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Regeneration status of woody species in a protected area of Western Himalaya

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ABSTRACT

Estimates of future species composition that exist following natural regeneration are very important to forest managers and silviculturists. The regeneration status/potential of a species in a community can be assessed from the population dynamics of seedlings and saplings in the forest community. Thus the main objective of the present study was to investigate natural regeneration status/potential of woody tree species in *Madhmeshwar* area of Kedarnath Wildlife Sanctuary and the study revealed that density of seedlings ranged from 155 individuals ha^{-1} (zone-II 2000–2200 m) to 695 individuals ha^{-1} (zone-I 1550–1750 m) and similar trend was found in the densities of saplings (160–330 individuals ha^{-1}) respectively. The new regeneration was found only in altitudinal zone-IV and altitudinal zone-V. The TBC was found highest in altitudinal zone-I followed by altitudinal zone-III for both seedlings and saplings. The distribution of density and individual percentage was observed highest in 0–15 GBH class at altitudinal zone-I followed by altitudinal zone-III however the girth class distribution of individuals showed a reverse J-shaped curve for all the species at all the altitudinal zones. The present study concludes that the regeneration pattern or the growth of seedlings and saplings decreases with increase in altitudinal gradient while the increase in biotic pressure in some pockets of higher altitudes is affecting regeneration pattern of species which may affect the species composition in future, however the shift of tree species toward upper altitudes might be variation in temperature.

1. Introduction

The successful regeneration of a tree species depends on the ability of its seedlings and saplings to survive and grow [1]. The population structure characterized by the presence of sufficient number of seedlings, saplings and young trees depicts satisfactory regeneration behavior, while inadequate number of seedlings and saplings of tree species in a forest indicates poor regeneration [2]. However, the presence of sufficient number of seedlings, saplings and young trees is greatly influenced by interaction of biotic and abiotic factors of the environment [3,4]. A sustained regeneration and growth of all species in the presence of older plants is required for the growth of any plant community [5]. In order to achieve sustainable forest management there is a need to assess the trends in forest conditions over time and regeneration is a critical phase of forest management, because it maintains the desired species composition and stocking after disturbances.

Regeneration of any species is confined to a peculiar range of habitat conditions and the extent of those conditions is a major determinant of its geographic distribution [6]. Population structure of a species in a forest can partly convey its regeneration behavior [2]. Forests of central Himalaya face a serious threat both natural as well as anthropogenic. Eventually, many species have become endangered. This implies a poor natural regeneration potential of the tree species. Regeneration and seedling distribution in conifer forests have been shown to be influenced by both large-scale disturbances such as wildfire and forest clearing [7,8]. Regeneration status of trees can be predicted by the age structure of their populations [9–11]. The study of regeneration of forest trees has important implication for the management of natural forests, and is one of the thrust areas of forestry. Regeneration is the process of silvigenesis by which trees and forests survive over time [12]. Research in this field contributes to planning, conservation and decision making in forest resources management programmes. Therefore the present study was carried out in *Madhmeshwar* area of Kedarnath Wildlife Sanctuary to assess its regeneration status of woody tree species.

2. Materials and methods

2.1. Study area

The study was carried out in *Madhmeshwar* area located between the coordinates 30°35′42″–30°38′12″N, 79°10′00″–79°13′00″E. The

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study area is the interior part of Kedarnath Wildlife Sanctuary in Western Himalaya, Uttarakhand India (Fig. 1). Kedarnath Wildlife Sanctuary (KWLS) was established in 1972 and is famous for the endangered Musk Deer. The KWLS is one of the largest protected areas (975 km^2) in the Western Himalaya located in Chamoli-Rudraprayag districts (25,293.70 ha in Chamoli district and 72,224.10 ha in Rudraprayag district) of Uttarakhand and falls under the IUCN management Category IV (Managed Nature Reserve) in the Biogeographical Province 2.38.12 of Himalayan highlands. The sanctuary lies in the upper catchment of the Alaknanda and Mandakini Rivers, which are major tributaries of Ganges. The area receives 300 cm of annual precipitation of which the rainy months (June–August) contribute approximately 60%. The relative humidity varies from 35 to 85% annually. There is moderate to heavy snowfall during winter (December–February), even in low altitude areas. The mean maximum temperature varies between 4 °C (January) and 33.5 °C (June). The sanctuary is bordered by high mountain peaks; Kedarnath (6940 m), Mandani (6193 m) and Chaukhamba (7068 m) and extensive alpine meadows that is, Trijuginarayan, Kham, Mandani, Pandavshera, Manpai and Bansinarayan in the north, and several dense broad leave oak mixed forests in the south [13–16].

2.2. Methodology

Regeneration status of tree species at every altitudinal zone was studied to understand the regeneration of species in its present form and can be predicted some of the changes in vegetation pattern in future. The regeneration status was carried out, following the stratified random sampling technique by placing random quadrats. Quadrats were laid down in a spatially distributed manner so as to minimize the autocorrelation. The data were collected from five (5) altitudinal zones *i.e.*, zone-I, zone-II, zone-III, zone-IV and zone-V from attitudes 1550–3550 m above mean sea level, along an altitudinal gradient. At each altitudinal zone 10 m × 10 m quadrats were placed. The enumeration for trees, seedlings and saplings was estimated by plotting twenty (20) 100 m^2 quadrats covering an area of 2000 m^2 at every altitudinal zone. In each 100 m^2 (10 m × 10 m) quadrats, individuals having >31.5 cm GBH (girth at breast height *i.e.* 1.37 m above the ground) were considered trees and were measured individually and species wise. Individuals having <10.4 cm girth were considered as seedlings and the individuals having the intermediate position between (31.5–10.4 cm) tree and seedling with respect to these circumferences were considered as saplings [17]. The density of seedlings and saplings was considered as an indicator of the regeneration potential and structured the regeneration pattern of the study area.

Regeneration status of individual tree species has been explored on the basis of their quantitative potential at different life-forms and it was based on the phytosociological data [18] with the categories: (a) Good regeneration, if seedlings > saplings > adults. (b) Fair regeneration, if seedlings > or ≤ saplings ≤ adults. (c) Poor regeneration, if the species survives only at sapling stage, but no seedlings (saplings may be >, < or = adults). (d) No regeneration, if a species is present only in adult form. (e) New regeneration, if the species has no adults but only seedlings or saplings. Population structure is the true representative of future prospects and healthiness of any forest area. The density–diameter distribution of stems has been used repeatedly to represent the population structure of the forests [19]. The same was followed in the present study to enumerate the structure of population of present forest community as the stems were classified in nine girth classes with an interval of 15 cm *viz.*, 0–15, 16–30, 31–45, 46–60, 61–75, 76–90, 91–105, 106–120 and >120 (cm). Population structure reflects as what is the density at particular population class. For the identification of plant species, voucher specimens were collected for all the seedling and sapling species and were deposited in the herbarium of Botanical Survey of India (BSD, BSI – North circle Dehradun) and Garhwal University Herbarium (GUH, HNBGU – Garhwal Srinagar).

3. Results

3.1. Altitudinal zone-I (1550–1750 m)

A total of eleven (11) species of seedlings were found in the altitudinal zone-I (1550–1750 m asl). *Alnus nepalensis* was the dominant species with density of 230 seedlings/ha, followed by *Quercus floribunda* (210 seedlings/ha). The lowest density (5 seedlings/ha) was observed for *Ficus neriifolia* and *Neolitsea pallens*. The total density and TBC of seedlings in this altitudinal zone were 695 seedlings/ha and 0.2242 m^2/ha respectively. The highest value of frequency was again recorded for *Alnus nepalensis* (60%) followed by *Quercus floribunda* (45%). The highest value of IVI (90.88) was observed for *Alnus nepalensis* followed by *Quercus floribunda* (78.65) while the lowest IVI (3.26) was found for *Ficus neriifolia*. The highest TBC was observed for *Alnus nepalensis* (0.0654 m^2/ha) and lowest TBC for *Ficus neriifolia* (0.0004 m^2/ha) (Table 1). Whereas a total of thirteen (13) species were recorded in sapling stage. *Pinus roxburghii* was dominant species with highest values of frequency (50%), density (105 saplings/ha), TBC (0.392 m^2/ha) and IVI (85.89) followed by *Alnus nepalensis* having a frequency of 25%, density of 35 saplings/ha, TBC of 0.155 m^2/ha and IVI of 34.51. The lowest density and frequency values were 5 saplings/ha and 5% for *Ficus auriculata* and *Ficus neriifolia* respectively. The lowest values of IVI (4.63) and TBC (0.009 m^2/ha) were observed for *Ficus auriculata*. The total density and TBC for saplings were 330 saplings/ha and 1.322 m^2/ha respectively (Table 2).

In this altitudinal zone, the seedling density (695 seedlings/ha) was found highest followed by tree density (530 trees/ha) and sapling density (330 saplings/ha) (Table 3). The reverse J-shaped density–girth curve was observed but a slight increase in density was observed in the 46–60 and 61–75 GBH classes. The highest density of individuals was observed in 0–15 GBH class and this class constitutes the maximum portion of the curve while the lowest density was found in 91–105 GBH class (Fig. 2). The maximum (47.1%) species were found fairly regenerating, 5.9% species were recorded as good in regeneration, 35.3% of species showed poor regeneration and 11.8% of species were found not regenerating and there was no new regeneration (Fig. 3).

3.2. Altitudinal zone-II (2000–2200 m)

A total of eight (8) species of seedlings were observed in the altitudinal zone-II (2000–2200 m asl). The highest density was found for *Rhododendron arboreum* (45 seedlings/ha) followed by *Quercus floribunda* (40 seedlings/ha) and the lowest density was found for *Carpinus viminea* and *Euonymus hamiltonianus* (5 seedlings/ha). Frequency values for *Carpinus viminea*, *Euonymus hamiltonianus* and *Lyonia ovalifolia* were highest (100% each) and the lowest frequency was recorded for *Alnus nepalensis* (50%). The total density and TBC values of seedlings were 155 seedlings/ha and 0.048 m^2/ha respectively. The highest value of IVI (67.77) was observed for *Rhododendron arboreum* followed by *Quercus floribunda* (56.33) while lowest IVI (20.85) was found for *Carpinus viminea*. The highest TBC (0.012 m^2/ha) was found again for *Rhododendron arboreum*, while the lowest TBC (0.001 m^2/ha) was found for *Carpinus viminea* (Table 1). A total of eight (8) species in sapling stage were found surviving in this altitudinal zone. *Quercus floribunda* was recorded dominant species with highest values of frequency (45%), density (60 saplings/ha), TBC (0.355 m^2/ha) and IVI (113.95) followed by *Rhododendron arboreum* having a frequency of 40%, density of 45 saplings/ha, TBC of 0.210 m^2/ha and IVI of 83.68. The lowest density (5 saplings/ha) was observed for *Juglans regia* and *Lyonia*