harsh environment of winter.

Further, *Brachythecium salisbrosum, Dicranum scoparium* and *Symbephelris* sp. were the epixylics and were not reported from any other habitat of silver fir forest. Soderstrom (1987) reported *Dicranum scoparium* as a late epixylic in his study. *Macrothamnium macrocarpum* and *Bryoecrythyrophyllum* of this study were also reported as rotten log species at higher altitude (3500m) by Tewari *et al*, (1994). But in this study, we cannot include *M. macrocarpum* as true epixylic because it was also reported from the tree stems of kharsu oak and silver fir (Joshi, 1993). On the other hand, *Ptilium crista-casterensis,* a ground flora species, collected from the forest floor of kharsu oak and maple (Joshi 1993) and from humus rich soil at high altitude (3500m-3800m) was absent in silver fir forest floor. The absence of this species from other habitats indicated that it perhaps required more mesic substratum for its growth. The accidental occurrence of *Ptilium* on the decaying logs may perhaps be due to the chanced colonisation of wind blown propagules from the adjoining sites during rainy season but failed to establish and expand due to low moisture status of the log in winter months.

Entodon plicatus, Thuidium cymbifolium, Macrothamnium submacrocarpum and *Brachythecium salisbrosum* were the most frequent pleurocarps. During (1990) reported *Thuidium tamariscinum* and *Brachythecium rutabulum* and others as fast growing pleurocarpic mosses. It appears, in our study, that the *Entodon plicatus, Thuidium cymbifolium. Macrothamnium submacrocarpum* and *Brachythecium salisbrosum* all are fast growing pleurocarpic mosses thus covering the log surface more rapidly compared to the acrocarpic mosses, Interestingly, excepting *Brachythecium salisbrosum,* all other pleurocarpic mosses, especially *Entodon plicatus, Thuidium cymbifolium* and *Macrothamnium submacrocarpum* exhibited a wide range of distribution as they were not only reported from higher altitudes but also from lower altitudes as well. This pattern indicated that these species had a broad spectrum of ecological amplitude with similar micro environmental conditions. The epixylics, on the other hand, had a restricted distribution suggesting narrow ecological amplitude.

In terms of IVI density, frequency and biomass, *Dicranum scoparium,* an acrocarpic moss, predomi-

Table 3 : Analysis of bryophyte community growing on decaying logs in silver forest of higher altitude.

S. No.	Species	Frequency (%)	Density (individuals m^{-2})	Biomass (gm^{-2})	Relative frequency (%)	Relative density (%)	Relative biomass (%)	Importance value Index
1.	*Porella* sp.	8.86	2702	16.86	3.15	3.77	2.99	9.91
2.	*Bryoerythrophyllum wallachii*	8.90	2356	23.11	3.17	3.29	4.09	10.55
3.	*Dicranum scoparium*	69.26	45742	133.82	24.69	63.96	23.73	112.38
4.	*Symbephelris* sp.	8.91	3991	19.56	3.17	5.58	3.47	12.22
5.	*Anodomon minor*	6.66	1369	15.11	2.37	1.91	2.67	6.95
6.	*Brachythecium salisbrosum*	42.22	1612	03.11	15.04	2.25	18.29	35.58
7.	*Brachythecium* sp.	4.46	729	9.810	1.59	1.01	1.73	4.33
8.	*Entodon plicatus*	64.43	6436	111.10	22.90	8.99	19.71	51.62
9.	*Luecodon secundus*	2.23	44	1.76	0.79	0.06	0.31	1.16
10.	*Macrothamnium macrocarpum*	20.01	2836	55.23	7.13	3.96	9.79	20.88
11.	*Macrothamnium submacrocarpum*	17.81	2098	39.12	6.34	2.93	6.93	16.21
12.	*Meteorium buchananii*	4.46	71	3.56	1.59	0.09	0.63	2.31
13.	*Ptilium crista-casterensis*	2.23	249	4.43	0.79	0.34	0.78	1.91
14.	*Thuidium cymbifolium*	15.6	1138	23.56	5.56	1.59	4.17	11.32
15.	*Trachypodopsis serrulata*	4.46	142	3.56	1.59	0.19	0.63	2.31

nated the community. *Entodon plicatus* co-dominated (Table 3). Another pleurocarpic moss, *Brachythecium salisbrosum* had relatiavely high biomass (103 gm^{-2}) compared to other pleurocarpic moss, on account of low relative density and frequency, this species had low IVI value and therefore it lagged behind *Entodon plicatus. Leucodon secundus* had maximum density and biomass, therefore, on the basis of IVI , the community of decaying logs was described as *Dicranum -Entodon* type. Joshi (1993) reported the communities on silver fir phorophytes across the different girth classes. Accordingly, the communities were *Brachythecium - Entodon* (A); *Brachythecium - Porella* (B); *Trachypodopsis Entodon* (C); *Trachypodopsis - Entodon* (D) and *Porella - Brachythecium* (E).

Seasonal changes in bryophytic biomass data (Table 4) exhibited the maximal values (238 gm^{-2}) in rainy season followed by sudden decline in winter (174 gm^{-2}) season. Similar pattern in biomass was reported by Joshi (1993) for epiphytic bryophytes on silver fir stems. The rapid decline in biomass during winter is due to the low moisture status of logs (29.2%) and the exposure of plants to high winds.

Table 4 : Biomass (gm) of bryophytes on decaying logs, across the season and position in silver fir forest of higher altitude in Central Himalaya.

Seasons	Biomass (gm^{-2}) Position on the log			
	Top	Middle	Base	Average
Rainy	126.6	282.6	305.3	238.1
Winter	153.3	196.0	173.4	174.2
Summer	170.6	122.7	226.7	173.3
Average	150.2	200.4	235.1	

Across the position, approximately 40% biomass was amounted to the base position followed by middle (34%) and top position. The low values of biomass at top position indicated the xeric nature of the substratum which was not favourable for the luxuriance of bryophytes whereas, the basal portion had enough moisture to support large amounts of biomass.

Among the different morphological groups, biomass varied significantly. Approximately 61% of the total bioamass was contributed by pleurocarpic moss (Table 5) which was about two times more than the acrocarpic moss. Rastorfer (1978) reported about 77% pleurocarpic biomass in wet tundra community. Pande and Joshi (2002) reported comparatively higher biomass, i.e. approximately 76% and 80% pleurocarpic biomass in decaying log communities of kharsu oak and horse chestnut forest of Pindar catchment. *Entodon plicatus* and *Brachythecium salisbrosum* added approximately 70% of the total pleurocarpic biomass whereas for acrocarpic mosses *Dicranum scoparium* was the main contributor.

Table 5: Across the season, percent biomass in different morphological groups of bryophytes on decaying log communities of silver fit forest at higher altitude.

Morphological Forms	Biomass(per cent)			
	Rainy	Winter	Summer	Average
Leafy liverworts	7.3			3.39
Acrocarpous mosses	39.3	43.4	26.15	35.5
Pleurocarpous mosses	53.3	56.5	73.84	61.1

By comparing the bryophytic biomass on decaying logs of silver fir forest to that of epiphytic bryophytic biomass of the same forest (Joshi 1993), the mean annual biomass value on decaying logs was approximately two times greater (585.7 gm^{-2}) than the epiphytic biomass of bryophytes on silver fir stems (337.2gm^{-2}). However, the value of biomass of this study was much less than the biomas on decaying logs of horsechestnut (1030gm^{-2}) and kharsu oak (716 gm^{-2}) forests. The differences in biomass, among the log communities of different forests may be due to comparatively more mesic conditions (mc=330%, in horse chestnut forest, and mc=114% in kharsu oak forest) of decaying logs in other two forests than the silver fir forest.

The net primary production of bryophyte community on the decaying logs was about 1125 gm^{-2} y^{-1} and the maximum value (481 gm^{-2} y^{-1}) was recorded

Table 6: Net primary production of bryophyte community on decaying logs in silver fir forest of high altitude.

Seasons	Net Primary Production (gm^{-2} y^{-1}) Position on the log			
	Top	Middle	Base	Average
Rainy	94	178	209	481
Winter	103	138	75	316
Summer	72	65	191	328

during the rainy season (Table 6). Across the position, the pattern of dry matter yield was in accordance with the biomass being highest in rainy season. The net primary production of decaying log communities was approximately two fold to that of the epiphytic bryophyte communities of silver fir stems where it was 657.8 gm^{-2} y^{-1}.

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