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Original Article

Population Demographic Characteristics of *Haloxylon ammodendron* (C.A. Mey.) Bunge ex Fenzl in Gobi Desert of Mongolia

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Abstract

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We measured the basal diameter, height and crown size of saxaul trees, and used survival curve and static life table in defining population structure and dynamics of *H. ammodendron*. The static life-table proved that population size in the first three age classes had high range of variation, seedlings, juveniles and small trees, and had a high rate of mortality. Because, considerable number of individuals was in the early life stage of *H. ammodendron*, the deficit of seedlings and high mortality of seedlings and juveniles are most considerable problems. The results suggest that studied populations of *H. ammodendron* are depleted, and efforts are required to minimize uncontrolled exploitation and overgrazing.

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Introduction

Mongolia is one of the countries, which most severely affected by desertification and land degradation. According to United Nations Convention Cambating Desertification's (UNCCD) proposed index of aridity (Thornthwaite aridity index), over 90% of total territory of Mongolia was classified as highly vulnerable to desertification and land degradation. The 77.8% of total land area of Mongolia is exposed to some degree to desertification and land degradation; among which 35.3 % at slight, 25.9 % at moderate, 6.7 % at heavy and 9.9 % at very heavy levels of desertification (Desertification Atlas of Mongolia, 2014). Hence, desertification and land degradation in Mongolia has reached at the national security level and desertification is still occurring at a rapid pace (MNET, 2010), the rehabilitation and ecological restoration are major tasks. Due to desertification and land degradation, the plant coverage and species composition have been changed. Excessive use of saxaul trees, which is the only forest component in the Gobi Desert area, caused loss of saxaul forests on 125.0 thousand ha area. Local people settling in arid zone continue to utilize woods, shrubs and bushes for their fuelwood consumption, becoming a crucial factor in sand movement and sand accumulation in settlement area (Khaulenbek, 2005; Khaulenbek *et al*., 2018).

The eudicot clade comprises approximately 75% of all flowering land plant species, including major subclades: rosids, asterids, Saxifragales, Santalales, and Caryophyllales (APG III, 2009). *Haloxylon* species, which include psammophytic small trees or shrubs, are positioned phylogenetically in the Amaranthaceae Juss of the Caryophyllales Perleb among core eudicots (APG III, 2009; Pyankov *et al*., 2001; Akhani *et al.,* 2007; Zhu *et al*., 2004).

The genus *Haloxylon* has 11 species, with collective distribution from the Mediterranean through Central Asia including northern China and southern Mongolia (Zhu *et al*., 2004). *Haloxylon ammodendron* (C.A.Mey.) Bunge ex Fenzl is found in the Gobi Desert region of southern part of Mongolia, which play important roles in wind control and sand fixation (Gal, 1975a, b; Batkhuu *et al*., 2017; Khaulenbek *et al*., 2018).

Due to its great drought resistance and saline tolerance, *H. ammodendron* occurs naturally in range of habitats, including gravel desert, clay desert, fixed and semi-fixed sand, and saline land in the Asian and African deserts (Chen *et al*., 1983; Tobe *et al*., 2000). As a dominant desert plant, *H. ammodendron* plays an important role in the maintenance of the structure and function of the whole ecosystem, reducing wind speed and ameliorating the forest microclimate, thus facilitating the settlement and growth of other desert plants (Shamsutdinov & Ubaidullaev, 1988).

The demographic study of plant population is important for understanding the status of population, assessment of population stability, predicting succession, and implementing programs for the conservation and management (Lorimer, 1980; Bonnicksen & Stone, 1982; Menges, 1986; Silvertown *et al.*, 1993; Schemske *et al.*, 1994; Caswell, 2000; Manuel & Molles, 2002; Coates *et al.,* 2006). Generally, tracing the whole life history, from birth to death of a long-living species are impossible, hence, a static investigation of age structure of population was often accepted in population dynamic studies (Harper, 1977; Stewart & Rose, 1986; Johnson & Fryer, 1989; Svensson & Jeglum, 2001). Population age structure may provide important insight into past and present regenerations (Agren & Zackarisson, 1990). Furthermore, static life table, which estimates the age-specific survival and mortality from the population age structure at moment in time, is used for long-living plants where it is not practical to follow the demise of a cohort through time (Silvertown, 1987). Life tables depict birth and death rates for each age or size class as well chance of seedlings in a population (Holla & Knowles, 1988).

The variability and severity of the arid environment and great longevity of many shrub species, makes age estimations difficult in arid environment (Crisp & Lange, 1976; Woodell, 1990). As the severity of the arid environment the growth of plant was not continued. Some shrubs in desert produced multiple rings in some years and none or partial in others (Webber, 1936; Fahn, 1953; Ginzburg, 1963; Lange, 1965; Vasek,

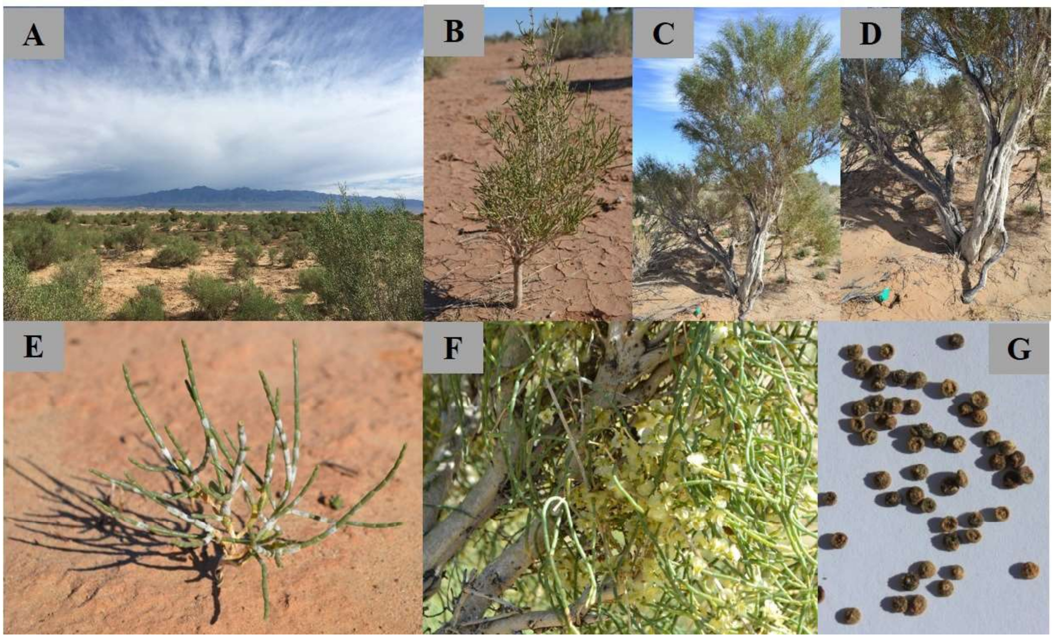

Figure 1. (A) Saxaul tree stand view, (B) Young tree, (C) Mature tree, (D) Stem, (E) Seedling, (F) Assimilating shoot and flowers, (G) Ripen seeds of *H. ammodendron.*

1980). As it is infeasible to determine the age of *H. ammodendron* using the tree ring, the size-class is used for the analysis of population dynamics. Moreover, size rather than age may be a better indicator of the reproductive capacity of trees (Harper, 1977; Khan & Shaukat, 1997; Shaukat *et al.*, 2012).

In the present study, the age and survival relationship of *H. ammodendron* is employed in identification of population demographic structure and predicting future trends. It may provide strategies for restoration and conservation of *H. ammodendron*.

The researches on saxaul trees started in the late 1970s in Mongolia. Depending on density, the saxaul forests were classified into closed and open woodlands. According to the first inventory conducted in 1975-1980, in total of 714 thousand hectares of saxaul stands were registered and included as component of forest resources of Mongolia. The later inventory results obtained during 1975-1980 concluded that total area of closed saxaul forests in Mongolia is accounted 491.3 thousand hectares. The open saxaul forest was 3.5 million hectares and increased to 3.8 million hectares during 2006-2011 (forest inventory data provided by the Forest Research and Development Centre). Meanwhile, the genetic diversity and population genetic structure of *H. ammodendron* are largely unknown, making the conservation and utilization in ecological restoration of this important desert species difficult.

Since 2014, an extensive researches on ecophysiological aspects of natural saxaul stands are conducted by us including breeding of saxaul seedlings; effects of salt stress on different age-seedlings; seasonal change in chlorophyll content and stomata characteristics; and seeding and seed quality of natural forest stands (Batkhuu *et al.*, 2015a, b, c, d). Effects of irrigation regime and soil types on the seedling growth, and population demography of saxaul were also studied (Batkhuu *et al.*, 2014, 2015, 2016, 2017).

The objective of this study was to explore population demographic structure of *H. ammodendron* from geographically distant populations in the Mongolian Gobi Desert.

Materials and methods

Study sites.

The sampling plots with dimension of 30 × 30 m were established in the five populations, which were divided into 9 subplots with size of 10 × 10 m. All trees in the subplots were marked and their GPS position, distance between trees, height, basal diameter, crown size, and number of branches were measured (Fig. 2; Table 1).

Population demography.

For determination of the population structure and dynamics of *H. ammodendron*, static lifetable

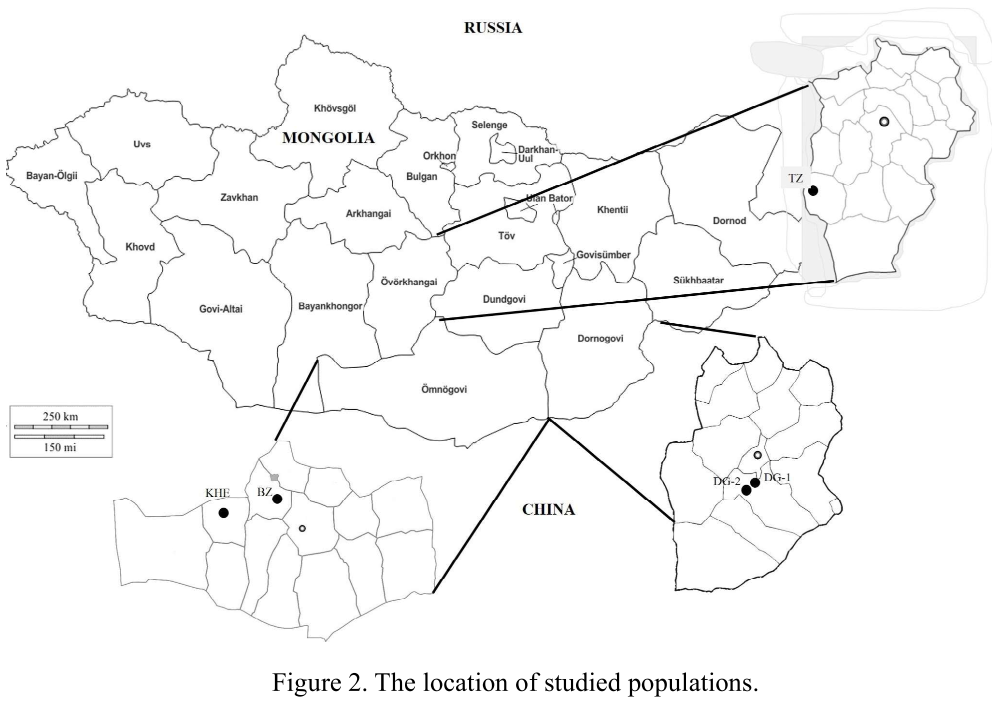

Figure 2. The location of studied populations.

Table 1. The geographical location of *H. ammodendron* populations.

Populations	Location	Latitude (^{0}N)	Longitude (^{0}E)	Altitud, m
DG 1	Dulaan Uul, Ulaanbadrakh soum, Dornogobi aimag	44.12	110.01	701
DG 2	Dulaan Uul, Ulaanbadrakh soum, Dornogobi aimag	44.17	109.58	705
BZ	Bayanzag, Bulgan soum, Umnugobi aimag	44.11	103.41	1138
KHE	Khongoriin Els, Servei soum, Umnugobi aimag	44.18	101.24	1095
TZ	Temeen zag, Baruun Bayan Ulaan soum, Uvurkhangai aimag	45.09	101.32	1186

and survivorship curve were used. Since it is infeasible to determine the age of *H. ammodendron* using the tree ring, the size-class is used for the analysis of population dynamics (Harper, 1977; Khan & Shaukat, 1997; Shaukat *et al.*, 2012). Age classes were defined based on basal diameter of each individual, the seedlings (basal diameter ≤ 1 cm) and saplings (1 cm_ basal diameter ≤ 3 cm) were defined as the first and the second classes, respectively, while the adults was grouped into 3 cm size classes based on basal stem diameter to give size-frequency distributions of each plot (Lu *et al.*, 2014). The static life table was constructed for each of the studied populations following Pielou (1977) and Hegazy (1992). The first column of the life table sets out the estimated age in size class (*x*) and the second column list the corresponding numbers per cohort (*Nx*). The data have been standardized in the third column. Starting with a value of 1.0, the proportion of the original cohort surviving to the start of each stage (*lx*) was obtained as:

$$lx=N_x/N_0$$

The proportion of the original cohort dying during each stage (*dx*) was calculated as:

$$dx=l_x-l_{x+1}$$

The stage-specific mortality rate (*qx*) was calculated as:

$$qx=d_x/l_x=1-(l_{x+1}/l_x)$$

The rate of mortality during any cohort, which reflects the killing power (*Kx*) was computed from the *Nx* values as:

$$K_x=\log_{10}N_x-\log_{10}N_{x+1}$$

As for l_x, K_x, was standardized but, unlike q_x summing the K_x, to find the long-term killing power is a legitimate procedure (Begon *et al.*, 1986).

The expectation of future life (*ex*) in age units was estimated as:

$$e_x = \sum_{j=x}^{\infty} lj/lx$$

Results

Population demographic structure.

Prior to sampling of plan materials the sampling plots (in total 5 plots) were established to determine the height, basal diameter, age and demographic structure of the *H. ammondendron* populations.

Statistically significant differences were found in height of trees and their basal diameter within populations and within geographical regions (Table 2). The total number of trees subjected to measurements in five populations was 727 individuals, highest number of trees were observed in population Temeen Zag (TZ=274

Table 2. ANOVA for individuals in five populations of *H. ammodendron.*

Variables	DF	MS	F value
Height, cm			
Geographic variation	2	84328.1300	24.41***
Within population variation	4	79036.1944	22.88***
Among population variation	273	3195.8512	0.934ns
Basal diameter, cm			
Geographic variation	2	1429.7875	36.68***
Within population variation	4	828.1411	21.25***
Among population variation	273	34.0911	0.87 ns

*Note: ns- not significant, *** - significantly different at 0.001*

Table 3. Means of tree measurement in each population.

Populations	Average height (*H*) of trees, cm	Average basal diameter (*BD*), cm
DG-1	94.09±4.64b	4.64±0.82b
DG-2	48.98±1.87d	1.87±0.22c
BZ	118.11±7.18a	5.65±0.52ab
KHE	88.90±11.25b	6.42±0.72ab
TZ	71.12±1.81c	6.88±0.48a
Mean	84.24±2.34	5.09±0.25

**Note: Means with different letters are significantly different according to Duncan's Multiple Range Test at 5% level.*

individuals), followed by Dulaan Uul-2 (DG-2=217), Khongoriin Els (KHE=95), Dulaan Uul-1 (DG-1=76) and Bayanzag (BZ=65).

The average height of trees was 84.24±2.34 cm, and their basal diameter was 5.09±0.25 cm. Bigger trees both in terms of height and basal diameter was measured in BZ population (H=118.11±2.78 cm) and TZ population (BD=6.88±0.48 cm), respectively, and smallest trees were observed in DG-2 population (H=48.98±1.87 cm and BD=1.9±0.22 cm, respectively) (Table 3).

The height of trees in all studied populations were significantly (P<0.0001) differed within populations and among geographical location

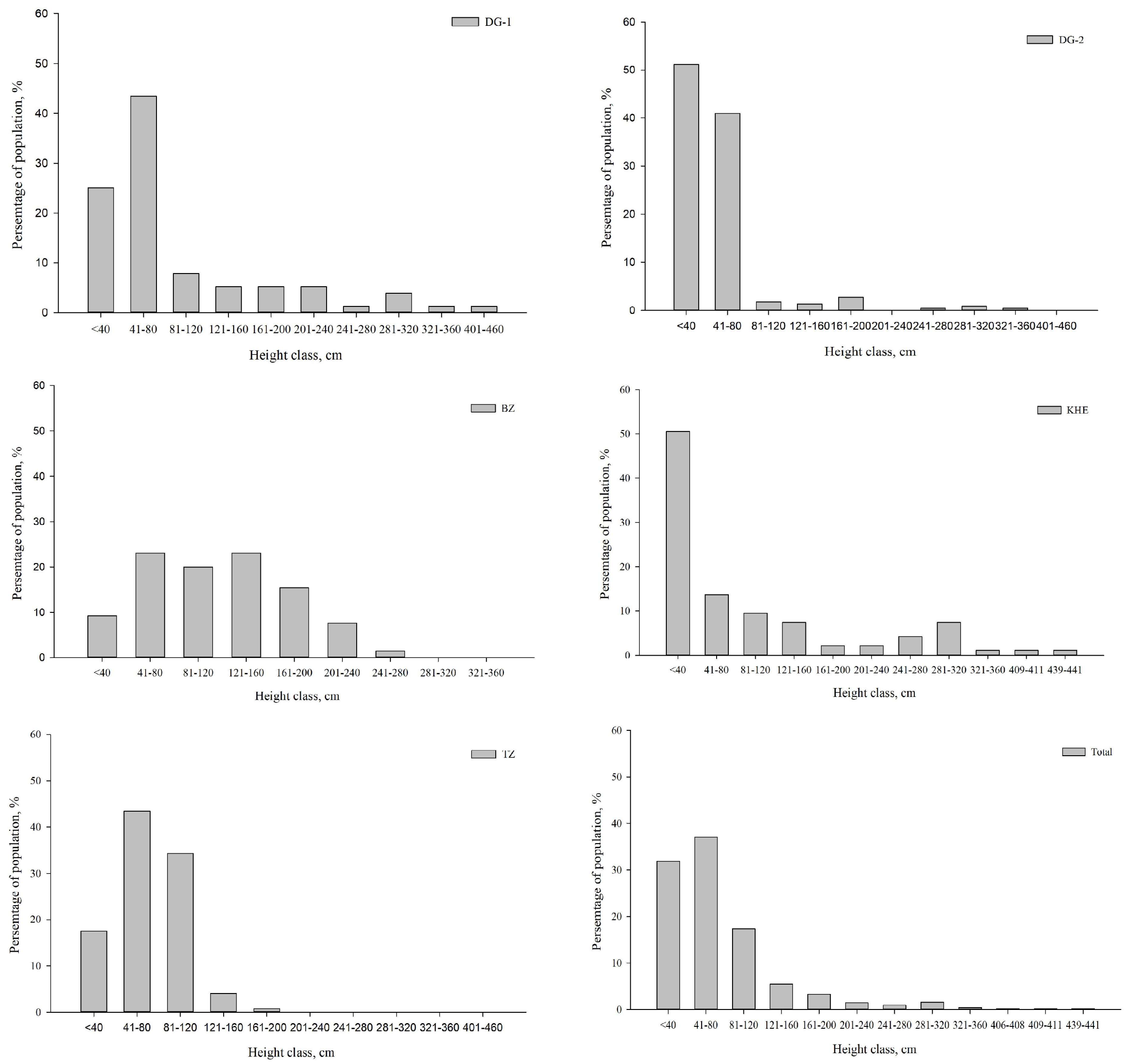

Figure 3. Height class structure of studied *H. ammodendron* population, %

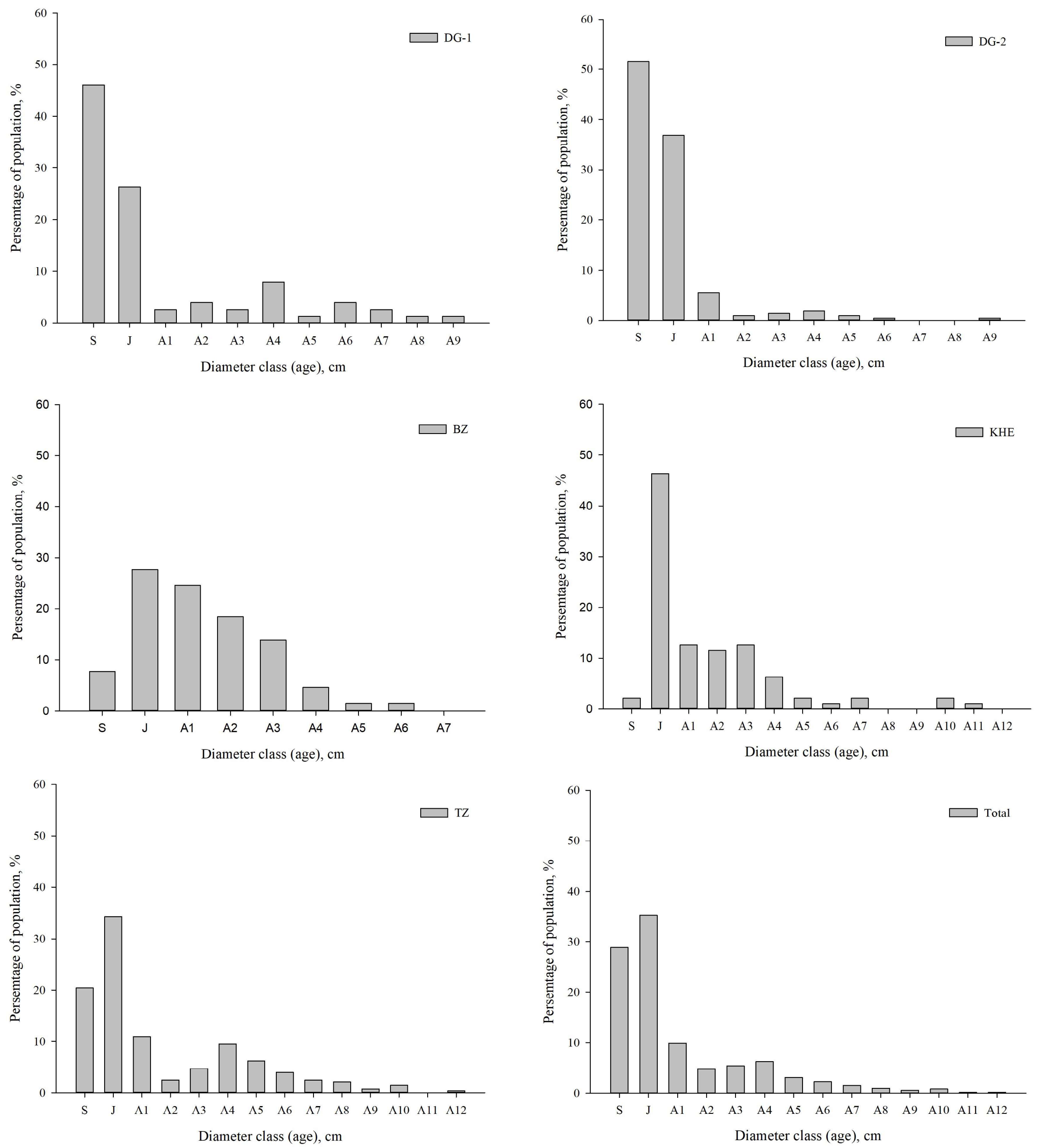

Figure 4. Diameter class (age) structure of *H. ammodendron* populations. S - seedlings, J - juveniles and A - adults (A1=3-6, A2=6-9, A3=9-12, A4=12-15, A5=15-18, A6=18-21, A7=21-24, A8=24-27, A9=27-30 and A10≥30 cm of tree basal diameter).

(Table 2). The six diagrams representing the population structure of five populations and total for all populations (Fig. 3). Among the studied populations, the majority trees were found with height between 40-80 cm with average percent of 63.61.

Higher proportion of trees observed in height class ≤40-80 cm ranging 13.68% for KHE population and 43.43% for DG-1 population. The percentage of taller trees were decreased with height class increases, and height structures were skewed towards larger size classes in all populations with exception of Bayanzag (BZ) which shows quite even distribution patterns in taller class of height (Fig. 3).

The sizes of trees (basal diameter) in all populations were significantly ($P<0.0001$) differed within populations (Table 1), and their structure (age determined based on diameter class) were shown in Fig 4. Six diagrams represented the

Table 4. The static life table of *H. ammodendron* populations in Mongolia.

Diameter class (age)	Nx	Ix	dx	qx	Log10Nx	Kx	ex
Dulaan Uul-1 (DG-1)							
S	35	1	-1	-1	1.5	0.2	35
J	20	0.6	0.4	0.75	1.3	1.0	20
A1	2	0.1	0.5	4.7	0.3	-0.2	2
A2	3	1.5	-1.4	-0.9	0.5	0.2	3
A3	2	0.7	0.8	1.25	0.3	-0.5	2
A4	6	3	-2.3	-0.8	0.8	0.8	6
A5	1	0.2	2.8		0	-0.5	1
A6	3	3	-2.8		0.5	0.2	3
A7	2	0.7	2.3	3.5	0.3	0.3	2
A8	1	0.5	0.2	0.3	0	0	1
A9	1	1	-0.5	-0.5	0		1
Dulaan Uul-2 (DG-2)							
S	112	1	0.29	0.29	2.05	0.15	112
J	80	0.71	0.56	0.79	1.90	0.82	80
A1	12	0.15	-0.02	-0.11	1.08	0.78	12
A2	2	0.17	-1.33	-8	0.30	-0.18	2
A3	3	1.5	0.17	0.11	0.48	-0.12	3
A4	4	1.33	0.83	0.63	0.60	0.30	4
A5	2	0.5	0	0	0.30	0.30	2
A6	1	0.5	0.5	1	0	0	1
A7	0	0	0			0	0
A8	0	0				0	0
A9	1	1	-1	-1	0		1
Bayanzag (BZ)							
S	10	1	-0.4	-0.4	1	-0.14	7
J	14	1.4	0.3	0.21	1.14	0.104	4
A1	11	1.1	0.2	0.18	1.04	0.08	4
A2	9	0.9	0.6	0.66	0.95	0.47	4
A3	3	0.3	-0.8	-2.66	0.47	-0.56	8
A4	11	1.1	0.6	0.54	1.04	0.34	2
A5	5	0.5	0.2	0.4	0.69	0.22	2
A6	3	0.3	0.1	0.33	0.47	0.17	2
A7	2	0.2	0.2	1	0.3010		1
A8	0	0	0				
A9	0	0	-6.8				
Khongoriin els (KHE)							
S	2	1	-21	-21.00	0.30	-1.34	47.02
J	44	22	16	0.73	1.64	0.56	46.02
A1	12	6	0.5	0.08	1.08	0.04	24.02
A2	11	5.5	-0.5	-0.09	1.04	-0.04	18.02
A3	12	6	3	0.50	1.08	0.30	12.52
A4	6	3	2	0.67	0.78	0.48	6.52
A5	2	1	0.5	0.50	0.30	0.30	3.52
A6	1	0.5	-0.5	-1	0	-0.30	2.52
A7	2	1	1	1	0.30		2.02
A8	0		0				1.02
A9	0		-1				1.02
A10	2	1	0.98	0.98	0.30	0.30	1.02
Temeen zag (TZ)							
S	56	1	-0.68	-0.68	1.75	-0.22	4.89
J	94	1.68	1.14	0.68	1.97	0.50	3.89

A1	30	0.54	0.41	0.77	1.48	0.63	2.21
A2	7	0.13	-0.11	-0.86	0.85	-0.27	1.68
A3	13	0.23	-0.23	-1	1.11	-0.30	1.55
A4	26	0.46	0.16	0.35	1.41	0.18	1.32
A5	17	0.30	0.11	0.35	1.23	0.19	0.86
A6	11	0.20	0.07	0.36	1.04	0.20	0.55
A7	7	0.13	0.02	0.14	0.85	0.07	0.36
A8	6	0.11	0.07	0.67	0.78	0.48	0.23
A9	2	0.04	-0.04	-1.	0.3	-0.3	0.12
A10	4	0.07	0.07	1.	0.6		0.09
A11	0	0.00	-0.02				0.02
A12	1	0.02	-4.88	-273	0	0	0.02

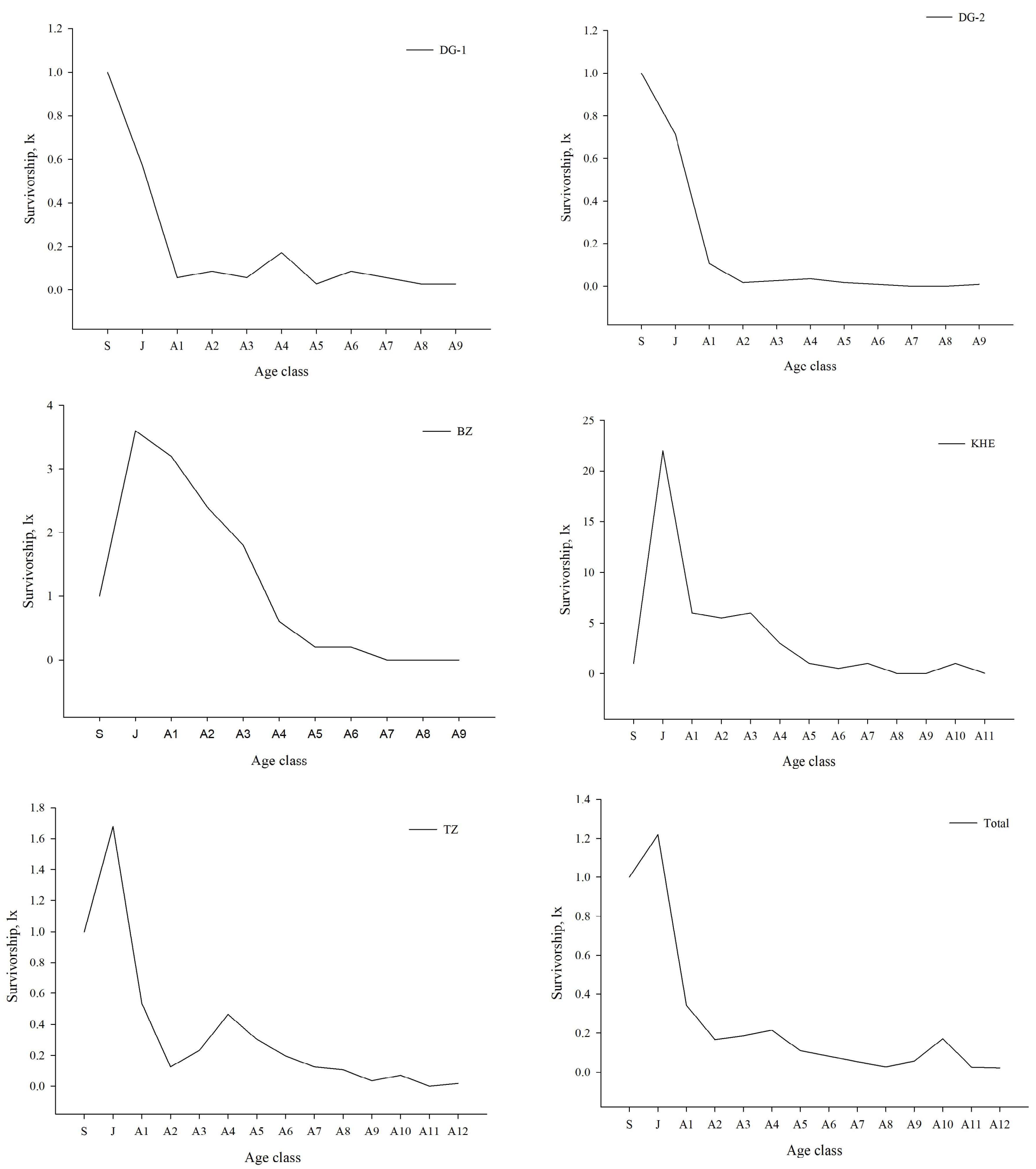

Figure 5. Survivorship curve of *H. ammodendron* populations. S - seedlings, J - juveniles and A - adults (A1=3-6, A2=6-9, A3=9-12, A4=12-15, A5=15-18, A6=18-21, A7=21-24, A8=24-27, A9=27-30 and A10≥30cm tree basal diameter).

population structures in the five sampling plots and the total of all plots, respectively (Fig. 4). Among the studied populations, fewer seedling (2.11%) was found in population KHE compared with other studied populations. Juveniles were discovered in all plots with the highest values in populations KHE and DG-2 (46.32% and 36.87%, respectively). In the remaining plots, the percentage of juvenile trees ranges varied between 26.32-34.3%.

Except population in Bayanzag (BZ) lacked individuals in the larger size class. Simultaneously, the percentage of adult individuals per cohort decreased with cohort size or age class increases. Taken together, all populations in the studied plots showed a deficit of individuals in the adult class, with the exception of population Khongoriin els (KHE) and Temeen zag (TZ), the most individuals were included in the juvenile and adult size classes.

Static life table and survivorship curve.

The static life table of studied populations is shown in Table 4. The survivorship of individuals and survivorship rate were decreased with the age of trees (Fig. 5, Table 4). The age-specific mortality rate (*qx*) varied in different size classes (ages). Higher mortality rate was observed in size classes S, J, A1, A2 and A3, and decreased with age of trees (size classes A3-12). The expectation of future life (*ex*) showed the highest values for seedling stage and the values declined in older stages. The survivorship curves showed the same tendency with the highest mortality in the early life stages (S, J, A1 and A2), and then stabilized in later stages. The survivorship curve of *H. ammodendron* was resembled Deevey's Type III (Fig. 5).

Discussion

The population demographic structure of *H. ammodendron* was shaped as irregular "Reverse-J shaped" in all studied populations of Mongolia, i.e., the most trees measured were included in younger age classes and the number of seedlings was limited. The static life-table proved that population size in the first three age classes have high range of variation, seedlings, juveniles, and small trees have higher rate of mortality which has been found in other desert shrub species (Barbour, 1969; Crisp & Lange, 1976; Woodell, 1990; Kuuseoks *et al.*, 2001; Hegazy *et al.*, 2008). The survivorship curves of the studied populations demonstrated high mortality of seedlings, juveniles and younger adults, followed by lower mortality of older adult trees, which was approached Deevey type III (Deevey, 1947), in which the highest mortality was found in the early life stages. It was believed that the early reproductive stages from seedling to juvenile and juvenile to younger adult are at greater risk relative to adult individuals. It was the key stage of successful regeneration.

Nearly all populations except DG1 and DG2 lack of seedlings, which indicates the extremely low seedling recruitment and higher mortality of seedlings that could be related to the adverse arid conditions and excessive livestock grazing in the region. Generally, stable snow covers in winter can be observed in the Mongolia's Gobi Desert, and the seed germination and seedling emergence occurs at the same time with the snow melting, followed by rapid increase of air temperature and drought in spring season, which resulting higher mortality of seedlings and juveniles of *H. ammodendron*. In contrast, considerable number of individuals was in the early life stage, and the deficit of seedlings, and the high mortality of seedlings and juveniles are most considerable problems in this region. These results suggest that studied populations of *H. ammodendron* are threatened, and therefore, efforts are required to minimize uncontrolled exploitation and overgrazing. Limited seedling recruitment requires conservation efforts in order to protect existing populations in the Mongolian Gobi Desert.

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References

Agren, J. & Zackarisson, O. 1990. Age and size structure of *Pinus sylvestris* populations on mires in Central and Northern Sweden. *Journal of Ecology*, 78: 1049-1062.

Akhani, H., Edwards, G. & Roalson, EH. 2007. Diversification of the old world Salsoleae *s.l.* (Chenopodiaceae): molecular phylogenetic analysis of nuclear and chloroplast data sets and a revised classification. *International Journal of Plant Sciences,* 168: 931-956. https://doi.org/10.1086/518263.

APG III. 2009. An update of the angiosperm phylogeny group classification for the orders and families of flowering plants: APG III. *Botanical Journal of the Linnean Society*, 161:105-121. https://doi.org/10.1111/j.1095-8339.2009.00996.

Batkhuu, N., Byambadorj, S. & Tsedensodnom, E. 2017. Population demographic structure and ecophysiological characteristics of two distinctive saxaul (*Haloxylon ammodendron* (C.A.Mey). Bunge.) stands in Mongolia. Expert Workshop on "Dryland Forest Restoration and Conservation in Central and Northeast Asia", 14-17 August, 2017, Ulaanbaatar, Mongolia.

Batkhuu, N., Enkhchimeg, T., Khaulenbek, A., Janchivdorj, L., Batkhishig, O. & Ser-Oddamba, B. 2017. Population characteristics and seed quality of two distinctive saxaul (*Haloxylon ammodendron* C. A. Mey.) Bunge stands from Mongolia. IUFRO 125th Anniversary congress 2017. 18-22 September 2017. Freiburg Germany. pp 458.

Batkhuu, N., Narantugs, D., Enkhchimeg, T., Ser-Oddamba, B., Tsagaantsooj, N. & Wuyanga, B. 2016. Seed quality traits of two distinctive Saxaul (*Haloxylon ammodendron* C.A.Bunge) populations of Mongolia. Abstract book of the IUFRO Regional Congress for Asia and Oceania 2016 "Forests for Sustainable Development: The Role of Research". 24-27 October, 2016. Beijing, China. pp. 354.

Batkhuu, N., Ser-Oddamba, B., Zoljargal, S., Batzorig, Y., Janchivdorj, L., Khaulenbek, A., Batkhishig, O. & Tsedensodnom, E. 2016. Effects of soil type and irrigation regime on the growth of Saxaul (*Haloxylon ammodendron* C.A. Bunge) seedlings. "The 7th EAFES International Congress" "One Asia Tied with Ecosystems: Living Harmoniously with Local People and Nature" 19-22 April 2016, Inter-Burgo Daegu, Korea, pp. 112.

Batkhuu, N., Tsedensodnom, E., Altantugs, O. & Byambadorj, S. 2016. Seed germination of saxaul (*Haloxylon ammodendron* (C.A.Meyer). Bunge) under different salt concentrations. "The 7th EAFES International Congress" "One Asia Tied with Ecosystems: Living Harmoniously with Local People and Nature" 19-22 April 2016, Inter-Burgo Daegu, Korea, pp. 338.

Batkhuu, N., Altantugs, O., Tsedensodnom, E., Batmunkh, T. & Byambadorj S. 2015. Seed quality of saxaul (*Haloxylon ammodendron* C.A.Bunge). *Mongolian Forests*, 5: 60-63 (in Mongolian).

Batkhuu, N., Byambadorj, S., Sainbuyan, Z., Yadamsuren, B., Lunten, J., Akhmadi, K. & Ochirbat, B. 2015. The effects of irrigation regime and soil types on growth performances of seedlings of Saxau (*Haloxylon ammodendron* C.A. Bunge). *Mongolian Forests*, 5: 55-59 (in Mongolian).

Batkhuu, N., Tsedensodnom, E., Altantogs, O., Byambadorj, S. & Batmunkh, T. 2015. Seed quality of Saxaul (*Haloxylon ammodendron* C.A Bunge) from Bayanzag (Mongolia). Ecosystems of Central Asia under Current conditions of Socio-Economic Development 2: 8-10 Sep. 2015, Ulaanbaatar Mongolia. 140-144.

Barbour, M. G. 1969. Age and space distribution of the desert shrubs. *Larrea Div Aricata. Ecology*, 50: 679-685.

Begon, M., Harper J. L. & Townsend, C. R. 1986. *Ecology: Individuals, Populations and Communities*. England: Blackwell Scientific Publications, Oxford.

Bonnicksen, T. M. & Stone, E. C. 1982. Reconstrution of a presettlement giant *Sequoia*-mixed conifer forest community using the aggregation approach. *Ecology*, 63: 1134-1148.

Caswell, H. 2000. Prospective and retrospective perturbation analyses: their roles in conservation biology. *Ecology*, 81: 619-627.

Coates, F., Lunt, I. D. & Tremblay, R. L. 2006. Effects of disturbance on population dynamics of the threatened orchid *Prasophyllum correctum* D.L. Jones and implications for grassland management in south-eastern Australia. *Biological Conservation*, 129: 59-69.

Chen, C. D., Zhang, L. Y. & Hu, W. K. 1983. The basic characteristics of plant communities, flora and their distribution in the sandy district of Gurbantunggut Desert. *Acta Physico*

Geography Sinica, 7: 89–99. (in Chinese)

Crisp, M. D. & Lange, R.T . 1976. Age structure, distribution and survival under grazing of the arid-zone shrub Acacia burkittii. *Oikos*, 27: 86-92.

Lu, C. Y., Zhang, X. & Liu, G. 2014. Population characteristics of *Haloxylon ammodendron* (C.A.Mey) bunge in gurbantünggüt desert, China. *Pakistan Journal of Botany*, 46(6): 1963-1973.

Deevey, E. S. 1947. Life tables for natural populations of animals. *The Quarterly Review of Biology*, 22(4): 283-314.

Desertification Atlas of Mongolia, 2014. Institute of Geoecology, Mongolian Academy of Sciences, Ulaanbaatar. pp 134.

Fahn, A. 1953. Annual wood ring development in maguis trees of Israel. *Palestine Journal of Botany*, 6: 1-26.

Gal, J. 1975. Biological and ecological concepts utilization of some Gobi Desert plants. *Mongolian Academy of Sciences*, Ulaanbaatar, pp. 215. (in Mongolian)

Gal, J. 1975. Breeding methods of Saxaul and some other shrubs. National Printing office, Ulaanbaatar. pp. 35. (in Mongolian)

Ginzburg, C. 1963. Some anatomic features of splitting of desert shrubs. *Phytomorphology*, 13: 92-97.

Harper, J. L. 1977. Population Biology of Plants. New York: Academic Press.

Hegazy, A. K. 1992. Age-specific survival, mortality and reproduction, and prospects for conservation of *Limonium delicatulum*. *Journal of Applied Ecology*, 29: 549-557.

Hegazy, A. K., Hammouda, O., Lovett-Doust, J. & Gomaa, N. H. 2008. Population dynamics of *Moringa peregrina* along altitudinal gradient in the northwestern sector of the Red Sea. *Journal of Arid Environments*, 72: 1537– 1551.

Holla, T. & Knowles, P. 1988. Age structure analysis of a virgin white pine, *Pinus strobus*, population. *The Canadian Field-Naturailst*, 102: 221-226.

Johnson, E. A. & Fryer, G. I. 1989. Population dynamics in *londgepole* pine–Engelmann spruce forests. *Ecology*, 70: 1335-1345.

Khan, D. & Shaukat, S. S. 1997. Population structure,intraspecific competition and phasic development of *Urochondra setulosa* (Trin.) CE Hubb., A coastal halophytic grass of Pakistan. *Pakistan Journal of Botany*, 29: 271-288.

Kuuseoks, E., Dong, J. & Reed, D. 2001. Shrub age structure in northern Minnesota aspen stands. *Forest Ecology & Management*, 149: 265-274.

Khaulenbek, A, 2005. Distribution and resources of saxaul forests. *Journal of Environment and Life*, 2: 31-32 (in Mongolian).

Khaulenbek, A., Ihanbai, Kh. & Batkhuu, N. 2018. Saxaul forests in Mongolia. Ecosystem, resources, values. Report prepared for UN REDD+ Programme in Mongolia. pp 88.

Lange, R. T. 1965. Growth ring characteristics in arid zone conifer. *Troy Society South Australia*, 89: 133-137.

Lorimer, C. G. 1980. Age structure and disturbance history of a southern Appalachian virgin forest. *Ecology*, 61: 1169-1184.

Manuel, C. & Molles, J. 2002. Ecology: Concept and Applications (2nd ed). New York: McGraw-Hill Companies, 186-254.

Menges, E. S. 1986. Predicting the future of rare plant populations: demographic monitoring and modeling. *Journal of Asian Natural Products Research*, 6: 13-25.

MNET, 2010. National Report to the Convention on Combat Desertification.

Pielou, E. C. 1977. Evaluating approaches to the conservation of rare and endangered plants. *Ecology*, 75: 584-606.

Pyankov, V. I., Artyusheva, E. G., Edwards, G. E., Black, C.C. J. R. & Soltis, P. S. 2001. Phylogenetic analysis of tribe *Salsoleae* (Chenopodiaceae) based on ribosomal ITS sequences: implications for the evolution of photosynthesis types. *American Journal of Botany* 88(7):1189-1198. https://doi.org/10.2307/3558329.

Schemske, D. W., Husband, C., Ruckelshaus, H., Goodwillie, I., Parker, M. & Bishop, J. G. 1994. Evaluating approaches to the conservation of rare and endangered plants. *Ecology*, 75: 584-606.

Silvertown, J., Franco, M., Pisanty, I. & Mendoza, A. 1993.Comparative plant demography relative importance of life cycle components to the finite rate of increase in woody and herbaceous perennials. *Journal of Ecology*, 81: 465-476.

Silvertown, J. W. 1987. Introduction to Plant Population Ecology (2nd ed.). Harlow: Longman.

Stewart, G. H. & Rose, A. B. 1986. The significance of life history strategies in the development history of mixed beech (Nothofagus) forests, New Zealand. *Vegetatio*, 87: 101-114.

Svensson, J. S. & Jeglum, J. K. 2001. Structure and dynamics of an undisturbed old-growth Norway spruce forest on the rising Bothnian coastline. *Forest Ecology and Management*, 151: 67-79.

Shamsutdinov, Z. S. & Ubaidullaev, S. R. 1988. Distribution of *Poa bulbosa* L. and *Carex pachystylis* within the phytogenous field of black saxaul. *Problems of Desert Development*, 1: 38–43.

Shaukat, S. S., Aziz, S., Ahmed, W. & Shahzad, A. 2012. Population structure, spatial pattern and reproductive capacity of two semi-desert under shrubs *Senna holosericea* and *Fagonia indica* in southern Sindh, Pakistan. *Pakistan Journal of Botany*, 44: 1-9.

Tobe, K., Li, X.M. & Omasa, K. 2000. Effects of sodium chloride on seed germination and growth of two Chinese desert shrubs, *Haloxylon ammodendron* and *H. persicum* (Chenopodiaceae). *Australian Journal of Botany,* 48: 455–460.

Vasek, F. C. 1980. Creosote bush: long-lived clones in the Mojave Desert. *American Journal of Botany*, 67: 246-255.

Webber, I. E. 1936. The woods of sclerophyllous and desert shrubs of California. *American Journal of Botany*, 23: 181-188.,

Woodell, S. R. J. 1990. Regeneration in the Shrub Acacia burkittii FvM. ex Benth. in the Arid Zone of South Australia. *Biological Conservation*, 51: 39-48.

Zhu, G. L., Mosyakin, S. L. & Clemants, S. E. 2004. *Haloxylon* Bunge (Chenopodiaceae). In: Flora of China Editorial Committee, ed. Flora of China. Vol. 5. St. Louis: Science Press, Beijing/Missouri Botanic Garden Press, pp. 395-396.

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