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AGE, STRUCTURE, SURVIVORSHIP, AND LIFE EXPECTANCY FOR FUTURE IN MURREE FORESTS

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Abstract

This paper examines the survivorship patterns of trees and seedlings of four conifer species including *Pinus wallichiana*, *P. roxburghii*, *Abies pindrow* and *Cedrus deodara* in the forests of Murree hills. The construction of life tables and key-factor analysis allows us to examine the demographic parameters of the four conifer species including their growth, age structure, survival, mortality and mean expectation of further life. The age of the trees of different species ranged between 35-185, 65-125, 30-120 and 45-135 years for *Pinus wallichiana, Pinus roxburghii*, *Cedrus deodara* and *Abies pindrow* respectively. The survivorship curves for conifer tree species were close to Deevy type II curves. However, the slope of survivorship curves for *P. wallichiana*, *P. roxburghii* and *C. deodara* became somewhat steeper in the later part of the curve indicating greater rate of mortality at old age of the trees. Except for *P. roxburghii*, mean expectation of further life declined in the old-aged trees. Seedling/sapling density was in the order: *Pinus wallichiana* > *Pinus roxburghii* > *Cedrus deodara* > *Abies pindrow.* The key factor analysis showed that killing power (K) was highest for *Pinus wallichiana* and *Cedrus deodara.* The survivorship curves for the seedlings/saplings also showed a pattern close to Deevy type II. Besides natural mortality owing to competition and disease pressure, one of the principal causes of tree loss is illegal logging that is depicted in the form of high mortality. It is concluded that if biological interference and deforestation is not reduced up to sustainable level, it would be a serious threat to the biodiversity, ecosystem and infra structure of that area.

Key words: Survivorship, Mortality, Life expectancy, Frequency, Fecundity.

Introduction

Life history of a forest is constructed to build up a useful account which could be sufficiently predictive about current and future expected growth of the forest. Forest life history refers to the pattern of growth, number of species present, survival, mortality rate and relative ages of a species that reflect the fecundity (Clarck *et al.,* 2004). Life tables are widely used to idealize the survivorship of any organism, plant species, pests etc. In forest management, life table of the inhabitant species is very helpful to study the fecundity of successful species and the mortality rate of eliminating species to obtain the idea for an average gain and loss of plant per year (Waters, 1966; Hett & Loucks, 1968). Births and deaths, emigration and immigration are the important demographic parameters for the estimation of size and composition of population, hence demographic models of a forest are solely designed by using life tables (Begon *et al.,* 1996). Little attention has been paid on the demography of tree species in Pakistan. The above mentioned variables are greatly dependent upon time or age of an organism *i.e.,* if higher level of mortality occurs at juvenile stage of a tree species, the structure of population could be different from those having greater mortality at post maturity stages. According to Aziz & Shaukat, (2011), demography is useful to study population dynamics, it is also effective to identify the relationship between physical and biological environment and how does it influence the survivorship, fecundity and mortality rate of a population. Different environmental factors such as competition, shade, plant density, grazing and seed production exhibit greater impacts on natural growth and vegetation dynamics in a forest (Barkhan, 1980; Gross, 1990; Harper, 1977; Bastrenta, 1991).

According to Beckage *et al.,* (2008) and Doorn *et al.,* (2011), the demographic parameters such as tree mortality, growth or recruitment provide a thorough investigation of population dynamics and their survivorship that could also be helpful in detecting stress factors in a forest. Began *et al.*, 1996 reported that life tables are the summary of fecundity and survivorship of individuals within a population. Standing forests in recent era are surviving in the presence of different natural and man made stresses. During 1920, Hubbard Brook Valley as Forest was cut down upto 49% for urbanization. In 1955, USDA Forest Services logged the north east area of Hubbard forest for water management purpose (Doorn *et al.*, 2011). Another study was conducted by Foster, (2002) who concluded that past disturbance history is a factor to shape the current ecological context of the forest. Life table of *Avicennia marina* in mangroves forest of Karachi is a helpful tool to conclude that *Avicennia marina* species is now threatened species of this mangrove forest due to various unnatural factors (Nazim, 2011 and Nazim *et al.*, 2013).

The approach of key-factor analysis is applicable to many plant and animal species (Varley & Gradwell, 1960). A key-factor is a biological or environmental condition associated with mortality that causes major fluctuation in population size. Therefore, key-factor analysis has also performed to identify the causes of mortality at various stages.

Life tables and killing power of species can be useful in developing the successional outcomes of an ecosystem. In present investigations, the numerical values of life expectancy of conifer species in the forest summarize the pattern of succession and future trend of forest. The goal of this study is to evaluate the current age pattern of highly disturbed conifer population and its regeneration potential on the basis of life tables. Construction of life tables brings a better understanding for comparison of mortality and population size. Previous researchers *i.e.*, Hussain, (2011), Akber, (2011); Siddiqui, (2011); Aziz & Shaukat, (2011) presented life tables in least disturbed areas and no work was presented in highly disturbed situation.

Material and Methods

This study was conducted in Murree, located at a latitude of 33°45'30'' in the North and East 73°26'30'' at 7,517 feet above sea level. Murree comprised of beautiful mountains experiencing long summers, short winters and approximately 3 months of wet season with 6.9 inches of average rainfall. Study area was divided into thirty sample stands of 100 x 100m size for sampling of conifers. To record seedlings density, 10m circular plots were made within each large plot. Ten healthy conifer trees were cored (2 cores/tree) from each large plot and subjected to regular dendrochronological methods *i.e.*, drying, mounting, sanding and finally polishing of obtained cores (Stokes & Smiley, 1968). The age of trees of each species was calculated as described by Fritz, (2012) and Ahmed, (2014).

Life table is a basic tool used for the study of changes occurring in density and rate of increase or decrease in any population. Following symbols and formulae were adapted to conduct life tables (Hett & Loucks, 1968; Aziz & Shaukat, 2011).

Formulae:

$$dx = [lx - l_{(x+1)}]$$

$$qx = \frac{dx}{lx}$$

$$L_x = [l_x - l_{(x+1)}]$$

$$T_x = \sum_x^{\omega} L_x$$

$$e_x = \frac{Tx}{lx}$$

where x = age, l_x = number of individuals of initial cohort alive at age x, d_x = number of individuals of dying during the interval x to $x+1$, qx = age specific mortality, Lx = average of l_x and l_x+1, T_x = cumulative value of L_x from bottom upwards, e_x = mean expectation of further life of an individual of age x. Since different species may behave differently, different age intervals and classes were established based on different age data for each tree species.

In *Pinus wallichiana*, age intervals were designed at 50 years interval as the starting age of the species was 15 years and the final age recorded was 205 years. Four classes were formed *i.e.*, Class 1 = 15 to 65 years, Class 2 = 66 to 105 years, Class 3 = 106 to 155 years and Class 4 = 156 to 205 years. For *Pinus roxbhurgii*, three classes were designed at 60 years intervals as the starting year was 35 and the ending year was 195. Class 1 = 35 to 95 years, Class 2 = 96 to 135 years, Class 3 = 136 to 195. For *Cedrus deodara,* six classes were constructed at 20 years interval. The starting year of this species recorded was 20 and the maximum age recorded was 140 years. Class 1 = 20 to 40 years, Class 2 = 41 to 60 years, Class 3 = 61 to 80 years, Class 4 = 81 to 100 years, Class 5 = 101 to 120 years and Class 5 = 121 to 140 years. In case of *Abies pindrow,* there were four classes were found appropriate to represent tree stages of this species which comprised of 30 years interval. The minimum age was 30 years while the maximum age was 150. Thus, Class 1 = 30 to 60 years, Class 2 = 61 to 90 years, Class 3 = 91 to 120 years, Class 4 = 121 to 150 years. All the classes and calculations of the life table were performed using the program LIFETAB developed in C++ software (Shaukat & Siddiqui, 2005).

Killing power: Killing power within a population specifies the intensity of mortality of individuals (Anderegg *et al.*, 2016). K_x can be calculated at each life stage of observed individual trees/organisms (k_1, k_2, $k_3, \ldots$) and the final mortality should be K_x which explains the overall mortality rate in the life cycle of a species (Shaukat & Siddiqui, 2005).
Statistically it may be defined as:

$$K_x = log_{10}l_x - log_{10}\, l_{(x+1)}$$

The calculations were made by using the program K-VALUE developed in C++ (Shaukat & Siddiqui, 2005).

Seedlings: Seedlings and saplings of the four species mentioned were also examined in the designated stands. Seedlings/saplings of the 4 conifers present in 1 ha plots were counted. In addition, the diameters (approx dbh) of the seedlings and saplings were recorded. Seedlings/ saplings were classified according to diameter range 0.5-4cm; 4.1-8.0; 8.1-10. The last two can be designated as saplings (+poles), while the first class can be designated as seedlings. The age of seedling/saplings was also determined as described above and the life tables were constructed.

Results

Life tables: The life tables of individual conifer species were represented in Table 1,comprised of four conifer species found in the study area *i.e., Pinus wallichiana* A. B. Jackson, *P. roxburghii* Sarg, *Abies pindrow* (Royle ex D. Don) Royle *and Cedrus deodara* (Roxb.) G. Donf. Life tables represented mean age of the trees, number was equivalent to the number of individuals that occurred in the corresponding age group. Table 1 illustrated the estimations of expected number of survivors and mortality in *Pinus wallichiana* trees with the increase in age. Thus, the expectancy of further life dwindled down respectively. The survivorship graph was found to be close to Deevy type II curve (Fig. 1a).

Table 1. Life table for 4 conifer species developed from 30 stands of Murree.

Age	Number of observations	No of survival	No of dying	Age specific mortality	Mean expectancy of further life.
			Pinus wallichiana		
35	56	1000	250	0.25	1.64
85	42	750	393	0.52	1.02
135	20	357	286	0.80	0.60
185	04	71	-	-	-
			Pinus roxburghii		
65	40	1000	500	0.50	1.09
95	20	500	325	0.65	1.67
125	07	175	-	-	-
			Cedrus deodara		
30	14	1000	429	0.43	1.75
50	08	571	214	0.38	1.70
70	05	357	214	0.60	0.40
90	02	143	0	0	1.75
110	02	143	72	0.50	0.75
130	01	71	-	-	-
			Abies pindrow		
45	06	1000	167	0.17	1.83
75	05	833	500	0.60	1.10
105	02	333	0	0	01
135	02	333	-	-	-

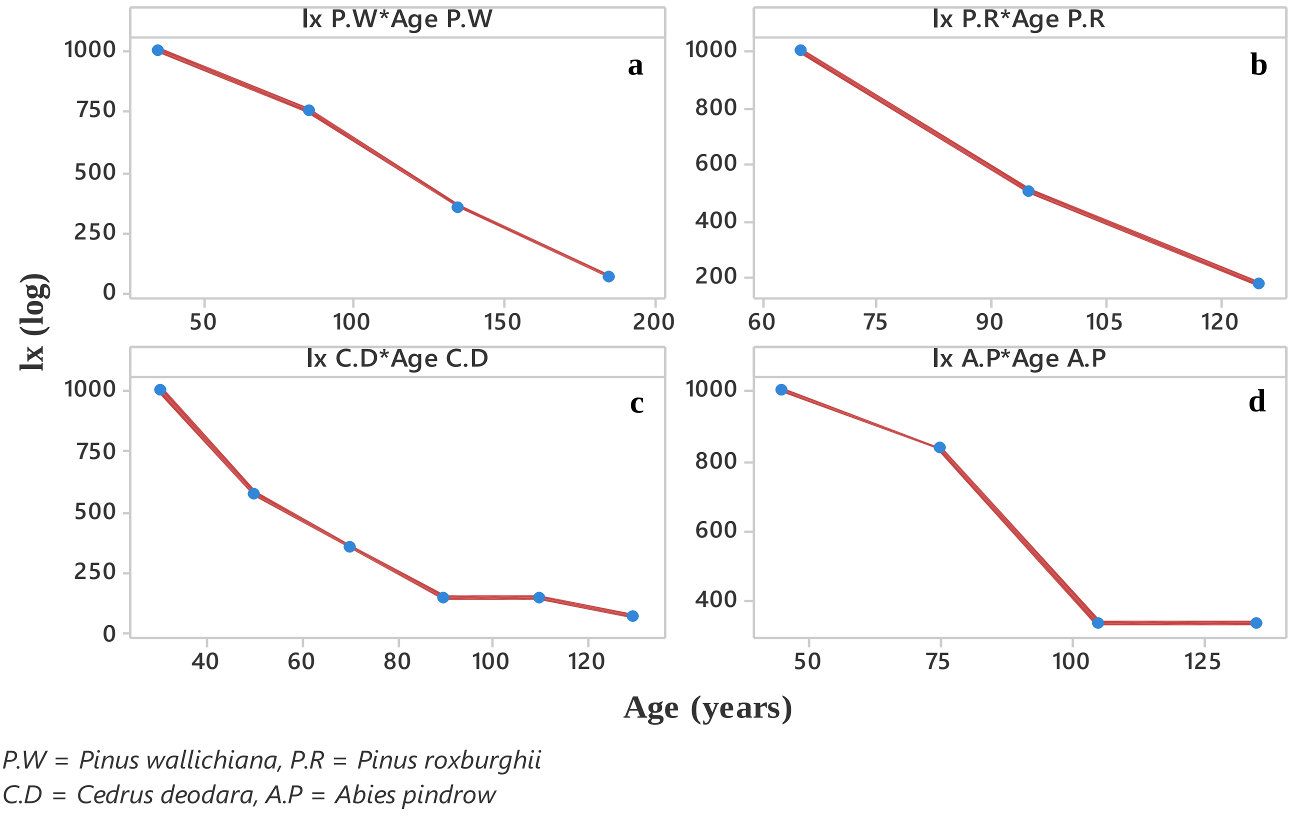

Fig. 1. Survivorship curves of four conifer species (a) *Pinus wallichiana*; (b) *Pinus roxburghii*; (c) *Cedrus deodara;* (d) *Abies pindrow*.

Table 2. Killing power of the four conifer species.

Classes	*Pinus wallichiana*	*Pinus roxburghii*	*Cedrus deodara*	*Abies pindrow*
k_1	0.1249	0.3010	0.2433	0.0793
k_2	0.3223	0.4559	0.2039	0.3982
k_3	0.7015	-	0.3973	0
k_4	-	-	0	-
k_5	-	-	0.3040	-
K=$\sum$ k	**1.1487**	**0.7569**	**1.1485**	**0.4775**

K = Killing power in each class; K = Total killing power

In the life tables of *Pinus roxburghii*, survivorship decreased rapidly with the increase in age group. Age specific mortality also increased with the higher age group. The mean expectation of further life, however, showed slight increase after the age of 65 years. The survivorship graph of *P. roxburghii* also depicted a trend close to Deevy type II (Fig. 1b).

It is noteworthy in *Cedrus deodara* that the age specific mortality was markedly high in the beginning, subsequently (30 – 50yrs.) it declined and once again it was accentuated. Mean expectancy of further life, as expected, declined more or less constantly during the life-span. The survivorship graph showed close to a Deevy type II curve (Fig. 1c).

Table 1 also exhibited the life tables of *Abies pindrow* in the Murree area. A pattern of low mortality was depicted in the beginning. Surprisingly the observations showed no mortality during the period 105–135 yrs. Mean expectancy of further life decreased steadily. The survivorship curve for *Abies pindrow* showed a trend towards Deevy types II (Fig. 1d). In two species, *i.e.*, *Pinus wallichiana* and *Pinus roxburghii* mortality increased linearly more or less with the same rate. Likewise mortality also increased with age in *Abies pindrow* but with a greater rate (Fig. 2).

Killing power: The classes were defined as k_1, k_2, k_3, k_4 and k_5 *i.e.*, from younger to the older based on recorded age of each conifer species (see Material and Methods). It was obvious from the results that the killing power of all the species increased with age, though the greatest variation was exhibited by *Pinus wallichiana*. On the other hand, *Cedrus deodara* showed consistent but slight increase with age group with regard to killing power (Table 2). K represented the total killing capacity in the whole life span of the conifer species which was highest for *Pinus wallichiana* and closely similar for *Cedrus deodara* while the least total killing power was exhibited for *Abies pindrow* of all the conifer species examined in the area.

Seedlings and saplings: With regard to seedling populations, the highest density was that of *Pinus wallichiana* whilst lowest was of *Abies pindrow*. In fact, the seedling/sapling density of *Pinus wallichiana* was remarkably higher than the rest of the three species in all size (dbh) classes (Fig. 2). There was also a neat trend of decreasing trend with the dbh size classes (*i.e.*, 4,8,10 cm). The survivorship curves for the seedling/saplings were given in Fig. 3. The survivorship curve for *Pinus wallichiana* followed a Deevy type II trend. *Pinus roxburghii* showed a trend akin to Deevy type II. *Cedrus deodara* and *Abies pindrow* exhibited a trend more or less approaching a Deevy type II curve.

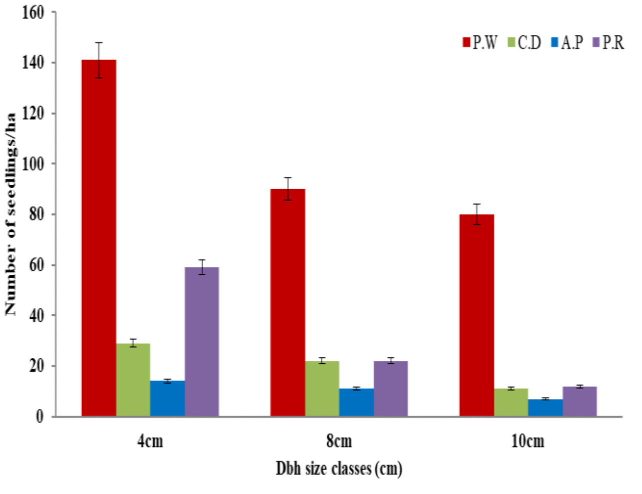

Fig. 2. Density of seedlings/saplings of different size classes (dbh) Ha^{-1}. P.W = *Pinus wallichiana*; P.R = *Pinus roxburghii*; C.D = *Cedrus deodara;* A.P = *Abies pindrow*

Discussion

Regeneration of a forest mainly depends upon the survivorship of the inhabitant trees including seedlings and saplings. Present study examined all the classes found in the disturbed sites to assess the degree of survival of species. As given in the results, *Pinus wallichiana* possessed only 4 age classes in the study area with a gradual decrease in survivorship when the trees attain older age. It was also shown that *Pinus roxburghii* consisted of only 3 age classes, *Cedrus deodara* possessed 6 age classes and *Abies \pindrow* consisted of 5 age classes in the study area and a gradual decrease in life expectancy estimated with age. The life expectancy showed similar trend. The young classes *i.e.* seedlings and saplings contained the higher values of survivorship. These old growth forests were uneven aged therefore determined age classes were constructed in different order and evaluated in accordance with their relative age structure specifically. However, their ecological factors were same hence their mortality can be compared. Edelfeldt *et al.*, (2019) found complications while combining the mortality trajectories of long-lived perennial herb in a pine-juniper mixed forest under disturbed condition. According to Edelfeldt *et al.*, (2019) long term studies may not be necessarily required for age dependant demographic studies in case of consistent mortality.

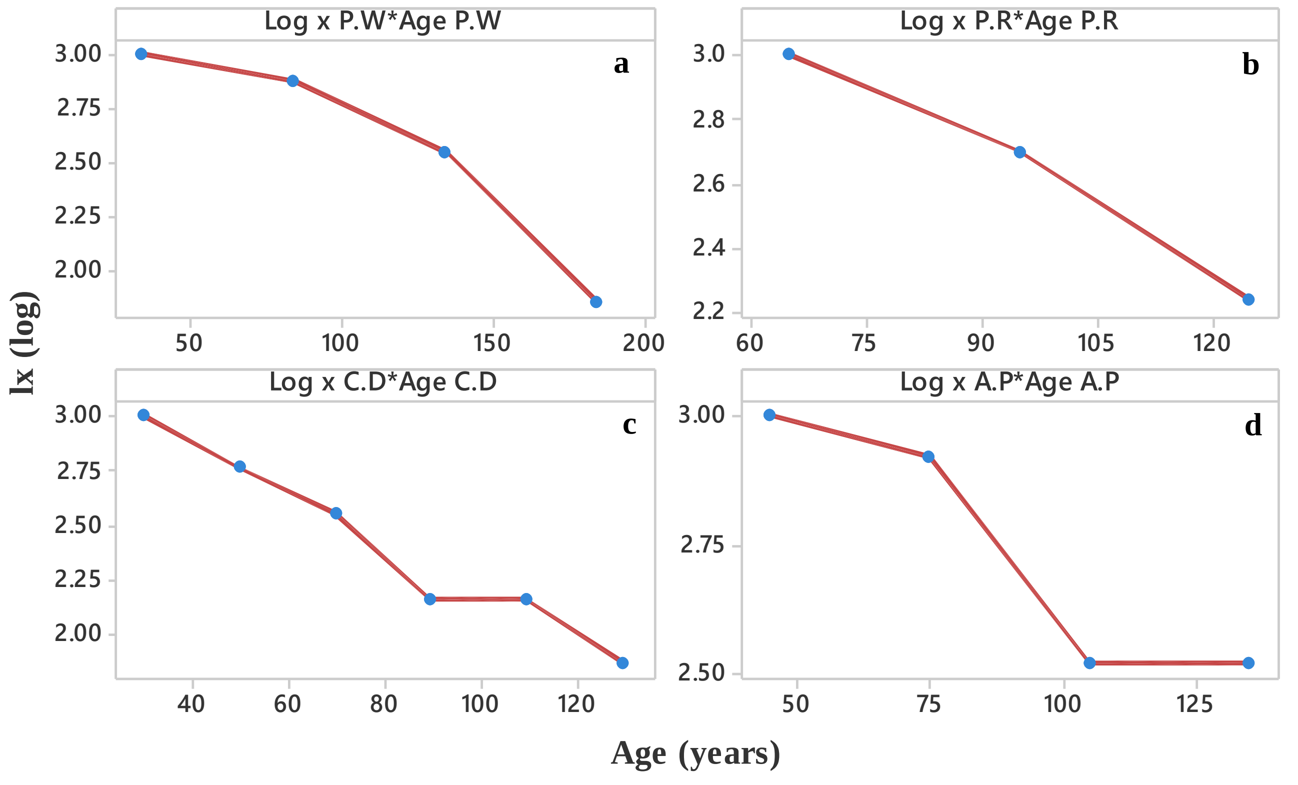

Fig. 3. Survivorship curves of the seedlings of four conifer species. (a) *Pinus wallichiana*; (b) *Pinus roxburghii*; © *Cedrus deodara;* (d) *Abies pindrow*.

Thus the mortality investigated in these classes may be due to human disturbance and grazing of animals, as the sampled areas were close to roads and villages, hence the frequency of livestock was rich. Villages were also present in the neighborhood and the mobility of animals also cause of damage in younger plants. Similar results were illustrated by Aziz & Shaukat, (2011) in which *Ipomea sindica* showed greater mortality in older stages of life cycle whereas survivorship was higher at early stages. In present study the mortality exceeded in the early phase of a tree's life. This was obvious from the age classes designed for the estimation of life tables of pine species which were very few in number in each species. The mortality of older trees may be natural at a certain age but in current situation the chances of natural mortality were very low due to the complete logging of older trees from the sites. This was a clear indication of poor regeneration in the forest in the next decades as the survivorship of older trees was extremely declined. Baskin & Baskin, (1989) stated that the environment controls the direction of population growth by its controlling factors such as light, temperature and moisture. Greater mortality was observed by Fox, (1990) in the later stages of life cycle of trees mostly in the months of September and October due to desiccation. Aziz & Shaukat, (2011) found drought as the main reason of mortality of older plants in their study. However, current findings were carried out in moist temperate zones of Pakistan and moisture does not act as a limiting factor in this region. The highest and lower life expectancy achieved in the older classes mainly could be because of the illegal cutting of the trees, removal of plants and over grazing. The clearing practices of land have lowered the competition which provides the opportunity for younger trees to grow; sufficient availability of light due to open canopy could also be a crucial factor for the growth of seedlings as well as trees. Lower frequency of mature trees would lower down the seed bank of pine species to regulate life cycle and regeneration potential of the forest. Seed bank is mandatory for the survival of any population in the area (Aziz & Khan, 1996; Shaukat & Siddiqui, 2004). Pine species could be reserved in the form of buried seeds but if the older trees will be eliminated and mortality will be continued at such defined range then, neither proper recruitment could be achieved nor the survival for the assurance of populations in the area. Rebertus *et al.*, (1991) and Castenha *et al.*, (2013) suggested that adult trees of pine recruit better in exposed elevations and their seedlings could be better transplanted under such conditions if compared with spruce. In our study, the sites were open but the regeneration level of other conifers was close to the diminished condition, this might be a reason of overgrazing and clearing of land for construction purposes. Every seedling responds differently across geographic, environmental and population range as suggested by Castanha *et al.*, (2013) which is in agreement with our findings *i.e.*, pine seedlings showed random mortality (q_x) because of heavy disturbance level in the area and they were not in accurate correspondence with Deevy type III survivorship model. On the other hand, the lx (survivorship) curve was resulted that conform to Deevy type II in both tree and seedling/sapling stages (Deevy, 1947). Reinhardt *et al.*, (2011) observed greater seed emergence and growth of pine trees at lower elevation when compared with conifers of high altitude. Similarly in our study, greater number of seedlings from early stages were observed in *Pinus wallichiana* and *Pinus roxburghii* while *Cedrus deodara* and *Abies pindrow* were recorded in lower numbers. Their survivorship decreased with time but became stable upon maturity and reach mortality gradually. In the current investigation, the study sites were largely disturbed; consequently, the mortality has shown to be more or less random with life expectancy estimated to be very low. A major alarming observation was the low number of mature trees and seedlings with a random mortality pattern; this has highlighted a rapid removal of forest in the coming decades.

Here k values appeared differently in different stages of life in each pine species *i.e.,* in *Pinus wallichiana*, the k value has significantly increased by age and became highest in the oldest age in the given age structure. In case of *Pinus roxburghii*, k-values also showed an increase by age with a slight difference between the age classes. An interesting result was found for *Cedrus deodara* where the killing rate of the deodar trees decreased very slightly in the two stages that might be juvenile and polar stages while after attaining maturity the third stage showed a gradual increase and eventually it became zero, right after that stage the killing factor increased at a greater rate in the oldest stage. *Abies pindrow* possessed similar results like *Pinus wallichiana* and *Pinus roxburghii i.e.,* increase in death of pines by age. The overall results showed a picture of diminishing of forest in the future. From successional point of view, forest would not be expected as a healthy habitat if higher numbers of seedlings will not produce and proper measures will not be taken place for the recruitment. Therefore, if proper conservative measures would not be implemented in the area, these forests will be expected to vanish from forthcoming decades.

Conclusion

In the light of predefined results, it can be concluded that conifer species thriving under influence of anthropogenic disturbance, hence attained an irregular age pattern. The age classes are random due to frequent cutting practice of older trees and presence of animal and human population. Biotic influence also decreases the chances of survival in seedlings. Therefore, the mortality rate declines in all conifers as well as the survival capability seems weaker most probably in *Abies pindrow* and *Pinus roxburghii* while *Pinus wallichiana* and *Cedrus deodara* attaining relatively better survival rate by increasing tolerance level in response of disturbance. It can be predicted that if current disturbed condition exists or increased, conifers will loose their tolerance capability as it can reach its optimum level and there will be chances to loose these forest representatives from the area.

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